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PROBLEMS OF REGULATING ENVIRONMENTAL EXTERNALITIES

1. Objectives: What is Regulation For?

Environmental regulation is obviously defined as regulation undertaken to protect environmental standards, and this suffices as a broad definition of its scope. But the precise objectives of environmental regulation are frequently far less clear, in some cases even to the regulator. For historical reasons regulatory practice often seems to be largely a process of negotiation between polluter and regulator, rather than a system based on objective criteria. Without a clear statement objectives, it is not possible to evaluate the efficiency or effectiveness of various regulatory tools. Definition of precise objectives of the regulation is therefore a crucial first step in the process of environmental regulation.

A huge variety of principles or approaches have been proposed and used as the basis for objectives setting, including:

* As low as reasonably achievable (ALARA)
* Best practicable environmental option (BPEO),
* Best available technology not entailing excessive cost (BATNEEC),
* Environmental Quality Standards (EQS)
* Integrated pollution control (IPC)
* The precautionary principle
* The polluter pays principle, and
* Sustainable development.

Out of this plethora of different, and often conflicting, principles it is possible to identify four broad approaches to setting objectives for environmental regulation. These are as follows:

1a Acceptable Abatement Costs

This is the traditional approach in many countries. Where environmental and health impacts exist and the responsible polluters are identified, the appropriate regulatory agency sets environmental standards for plant emissions, primarily with reference to the costs which will be incurred by the polluter in meeting those standards.

Adequate monitoring (continuous or spot checks) is required to ensure that the standards are respected, but detailed quantitative monitoring is not necessary.

The principle used for setting standards is best available technology not entailing excessive cost (BATNEEC). Whilst this is widely acceptable as a form of words, it is not in itself a clear definition. In particular, the word "excessive" is open to a variety of interpretations. In practice, application of BATNEEC tends to involve negotiation between polluting industries and their regulators. The results depends upon general perceptions of relative importance of the pollution and increasing abatement costs, as well as the political forces at work.

The same issues apply in long range transboundary pollution negotiations, except that there is usually a larger number of actors. The most famous example in the energy sector is the negotiation of the Large Combustion Plant Directive. Designed principally to address the issue of European ecosystems sensitive to acid emissions from power stations, refineries and large industrial boilers, the original proposal from the Commission included both standards for emissions from new plant and national limits on emissions from existing plant. The negotiating process took 8 years in the face of conflicting national, industrial, political and consumer interests before finally emerging as a directive in 1988.

It is now clear that the objective of protecting sensitive ecosystems will not be achieved by the Directive. Negotiations under the auspices of UNECE, which will begin later this year, are likely to result in revision of the Directive, placing more emphasis on higher environmental standards.

1b. Adequate Safety and Standards

This approach emphasises the impacts on the environment and human health. The underpinning assumptions are that there are "safe levels" of pollution or levels which result in an "acceptable risk". The role of environmental regulation is then to ensure that these levels are not exceeded. This is achieved by the setting of standards or goals for environmental conditions, environmental quality standards (EQS). These may then be converted into emissions standards by use of suitable models. Good scientific data and analysis is required in the first instance to ensure that these standards achieve the desired objective. Adequate plant monitoring is required subsequently only to ensure that the standards are respected, but quantitative monitoring is not necessary. Improved understanding of environmental science may also result in revision of standards.

It has also been recognised that many environmental control technologies only transfer hazardous substances from one medium (air, water or land) to another. In addition, some technologies abate one pollutant at the expense of producing another. It is therefore necessary to control emissions to all media and to consider pollution control technologies in the light of all their emissions, hence the concept of integrated pollution control (IPC).

The philosophical basis of the standards is often not clear. For example, the standards operated in the nuclear industry for exposure to ionising radiation have historically differentiated between workers in the industry and the general public. The underlying assumption is that people who have chosen to work with radiation have accepted a higher level of risk of acquiring cancer than is appropriate for a non-voluntary risk. There is some evidence that public opinion would support such an assessment. But the basis of the acceptable levels of risk in each case is rarely made explicit. In general, the definition of safe or acceptable levels has in practice usually been achieved by a political bargaining process around the concept of "as low as reasonably achievable (ALARA)", which clearly relies heavily on consideration of abatement costs.

Uncertainty poses a major problem for the setting of acceptable standards. Whilst it is frequently possible to define the effects of large (unacceptable) pollution levels, there is often considerable scientific uncertainty and disagreement about the risks resulting from smaller pollution levels. Under these conditions, epidemiological and ecological data sets are usually "noisy" and therefore preclude any accurate assessment of dose/response functions. In these circumstances, more environmentally concerned commentators tend to urge the application of the precautionary principle, in other words assessment based on a worst case analysis, particularly where human health is concerned.

Implicit in this approach to environmental regulation is that it is the harm done to the most affected person (or ecosystem etc), which is the criterion for acceptability. There is no consideration of the numbers affected or the aggregate effect over the whole population. This approach to regulation tends therefore to impinge most strongly upon environmental impacts which are local in character, with much less severe implications for long range pollutants with a small effect on a large population. This is consistent with perceptions of equity - that a polluter should not be able to impose a severe impact on any population. However, it bears no necessary relationship to considerations of economic efficiency. Very large investments in pollution investment, and therefore losses in welfare, may be required to produce benefits for a very small affected population. Conversely, small marginal abatement costs may not be required even where they would give significant benefits aggregated over a large population.

1c Economic Efficiency

This approach derives from the principles of welfare economics. It is assumed that the impacts environmental and health effects can be described in terms of changes in welfare of individuals affected, and that these welfare changes can be measured in monetary units. In this case, the analysis of pollution abatement is amenable to conventional cost benefit analysis. Environmental regulation is not determined primarily with respect to either abatement costs or environmental impacts (as in the previous two approaches), but with an even-handed consideration of the two. The aim is to reach the "optimum" pollution level, at which the marginal costs of abatement are equal to the marginal costs of damage.

Cost-benefit analysis of environmental regulation has grown in popularity over recent years along with the use of market mechanisms, such as taxes and tradable permits for environmental regulation. The two are not necessarily linked, as market mechanisms can be used to meet standards based on a "safe limit" approach and regulatory standards can be used within a cost benefit framework. However, both are consistent with the consideration of environmental impacts as an extension of the market economy, the dominant paradigm of economic development in most of the world. The use of market mechanisms is also consistent with the "polluter pays" principle. This principle has gained very considerable support in recent years as it combines the theoretical economic efficiency advantages of market based instruments with the popular attractiveness of environmental justice.

There are some practical problems in implementing this approach. In general the pollution abatement costs can be ascertained fairly accurately by engineering approaches, but the values of environmental damages are much less certain. Uncertainties in environmental modelling and valuation multiply to make most estimates of damage values no better than an order of magnitude. Any attempt to justify fiscal instruments with reference to exact estimates of damage values should therefore be treated with considerable caution. However, in many cases, order of magnitude estimates are useful in defining priorities, developing policy and regulatory goals and identifying appropriate technologies

1d Sustainable Development

This approach has its origins in the report of the World Commission on Environment and Development (The Bruntland Report), which recognised that, particularly in developing countries, economic development and environmental protection are both required and must proceed together. The concept is more notable for having widespread support than an agreed definition. However, it is clear that any sensible definition must include not reducing the stock of key global resources such as forests and soil or impairing the operation of essential atmospheric and climatic systems.

Sustainable development is therefore an increasingly important paradigm for large scale changes such as deforestation, desertification, stratospheric ozone destruction and global warming. These have macroeconomic consequences and cannot be controlled effectively by local regulation alone. They require a recognition that environmental resources and services are fundamental to economic activity rather than a marginal perturbation of it.

In principle the monitoring regimes required to implement sustainable environmental regulation are not technically problematic. The relevant issues such as emissions of carbon dioxide and CFCs, loss of soil and forest resources, are easily measurable to the accuracy needed. The technical and scientific problems are in the understanding and modelling of highly complex systems rather than the measurements.

Regulatory systems designed with respect to this concept are in their infancy. The only firmly established example is the Montreal Protocol for the protection of the ozone layer. This seeks to reduce releases of halogenated compounds to the stratosphere to levels consistent with preventing further ozone loss and eventual regeneration. Binding commitments on carbon dioxide emissions would be the key development along these lines for the energy sector.

2. Measuring benefits - How do we do it?

For the reasons described above, the application of cost-benefit analysis to environmental regulation is becoming more important in most contexts. This poses problems for measurement, monitoring, modelling and analysis.

The calculation of values of environmental impacts requires major inputs from both environmental sciences and economics. The scientific process can be generalised as a series of operations, usually known as an impact pathway, which follow the chain of events from its anthropogenic cause through to an observable change in health or the environment.

Figure 1 illustrates the process used for the specific example of the impacts of sulphur dioxide emissions on crops. Similar diagrams may be drawn for the effects of a range of different pollutants on various receptors, that is human beings and the environment (both natural and human made). In general there is some complex scientific work to be undertaken to understand both the transportation of pollution through the environment and the dose/response relationships at the receptor. In addition a calculation of the aggregate impact of a polluting source requires knowledge of the number and location of sensitive receptors. For long range pollution this can be problematic.

The complexity and reliability of the economic valuation depends upon the asset which is being affected. Where the damage is inflicted upon capital or goods which are traded in real markets, prices in those markets can be used to estimate value. This is relevant for damages to crops, timber, building materials etc. The theoretically correct valuation is the change in producer plus consumer surplus. However, where the losses are small in the context of overall values, it may be assumed that prices are unaffected. The product of the quantity lost and the market price is then an adequate valuation.

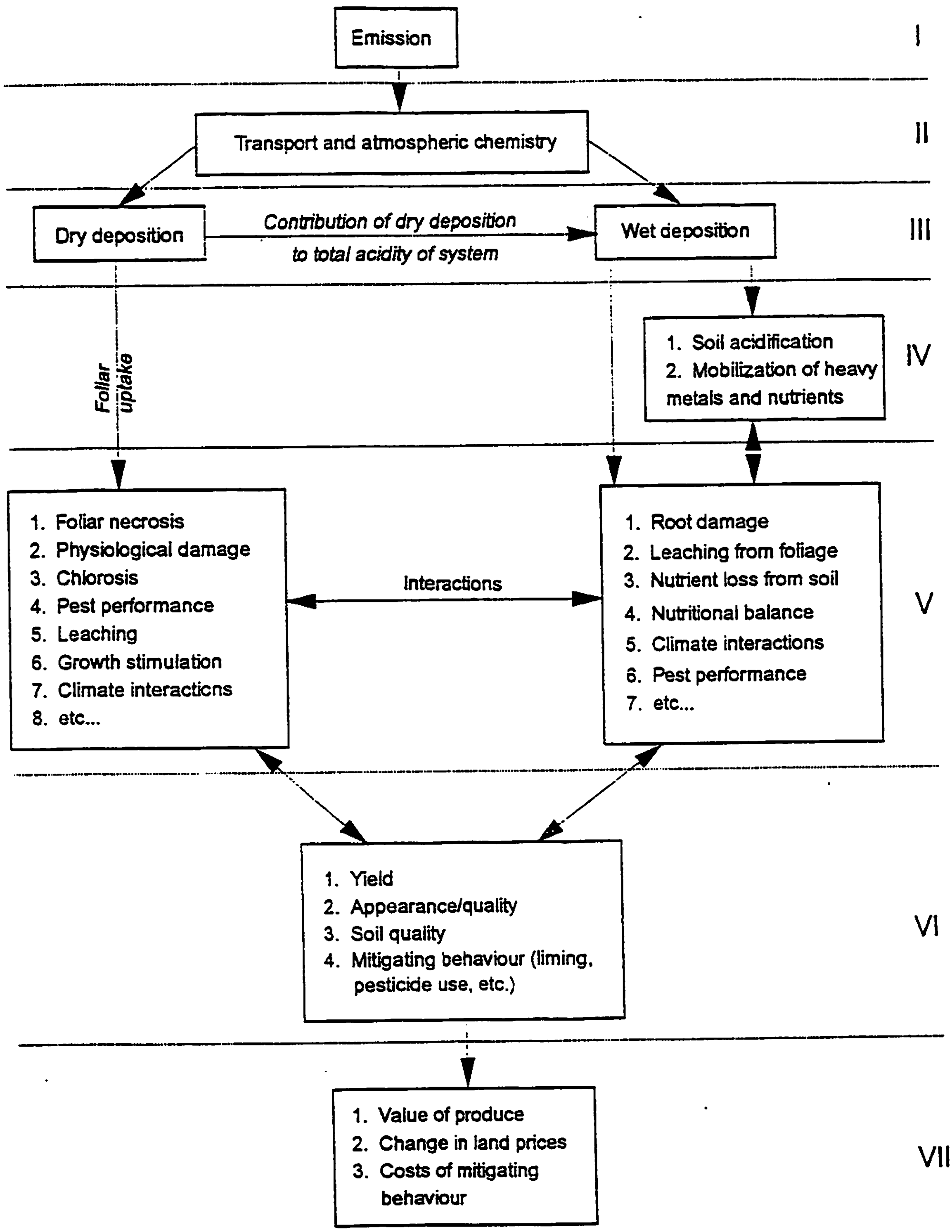
Emission
I
Transport and atmospheric chemistry
II
Dry deposition
Contribution of dry deposition to total acidity of system
Wet deposition
III
Foliar uptake
1. Soil acidification
2. Mobilization of heavy metals and nutrients
IV
1. Foliar necrosis
2. Physiological damage
3. Chlorosis
4. Pest performance
5. Leaching
6. Growth stimulation
7. Climate interactions
8. etc...
Interactions
1. Root damage
2. Leaching from foliage
3. Nutrient loss from soil
4. Nutritional balance
5. Climate interactions
6. Pest performance
7. etc...
V
1. Yield
2. Appearance/quality
3. Soil quality
4. Mitigating behaviour (liming, pesticide use, etc.)
VI
1. Value of produce
2. Change in land prices
3. Costs of mitigating behaviour
VII

Figure 1

any cases, however, the environmental impacts are upon human health, amenity natural resources. These are free goods, but not without value as they are ortant components of human welfare functions. Alternative methods of ation are therefore required. A variety have been developed and used isively, for example hedonic pricing, the travel cost method and contingent ition. These rely on the use of linked markets, or in the case of contingent ition hypothetical markets constructed in surveys, to identify monetary value.

easuring the benefits - How good is the science ?

isive assessment of environmental impacts over many years has led to a vastly oved understanding of most of the major anthropogenic environmental ems. A casual observer might therefore be forgiven for assuming that ification of the environmental impact of polluting activities should be vely easily. Unfortunately, this is not the case. In particular, for the long , energy related impacts (acid deposition, regional air pollution and global ing), major uncertainties remain. These come in many forms as follows:

arameter Uncertainty

ny cases the form of a relationship is known but the parameters in a dose ise relationship are uncertain. For example, the rate of corrosion of some ng materials under acid conditions is known to be a linear function of acidity, e reaction rate varies from study to study, probably because of the variability terials. This is a relatively easy from of uncertainty to handle. A range of eter values can be derived from good studies documented in the open ure and carried through the remainder of the analysis.

ivironmental Data Uncertainty

ification of environmental impacts can require very detailed databases on the phical distribution of receptors, people, crops, forests etc. In some cases very eographical information systems exist. For example, land use in the UK is d to a very high resolution. However, in other cases data is not available in m required and has to be estimated, introducing uncertainties. For example, impact of acid emissions from UK power stations on building materials, one

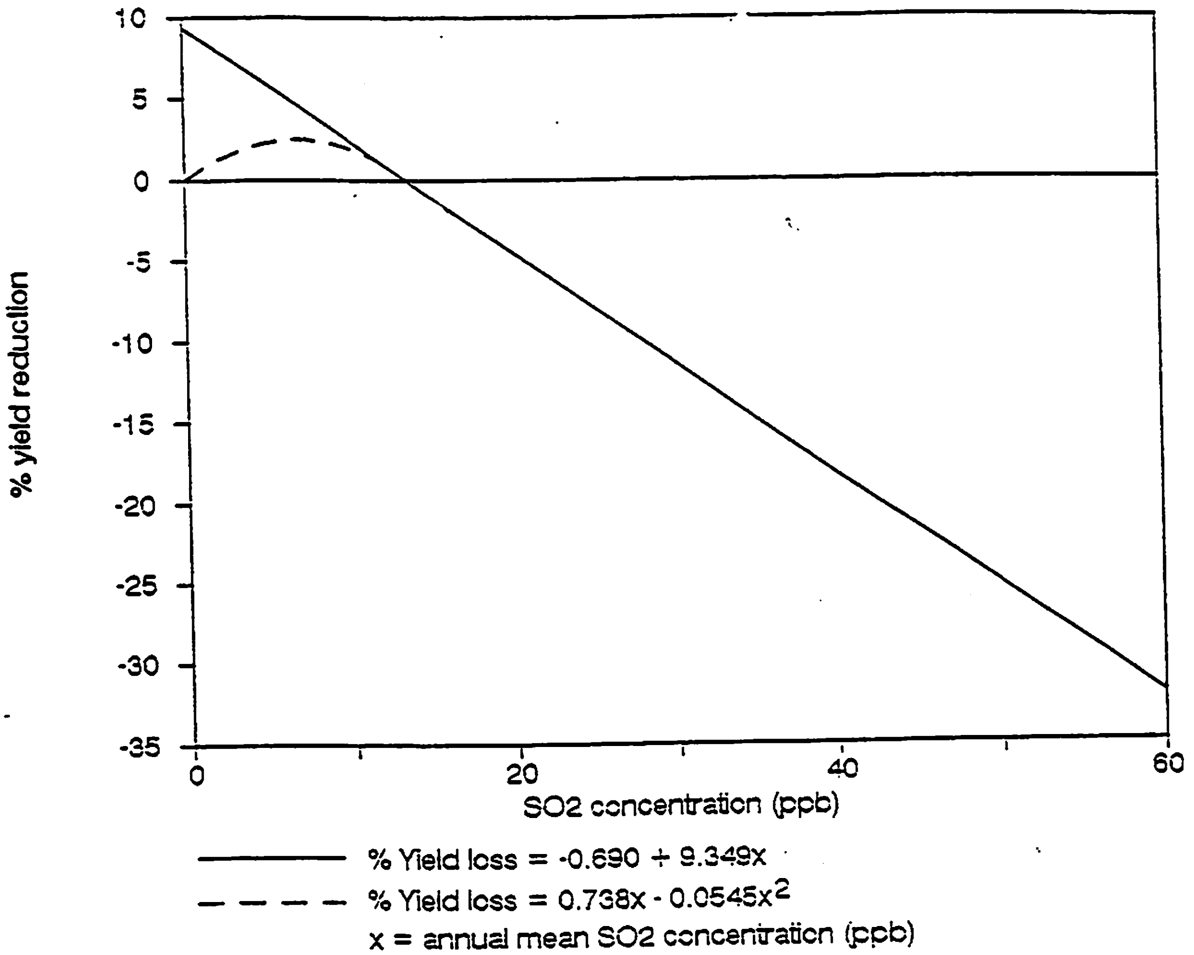
10
5
0
-5
-10
-15
-20
-25
-30
-35
% yield reduction
0
20
40
60
SO2 concentration (ppb)
% Yield loss = -0.690 + 9.349x
% Yield loss = 0.738x - 0.0545x2
x = annual mean SO2 concentration (ppb)

Figure 2

The long term effects of low doses of ionising radiation is an example. The assessments of the International Commission on Radiological Protection and others use data derived from the survivors of the nuclear weapons attacks on Hiroshima and Nagasaki. These have been extensively evaluated over the following 45 years to derive a relationship between health effects and total dose. However, the dose following the bomb blasts was over a relatively short period. The low dose received by a power plant worker over many years may give an equal accumulated dose, but with a quite different time profile. In the absence of clear medical understanding of carcinogenic mechanisms, it is difficult to be sure that the two will have equivalent effects.

In the field of ecological effects, geographical transferability is a frequent problem. The nature of ecosystems depend on climate, soil and other environmental factors, so that no two locations are identical. Some environmental impacts, such as forest decline, are observed quite widely, but many observers believe that the causes vary significantly from place to place. If this is true, simple, geographical invariant models of pollution related forest decline are invalid. Some well publicised estimates of timber related damaged are base upon a single model derived in eastern Germany, and may therefore be unreliable.

3e. Existence uncertainty

The most extreme form of uncertainty in environmental impacts is the question of whether the impact exists or not. Perhaps the best known example relates to the case of power line electro-magnetic radiation health effects. Although some studies show a positive effect, epidemiological evidence overall is insufficiently good to establish any firm relationship. However, although there is no proven medical effect, there clearly are some social effects, for example on property prices in the neighbourhood of power lines and on the location of new housing developments.

This particular example illustrates an important general point. It is scientifically impossible to prove the absence of an effect, the best that can be done is to establish (within some confidence limit) a lower limit for the magnitude of the effect. It follows that absolute safety and environmental protection are not achievable; standards can only set with reference to concepts of cost, minimum impact and risk.

Measuring the benefits - How good is the economics?

4a. Valuing traded goods

Where environmental impacts are on goods normally traded in markets, such as crops and building materials, the valuation is a relatively simple process based upon market prices and volumes. Where markets are distorted for some reason, prices may not represent values very well. For example, agricultural prices in the European Community are raised above world prices by the operation of the Common Agricultural Policy. In general, economic modelling should allow corrections to made with reasonable accuracy.

4b. Valuing free goods

More problematic is the valuation of free goods. For example, civilised countries tend to provide health care free at the point of need, largely out of general taxation, but this clearly does not imply that good health has no value, indeed quite the opposite. Procedures for valuing free goods, therefore, need to be addressed with care.

Where some market which is related to the free goods can be found, values of the free goods can be deduced from observation of behaviour in the related markets. For example, travel costs can be used to deduce the value of recreational amenity sites, and house prices (hedonic pricing) the value of housing amenities. These techniques have been refined to a stage where they can be used with some confidence. However, there are limitations on their use. For example, hedonic pricing will measure all of the relevant amenity attributes of a neighbourhood. Determining the value of a particular pollution related benefit requires separation of other benefits affecting prices. In addition, these techniques do not measure all possible aspects of value; they only measure amenity (or user) values. Values associated with the existence of cultural and ecological assets (existence values) are not included. Yet it is existence values which are likely to be dominant for many species, habitats and ecosystems.

4c. Contingent valuation

Contingent valuation is the only valuation technique which can incorporate existence values, as it relies on purely hypothetical markets. It is sometimes presented as an alternative (based in the social sciences) to scientifically based "dose-response function" approaches to valuation of environmental assets. This is a false dichotomy based on a misunderstanding of the valuation process. The thesis is that CVM studies can ask respondents questions such as "What is your willingness to pay for the abatement of pollution from power station X?". However, valuation of pollution without reference to its impacts is a meaningless process, because it is the impacts which are relevant to human welfare functions and not the pollution *per se*. To attempt to short circuit the process by avoiding the impacts stage is akin to asking someone to value a shopping basket without knowing its contents. Without any information on which to make judgements, markets, even hypothetical ones, do not function and prices cannot be established. Contingent valuation methods are therefore most appropriately applied to the output of dose-response analysis, to environmental impacts whose significance is clearly understood by the respondent.

There have been major advances in recent years in the practice of CVM to avoid some sources of bias. Nevertheless, even where the impact to be valued is well defined, some problems remain. Ecological systems are particularly difficult. Some CVM studies have attempted to value individual species by willingness to pay to prevent extinction. But real ecosystems are complex and highly interdependent. Any attempt to value a species out of this context is therefore unrealistic. A related problem is "embedding": a series of individual CVM valuations of a set of natural assets tends to produce declining values and to give a sum which is higher than a single valuation of the whole set. Not surprisingly, responses to CVM surveys are conditioned by disposable income, and therefore problems are encountered when it is hypothesised that large numbers of assets lose their "free goods" status.

6. Is Valuation the Answer? - Some Paradigm Issues

Valuation of the impacts of pollution tends to rely on the identification of assets which will be damaged and their individual values. These seems acceptable for most of the traditional pollution problems which are local or regional in scale. However, the "newer" global pollution issues such as climate change throw up new problems.

Expected changes include large scale desertification, flooding of whole regions and countries, mass migration and risk of war - damage categories well outside the scope of usual micro-economic analysis. Clearly for these issues it is necessary to understand interactions within the whole socio-economic systems. Ideally a world environmental-socio-economic models are required in which all of the interactions can be analysed. Needless to say such models are difficult to build.

Many impacts have very long characteristic timescales, and therefore their value as a function of time needs to be considered. The practice of discounting has been designed to ensure efficient allocation of scarce capital in real markets. Discounting of the value of free goods and discounting across generations are controversial. There is no reason to assume that questions of inter-generational equity in a sustainable economy are handled effectively within the same conventional market framework.

The problems in valuing key natural assets, such as major ecosystems and the services of the atmosphere and oceans are more than technical questions for environmental economists. They throw in to sharp relief the whole paradigm of placing monetary values on the natural environment. It is clearly inappropriate to allow constraints upon disposable income to determine the value of natural assets which are critical to human survival. These natural assets cannot be treated as an extension of existing market economies - they are the *sine qua non* for the operation of any economy.

The concept of sustainable development seems to offer a way forward, in which these key natural assets are protected from significant degradation. But the questions of which assets should be treated in this way and the level of change which is acceptable then need to be resolved.

Ultimately many of these questions are philosophical. Is it possible to reduce all human experience to a single quantifiable dimension called value? Is it acceptable to make decisions solely on the bases of human welfare without regard to other species except in so far as they impact on us? These questions do not have simple agreed answers.

7. Conclusions

Environmental regulation can be undertaken with a range of different objectives. Requiring polluters to take reasonable steps to minimise their emissions, securing good environmental quality standards, maximising economic efficiency and promoting sustainable development are all possible objectives. The choice has very significant consequences for the level, type and complexity of regulatory instrument and monitoring regime.

Measuring the benefits of environmental regulation in monetary terms is an increasingly common goal. This is difficult to achieve. Uncertainties in both the science and the economics are significant and in many cases are likely to persist for some time. Benefit estimation is therefore unlikely to provide a justifiable approach to the setting of precise levels for financial instruments such as emission fees. However, benefit estimates will increasingly provide good order of magnitude estimates, useful for identifying major environmental problems and providing guidance on BATNEEC.

For global environmental problems, the whole paradigm of valuing the environment runs up against major problems. Macroeconomic changes, intergenerational equity and environmental assets critical to human existence cannot easily be factored into conventional benefit estimation procedures. As an alternative paradigm, sustainable development provides a useful goal, but has yet to be converted into concrete policy and regulatory objectives. The problem of how to account for the natural environment in decision making is therefore not going to be solved easily.

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