Valuing the Unknown:
Cost-Benefit Analysis and Air Pollution

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CONTENTS

1 INTRODUCTION

This paper explores some of the issues arising from energy related air pollution in developing countries. We examine the suitability of cost-benefit analysis as a method for assessing alternative abatement strategies and for helping to identify the optimal course of action.

1.1 What is the Air Quality Problem?

In many areas there is a growing awareness that air pollution presents a major problem that policy should address; however, the complexities of the phenomena involved mean that identifying the appropriate level and type of abatement is often very difficult. Typically a multitude of individual pollutants are involved which can cause damage both alone and in conjunction with each other. The key relationships between emissions and concentrations and between concentrations and damage are very complex and will depend on the precise conditions under which emissions are released. Any information shedding light on the situation in a particular city will tend to be very site-specific and not easily or reliably applicable elsewhere.

Air pollution causes various types of damage that are normally inflicted on society at large rather than on those directly responsible. In the past these external impacts tended to be ignored but recently emphasis has been placed on the fact that such effects do involve an economic cost. This is reflected not only in people's willingness to pay for improvements in air quality, but also in reduced agricultural yields, corrosion of buildings and materials and health damage, resulting in lower labour productivity. Pressure on governments has mounted, both domestically and from the international community, to address air pollution problems explicitly through policy.

The problem for policy lies in the determination of the appropriate level of pollution abatement. To prevent all pollution would entail enormous expense and would not be desirable, given that scientific evidence indicates that pollution at low levels causes little or no damage. Yet to let pollution go unchecked may not be worthwhile either, if the costs of the damage described above are greater than the price of abatement. But between these two extremes of no action and a complete ban on pollution, there is a great deal of uncertainty. In practice this has often meant that a position nearer to the extreme of no action has been tacitly adopted. In turn this has led to severe air pollution problems in many cities. In some cases emergency remedial action has been or is now being hurriedly taken. This usually involves greater expense than that which a carefully planned strategy aimed at avoiding or reducing pollution would have entailed.

According to economic theory, the optimum level of pollution abatement occurs at the point where the marginal cost of the last unit of abatement exactly equals the benefits from the resulting reduction in damage. In order to identify this optimum point values must be attached to damage costs and to abatement options in a manner that facilitates comparison. Interest in cost-benefit analysis has grown because of this method's emphasis on deriving monetary values for abatement measures and pollution damage and a large literature has emerged on its application to environmental issues, including air pollution.

1.2 What is Cost-Benefit Analysis?

Cost-benefit analysis is an economic exercise which compares the net present value of investment expenditures (in this case the costs of an abatement option) with the net present value of the benefits generated by the investment (in this case the pollution damages that are avoided). The process requires monetary values to be placed on the different types of damage caused by the various aspects of energy use; preferably in a 'cradle to grave' analysis, which incorporates impacts from each stage of the energy supply, distribution and use chain. The damage costs of, for example, emissions of air pollutants from a power station can then be compared with the costs of preventing or reducing those emissions. Thus if the benefits of abatement measures, in terms of the value of the damage avoided, exceed the costs, this may help decision-makers identify the 'optimum' level of pollution control.

In this paper we argue that there are a number of dangers inherent in applying cost-benefit analysis to air pollution issues in developing countries that may undermine the usefulness of the method. Firstly, the onerous data requirements of the approach may deter governments from taking any action at all with adverse consequences for air quality. Secondly, if these requirements are evaded by using data already collected in other areas, especially in industrialized countries, the reliability of the results will probably be seriously jeopardized and decisions made on the basis of inaccurate information. Thirdly, even well conducted applications will tend to yield wide ranges of possible damage costs leading to considerable uncertainty about the desirable reduction in pollution. This may mean that crucial decisions are postponed or abandoned. Fourthly, some cost-benefit studies have obtained small ranges or single values for damage costs which tend to reflect numerous simplifying assumptions that again reduce the reliability of the results and provide a weak basis for policy-making.

Essentially the search for pollution abatement policies must be a trial and error process because of the extent of the unknowns involved. This is often not explicit in cost-benefit studies since putting distinct values on damage costs tends to obscure the key uncertainties. Even if the limitations of the method are spelled out, in many cases other types of information and methods of assessing pollution abatement policies will be desirable supplements.

Cost-benefit analysis of abatement decisions requires two types of information; firstly concerning the costs of different abatement options, and secondly about the damage costs avoided by each measure or combination of measures. It is the latter type of information that involves the main difficulties and uncertainties. The major hurdles involved in calculating damage costs relate to the following issues:

(i) identifying the effects of pollution;

(ii) valuing these impacts;

(iii) understanding the relationships between emissions, concentrations and damage. The complexities of these issues lead to an aggregation problem.

(iv) dealing with uncertainty.

1.3 Structure of the Paper

In Chapter 2 we examine the difficulties encountered by cost-benefit analysis of air pollution issues in the context of developing countries, where the key data required tend to be less readily available. Chapter 3 investigates the extent to which the specific problems involved in applying cost-benefit analysis in developing countries may be alleviated by using estimates of damage costs from studies carried out in industrialised nations. In Chapter 4 the need for an alternative methodology that can supplement or replace cost-benefit analysis is explained and an example given. Chapter 5 concludes the discussion. The specific techniques of cost-benefit analysis are described in the Appendix.

2 COST-BENEFIT ANALYSIS AND AIR POLLUTION: THE PROBLEMS

In this chapter we examine the problems that arise in undertaking cost-benefit studies of air pollution and abatement options, particularly in developing countries. Two types of monetary valuation are required in the exercise; the costs of the various pollution abatement options available as well as the damage costs avoided by each alternative.

2.1 Costs of Emission Abatement

Abatement techniques tend to involve controls on emissions of pollutants which can take various forms. Policies often involve quantitative restrictions on the amount of emissions permitted from various sources but could also involve land use planning or restrictions on the time that pollutants might be released. However the damage caused by pollution is related primarily to concentrations rather than to levels of emissions. The relationship between emissions and concentrations is extremely complex and varies depending on local and site-specific conditions. Consequently it is very difficult to predict what impact a change in the level of emissions will have on concentrations of pollutants, or how much emissions would have to be reduced to meet a pollution target. Many difficulties emerge in trying to compare the impact of different levels and types of emissions controls with the corresponding effects on concentrations. These affect all methodologies for assessing pollution abatement policies.

Although cost-benefit analysis could compare damage and abatement costs in terms of either emissions or concentrations, most studies have used the former. In this paper we also approach the issues and problems from this angle. Most of our comments would still apply however if the comparison were carried out in terms of concentrations, although they would be expressed differently.

The uncertainties involved in the relationships between emissions and concentrations and between concentrations and damage, and the problems these cause for all methods of assessing pollution abatement measures, will be examined in more detail in Section 2.5. Here we explore the possibilities of calculating the costs of abating emissions.

Although there may be some difficulties involved in calculating the costs of the different abatement technologies, these are likely to be manageable. In many cases the costs will be clearly identifiable. For example technological measures such as flue gas desulphurization units (FGD) or filters for particulates are bought and sold in the market. The costs of fuel substitution measures can also be easily assessed because different types of fuel have a market price. Although markets may be distorted in many countries, for example elements of tax or subsidy may be included in the price, it is usually possible to take these into account, for example by using border prices for fuels.

Abatement measures and combinations of measures must be looked at individually. The potentials for reduced emissions from each control option are not necessarily additive and some measures may be mutually exclusive. The least-cost strategies for meeting different targets may consist of very different techniques. For example, a target may be met by fitting pollution controls onto coal-fired power plant. However, more stringent requirements may require intervention in other sectors. In this case the cheapest method might be to install a gas distribution network to include the power sector as well.

Some measures will affect more than one pollutant, such as fuel switching from coal to gas in power stations, which leads to lower emissions of all the major pollutants; while others will only reduce one pollutant. For example FGD reduces SO_2 but will probably lead to a small increase in NOx (nitrogen oxides) and SPM (suspended particulate matter), as well as leaving a toxic sludge which may contribute to land and water pollution if disposed of carelessly. The potential for emissions reductions from different options will vary, for example FGD is usually only practical for power stations, whereas gas substitution is possible in a number of sectors.

The costs of pollution abatement will vary between locations and some local knowledge is vital for accuracy. The costs and availability of the measures are subject to variation, for example the possibility of using natural gas will often depend on access to supplies either through geographical proximity to the source, or to pipeline infrastructure.

The relevant costs will depend on local conditions, the existing pattern of energy use and the potential changes that could be implemented.

2.2 Estimating Pollution Damage Costs

Most methodologies for assessing different pollution control strategies will involve comparison of the costs of the different abatement options available. Cost-benefit analysis differs from other approaches because of the second type of information it requires, namely estimates of the damage costs of pollution. This enables the benefits of pollution abatement, in terms of the value of the damage avoided, to be compared with the costs of the different measures available. The rest of this paper focuses on this aspect of cost-benefit analysis.

The economically 'correct' cost of air pollution damage is the value of the willingness to pay (WTP) for improvements or of the willingness to accept (WTA) compensation for deteriorations in air quality. The measurement techniques available can be divided into two main categories. Firstly, there are those that seek to value WTP or WTA by using methods based on observed behaviour in surrogate markets, in which some element of the price of a good or service reflects environmental quality; or by asking respondents how they would behave in hypothetical situations. The second category includes methods which aim to value physical, easily identifiable effects by using market prices of related goods and services. The individual techniques involved and the specific strengths and weaknesses are described in the Appendix. Here we identify some general problems with the concepts and in their application to air pollution issues in developing countries.

2.3 Identifying Pollution Damage

Both categories of valuation techniques rely on the identification and measurement of the effects of air pollution. The methods which seek to calculate willingness to pay by examining observed behaviour in existing or hypothetical markets require that people are fully informed about and aware of the damage under examination. For, without such knowledge, the values they place on changes in the level of air pollution are unlikely to reflect the true costs to society of such environmental damage. The physical methods of valuation depend directly on information about the nature and extent of air pollution related effects which are valued with reference to productivity losses or medical costs. This section highlights the fundamental uncertainties involved in the identification and quantification of the damage caused by concentrations of air pollutants.

The main types of damage, attributable at least in part to air pollution, may include health impairment, reduced agricultural yields, and damage to buildings and to unique assets, both man-made and natural. The extent of the impact will be influenced by a wide variety of factors; for example health effects will depend critically on prevailing levels of health and nutrition, the age structure of the population and access to medical facilities. Ill effects often have multiple causes and it is likely to be difficult to attribute degrees of responsibility to all the causal agents involved. For example, people in developing countries may be more susceptible to air pollution related illnesses because of poor prevailing levels of health, nutrition and medical facilities. But assigning 'blame' between all the individual factors involved and targeting policy action for maximum effect given limited resources is complicated.

Enormous data sets are required even to begin the process of identifying and evaluating environmental costs. Even in industrialized countries where data is generally more readily available and reliable, and where most of the cost-benefit studies of energy use have been carried out, it is still extremely difficult to quantify the physical link between air pollution and effects on health, infrastructure and agriculture. In many developing countries even the preliminary steps, such as the systematic measurement of concentrations of air pollutants, have not yet been taken.

Impacts on health may appear at first to be the easiest to assess without the benefit of specialized studies, because the incidence of diseases is reported and this information is often available, unlike the effects of air pollution on agriculture and infrastructure which may go unnoticed[1] as well as unreported. However there are still considerable problems in the coverage of the health data available. As the World Health Organization puts it:

> *the availability of useful data on health outcome is severely limited ... Reasonably accurate incidence data are available only for cancer, and then only for some European countries (WHO, 1989, pp. 50-1).*

Data is only available for illnesses that cause visits to the doctor or hospital and the value of many health impacts may be inadequately described by this kind of statistic, for example long-term effects and those that affect welfare but do not warrant medical treatment. And often;

> *even individuals who suffer severe short-term discomfort either do not receive medical attention or are not given a specific diagnosis. Further systems for reporting diagnosed cases are often informal. Incidence is thus often grossly underestimated (ibid, p. 51).*

The general problem of under-reporting of health effects is compounded in developing countries not only by the lack of reliable statistics but also by the fact that even if they have severe symptoms, a large proportion of the population may simply be unable to pay for medical treatment or it may be unavailable to them for other reasons. This means that if it were possible to make an assumption that, for example, a certain proportion of respiratory illnesses were the result of air pollution, the total number of people with respiratory diseases and thus the full effects of air pollution would still be unknown. As a consequence, data are generally insufficient to link causally or even statistically air pollution to health damage in developing countries.

The effects of air pollution on infrastructure and agriculture are also difficult to assess. Scientifically established dose-response relationships may provide some understanding of the sensitivities of different crops and types of soil to pollution, but more information will be

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[1]Unnoticed in the sense that deterioration is not attributed to air pollution.

required. For example the impacts of air pollution will depend on which crops are grown and under what conditions. Damage to buildings will be influenced by the regularity and nature of maintenance and repair work. Again this information may be unavailable, difficult to collect or it may be problematic to isolate the impact of air pollution from other influences.

2.4 Valuing Pollution Damage

Both the willingness to pay and physical methods of estimating environmental values described above would require a substantial degree of data collection, not just relating to the effects of pollution but also to the values that are or should be placed on such impacts. Widespread or general application of the various techniques in developing countries is likely to be difficult because of the dearth of the basic data required for even a rudimentary cost-benefit study. To gather all the information required for a complete cost-benefit study would demand an enormous amount of resources in terms of time, technical expertise and expenditure. In the industrialized countries where most cost-benefit analyses have been undertaken, much of this information did not have to be collected specifically for the studies but was already available in some form. This is not usually the case in developing countries.

Apart from the absence of the necessary data, further problems are involved in the use of the various techniques in the context of air pollution in developing countries. We discuss these below.

(a) Measuring Willingness to Pay or to Accept Compensation

The first category of techniques aims to identify people's willingness to pay for (WTP) environmental improvements or their willingness to accept compensation for (WTA) environmental degradation. The techniques are examined in the Appendix. There are general conceptual and practical problems with these methods which we discuss here.

The problems of imperfect information about the effects of pollution have already been mentioned in the preceding Section. WTA and WTP methods are more susceptible to such problems than are the physical methods. The identification and measurement of pollution related effects are normally carried out by experts in the relevant fields for the physical techniques whereas WTP and WTA values are derived from the public at large, who are likely to be much worse informed. This is particularly true in developing countries where people tend to be less aware of the effects of pollution related damage and information about such impacts is less readily available.

High levels of widespread poverty mean that the values for environmental amenities obtained through WTP methods are likely to be small in developing countries. In some instances the extent of this may be exaggerated by the technique used. For example, there are good reasons for arguing that WTA methods will more accurately portray the real value of environmental goods and services than will WTP methods (See Appendix for details). However, even when such cases are taken into account, the fact remains that poor people will tend to value the environment less highly than the rich; and this may be so even if the environmental degradation in question has a more adverse impact on the poor than on the rich. Consequently, *ceteris paribus*, cost-benefit studies that use WTP techniques will tend to favour abatement action in rich rather than low income areas. Some may claim that this represents an injustice. Others may argue on the other hand that such a situation represents reality; the poor are indeed unable to afford to pay as much as the rich but any criticisms of this fact apply to the whole of the economic structure and certainly not to environmental amenities alone.

Such problematic issues are thrown into sharp relief by the extremely unequal distributions of income that exist in many developing countries. This is likely to mean that values placed on environmental amenities will vary significantly between people depending on their income. This obviously creates a need to obtain a representative sample of the population in question to ensure that values are not distorted. However it has also been claimed that using unadjusted estimates of willingness to pay in situations of extremely unequal income distributions can imply tacit acceptance of the status quo. This is a controversial issue as some will claim that abatement policies should be used to redress the balance between rich and poor, for example by giving more weight to the preferences and priorities of low income groups and others will contest that the poor should be helped in other ways.

In the light of these controversial issues, it may seem easier to use physical techniques to estimate damage costs. These may avoid some of the problems associated with WTP and WTA methods, for example impacts on low income groups can be taken into account more easily and the difficulties associated with poor public awareness of the effects of pollution can be alleviated in part.

(b) Physical Methods

These methods are based on identifying the physical impacts of pollution on health or agricultural output and then valuing these using estimates of productivity losses and medical costs. The specific techniques involved are described in the Appendix. Here we focus on general aspects and difficulties.

Physical methods are designed to evaluate easily identifiable effects of pollution and the literature has focused on health and crop damage. Many other impacts where measurement is problematic are excluded from the analysis. For example all of the non-health quality of life aspects associated with air pollution such as visibility and the enjoyment of clean air for its own sake remain unvalued by these methods. Thus estimates of damage costs from physical methods are likely to undervalue the environment and should be regarded as a minimum. However, it can be claimed that the most important elements of value for developing countries are covered by these approaches, and that estimates may be particularly convincing, for example:

> *This class of effects, which relates marketed goods and services affected by environmental change to national income, is the most powerful illustration of why developing countries pursuing sustained development must consider measures for protecting the environment (Hufschmidt et al, 1983, p. 58).*

The application of physical techniques is complicated by the uncertainties involved in identifying and measuring the effects of pollution on health and crop yields which have been discussed in Section 2.3. Further problems arise from the valuation methods.

Physical approaches use wages missed through days off work due to air pollution related illnesses as a proxy for productivity losses. A possible area of controversy may arise over this part of the process as it means that the lower the average wage, the lower the value that is given to human life, so that the life of a worker in a developing country will typically be worth many times less than one in an industrialized nation. This is a similar problem to those of income distribution and ability to pay discussed earlier. Again some people will argue that such a state of affairs represents the reality of the situation whereas others will maintain that such a view is unacceptable.

Despite the problems with physical methods, many believe that they offer the most realistic means of undertaking cost-benefit analysis in developing countries. Dixon summarizes this point of view as follows:

> *'the most useful approaches for valuing environmental effects especially of projects, have frequently been the simplest... The more experimental techniques, or those that require extensive data sets ... have had much more limited applications to date. In developing countries the most useful approaches have been those that require the fewest assumptions and the least amount of data ... It has proved much harder to 'sell' the results of more hypothetical or abstract techniques' (Dixon, 1991, p. 197).*

2.5 Emissions, Concentrations and Averages

All methods of assessing pollution abatement policies are complicated by the non-existence of easily identifiable and predictable relationships between emissions and concentrations and between concentrations and damage. As a result it is difficult to know in advance exactly what impact abatement policies (which normally target emissions) will have on concentrations of pollutants and on damage. For example a 20 per cent reduction in emissions in a polluted area will not necessarily reduce concentrations or damage by an equivalent amount. This means that achieving a set goal in terms of a specified reduction in damage or concentrations will inevitably involve a process of trial and error.

The effect that emissions have on concentrations and damage will depend on a wide range of factors, some specific to the source such as the height of the stack, and some to the surrounding area, for example average wind speed and direction.

Cost-benefit analysis can approach the situation in two different ways. 'Bottom up' studies focus on individual sources and emissions and their consequent damage is traced or simulated. If required, a more general picture is built up, based on these detailed analyses which are often supposed to be representative of other sources. 'Top down' approaches essentially seek to quantify total damage over a given area, often at the level of the country, and divide this by the total emissions, giving an average cost per unit of pollutant emitted. Both approaches are problematic in the context of urban air pollution in developing countries.

The primary strength of cost-benefit analysis lies in the assessment of highly local and relatively simple problems, for example when trying to calculate the impact a specific power plant has or would have on air quality in its immediate vicinity. In such cases bottom up analyses can be very helpful. Dispersion models are available whereby emissions from a single source or small group can be tracked and their impact on concentrations assessed fairly reliably by using a large number of variables in the simulation exercise. However, if a whole city is considered, where millions of individual emitting sources are the norm, numerous simplifications will be required to make the model manageable, which will inevitably reduce the accuracy of the predictions. Many developing countries do not have such dispersion models already in operation and to establish even a relatively simple one would require a considerable amount of data collection.

Most applications of cost-benefit analysis to more general air pollution problems have therefore taken the form of top down studies. These divide the estimated total damage costs by the total quantity of emissions and can involve simplification to the point of inanity. The two fundamental relationships involved in the problem, namely the links between emissions and concentrations and between concentrations and damage are obfuscated by such a process. This tends to be more problematic the larger the area covered by the study. The contribution made by a unit of emissions to damage can vary so much, depending on local and site-specific conditions, that using an average damage cost over an area where conditions vary significantly is likely to lead to substantial distortions.

The concept of a critical load is relevant here. This means that below a certain level, concentrations of pollutants will have no perceptible ill effect and people will be unlikely to pay anything towards reducing pollution below this level. Thus, in an area where pollution loads are below the critical level, as, for example, in many rural locations, the damage cost of a unit of pollution will be zero. Only in areas where air pollution is above the critical load will damage have a positive value.

If only one area suffers pollution above the critical load then the damage costs in this area when divided by the total emissions in the whole country would probably lead to a small damage cost per unit of emissions. When compared with the costs of reducing emissions it might appear that abatement is not cost-effective. This may mask the possibility that emissions control in the polluted area might be worthwhile, though not for the country as a whole. Such a scenario is not exceptional; air pollution problems are often highly localized, especially in developing countries.

Even if it is found that emissions controls do lead to benefits in excess of abatement costs, using an average damage cost per unit of emissions means that no priority is given to reducing emissions in heavily polluted areas over those in areas where there are no problems. And, if it were cheaper to reduce emissions in non-polluted rather than polluted areas, this would be the preferred policy according to a cost-benefit study that used average damage costs per unit of pollutant.

The problems are fewer when a smaller area is the focus of attention. For example some of the factors that influence the impact of a unit of emissions on damage may be similar for all sources in a city centre. These might include wind speed and direction as well as the existing level of pollution. However, other factors will vary, such as the stack height of the emitting source and its location upwind or downwind of the city centre. Use of an average damage cost does not enable a realistic comparison of costs and benefits and may undermine the point of the whole exercise. For example, abatement policies that target high stack sources such as power stations may be the cheapest when other methods of reducing emissions by the same amount in other sectors are considered; but at the same time emissions reductions from such sources are likely to be less effective in reducing concentrations and damage than other options because high stacks disperse pollution further away from the immediate locality. A similar story is true for upwind and downwind sources. *Ceteris paribus*, it will be more cost-effective to target sources upwind of the problem area as these have a greater impact on damage than do downwind sources. In both cases, the use of an average damage cost masks the reality that different sources contribute unequally to pollution damage. Of course it is possible to take this sort of consideration into account in the policy-making process either by simply using common sense or by giving different values to different sources. But unless one of these paths is followed, costly policy mistakes may be the result.

Although average damage estimates on a national scale may be very misleading, it may be desirable to build up a broader picture of air pollution and not focus on a small area. Some abatement policies will have an adverse impact on pollution elsewhere and may merely result in a shift in the location of the pollution rather than a genuine reduction. For example the use of high smoke stacks on power stations in the UK from the 1960s onwards reduced pollution in nearby city centres but is now being blamed for extensive forest damage in Scandinavia. However, a national view will have to be made up of a number of disaggregated studies focusing on smaller areas where different conditions hold sway.

The fact that a predictable and simple relationship between emissions and concentrations and between concentrations and damage does not exist causes problems for all methodologies for assessing pollution abatement options. However, because cost-benefit analysis concentrates on comparing the value of damage and abatement costs, the complexities of the physical relationships involved are often obscured. This is particularly dangerous when costs and desirability of policies are expressed in terms of emissions, which is the standard practice. For example, the results of a cost-benefit study might indicate that abating emissions from power stations would be the most beneficial option when abatement and (average) damage costs were compared, even though this might have little impact on concentrations and hence damage - the original cause of concern. Other methodologies such as that outlined in Chapter 4 concentrate on the physical phenomena and ensure that policies are judged in terms of the actual effect they have on pollution.

2.6 Uncertainty

In the absence of accurate information about the effects of air pollution, the results of cost-benefit analysis will be subject to some degree of error, in that they do not reflect the real state of affairs. This is compounded by the very large ranges of values that emerge when comparing different studies of similar issues and often in the results of individual studies.

A well-regarded survey of estimates of damage costs in the US electricity sector was published in 1991 by the PACE University Center for Environmental Legal Studies. This reviewed a number of studies that had been made of environmental costs. A very wide range of estimates was found. This can be seen in Table 1 below, together with PACE's suggested 'starting points', which are the figures 'that seem to most reasonably represent the range of values in the studies reviewed', (PACE, 1991, p. 28).

Table 1: Damage Costs of Emissions. $1989/lb pollutant

Pollutant	Low point of range	High point of range	'Starting point'
SO_2	0.140	4.540	2.030
NOx	0.001	1.700	0.820
SPM	0.000	5.510	1.190

Compiled from PACE 1991.

Andrew Stirling recently reviewed a small number of cost-benefit studies of the external environmental costs incurred by coal-fired power stations. He found that the difference between the lowest and highest values represented a factor of 50,000 (Stirling, 1992).

It is clear that damage costs ranges are very large and will introduce a wide degree of uncertainty into any decision-making process that involves comparing the costs and benefits of abatement. Very often a single figure is chosen from the range and used instead. Whereas this may appear to be a desirable simplification, it also serves to mask the very real level of doubt that is inherent in the range and implies a level of precision that is far from justified. PACE took a starting point based on their assessment of the estimates surveyed, but it is important to point out that only a few studies were reviewed; if more had been included, the range might have been much wider. Other authors have used ‘best estimates’, dismissing ‘unrealistic’ figures and using those they believe to be more reasonable. A number of criticisms can be levelled at this approach. Firstly, people may disagree about what is ‘reasonable’. Also, if the researcher already has an unchallengeable view of what the answer should be, there seems to be little point in carrying out a costly and time-consuming exercise to estimate damage costs and then dismissing part of the end result. Finally, if a part of the results is regarded as flawed by those actually undertaking the study, this casts doubt on the integrity of the method itself.

Sensitivity analysis is often applied to the results of cost-benefit studies. While this is useful in identifying the key variables, it does not resolve the uncertainty about the values that should be placed on the individual factors in each particular case.

The uncertainty reflected in the range of damage cost estimates is not the whole story. In addition, because of all the problems with valuing pollution damage in developing countries, there must also be considerable doubt about whether the range itself fully represents all the possible values. Due to the nature of the problem under investigation, all cost-benefit studies are forced to make simplifying assumptions which do not reflect the real and highly complex state of affairs. In addition some costs are excluded from the analysis, both environmental such as damage from the front end of the fuel cycle through the production and distribution of energy; and non-environmental, such as balance of payments and security of supply issues relating to energy imports. These factors, as well as problems with specific valuation techniques (see Appendix) may mean that the real range of uncertainty may be even greater than that suggested in the results of cost-benefit studies themselves.

2.7 Discounting

Assuming that the problems above can be solved satisfactorily, another area of controversy emerges in the treatment of costs and benefits which occur in the future. Measures to abate air pollution tend to achieve sustained improvements in air quality, involving for example a lower annual level of emissions, compared to the situation as it would have been without the abatement measures. Consequently damage costs will be avoided for the lifetime of the measure undertaken. Specific abatement techniques may also require future expenditure, for example repair and maintenance costs, which should ideally also be taken into account when comparing the costs and benefits of different options.

Discounting involves placing a lower value on costs and benefits, the longer into the future that they occur. The justifications and reasons for this common practice are twofold. Firstly it reflects the existence of time-preference; that is that people prefer benefits today rather than at some point in the future. This in turn is because of impatience and uncertainty about the future, including the risk of death before the benefits are acquired. Secondly capital is productive; when invested it is expected to yield future returns.

Many environmental costs are important mainly in the long run and discounting tends to reduce the importance of these in current decision-making. High discount rates also encourage the rapid use of exhaustible resources such as fossil fuels which will tend to increase air pollution as well as other environmental problems if abatement action is not taken. Discounting, especially when high rates are used, also prejudices inter-generational equity, in that the interests and preferences of future generations are not included in the analysis. Some commentators have argued that discounting should be removed or the rates lowered for all investment decisions or solely for those with an environmental dimension (see for example Goodin, 1986; Parfit, 1983; and Foy and Daly, 1989).

However, using lower discount rates is not necessarily environmentally beneficial. More projects would be likely to proceed and particularly those with high capital requirements, a trend that might be harmful in developing countries with capital shortages and a need for quick returns on investments. Numerous complications would follow from a policy to use different discount rates for different types of investments.

An alternative means of dealing with problems over the choice of discount rate would be to use the normal discount rate and optimize subject to specified constraints, such as a sustainability criterion (for example see Pearce et al, 1990 and Winpenny, 1991). Long-run environmental costs and benefits could be spelled out and decisions made on the basis of economic calculations and this additional information.

2.8 Opportunity Cost

Even if cost-benefit analysis is carried out under perfect conditions and the results are unambiguous, it still cannot normally indicate clearly the appropriate direction for policy. It is a technique that is normally used at the micro-economic level, when looking at a single type of policy and this means that the opportunity costs of resources, that is the potential returns available in alternative uses, are ignored. For example, even if pollution abatement appears to be worthwhile because benefits exceed costs, there may be greater returns available through other investments, such as in education or hospitals. If these alternative uses are to be taken into account, cost-benefit analysis should be carried out in all areas of policy. Only in this way can opportunity costs be incorporated and the optimal pollution abatement policy defined. This is not generally carried out, suggesting that some of the problems involved with using cost-benefit analysis for assessing pollution abatement decisions are mirrored by difficulties in other policy areas.

Under certain special conditions, cost-benefit analysis might provide a definitive result. For example if the costs of an action would significantly outweigh the benefits then it would be obvious that the action would not be worthwhile - assuming of course that the results were accurate which may be debatable in many instances. In most situations where air pollution is severe enough to merit a cost-benefit study, the result is unlikely to be that no abatement is worthwhile. The real question will concern the appropriate level of abatement, and as we have explained, cost-benefit analysis can rarely provide a categorical answer on this point.

2.9 Conclusions

In this chapter we have identified numerous problems with applying cost-benefit techniques to air pollution problems in developing countries. These will contribute to significant uncertainty in the identification and evaluation of the effects of pollution, part of which will be reflected in wide ranges of possible values for damage costs. The data requirements of the method are particularly onerous for developing countries where resources are very scarce. In Chapter 3 we examine the extent to which some of these problems may be alleviated by using estimates of damage costs that have been obtained in studies undertaken in developed countries.

3 RELEVANCE OF DAMAGE COST ESTIMATES FROM INDUSTRIALIZED COUNTRIES

The vast majority of cost-benefit studies have been carried out in industrialized countries. Competing priorities and tight budgets will mean that many developing countries will be unwilling to undertake costly and time consuming cost-benefit studies themselves. It may therefore seem desirable and practical to adapt the results of studies carried out in industrialized countries, particularly estimates of damage costs, to the assessment of pollution abatement policies in developing countries. In this chapter we identify a number of problems with this approach which jeopardize the reliability and usefulness of any results obtained in this manner.

3.1 Variation in Physical Effects of Pollutants

There are many factors specific to a country that will determine the effects of pollution. The distribution of population and of energy use and their relation to each other is of vital importance. If most of a country's pollution is situated in areas where critical loads are not exceeded,[2] then overall air pollution damage costs, measured by WTP or the physical method will not be very high. In countries where many areas have pollution levels above the critical load, damage costs will be higher even if total emissions are the same or even, in some cases, less.

The relevant critical load will also vary from place to place. This will depend on a number of factors. For example natural buffering capacity plays an important role in the extent to which lakes and vegetation including crops are affected by pollution: the more alkaline the soil or the water, the more it is able to withstand deposition of sulphur and

[2]This could be the case even if emission sources were relatively concentrated geographically, for instance if high chimney stacks dispersed emissions over a wide area or if emissions controls were in operation in city and industrial centres.

nitrogen oxides. Some countries are known to have sensitive soils and lakes while others are less vulnerable. Also differences in crops grown and working practices, or, in the case of materials damage, variations in standards of repair and maintenance will mean that the level of pollution at which damage starts to occur is likely to vary considerably.

A similar story is true for health effects. As noted earlier, in developing countries, because of the much lower levels of health and nutrition the effects of air pollution on health may be more severe.[3] Critical loads for health are therefore likely to be lower in poorer countries with fewer medical, sanitation and other facilities, implying that adverse effects will begin to occur at lower levels of pollution than elsewhere.

The effects of pollution above the critical load will also vary as well as the critical load itself. It is usually assumed that there is a linear relationship between the concentration of a pollutant and the damage it causes. This proportional relationship is unlikely to hold in reality but even if it is used for the sake of simplicity, there are variations of the kind already discussed in determining the relevant physical effect. Dose-response curves, even when proportional are likely to vary significantly between countries. For example, above the critical load, a high concentration of pollution is likely to have a greater physical impact on a person from a developing country than on someone from an industrialized nation.

In the preceding paragraphs we have concentrated on the reasons why the physical effects of a unit of pollution may vary between countries. This will lead to uncertainty when applying to one country the results of cost-benefit analysis obtained in another. Another source of variation is in the valuation of the effects.

[3]Problems arise when trying to decide which policy areas should be prioritized. For example is it more important or cost effective to tackle air pollution or the underlying factors that make its effects so much worse in developing countries, i.e. health and nutrition?

3.2 Valuation of Physical Effects

The value attached by people to the same physical effect is likely to vary significantly both within and between countries. A major source of this variation is the per capita income in the countries concerned. For a number of reasons, a lower value is likely to be placed on air pollution damages in developing countries than elsewhere. Obviously the poorer people are, the less money they are able to spend on environmental goods, particularly ones that may be seen as luxuries compared to more urgent needs. Many of the valuation techniques available in cost-benefit analysis resort to wages and expenditure to assess damage costs (for example, an illness might be valued in terms of income lost from days off work) and as these are likely to be much less in developing countries, damage cost estimates will be lower. The possible moral dilemmas posed by such issues have been indicated in Section 2.4.

Another source of variation between countries might be the extent to which the general public are aware and concerned about environmental problems. In general, people's interest in environmental affairs and specifically in the problem of air quality is much greater in industrialized countries. This may lead to higher estimates of damage costs even for the same effect and should be borne in mind when seeking to apply to other areas the results of cost-benefit studies of industrialized countries.

3.3 Conclusions

Given all the uncertainties and problems inherent in cost-benefit studies, it seems of little value to compound these by using damage cost estimates from other countries, where conditions are likely to be very different, as anything more than a very rough guideline. Clearly policy decisions need to be informed by other types of information. In Chapter 4 we briefly examine another popular methodology, that can help to incorporate environmental concerns into the decision-making process.

4 AN ALTERNATIVE METHODOLOGY[4]

Exponents of cost-benefit analysis recognize that there are problems with applying the available techniques in developing countries but maintain that in many cases it may still be worth applying. Even if cost-benefit analysis cannot identify the optimum abatement policy, there may be a number of associated advantages that can contribute constructively to the policy debate. For example, the attempt to place values on pollution costs is a reminder that the environmental amenities are neither free nor unlimited in supply. Also the more information that can be gleaned about damage and its value, the better, even if it is incomplete. This can help inform policy decisions. In some circumstances the case for cost-benefit analysis may be supported by political factors - it may be easier to convince decision-makers of the need for abatement action if this would demonstrably result in economic savings.

Whether or not cost-benefit analysis can provide useful information will depend on the individual case at hand. It seems likely however, that in a practical application the uncertainties and problems involved in applying the various techniques to air pollution issues are such that cost-benefit analysis will be unable to provide definitive answers. In this Chapter we examine an alternative approach that may be used in place of cost-benefit analysis, or that can play a supplementary role. This approach is used in many countries worldwide and is a pragmatic response to the uncertainty that shrouds the debate. It essentially involves identifying and following the least-cost path to attaining a defined set of air quality standards.

The standards approach explicitly recognizes the uncertainties in identifying the optimum level of pollution abatement. A set of air quality standards is selected and the least-cost means of attaining the targets calculated. The main problem with this approach is in the selection of the set of standards. Like cost-benefit analysis, the method does not include a methodology whereby the 'correct' targets may be discovered. It may be claimed therefore

[4] A full definition and discussion of this methodology is the subject of work carried out by the O.I.E.S. under a research contract with the World Bank, the results of which will be published in 1994.

that the least-cost methodology fails to answer the critical question.

In response to this complaint, advocates of the standards approach can put forward a number of arguments. The optimum level of pollution abatement can only be identified if cost-benefit studies are carried out over all the policy areas and alternative strategies available. Even if this were a practical option, the difficulties in obtaining accurate and sufficiently specific results for air pollution and probably many other issues, means that it will almost certainly never be possible to quantify precisely how much abatement is desirable. The standards approach highlights this gap rather than obscures it. That the choice of standards is independent of the methodology and not an integral part of it is obvious from the beginning.

The question is now as follows: if we accept that the *optimum* level of standards cannot be identified, how can targets sensibly and acceptably be chosen? There may be a number of useful inputs to the decision-making process. If cost-benefit studies of the problems under examination are available, the ranges of damage costs estimated may yield some useful information. The argument of this paper has not been that cost-benefit analysis is worthless, merely that it is insufficient to act as a foundation for policy concerning air pollution in developing countries.

It is possible to narrow down the choice of air quality standards quite considerably by looking at choices that have been made by other countries and organizations. For example the WHO guidelines on ambient air concentrations are based on medical and scientific criteria rather than political lobbying and consequently are much stricter than those adopted in most countries. They do not have an economic content either; that is there is no comparison of the costs and benefits of different levels of standards. The WHO guidelines could probably be seen as one extreme of the range of choices, the other extreme being no standard at all which is the case for many developing countries. Within this range different countries have taken different positions. A developing country may feel that it cannot afford to have as high a quality of air as richer countries: this will narrow the range of acceptable standards further.

Other relevant factors will include the importance of air quality in relation to other priorities. This in turn may depend on public awareness and concern about air pollution, existing levels of provision of other services, the numbers and type of people affected and so on. There is likely to be disagreement concerning the appropriate level of standards as for other areas of policy, which reflects the fact that the optimal level of abatement cannot be defined. The debate is likely to be settled through the political process, as for other issues.

A fundamental theme running through all the influences on the choice of standards is that of cost. The amount of money available to spend on air pollution is likely to be constrained and often this alone will determine the level of abatement expenditure undertaken. The standards approach can be used to calculate the most cost-effective means of using the available resources. Least-cost strategies for a number of different sets of standards can be identified. In this way the standards approach can provide crucial information to assist decision-makers in the choice of targets although the appropriate targets do not emerge from the methodology itself. It is important to recognize in addition that the standards approach is essentially flexible; if the standards assessed are prohibitively expensive to meet, then a lower level can be chosen. Ultimately this method is based on the belief that the level of abatement chosen will depend on a number of factors, and given that individual circumstances, resources and priorities will vary among countries, this is preferable to reliance on an approach that offers spurious accuracy and masks the complexities involved.

There are a number of other advantages to the standards approach. It focuses on concentrations which are closely linked with damage rather than on emissions. We have discussed some of the problems with average damage estimates. Air quality standards would highlight the areas with the most severe pollution and target resources accordingly. Areas where concentrations of pollutants were low in relation to the standard would not require emissions controls. Within a city, account would have to be taken of the differential impact on concentrations and damage of emissions from various sources. We have already said in Section 2.5 that this would be possible either by using common sense alone or by attaching higher priority to the sources which contributed more than proportionately to damage. Because the standards approach is concerned with concentrations rather than with emissions, a proper application would require such a step. This step would be easier to ignore for cost-benefit analysis where the emphasis tends to be on emissions.

The key to the success of a standards based policy is of course the action that is taken to achieve the standards. Many developing countries have elaborate environmental legislation on the statute books, including stringent air quality standards, but give enforcement a low priority. A related point is the danger of over-ambitious goals which may deter rather than inspire effective abatement action. The emphasis of the standards approach on cost will help to ensure that realistic aims are chosen, although more stringent targets can be retained as a long-term objective.

The standards approach is relatively easy to apply. Some data collection will be required, namely air quality measurements and the costs of different abatement options and strategies. Both types of information would also be required in a cost-benefit study. Air quality standards do not necessitate the collection of extremely complex data about the physical effects of pollution and how people value these. This is a considerable advantage in a developing country where much of this data may be currently unavailable and very difficult, expensive and time-consuming to obtain. This is not to say that information about the impact of pollution is worthless, indeed it may be very useful, for example if it persuades governments to adopt air quality standards. However, the detail required by cost-benefit analysis to yield accurate and definitive results is unlikely to be achievable in practice.

5 CONCLUSIONS

The use of cost-benefit analysis as the basis for decisions about air pollution in developing countries is fraught with problems. The benefits of abatement, that is the damage costs avoided, are notoriously difficult to identify let alone value. Some of the fundamental relationships between pollution and damage to health, materials and vegetation remain a mystery and the enormous variation in impacts depending on local conditions makes information of a general nature inadequate. A large amount of data will be required to carry out the valuation process, much of which will be unavailable and difficult to collect in developing countries. The use of damage cost estimates taken from other countries will only compound the problems and uncertainties involved.

The estimation of damage costs tends to result in wide ranges of possible values. Uncertainty exists not only within these ranges but also surrounds the whole cost-benefit process itself. Unless similar exercises are carried out for all policy areas, an optimum level of pollution abatement cannot be identified. Consequently cost-benefit analyses are unlikely to indicate securely and definitively a solution to air quality problems.

Alternative tools will be needed by policy-makers. We have examined one methodology which can be used in place of cost-benefit analysis or as a supplement. The standards approach is a pragmatic response to the complexities and uncertainties of the issues concerned, which highlights the trade-offs and the political nature of the decisions rather than shrouds them in a cloak of spurious accuracy.

APPENDIX

TECHNIQUES OF COST-BENEFIT ANALYSIS

In this paper the general issues and problems involved in placing values on damage caused by air pollution in developing countries have been explored. Here we briefly summarize the specific techniques of valuation that have been developed. More detailed expositions can be found in Pearce (1978), Hufschmidt at al (1983), Dixon et al (1988) and Winpenny (1991).

Valuation methods can be divided into two main categories. The first group seeks to estimate the willingness to pay for environmental amenities, or the converse, to accept compensation for environmental degradation. The second category concentrates on the physical impacts of pollution and seeks to value the changes in productivity (for example in terms of crop yields or working days lost due to pollution related illness) and related expenses, such as medical and other costs.

A.1 Willingness to Pay or to Accept Compensation

This group of methods seeks to define a price for environmental goods and services based on observed behaviour in existing or hypothetical markets. As a consequence the accuracy of the techniques outlined below rely on people having full information about the nature and extent of environmental impacts. This requirement is unlikely to be the case for air pollution and especially in the context of developing countries. Another potential problem with the techniques involves the relationship between the ability and willingness to pay for environmental amenities. Because of widespread poverty many people in developing countries will behave in a way that some techniques will indicate involves a low value placed on the environment. These two issues were discussed in more detail in Sections 2.3 and 2.4.

(a) Contingent Valuation (CV).

Contingent valuation seeks to create a hypothetical market for the environmental amenity in question (see Cummings et al, 1986 and Mitchell and Carson, 1989). Surveys ask respondents how much they would be willing to pay (WTP) for a specified environmental improvement, or willing to accept in compensation (WTA) for a deterioration in environmental quality. A bidding process is often used.

The main advantage of this method over all others is that it is the only way of calculating what the literature terms 'option' and 'existence' values. An option value measures the willingness to pay of consumers for the choice to use a good or asset at some time in the future. It is unrelated to current use. Existence value measures the utility people gain from merely knowing that something exists, such as a rare animal; it is unrelated to use, either current or future. Other methods are unable to capture these values because generally markets for them do not exist. Option and existence value will be more important for some environmental amenities than others. Areas where they are likely to be significant include the preservation of species and other unique assets. In the area we are focusing on, that of air pollution caused by energy use, option and existence values are likely to be very small in comparison with the values associated with current use. Thus that particular advantage of contingent valuation methods is not as important in the specific context of this paper.

Contingent valuation is susceptible to a number of different biases. *Hypothetical bias* occurs because payment or compensation is not real and people may state values which they would not be willing to pay or accept in reality. Contingent valuation does not require respondents to back up their opinions with cash. Studies have found that this particular type of bias can be statistically significant for WTA methods but is less so for WTP. *Strategic bias* occurs if respondents hope to influence the course of events by their answers; for example if they believe their response could prevent an undesirable action, they may state an excessively high WTP or WTA. There are various kinds of potential *design bias* depending on how the questions and bidding procedures are organized and what information is emphasized. For example, *starting point bias* comes from the researcher suggesting starting bids for WTP or WTA and thus skewing the possible range of answers. Another form is *instrument bias* where respondents react strongly against any of the hypothetical methods of payment included in the survey. It may be however that WTP and WTA are in fact contingent on method of payment and that different responses for different instruments are perfectly justifiable and do not represent bias at all. Careful design of surveys and use of appropriate statistical and survey techniques can reduce biases significantly, but this is likely to require a great deal of effort and double checking as well as comparing the results with those obtained by other methods.

Contingent valuation only works well where people have experience of survey and market research techniques and are well aware of the characteristics of what they are being asked to value. Even in industrialized countries people do not have much experience in buying environmental improvements especially when these are of a rather general nature (such as air quality improvements), rather than designed to target specific problems (e.g. double glazing to abate noise pollution). Few developing countries have any tradition of market surveys and general awareness of environmental issues is lower.

The formidable data gathering and processing requirements of this method are likely to make CV a prohibitively expensive evaluation method in developing countries. Its most successful applications in developing countries have been in valuing water, sewerage and tourism benefits, though these have been few and far between. It is most likely to be useful when evaluating relatively uncomplicated, easily perceived and understood environmental changes. The uncertainties and complex interactions inherent in air pollution issues make it unsuitable for use in this context.

Another problem with CV is that some people, however few, will claim that they cannot be compensated sufficiently for certain losses, for which their WTA is infinite: for example, if no amount of money can compensate a respondent for the loss of the giant panda. Unless it is thought right that such people have the right to effectively veto decisions that many other people would benefit from and support, there will have to be some kind of decision about the maximum value that is allowed to be put on an environmental asset. It is clear that this would be a subjective assessment and one which would probably vary according to which environmental good is being valued.

Large differences between WTA and WTP values have been observed in CV studies. According to economic theory, when evaluating small changes in overall environmental quality there should be little difference between the results obtained from the two procedures.

In practice, WTA estimates are often much larger than WTP, typically by factors of between 3 and 5 (Winpenny, 1991). As changes in environmental quality can usually be presented either as gains or losses,[5] the fact that the two methods are likely to produce very different values leads to doubts about what technique is appropriate in which circumstances and indeed about the whole validity of the concept itself. Various possible explanations have been advanced to try and account for the disparity but these are not entirely convincing and often give little help in determining suitable applications.

The division between WTP and WTA estimates is likely to be significant for the very poor because of the link between ability and willingness to pay mentioned earlier. WTP studies may indicate a low value for the environment but WTA analyses of the same effect may be much higher. For example in the case of water supply projects WTP measures for improvements have yielded estimates of zero while WTA measures were much higher and are more in keeping with other indicators of the demand for water (see Markandya, 1991). This highlights the importance of choosing the most appropriate techniques and of double-checking with other methods and with different types of information.

(b) Travel Cost Method (TCM).

While CV attempts to create a hypothetical market in environmental attributes, TCM and other WTP methods attempt to derive values for the environment from surrogate markets - that is from the demand for and price (implicit or explicit) of other goods and services for which the demand is held to be related to levels of environmental quality. The scope for TCM is usually small, concentrating mainly on improvements in recreational facilities or cultural sites that are visited by people from many different locations, or on the implicit value of fuelwood where people 'pay' by spending time collecting it (see Hotelling, 1949 for the theory behind the method and Clawson and Knetsch, 1966, for an early example of an application).

[5] The same question can be couched in different ways, for example (1) what would respondents be willing to pay for an improvement in air quality from A to B and (2) given that a decision has been made to improve air quality from A to B, what would respondents be willing to accept in compensation were the decision to be rescinded?

The value of a good environmental location is inferred by the time and cost people incur in travelling to it. The cost of time is usually calculated by using some proportion of the average wage.

There are numerous problems with applying TCM in both industrialized and developing countries. The valuation of time is particularly controversial. It can be argued that if a trip takes place in leisure time it is inappropriate to use the average wage or some proportion of it as some kind of opportunity cost of the visit. In many instances travel may be part of the pleasure of the trip. Also the wage method raises questions about the treatment of non-wage earners who, in developing countries, form a much higher proportion of the population. If the trip is multi-purpose, then using travel and time costs to evaluate the demand for the environmental attributes of a specific site is likely to lead to significant over-estimates.

The method again requires very detailed information that will be expensive and time consuming to acquire, not only about the characteristics of the trip, its duration, the length of the journey, the method and cost of travel and so on but also about the socio-economic status of visitors and other factors. Again it assumes that people are fully aware of environmental characteristics and that their behaviour fully reflects the value they attach to them. Also some difficulty is likely to be experienced when attempting to distinguish between the value that can be attached to air pollution specifically, and the total influence of all the other relevant environmental factors.

While this method may be of potential use in some developing countries, for example in those where international tourism is important, its applications are likely to be strictly limited, particularly in valuing air pollution.

(c) Hedonic Pricing.

In this method surrogate markets are used to evaluate environmental externalities, the main ones being those for property and labour.

The *property value* variant (see Rosen, 1974) is based on the assumption that among the factors influencing the demand for housing in different locations are environmental characteristics, and that these will be reflected in prices. Rental price data is more commonly used as house prices may reflect expectations of future environmental quality and it may be very difficult to allow for the possibility of this in the calculations.

Like the approaches already described, the property value approach requires enormous quantities of data concerning all the different attributes of housing in different areas including intangible factors such as exclusivity and the value that tenants attach to each of these. Again, this method works badly if the effects of pollutants are unclear to the affected and cannot easily be measured as is the case for many of the effects of air pollution.

People may take other forms of action to avoid the effects of environmental damage which are not directly reflected in house or rental prices. For example, noise pollution may be averted by double glazing or air filters could be used to reduce the impact of air pollution.

Additional problems with the property value approach in developing countries relate to the fact that it assumes that people are free to move wherever they can afford. In fact many housing markets are segmented. Cities are split by class, occupation, tribe and so on (Hyman, 1981). The most rapidly growing cities may have severe housing shortages and poor people usually have little choice where they live, since even though environmental factors may be important to them, their effective demand is restrained by their income. The method approach only works if rental costs are market clearing prices. Widespread rent controls make this a rather unrealistic assumption in many developing cities. Mäler (1977) provides a more detailed critique of the assumptions involved in the use of the property value method.

In addition, while in certain circumstances the PV approach may have some use - for example schemes to clean up rivers, install proper water supplies and sanitation have been shown to have clear and immediate effects on property values - in the context of air pollution, where the impacts are not easily measurable or even identifiable (see Section 2.1) it is largely inappropriate.

The *wage differential* approach assumes that people's willingness to accept compensation for increased risk of illness or death for example as a result of air pollution can be inferred from the premium received by workers in riskier than average jobs (see Meyer and Leone, 1977). Many of the same problems are inherent in this method. If workers are unaware or badly informed of the risks they face, the wage premium may not reflect their real WTA. It is likely that certain dangerous occupations attract risk lovers so that their WTA may be significantly below that of the general population. Like the property value approach it is likely to be very difficult to properly account for all the other factors which may influence price.

Developing countries often have higher levels of unemployment than those prevailing in industrialized countries. This means that people may not be able to afford to pick and choose between jobs with different environmental risks, although they might like to. Poverty makes people disregard environmental risks. Differential rewards of occupations may be heavily influenced by custom, caste or law and be relatively insensitive to risk.

It is not clear how, or indeed if, values of risk obtained by looking at wage differentials can properly be used to evaluate other environmental factors such as air pollution. One important issue is that even if wage differentials do reflect riskiness, then this type of risk is voluntarily incurred, assuming as always that workers are perfectly mobile. A risk voluntarily incurred is likely to have a very different value to one that is involuntarily imposed, as is the case with air pollution, and indeed this has been borne out in various studies. Again this method is of little practical use in developing countries.

(d) Preventative Expenditure and Replacement Cost.

There are two variants of this type of approach. In the first the value of environmental degradation is assumed to be the cost of either preventing it in the first place, or once it has occurred, of replacing or restoring the goods and services affected. In other words, the value of an environmental attribute is equal to the cost of replacing or maintaining it. This is obviously an unsatisfactory method which seeks to address the problems of valuation by escape rather than solution. It assumes that environmental attributes are always worth keeping in pristine condition, when clearly this is not always the case. In fact the costs and benefits of environmental degradation should be considered before making the replacement/maintenance decision. This approach arbitrarily assumes that the costs of environmental degradation equal the costs of prevention, yet there is no reason to believe this is the case. It ignores notions like willingness to pay and to be compensated and any valuation of the physical damage caused. In addition, further complications arise with the valuation of unique assets, for which replacement or repair may be physically impossible.

In the second and more common variant, the value people place on environmental attributes is inferred from what they are prepared to spend to prevent its degradation (PE) or to restore it to its original condition after it has been damaged (RC). This kind of behaviour may take a number of forms including the replacement of a degraded environment by relocation or the purchase of surrogates designed to compensate for deteriorating environmental services (such as private water supply, double glazing and so on). Valuation may be based on observed expenditure, that is on what people do actually spend or on the results of surveys asking people what they would spend as a result of changes in their environment. This method assumes that people pay an amount equivalent to the environmental benefit they gain when replacing damaged assets or when preventing such damage occurring.

Again this method only works well when people are fully aware of environmental characteristics, something which is often not the case for the effects of air pollution. Consequently, observed levels of PE and RC will be poor approximations of the full environmental costs to society. It does not take into account other motivations for expenditure that may be classed as related to environmental changes - for example double glazing may be carried out partly to abate noise pollution but partly for security or insulation reasons. There are problems involved with looking at expenditures over a short period of time, as this fails to take into account people who have already moved away from the area for environmental reasons. These will be the people who value the environment most highly so some bias is likely to result.

The relevance of the preventative expenditure and replacement cost methods to the evaluation of the external environmental costs of energy use in developing countries is likely to be small.

A.2 Physical Methods

This group of methods relies on identifying the physical impacts of environmental changes. The consequences of these effects are then quantified and values are calculated by using market prices or related expenditure.

(a) Effect on Production.

This technique is normally used when seeking to value changes in agricultural output. The effect of the pollution is identified by using scientific knowledge of the dose-response relationships between pollution and its effect on crop yields. Such relationships depend critically on the type of crop and the conditions under which it is grown, such as climatic factors, use of fertilizer and so on. Consequently information about the particular conditions faced will be required to identify the nature and extent of pollution related impacts. In its most simple form this method then values the damage caused by pollution by reference to the market price of the crops in question.

Problems in applying this method in developing countries may reflect the absence of certain key data. Market prices can only exist if there is a market for the output; in the case of the subsistence farming that is widespread in parts of many developing countries, this may not be the case. It may be possible to derive a representative value using 'border prices' from the nearest actual markets. Non-marketed output may be valued with reference to markets for substitute or similar goods if available. If the change in output is likely to affect the market price, for example if a large proportion of national crop yields are affected or if local and national markets are separated, it may be necessary to value the damage at the previous market price rather than at the new level. If the price is not a market-clearing one, for example because of subsidies, further adjustment may be needed.

Economic theory indicates that when faced with a change in conditions, rational economic agents will change their behaviour to reflect the new state of affairs. This adaptive action must also be taken into account if accurate results are to be obtained. For example if farmers attempt to offset the damaging effect of environmental degradation by using more fertilizer or switching to hardier crops, the reduction in yields and/or revenues, might be smaller than would be expected if the pollution related effect was considered in isolation. However, the extra expense caused by the adaptive action is a cost of the environmental change and should be taken into account when estimating total damage costs. If valuation of the effects is carried out before people have adjusted their behaviour, the costs of pollution will be overestimated, but if the study is carried out after adaptive action has been taken, and the costs involved are not included in the analysis, the damage will be overvalued.

(b) Human Capital.

This approach focuses on health effects and seeks to estimate the costs to society of pollution related mortality and morbidity impacts. Like the effect on production method, dose-response relationships must be established between pollution and the incidence of disease and death. Again such relationships are not constant but vary depending on a number of local factors such as prevailing levels of health and nutrition. The role of air pollution must be separated from other influences - this is likely to be problematic as usually a number of causative agents will be involved.

Valuation can take a number of forms. Firstly, the number of working days lost that are attributable to pollution related disease and death can be estimated. By using some definition of the average wage, the cost to the economy of this lost productivity can be calculated. In theory only the worker's net productivity should be included, that is the amount over and above the quantity equal to his/her own consumption. The medical costs of treatment for pollution related illness can also be calculated and included in the evaluation of pollution damage.

The human capital method has a number of disadvantages. Only the medical treatment costs of health impacts on unproductive members of society for example old people, children and people who do not work for wages are taken into account. The method does not capture any of the disutility and suffering involved which would be reflected in people's willingness to pay more than the direct costs of their treatment to avoid illness, particularly if it is likely to be of long duration. Consequently only a minimum evaluation of health costs is derived. This may be a useful starting point providing that the underlying assumptions and problems are explained at the outset (Pearce, 1978).

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