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ECONOMICS AND THE ENVIRONMENT: A SURVEY OF ISSUES AND POLICY OPTIONS

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INTRODUCTION AND SUMMARY

This paper addresses *two* issues: how economic considerations should be given due weight in environmental policy-making and how environmental considerations should be better integrated in economic policy decisions.

The intensified interest in the environment in economic policy discussions can be attributed to several related factors:

- a growing awareness that environmental problems have important economic dimensions that must be brought to the forefront in order to enhance social welfare;
- the recognition that charges and other economic instruments, which have important effects on both the macroeconomic level and the structure of economies, are likely to have a key role in this process;
- the fact that market failures or distortions not directly related to the use of environmental resources may lead to sub-optimal environmental outcomes, for example when road congestion in urban areas boosts the exhaust emissions associated with a given amount of travel;
- the transborder or even global nature of many environmental problems which accentuates the need for improved international co-ordination of environmental policies: concerns about the effects of certain emissions on the ozone layer and global climate are the two most notable examples and have provided the catalyst for new debate.

Although global scarcity of natural resources was much debated in the **1960s** and **1970s,** few now accept the view that the world economy is moving towards a resource crisis. Concerns persist, nevertheless, but have shifted towards issues such as degradation of the atmosphere, soil, ground water and oceans. There is an important economic dimension to such environmental problems for two basic reasons:

- the divergence of the private costs of an activity from the social costs, which characterises the use and hence misuse of many environmental resources, notably air and water, means that the desired trade-off between environmental amenity and the production of goods is not achieved by market forces under laissez-faire conditions;
- environmental policies and developments increasingly have significant

macroeconomic repercussions while the pace and structure of economic growth impinges on the environment.

The issue of externalities and the link with the concept of sustainable growth is considered in Section I. The following section deals with the setting of environmental policy (Section II). The costs and benefits of environmental policy are discussed in Section III. The concluding section then addresses current policy issues, focusing in particular on those with an international dimension (Section IV). The remainder of the current section summarises the main points of the paper.

Externalities. A major cause of environmental degradation is the presence of external environmental costs. Open access to many environmental resources, which are regarded as common property by economic agents, means that these agents lack incentives to take the full costs of environmental degradation into account. Such costs will tend to increase over time as resources are degraded or depleted and thus become scarcer.

Sustainable growth. Economic growth is influenced by the relative scarcity of environmental resources, as the environment is used for the extraction of material inputs and the disposal of residuals. Establishing a meaningful definition of sustainable growth is a first step in analysing the interactions between the environment and economic growth. It is conceivable that the degradation of environmental resources might significantly reduce future consumption potential. On the other hand, measures taken to reduce environmental degradation may entail costs in terms of foregone production and consumption. There is thus a cost-benefit trade-off that needs to be clarified.

Policy instruments. The proper policy response to such problems is to internalise the cost of environmental degradation. Regulatory approaches have generally been preferred to date, and have in some cases been relatively successful in reducing pollution. But regulations ignore market mechanisms and provide no incentive to reduce environmental degradation at the margin. Expanding the use of economic instruments could increase the overall efficiency of environmental policies. This will become an even more important consideration to the extent that the scale of response to environmental problems increases. The relative efficiency of different policy instruments depends on specific considerations such as the regional extent of the problem, the number of pollution sources, whether monitoring is easy, the importance of transaction costs and the pervasiveness of other market distortions. Policy options should be as far as possible informed by cost-benefit analysis. A better integration of environmental and economic concerns may also be achieved by developing resource accounts alongside the national accounting system and by establishing indicators linking environmental and economic developments.

Sequencing of ***policy.*** Since the potential risks involved in the degradation of environmental resources are largely unknown, and may remain so for some time, it is important to have a strategy to cope with uncertainty and environmental risks.

The risk problem has implications for the extent and sequencing of policies. If some pre-emptive measures were to be carried out, it would be sensible to start with the cheapest and most cost-effective measures. For example, while it would seem that the shadow cost implied in stabilising the concentration of greenhouse gases could be substantial, there is considerable scope for reducing emissions of the most "efficient" greenhouse gases, CFCs, together with some substitution away from CO_2 emissions, at relatively low cost. Another step could be to identify those environmental measures which would serve to improve general economic efficiency, while at the same time increasing future options and flexibility. Such policies could include environmental tax reforms, and a reduction of those subsidies and regulations that significantly increase pollution by distorting market incentives.

International co-operation. The evidence on whether global environmental threats will cause substantial and irreversible damage is inconclusive. However, while it would seem necessary to be prudent, there is no reason to neglect the possibility of significant future environmental damage. Carefully prepared measures to curb global environmental pressures could thus be justified. Although there are obvious difficulties in setting up credible international agreements, policy responses in this domain will involve international co-operation if they are to be effective. A feature dominating environmental agreements to date is that they have generally involved equi-proportional targets for signatories. A less costly solution, globally, would be to let emission reductions vary according to abatement costs.

I. THE ECONOMIC DIMENSION OF ENVIRONMENTAL PROBLEMS

A. Environmental externalities

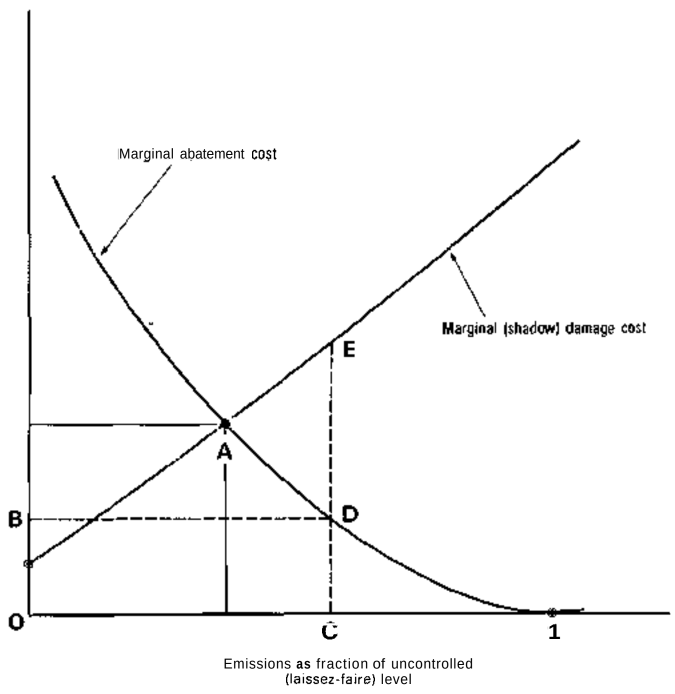
The production process and the consumption of goods often carries with it external environmental costs. Externalities arise because of the non-excludable nature of environmental goods. As no property rights are assigned to these resources, the environment is, in this respect, a public good. Herfindahl and Kneese **(1974)** state that air and water pollution, for example, occur because air and water are assets held in common, but with open access to depletion. In a market economy, unless private market agents own the affected recipients, some costs will be external and there will tend to be "excessive" environmental degradation. Some environmental problems may, therefore, be resolved by defining property rights (Coase, **1960).**

The abatement cost function illustrated in Chart 1 shows the marginal cost of preventing pollution. For most pollutants, marginal abatement costs typically increase with the amount of emissions abated. The optimal point of emissions is where the incremental cost of additional abatement just outweighs the gains from reduced emissions (the intersection point A in Chart 1). Any marginal cost of abatement less than the optimum (such as B) will lead to a level of emissions which is greater than the optimum (C), with marginal external costs amounting to DE not being internalised. Quantification of this sort of analysis is being carried out on a regular basis by the United States Environmental Protection Agency, and to some extent by other governments. It has also been attempted by Nordhaus (1990) for the case of climate change. As discussed in Section II, it is, however, not easy to derive robust estimates of both damage and abatement costs so that establishing an optimum policy is usually difficult in practice'.

There are both spatial and intertemporal dimensions of the externalities issue which need to be considered in judging how externalities should best be treated. ***The spatial dimension*** is important because the geographical diffusion of external costs, and hence the optimal choice of policy instruments, varies according to

CHART 1

ABATEMENT COST AND DAMAGE FUNCTION



specific geographical conditions. For instance, the impact of sulphur emissions may vary with soil quality in the immediate surroundings of the emission source, as well as with the amount transported long distances by weather systems. If sulphur is deposited on lime-type soils, the damage may be negligible, while it can be severe in more sensitive soils. This is an important issue for both air and water pollution (see boxes) but is also important in the case of wastes, particularly in densely populated and industrial areas. At the limit, as with the effects of CFCs on the ozone layer and of "greenhouse gases" on climate change, the external costs may be suffered globally.

The intertemporal dimension is relevant when damage arises from the build-up of pollution stocks as well as from pollution flows. Some pollution issues may

AIR POLLUTION

Emissions of substances to the air are in general dominated by natural processes; what is released into the atmosphere by human activity often consists of substances that are also emitted by natural processes such as plant decay or volcanic activity. Before human activities contributed substantially to emissions, natural systems evolved so that emissions and uptakes of compounds in ecological cycles were roughly in balance. Human activities have altered these cycles much more quickly than the natural systems can adapt through evolution. What we call air pollution are emissions which can be proven or suspected to imply substantial damage either directly to human welfare or indirectly through damage to our natural environment. The latter may vary greatly depending on local weather conditions, soil composition (e.g. acidification) and the ability of renewable environmental resourcesto regenerate.

Local air pollution in densely populated areas is largely responsible for most direct adverse health effects (see Annex Table A). The adverse effects of traditional air pollutants have been known for many years, and emissions of some pollutants have been cut back successfully, action against smog in London in the 1950s being an early example. Another example is the local or regional formation of photochemical oxidants and their effects on health and vegetation. The effects of photochemical air pollution – eye irritation, plant damage and visible smog (OECD, 1979) – first became manifest in the 1940s in the Los Angeles basin.

The acid rain problem is an important transborder problem in both Europe and North America. The main air pollutants causing acid rain are sulphur and nitrogen oxides that undergo chemical transformations in the atmosphere, forming acids and acid salts which may then be transported through the atmosphere. Policy action often co-ordinated by international agreements, has resulted in sharp reductions of SOx emissions since the 1970s. Progress in reducing NOx emissions was slower in many countries (OECD, 1988).

WATER RESOURCES

Water resource issues have been, over a long period of time, concerned mainly with quantitative matters: having enough water for household use and for agriculture. In some OECD countries (such as Australia, Spain and Turkey), this concern is still of prime importance. In the last few decades, however, emphasis has shifted from quantitative to qualitative water resource management. Water pollution abatement is responsible for about half of all pollution abatement expenditure.

Sources of water pollution can be divided into three categories:

- ***Municipal sewage*** or waste water is a major source of water pollution containing suspended solids, nutrients, heavy metals and bacteria that can cause disease;
- ***Industrial waste water*** is discharged into waterways and can contain persistent organic matter, cyanide, acids, alkali material, and heavy metals. The major polluting industrial groups are: pulp and paper, alkali, petroleum refining, fuel processing, chemicals, metal finishing and metal mining;
- ***Non-point pollution sources*** from land-based activities such as agriculture (through intensive use of fertilisers and pesticides), forestry, urban drainage, transportation, construction and sanitary landfill have become significant. For example, Annex Chart A shows a rising trend in use of nitrogenous fertilisers in all OECD countries over the past two decades, with the Netherlands being the most intensive user.

Progress has been made in many countries, particularly with pollutants that have been the object of control measures for more than a decade, such as organic oxygen-consuming substances, certain micro-organisms and some heavy metals like mercury or cadmium (Annex Chart B).

be regarded as strictly a problem of flows, as the substance in question will disintegrate or dissolve relatively quickly without any further damage to the environment. In many cases, however, pollutants accumulate in the atmosphere or in the soil, and it is the cumulative effect of pollutant stocks that has an environmental impact. Hence, flow problems can become stock problems: while nature for some time may seem to tolerate a certain flow of pollutants without any visible environmental impact, environmental degradation may then pass certain thresholds. Stock-flow relationships thus imply the presence of potentially large intertemporal externalities.

Such intertemporal user costs – or scarcity rents – represent the social opportunity costs of polluting today at the expense of tomorrow's environmental quality. Generally speaking, the more environmental quality is degraded, the scarcer it is, and the higher are implicit user costs (Howe, 1979; and Herfindahl and Kneese, 1974). User costs of pollution will not increase over time as long as natural regeneration, for instance the cleansing of acid rain in lime-type soils, offsets pollution. But beyond the thresholds determined by natural regeneration, environmental quality will decrease and user costs increase. The external costs of pollution may therefore increase at the margin as pollutants accumulate in natural recipients. As long as environmental quality is unpriced or undervalued, the magnitude of these externalities will tend to increase over time so that, ultimately, such externalities may threaten the sustainability of economic growth (Pearce, 1989). If damage costs can be shown to be significant, continued degradation of environmental quality, if unchecked, presents a ***prima facie*** case for government intervention.

B. Sustainable growth; concept and interpretation

The concept of sustainable economic growth is certainly not new. It was discussed by Malthus and Ricardo, who speculated on the "natural" limits to growth, the former focusing on rapid population growth, the latter on the limitation of land resources. Recently, the Brundtland Report (WCED, 1987) set out a concept of sustainable development, which focused on the achievement of a range of global goals encompassing sustained economic growth, the elimination of poverty and deprivation, conservation of the environment and enhancement of the resource base. Researchers have tried to flesh out different definitions of sustainable development, with Pearce ***et al.*** (1989) citing 30 examples. This paper limits the scope of the analysis, by focusing on the interaction between environmental developments and growth as conventionally defined.

If current economic growth leads to a decline in future welfare, measured as the per capita consumption potential of both marketable and environmental goods, the growth path would not be considered sustainable (Haveman, 1989). Hence, in per capita terms, sustainability can be defined as non-declining consumption potential – broadly defined. Consumption potential is in turn linked to future production potential and hence to capital stocks, measured in efficiency terms so as to include the effects of technological progress. If environmental resources are considered as part of the capital stock, then the total of man-made and environmental capital cannot decline if total consumption of marketed and environmental goods is to be sustained. Thus, in per capita terms, sustainable growth requires either non-declining stocks of both kinds of capital or sufficient substitution of productive capital for environmental capital to keep total capital stocks intact (Haveman, 1989 and Pearce, 1989).

The consumption – or welfare – potential will in each time period be an increasing function of the amounts of the two types of capital:

$$W = W(K,E) \quad [1]$$

where in each period in time and in per capita terms W equals consumption potential (welfare), K the stock of man-made capital, and E the stock of environmental capital. Introducing the "sustainability constraint" – that W is not allowed to decline in any period – yields as a necessary and sufficient condition for sustainable development:

$$-q\Delta E \leqslant AK \qquad [2]$$

where AE and AK are the changes in E and K over time and q is the real shadow price of environmental capital measured in terms of man-made capital, i.e. $q = (W'_E)/(W'_K)$. Hence, q is the shadow price (or cost) attached to an incremental change in environmental capital, measured in terms of man-made capital. According to [2], sustainability requires that the real value of environmental depletion must not exceed the real value of net investment in man-made capital.

In the presence of externalities, the market cost of pollution (i.e. the price paid in the market for the use of environmental resources) will fall short of the real shadow cost as expressed by q, the difference being the external costs imposed by polluters. External costs, which imply over-use of environmental resources, pose the inherent risk that the economy could follow an unsustainable path. Moreover, two factors strengthen the probability of such an outcome. First, as E falls, the marginal shadow price (q) of the remaining stock will rise; hence, given unchanged market costs of pollution, so will the external costs. Second, even if the stock of environmental capital is stabilised, its shadow price in terms of efficiency-augmented man-made capital will rise with income. Hence, for constant market costs of pollution, the total value of environmental degradation ($-qE$) will keep rising with growth in output and man-made capital stocks. In order to prevent this loss of welfare, the market costs of pollution may eventually have to increase. To ensure sustainability, the value of both types of capital should thus reflect their relative scarcity in the long run – as expressed by shadow prices.

Some argue that there is a high degree of substitution between the two types of capital, so that the accumulation of man-made capital and associated efficiency increases due to technological progress will easily offset environmental degradation. If this is the case, there should be little reason for concern about sustainability, as future generations will benefit from new opportunities.

Nevertheless, the known possibilities for substitution are limited, their expansion is far from clear and population growth is likely to put further pressure on the environment. If the scope for substitution is limited, the marginal cost of environmental capital could be expected to increase rapidly as environmental resources degrade, threatening sustainability.

Thus, there is strong reason to believe that sustainable growth, as defined above, cannot be achieved in the long run unless real market costs of pollution are rising towards the real shadow cost of environmental degradation. In addition, the development and adaptation of technologies to induce sustainable growth may itself be largely determined by the correct pricing of environmental resources. Moreover, as the environment is probably not an inferior good, the real shadow price of environmental services will continue to rise over time with economic growth and hence the market cost of pollution should increase accordingly. The sustainability issue is therefore intrinsically linked to the treatment of externalities.

II. ENVIRONMENTAL POLICY

A. Responding to market failure

In the first half of this century, Pigou and other economists recognised externalities as a source of market failure and suggested the use of fiscal instruments for internalising external costs. Since then, a substantial literature has accumulated concerning environmental externalities, various forms of related market and government failure, and the policy options available to deal with them[2].

In the early 1970s, the OECD formulated the Polluter Pays Principle. It states that the polluter should bear the cost of measures to reduce pollution decided upon by public authorities (OECD, 1986). Contrary to optimum principles, however, the Polluter Pays Principle does not specifically address the allocative efficiency of specific pollution control policies – that is, the question of *what* the polluters should pay. For instance, if the cost of mandated abatement measures exceeds the social cost of pollution at the margin, the application of the Principle will involve an over-optimal level of pollution control expenditure. Rather, the Principle is a "non-subsidy principle", according to which the costs of pollution *control* – not necessarily the costs of pollution – should be paid by the polluter.

In considering the choice of policy instruments a distinction is usually made between various forms of direct regulations (also known as the "command and control" approach) versus what are usually termed "economic instruments"[3]. The application of economic instruments usually implies that the market mechanism is used in controlling pollution. Examples of the two types of instrument are shown in the menu of instruments summarised in Table 1 and the relative advantages and disadvantages of each are discussed below. When environmental policies became more pervasive in the late 1960s and early 1970s, most OECD countries relied on regulatory controls[4]. By contrast, economic instruments were used rather rarely, and were subject to controversy and resistance by industry, government and the general public.

Table 1. Policy instruments for environmental policies

ECONOMIC INSTRUMENTS	
Redefining property rights	Tradeable emission permits; liability insurance legislation.
Charge systems	Effluent charges, user charges, product charges and administrative charges. Product charges would be for instance charges on the content of pollutants in products or input factors, whereas effluent charges and user charges aim directly at charging the cost of resource use.
Subsidies	Financial aid in installing new technology; subsidies to environmental R&D expenditure (often in conflict with PPP).
Deposit-refund systems	Combines charges and subsidies so as to provide incentives to return pollutants for recycling. Particularly relevant to waste management.
Enforcement incentives	Non-compliance fees, performance bonds. Although enforcement incentives can be regarded as a type of economic instruments, they are inseparable from regulatory measures.
REGULATION	
Standards	Effluent standards, ambient standards, technology standards. Setting requirements to be met usually by a limited number of market agents such as certain industries or individual companies.
Resource use quotas	Emission quotas, harvesting quotas (e.g. fisheries); by allowing quotas to be traded among market agents, the quota system would be transformed to a system of tradeable permits.
Negotiation	Negotiating rules to be set up for a particular industry or company. The distinction between this form and other types of regulation is that enforcement is often left to the industry itself (subject to the threat of further measures in the future).

Source: OECD (1989*b*).

B. Direct regulation

The arguments used for preferring regulation to economic instruments, which are elaborated below, include:

- substantial costs of implementing certain economic instruments which may be lower under regulation, depending on the case;
- the greater certainty of the effects of regulation on environmental quality may be more acceptable to legislators and/or electorates, although some economic instruments may be able to deliver the same certainty;

- economic instruments may have politically unattractive effects on income distribution that are to some extent avoided, or at least masked, under direct regulation.

The enforcement of environmental policies will tend to generate transaction costs that may significantly influence policy efficiency (Coase, **1960).** For instance, the efficiency of different policies depends heavily on the geographical diffusion of pollutants, with both damage costs and abatement costs of local pollution varying with geographical characteristics. When a small number of polluters is involved, such as with a single factory, this would tend to favour direct regulation. On the other hand, local regulations involve screening and compliance costs that could be reduced by using economic instruments, even though the latter may also involve monitoring and enforcement costs[5]. New information technologies may reduce these costs substantially.

The argument that regulation minimises uncertainty for both polluters and governments has some intuitive appeal. It may in some cases be an advantage for polluters. However, the authorities still have to choose between either price corrections or volume corrections. If one wishes to minimise the uncertainty of reaching a specific volume goal, such as a "ceiling" on emissions, it would seem that this might equally be achieved by assigning property rights (emission trading).

In some cases, regulatory policies might be perceived as "fairer", and hence be politically more viable. On the other hand, the main reason for this preference is perhaps not that regulation is fairer in terms of income distribution, but rather that it is a more effective way of hiding the real costs of pollution control and their distribution.

Regulatory regimes are likely to reduce incentives to search for clean technologies as administrative bodies have to prove that more stringent standards are technically feasible at low economic cost. Given the compliance cost and, therefore, low incentive for enterprises to co-operate on the one hand, and information being difficult to obtain on the part of the administration on the other hand, the outcome of negotiations to change the regulatory ***status quo*** is likely to be suboptimal.

C. Economic instruments

Economic instruments have tended to be used as supplements to direct regulations in mixed systems rather than being used as substitutes for regulation. A recent OECD survey (OECD, 1989*b*) covering 14 Member countries, identified some **150** cases of various economic instruments, including 80 applications of pollution charges (Table 2 and box). When properly designed, they should equalise market and shadow cost of pollution and oblige polluters to pay for the environmental services they consume, for example when they dispose of waste in a river. Such charges act as incentives by encouraging polluters to reduce discharges to the

Table 2. Application **of** different types **of** charges

	Type of charge							
	Effluent charges				User charges	Product charges	Administrative charges	Tax differentiation
	Air	Water	Waste	Noise				
Australia		x	x		x		x	
Belgium			x		x		x	
Canada					x			
Denmark					x	x	x	x
Finland					x	x	x	x
France	x	x		x	x	x		
Germany		x		x	x	x	x	
Italy		x			x	x		
Japan	x			x				
Netherlands		x	x	x	x	x	x	x
Norway					x	x	x	x
Sweden					x	x	x	x
Switzerland				x	x		x	
United Kingdom				x	x		x	x
United States			x	x	x		x	

Source: **OECD (1989*b*).**

extent that it is cheaper to treat them than to incur the charge (i.e. to the level where the unit rate of the charge equals the marginal abatement cost).

The use of emission trading is an alternative to the use of pollution charges. This innovative approach was developed in the United States, mainly in air pollution control (but also lately in water pollution control). The results are promising compared with the usual approach of direct regulations alone, and are leading to substantial savings. Where a statutory ceiling on pollution has been reached in a given area, a polluting firm can set up or expand an activity only if its additional emissions do not worsen ambient quality. The firm must therefore buy "rights" to pollute from other firms, which then are required to abate their emissions by an amount equal to the traded emission rights. The aim of emissions trading is twofold: first, to minimise the cost of pollution abatement by reducing emissions where marginal abatement costs are the lowest and second, to reconcile economic development with environmental protection by allowing new firms to set up activity in a given area without increasing the total amount of polluting emissions within it. In the face of the seemingly superior efficiency of tradeable emission allowances, one may ask why this system is not more widespread[6].

CHARGES

Effluent charges are payments on direct releases into the environment. They are often used in water pollution control (in Australia, France, Germany, Italy, Netherlands). Effluent charges are also applied in solid waste management (Australia, Belgium, Denmark, Netherlands, United States) and in the abatement of noise from aircraft (France, Germany, Japan, Netherlands, Switzerland). Implementation for these activities is eased by fixed and easily identifiable points of discharge and by applying the charges most often only to large sources of wastes. Effluent charges are chiefly used for financing individual or collective systems of pollution control. In the Netherlands, the level of charges for effluents to water are so high that they constitute a strong incentive to clean up water pollution.

User charges are payments for the cost of effluent discharge and treatment services. These are commonly used by local authorities for the collection and treatment of solid waste and sewage water. In many cases such charges are flat-rate and therefore fail to act as an economic incentive to pollute less.

Product charges are applied to the prices of products which create pollution either as they are manufactured, consumed or disposed of: for example, lubricants, sulphur in fuels, fertiliser, mercury and cadmium batteries, non-returnable containers, pesticides. Product charges are intended to modify the relative prices of the products and/or to finance collection and treatment systems, such as deposit-refund systems.

Administrative charges are chiefly aimed at funding systems of licensing and licence monitoring. Many countries apply them: for example, a charge on registering new chemical products (Norway), or for the cost of studying and authorising activity which will cause pollution (Sweden) or for inspection of motor vehicles (United States).

Tax differentiation, a practice similar to product charges, modifies the relative prices of products by penalising those harmful to the environment. In several countries (Denmark, Finland, Germany, Netherlands, Norway, Sweden, Switzerland, United Kingdom), tax differentiation on petrol is aimed at encouraging the use of lead-free petrol.

Economic instruments, if properly designed, have several appealing properties. They can:

- promote economic efficiency by allowing market agents themselves to decide upon the best way to reduce pollution; if the problem is to ensure proper pricing, economic instruments are intuitively appealing because they aim to treat market failures by adjusting prices for external effects;
- provide permanent incentives for technological improvements;

– reduce the size of the bureaucracy involved with regulatory approaches and minimise compliance costs; such approaches do not do away with all overhead costs, however, since, at a minimum, compliance must be monitored and enforced.

D. The choice of appropriate policy instruments

No single instrument can be said in general to be superior to others with respect to environmental policies. The particular properties of each issue need to be studied in detail before policy recommendations can be made. Nevertheless, current regulatory regimes seem to suffer from complexities and distortions that potentially involve serious efficiency losses. Where economic instruments have replaced regulation, substantial savings have been achieved, as with tradeable emission rights for air pollutants in the United States. The costs of distorted incentives are of special concern in the context of long-run effects on technological development and economic growth. In the area of global pollution, the relative advantages of economic instruments would seem to be greater than in the case of many traditional pollution issues, since the cost of pollution in this case does not depend on the location of the source.

Policy choices with respect to environmental protection can be framed in two ways – in terms of physical standards (for emissions or ambient quality) or in terms of abatement cost objectives. Setting volume standards without adequate information about costs is insufficient and may lead to inefficient outcomes, as the error on costs would be open-ended. Deciding on a certain level of abatement costs, and reducing all emissions where abatement costs are smaller than this target level, would bring efficiency considerations more to the fore. This approach fits with implementing policy by means of economic instruments, but it would focus on costs rather than volumes, and leave the error margins largely on the volume side.

E. Integration of decisions in a wider policy context

In addition to the use of appropriate environmental policy instruments, policy choices on environmental protection may have implications for the efficiency of policies in other sectors which impinge upon environmental issues, such as agriculture, transport and energy’. Pressures on soil and water resources, for instance, are being made worse by existing agricultural policies in most countries which encourage intensive farming. Agricultural subsidy schemes are often such that trying to control the environmental damage, rather than correcting the inefficiency in agriculture, is either futile or extremely costly.

Moreover, the interactions between various policies and concerns over the efficiency of environmental policy bring up the issue of *environmental tax reform.*

If environmental taxes are used to correct externalities and such revenue becomes significant, aggregate effects could be mitigated by lowering taxes on other inputs, such as labour and capital. This would be in accordance with general principles for efficient taxation: namely that taxes should first be levied on activities causing negative externalities.

III. THE MEASUREMENT AND ASSESSMENT OF THE COSTS AND BENEFITS OF ENVIRONMENTAL POLICY

A. Cost-benefit analysis

Given the significance of the costs of pollution and the shadow price of environmental capital, it would seem appropriate to use cost-benefit analysis to establish estimates for environmental damages and abatement costs. The United States, for instance, made all major regulations subject to a compulsory cost-benefit analysis in 1981 and similar techniques are also used in most other OECD countries, though on a more irregular basis. The value of attempting environmentally relevant cost-benefit estimates has been summarised by Schulz and Schulz (1989) as helping:

i) to make the economic dimension of environmental degradation clearer;
ii) to make the environmental debate more objective;
iii) to direct scarce financial resources to those areas of the environment where they are most urgently needed;
iv) to make polluters aware of the costs arising from their actions; and
v) to further develop statistical measures of welfare.

Assessing benefits. Two limitations of the cost-benefit approach can be identified on the benefit side. First, measurement of the concrete benefits (in terms of damage avoided) is inherently uncertain, although benefit studies can throw some light on the extent of environmental damage. Calculating monetary values for damages due to degradation of air quality, for instance, involves estimates of damages to property values, agricultural crop losses, health and so on, long into the future (OECD, 1989*c*; Pearce ***et al.***, 1989; Miltz, 1988; Freeman, 1985). Second, the general problem of putting a value on a public good arises in assessing the benefits from damage avoided. Willingness to pay for environmental quality, and thus the preferred trade-off between environmental and other goods, depends upon the preferences of the general public, as does the question of how to weigh the preferences of current and future generations. In practice, these preferences can only be made explicit through the political process. Assessment of benefits can nevertheless make these processes more informed.

While monetary evaluation techniques of ***environmental damage*** have improved considerably, few aggregate damage estimates are available. Where there are estimates, as for Germany and the Netherlands in the mid-1980s, they vary by large amounts owing to different approaches (Table 3). While the Dutch estimate shows damage of only ½ to 1 per cent of GDP, the German estimate is roughly 6 per cent of GDP. Both studies take pollution effects such as health, material, agricultural and ground water damage into account. The higher estimates in the case of Germany are largely due to allowing for the disamenity effects of air pollution and for the effect of noise on property values. While such aggregate estimates are, at best, "ball-park" numbers, they show that measured aggregate damage is a significant cost to the economy. No aggregate estimates over time are available for any country. Anecdotal evidence suggests that environmental pressures may have increased in some respects, but may have diminished in others such as with the large reductions of traditional air and water pollutants achieved in certain countries.

Table 3. Damage estimates for Germany and the Netherlands

	Germany	Netherlands[1]
	DM bil., 1983/85	Gld bil., 1985
Air pollution		
Health, crops, buildings, etc.	10.3	1.7 to 2.8
Disarnenity	48.0	
Water pollution	9.3	0.3 to 0.9
Noise	35.4	0.1
Total	103.0	2.1 to 3.8
per cent of GDP	6.0	0.5 to 0.9

1. Excludes disamenity effects.
Source: OECD (1989*c*).

Assessing costs. Analysis on the ***cost*** of ***abatement*** side, where greater precision may be possible, seems to have a more central role in informing political debate. Sound decisions can only be made knowing what the cost of abatement will be in terms of foregone consumption of other goods. Aggregate spending on abatement is a significant fraction of GDP. Aggregate abatement expenditure by the public and business sectors is roughly 1 to 2 per cent of GDP for most countries (Table 4). Around half of total expenditure is used on water pollution abatement,

Table 4. Abatement expenditure

Per cent of GDP

		1978	1985
United States	Total	1.6	1.5
	Public	0.7	0.6
Japan	Public	1.5	1.2
Germany	Total	1.3	1.5
	Public	0.8	0.8
France	Total		0.9
	Public		0.6
United Kingdom	Total	1.7 (1977)	1.3
	Public	0.8 (1977)	0.6
Canada	Public	1.1	0.8
Austria	Total	1.1	
	Public	0.8	
Denmark	Public	0.9	0.8
Finland	Public		0.3
Greece	Public	0.3	
Ireland	Public	1.0	
Netherlands	Total	1.1 (1980)	1.3
	Public	0.9	1.0
Norway	Total		0.8
	Public	0.8	0.5
Sweden	Public	0.8	0.7 (1986)
Switzerland	Public	1.0	

Note: Data cover operating expenses and investment expenditure by government and the goods producing business sector. In some cases outlays on charges and fees are also included. Coverage of data differs considerably between countries.
Source: OECD (1990).

while expenditure on waste management and air pollution control varies between slightly over 10 per cent and one-third of total expenditure (Table 5). The share of expenditure on air pollution control has been rising since the early 1970s, but total expenditure is still dominated by traditional public services such as water and waste management. For household expenditure, the statistics are sparser and more uncertain: in 1986, household spending on pollution abatement was estimated at 0.2 per cent of GDP in France and 0.4 per cent in the United States. Changes in aggregate expenditure as a per cent of GDP between 1978 and 1985

Table 5. Abatement expenditure by sector

Per cent of total expenditure, 1985

	United States	Germany[1]	France	United Kingdom	Netherlands
Water	50.5	52.2	52.2	37.6	45.6
Waste	23.2	20.1	33.6	33.9	26.2
Air	21.4	20.8	11.5	25.4	12.6
Other[2]	–1.1	6.3	2.1	3.1	15.6

1. 1984.
2. Other expenditure include items such as control of noise and radiation; in the case of the United States the negative sign reflects the fact that costs recovered due to resource recovery are deducted from the other expenditure.

Source: OECD (1990).

were small. Environmental protection investment was in some countries well above **10** per cent of total investment in certain energy-intensive industries, notably for energy production in Germany **(19** per cent), for the refining industry in the Netherlands **(22** per cent) and for the steel and metals industry in the United States **(11** per cent) (DRI, **1989).**

The ***effects*** of ***abatement spending on economic growth*** have been evaluated using macroeconomic models (OECD, **1985),** a growth-accounting framework (Denison, **1985)** and applied general equilibrium models (Jorgenson and Wilcoxen, **1989).** Negative effects on ***growth*** range from being negligible to a moderate **0.2** per cent per annum in the case of the United States over the period **1973-82** (Jorgenson and Wilcoxen, **1990).** The results reported by Jorgenson and Wilcoxen indicate that crowding-out effects of environmental control policies may have been under-estimated in previous studies*. As regards the future, it is quite likely that low-cost measures have been taken to date, and that further abatement could involve higher costs. There is certainly concern that both damage and abatement costs may increase significantly, in particular with regard to global issues.

B. National studies

Several national studies have evaluated likely future emissions and concentration levels and policy options for reducing discharges to certain target levels. The Dutch National Environmental Policy Plan (NEPP, **1989)** is the most comprehensive to date. **It** provides target values for emission, waste and noise reductions to the year **2010** (Table 6) and estimates of the costs and macroeconomic effects of different policy options. Several policy options are considered: a significant further tight-

Table 6. Dutch emission scenarios

Per cent changes

	Results in 2010		
	Scenario I	Scenario II	Scenario III
CO_2	t35	f35	–20 to –30
SO_2[1]	–50	–75	–80 to –90
NOx[1]	–10	-60	–70 to –80
NH_3[1]	–33	–70	–80
Hydrocarbons	–20	–50	–70 to –80
CFCs	–100	–100	–100
Discharges to Rhine and North Sea	–50	–75	–75
Waste dumping	0	–50	–70 to –80
Noise (leading to serious nuisance)'	t50	0	–15
Odour'	+10	–50	-60

1. Relative to 1980.
2. The changes for noise and odour refer to percent changes in numbers of people experiencing nuisance.

Source: NEPP (1989).

ening of emission control legislation, intensification of energy conservation regulation, increases in levies and charges on pollutants and the stepping up of public sector investment. For the scenario with the most stringent targets, annual expenditure on environmental protection would double to **4** per cent of GDP by **2010** and GDP would be **4.2** per cent below baseline by the year **2010** (Table 7).

Similar studies have been carried out in Norway. In the SIMEN study (Bye et al., **1989),** a policy analysis is carried out for stabilising CO_2 and decreasing SO_2 and NOx emissions substantially. In the base scenario – involving no further policy measures – emissions are projected to increase substantially by the year 2000. Scenarios with tighter regulations and higher pollution taxes suggest that the target of stabilising CO_2 emissions could be reached only by a substantial tax increase on fossil fuels, giving an increase in the real price of about 75 per cent. Such a tax increase induces a change in the fuel mix (towards natural gas and hydro power) and gains in energy efficiency. It would have to be complemented by additional regulatory measures to reach the targets for SO_2 and NOx. GDP would be **1** to **2** per cent below baseline by the year 2000, but sectoral output consequences would be much larger for some industries. In the "tax scenario", aggregate effects are mitigated by reductions in other market distortions. The net revenue increase due to fuel taxes, amounting to approximately **2** per cent of GDP, is used to cut direct taxes on labour and capital. Another study (Glomsrød et al.,

Table 7. Costs of the Dutch emission scenarios

Costs of the environmental scenarios I, II and III[1], in billions of 1985 guilders

	1988	2010 I	2010 II	2010 III
Gross annual costs	8.3	16.0	26.3	55.8
Annual savings	–	–	–	202
Net annual costs	8.3	16.0	26.3	36.8
Idem as per cent of GNP	1.9	2	3	4
Total investments in the period 1990-20 0	–	100	200	350
Cumulative effect on real GNP	–	-1.3	-3.5	-4.2

1. See Table 6.
2. Savings in energy and raw materials; these dependent on the development of energy prices. If the sudden 1985 price drop of 40 per cent were to be set aside, savings could amount to about Gld 30 billion.

Source: NEPP (1989).

1990) that investigates the effects of stabilising CO_2 emissions from 2000 onwards, gives similar findings. The relative price of fossil fuels would increase sharply and the average annual growth rate would be reduced by %percentage point compared to the baseline scenario.

C. The use of environmental indicators

Indicators of the discrepancy between actual developments and targets are required in order to monitor progress in meeting environmental objectives and hence to adjust policy as necessary. These indicators need to cover measures of emissions (or ambient quality), as well as measures of actual abatement costs. Developing indicators that link economic and environmental developments should enhance the integration of environmental and sectoral policies.

The System of National Accounts (SNA) records market transactions and gives imputations of some non-market transactions. Market-priced reductions in output due to environmental degradation are recorded as well as spending on abatement, waste disposal, environmental charges, etc. In connection with fairly disaggregated input-output tables the SNA may give a more accurate picture of monetary flows associated with environmental policies than survey-based results (Schafer and Stahmer, 1989). Apart from the identification of these expenditures it is often argued that spending for defensive purposes, now included in final demand categories, should be reclassified to be intermediate inputs, thereby subtracting them from GDP. Alternatively, to develop a better measure of welfare, it has been proposed to deduct pollution costs directly from GDP numbers, reflecting for example the disamenity cost of breathing polluted air. However, such imputations imply a normative judgement of environmental quality, whereas the current GDP measure is aimed at monitoring factual market activity rather than general welfare levels. The treatment of environmental spending and degradation will probably not be changed in any fundamental way during the forthcoming revisions to the SNA (Blades, **1989)**[9].

Nevertheless, knowledge of environmental policy objectives makes it possible to calculate the cost of the measures needed to achieve such objectives, and hence to construct a "green" GDP. Uno **(1988)** and Uno and Shishido **(1988),** for example, have estimated that the cost of moving to more stringent environmental standards in Japan would have reduced the level of GDP by about 4 per cent of GDP in **1960.** With the actual tightening of standards, these costs had fallen to about 2 per cent of GDP by **1985.** The introduction of a similar approach to calculate a "green" GDP is contemplated in the Netherlands (Hueting, **1989).**

An alternative broad aggregate indicator that has been suggested is the estimation of service flows from total environmental capital. Given that opportunity costs can be calculated by using targeted abatement costs, these prices can be connected to information on actual pollution or resource stocks in physical units. Hence, available information on the state of the environment may be translated into measures of flows of environmental services and estimates of damage caused by degradation of environmental resources. The use of extended (satellite) accounts is a comprehensive approach which links physical stocks of resources (material and environmental) to national balance sheets and resource use to (national) flow accounts. Such physical accounts – which have been established in France and Norway – would seem useful tools for including environmental assets in calculations of wealth (Pearce *et al.*, **1989;** Repetto and Pezzey, **1990).** However, there are still many practical difficulties regarding both the actual measurement of physical stocks and their conversion into monetary **values**[10].

IV. THE INTERNATIONAL DIMENSION

In current debates, global and regional air pollution issues have emerged as a particular problem, due not only to the complications involved in setting up credible environmental policies across borders, but also to the potential for high damage. The recognition that emissions of "greenhouse gases", in particular fossil-fuel related CO_2 emissions, are contributing to a global warming and hence a potentially damaging climate change has led to more emphasis being placed on the international dimension of environmental problems. A major complication in setting policy in this area is the uncertainty and risk associated with the issue of climate change. The way in which this problem might be treated and the main implications for international co-operation are dealt with below.

A. Dealing with uncertainty and risk

It is the element of uncertainty that makes the climate change issue such a difficult one on which to reach international agreement. Uncertainties concern the path of future emissions, concentration levels and their impact on climate change, as well as the cost of reducing GHG emissions. The scientific community has started to disentangle some of the main inter-relationships and cycles within and between ecosystems, such as the carbon cycle and the effects of CFCs on the ozone layer. However, major uncertainties persist as regards our understanding of these systems – the accumulation, the interaction and the geographical diffusion of pollutants – and their long-term effects on the economy. Damage, in both physical and economic terms, is particularly uncertain. The physical and chemical processes at work could induce unstable dynamic processes. Long lags and natural threshold effects further raise the possibility that very large and perhaps irreversible damage could become unavoidable by the time there was conclusive direct evidence of damage. Costs of abatement are also uncertain but would be likely to be very high if the objective was to prevent climate change. While recent research and policy experience have provided valuable knowledge, abatement costs often depend on unknown or hardly predictable technological developments that make the effects of control policies equally difficult to predict.

The attitude towards environmental risks may depend on the risk aversion of society as a whole, society's time horizon and discount rate, the magnitude of risks involved and the expected possibilities for substitution or technological improvements. Basically, these large-scale and long-term environmental issues pose a policy problem involving the social discounting of low-probability but high-damage events. One might think of these events as occurring in a large lottery with mostly tolerable outcomes – except for a few disastrous ones. The issue is what, if anything, governments could do, or should do, to reduce the probability of such outcomes even further. In particular, the question arises as to whether policies should be instigated to deal with improbable but potentially calamitous events.

The risk of committing society to substantial future damage costs is closely connected to the potential for irreversible resource depletion, such as might be the case for CFC emissions or for hazardous wastes that accumulate over time without disintegrating. The possibility of irreversibility poses a particular risk problem, which may be stated as follows: suppose that degradation of an environmental resource may lead to infinite recovery costs. The related expected damage costs may not be large enough in themselves to validate prevention of the resource being diminished. However, infinite recovery costs imply that the resource is irreversibly lost, and thus that there has been a narrowing down of alternative resource uses. This loss of alternatives may – in an uncertain world – have a value in itself, a so-called "option value", which in many cases may exceed the costs of preventing further depletion. Siebert *(1987)* describes an option value as "an insurance premium against the irreversible loss of an alternative"[11].

Two alternative response strategies can be distinguished: reaction and pre-emption. A ***reactive approach*** which involves taking action only as damage becomes manifest, including adaptive measures such as construction of dikes and dams to minimise the costs of a sea level rise. A ***pre-emptive approach*** would involve action to avoid the damage occurring in the first place, such as efforts to reduce greenhouse gas emissions or invest in an increase in carbon sinks through reforestation. While a purely reactive strategy might well turn out to be the least disruptive, it could also be the high-risk strategy, since it might induce action too late and fail to prevent some very costly outcomes. As a practical matter, the issue is where on the spectrum between purely reactive and fully pre-emptive action policies ought to be set.

Pearce ***et al. (1989)*** stress the way in which the interface between technological optimism and risks may influence policy. They indicate that, although one may be optimistic as regards future technological possibilities, high risk aversion or the presence of potential irreversibilities might nevertheless justify an "insurance approach", though not regardless of its costs.

The risk problem that has to be considered thus concerns also the extent of policy. Adopting an extreme strategy carries high risks with respect to the costs implied, be it risks of high environmental damage or over-investment in environmental safety. Whatever strategy is chosen, policy should be kept flexible so as to be able to take new information into account.

Concerning the climate change issue, a survey of model simulations by Nordhaus **(1990*a*)** confirms a conclusion that would hold qualitatively over the range of model simulation results: a carbon tax aimed at reducing CO_2 emissions would need to be large, increasing over time and in the long run encompass more than the OECD countries to stabilise emissions at current levels. This conclusion is confirmed by a survey of different models which address the cost of reducing greenhouse gas emissions (see Hoeller ***et al., 1991,*** in this volume).

The dimensions of the climate change issue are large – both in terms of potential, although as yet ***uncertain,*** damage costs and in terms of the adjustment needed to stabilise greenhouse gas concentrations. Hence, if policy is aimed at limiting greenhouse gas emissions, a sequential approach, by which low-cost measures would be phased in before measures with higher costs, could be desirable to reduce disruption and to allow time for adaptation. There might be scope for considerable overall improvements of efficiency that could at the same time increase future options and flexibility. This approach would seem likely to be particularly fruitful with regard to activities and market conditions closely tied to potential environmental degradation, such as:

- Increased taxation of the perceived external costs of air pollution and – if tax revenues were to remain constant – a consequent decrease in other tax rates. If applied gradually and on a general basis, a shift in taxation towards charges on externalities ("Pigovian" taxes) could result in overall efficiency gains and increase the potential for and profitability of innovations in "clean" technologies.
- A standardisation of tax rates across fuels to better reflect their environmental impact, so as to minimise distortions in consumption patterns due to existing tax differentials, for instance between close substitutes such as gasoline and diesel or coal and gas.
- Policies in the field of ***urban congestion and related transport policy incentives*** that, if applied consistently, could provide overall efficiency gains and at the same time reduce emissions of air pollutants – including emissions of CO_2 (OECD, 1988). Even when excluding environmental damages, the social costs of urban traffic congestion and motorised goods transport are often much higher than the private costs, and also higher than those of near substitutes such as public transport and railways (ECMT, 1989).

B. International co-operation on global and regional issues

Environmental agreements and conventions are covering a broadening field of policy areas, so that the cumulative effect on overall economic performance may become considerable. As the scope of environmental policy widens, it is increasingly important not to neglect the effects of control policies on overall investment and its allocation. Also, effects on the world economy and on international trade are likely to grow. Resort to trade restrictions on environmental grounds could pose a further threat to longer-term growth prospects.

A main conclusion of work by the OECD on transborder pollution, which dates back to the early 1970s, was that in order to ensure economic efficiency across country borders, it would be convenient to internalise both the costs of pollution and the costs of abatement. This led to the suggestion of the so-called "mutual compensation principle". The mutual compensation principle is a counterpart to the Polluter Pays Principle to deal with the efficient distribution of abatement and pollution costs between countries[12]. The polluter should pay for the pollution damage, thus encouraging polluting countries to take account of the external costs of pollution, while the "victim" country should pay for abatement, giving it an incentive to absorb pollution as long as this is the cheapest solution. Otherwise, if polluting countries are not compensated for at least part of the abatement cost, they have very little incentive to agree on cleaning up polluting activities that induce damage in other countries.

Since the mutual compensation principle was suggested, it has not been applied directly to any significant pollution issue. Two important reasons seem to be:

- The polluting country has no incentive to agree to mutual compensation as long as the "victim" will otherwise have to pay the damage costs. In other words, the polluting country would always be in the strongest position before and during negotiations.
- Because of the uncertainties involved, the "victims" of pollution have usually not easily been able to prove that the pollution is really causing economic damage. In many cases, it is difficult to prove even the extent of environmental damage, let alone to identify the polluter (atmospheric pollution, for instance, usually originates in more than one country).

As a consequence, the international community has started to take concerted action through ***international agreements and conventions on general policy goals*** rather than working out detailed compensation systems. The United Nations is the main negotiating body. Most OECD countries participate in discussions and negotiations under the auspices of the U.N. Economic Commission for Europe (ECE), which includes North American, as well as European Members of OECD and, importantly, Eastern European countries. The auspices of the U.N. Environmental Programme (UNEP) and various regional agreements under the UNEP framework have also played an important role. Over the years, a substantial number of agreements and conventions have been signed by varying numbers of participating countries. Some of the more important agreements as regards international or global pollution are shown in Table 8. Agreements or conventions that are likely or foreseeable in the near future include: a protocol on volatile organic compounds (VOC), which might be included under the Convention on transborder air pollution, and conventions on climate change and the emission of greenhouse gases arising from the work of the Intergovernmental Panel on Climate Change (IPCC), which was set up by UNEP and the World Meteorological Organisation, a process which may result in a proposal to the U.N. Conference on Environment and Development in **1992.**

Since the agreements and conventions usually do not include specific recommendations as regards policy instruments, it is often difficult to judge their effectiveness. Moreover, most of the agreements involving specific and quantified goals for emission reductions have "deadlines" well into the **1990s** and have thus not yet been put to the test. Nevertheless, for some substances, notably for sulphur oxide emissions, there has been considerable scope for reducing emissions using traditional abatement technologies and also considerable progress. One feature dominating the quantitative agreements to date is that they have involved equiproportional reduction targets for signatories. Such proportionate reductions gen-

Table 8. **Some international agreements and conventions on environmental protection**

The ECE Convention on Long-range Transboundary Air Pollution:

Signed by 34 countries in November 1979, and entered into force in March 1983, having been ratified by 24 countries; to this convention was added:

- *The Helsinki Protocol,* which was signed by 20 countries and entered into force in September 1987. In broad terms, the Helsinki Protocol states that the signatories reduce their national annual sulphur emissions or their transboundary fluxes by at least 30 per cent by 1993 at the latest (using 1980 emission levels as the base year);
- *A protocol on nitrogen oxides* (NO_x), which was signed by 25 countries in October 1988 in Sofia. This protocol will enter into force when ratified by 16 signatory countries. As a first step, the signatory countries agreed to take measures against further increases of NO_x emissions so that national NO_x emissions do not increase beyond 1987 levels after 1994.

The UNEP Convention for the Protection of the Ozone Layer:

Signed in Vienna in 1985; in 1987, the Montreal Protocol was added to this convention, in which signatory countries (46) agreed to halve their production of five chlorofluorocarbons (CFCs) and three halons by 2000; in 1990, a phase-out of CFCs was agreed in London by about 100 countries.

The UNEP Basel Treaty to control international trade in hazardous waste:

Signed in March 1989 by 34 countries and the EC; the signatories agree in principle to ban and establish notification procedures for all trade in hazardous waste.

Conventions to protect the marine environment include:

- *The 1972 London Agreement* on Prevention of Marine Pollution from Dumping of Waste and Other Materials;
- *The 1974 Paris Convention* for the Prevention of Marine Pollution from Land-based sources;
- *Conventions regulating the use of regional seas* (UNEP regional seas programme), such as the 1976 Barcelona Convention in which the 16 signatory countries agreed to the Mediterranean Action Plan, the 1974 Helsinki Convention on the Protection of the Marine Environment of the Baltic Sea Area (7 countries) and the 1987 London Ministerial Declaration on the protection of the North Sea (8 countries).

Other international agreements on resource preservation include the Law of the Sea (1982; 160 signatories), agreements on whaling, wetlands and migratory birds, Antarctica and the trade in tropical timber. UNEP (1989) lists altogether 140 various international agreements, conventions and protocols.

Source: **ECE (1989).**

erally involve efficiency losses, since both abatement costs and the consequence of damages vary between countries. In general, a less costly solution would be to let emission reductions vary according to abatement costs. This might not be of great importance if abatement costs are very limited, if regulations would have been imposed anyway (as might have been the case for SOx) or if the substance in question in any case will be totally banned (as occurred with CFCs). However, if the degree of international co-operation on these issues increases, the need to improve economic efficiency will be more pronounced. For instance, a proportionate cut in CO_2 emissions would involve significant efficiency losses as fuel and energy efficiency vary enormously between countries.

To ensure transnational economic efficiency, further efforts will be needed to reduce differences in marginal abatement costs between countries (see for instance Whalley and Wigle, **1990).** What this amounts to is an international agreement on cost objectives, rather than on equi-proportional quantity reductions. For instance, there would seem to be scope for substantial efficiency gains by allocating funds at the margin towards low-cost measures in Eastern Europe rather than high-cost measures in the OECD countries.

Monitoring the application of environmental policy instruments across several countries would, however, require substantial resources. Another and perhaps more appealing alternative, therefore, could be to agree quotas on emissions of polluting substances and then make these quotas tradeable between countries. Such quota trading would come close to the "mutual compensation principle" in that both abatement and damage costs would be internalised, at least at the country level, with the decision on whether to buy or sell quotas. The possibility of setting up a system of tradeable permits or quotas has been proposed in several connections, for instance to optimise the CFC phase-out process and to improve the efficiency of water management (OECD, **1989*a*).** Similarly, introducing tradeable CO_2 quotas as an alternative to proportionate cuts in emissions across countries would be an obvious possibility. A serious obstacle to this approach, however, is the difficulty involved in negotiating the initial distribution of the property rights assigned. For instance, it is not clear whether the initial quota distribution should be based on current emissions, emissions per capita or per GDP unit, or any other feasible criterion. Substantial income transfers could be involved, particularly if quotas were fixed in per capita terms and later extended to LDCs.

While it is conceivable that some countries could agree on policies to counter global environmental problems, countries not party to the agreement might conduct policies which would significantly reduce the value of the agreement in the long run. One possible solution to this problem would be to provide at least some economic incentive for such countries that would be based on conditions similar to those faced by signatories to an agreement. For instance, transfers could be conditioned on the basis of the same CO_2 quotas as applied by a hypothetical quotas-trading agreement. A somewhat different concept that has been agreed upon in connection with the phase-out of CFCs, is to make "green" technology easily available through subsidies from a transfer fund.

The appropriate response to global environmental problems will probably have to involve concerted international efforts, but setting up a credible global environmental policy is by no means a trivial task and one that will undoubtedly take time and patience. This underlines the need to proceed in steps, identifying and implementing the least cost and most clearly agreed policies and moving to more ambitious proposals as evidence and international consensus become clearer.

NOTES

1. Marginal damage could increase abruptly if there are threshold effects in the chemical and biological processes at work or within the ecosystem as a whole. For example, soils will have a certain absorption potential for acid rain, as acids are at first easily accumulated and may actually add nutrients to lime-type soils. If acidification continues, however, this might trigger damage to forest and soil as the acidity level exceeds natural toleration thresholds.
2. See, for example, Baumol & Oates (1988), Herfindahl & Kneese (1974) and Howe (1979).
3. The term "economic instrument" covers instruments involving a financial transfer between polluters and the community. Economic instruments operate as financial incentives to polluters, who then choose their levels of inputs and output accordingly. Broadly speaking, polluters may opt to pollute and pay for it or incur costs in reducing pollution.
4. A comprehensive overview of pollution control measures is given in OECD (1987).
5. As regards spatial differentiation of economic instruments, Siebert (1989) points out that "... a heavily polluted area requires higher emission taxes (than other less polluted areas)... Assume, for instance, one were to raise emission taxes for SO_2 generally in Europe in order to reduce the level of pollutants ambient in the environment and thereby reduce the transborder (pollution) problem. Then, abatement clearly would not be cost minimising, and the costs of environmental quality would be too high. Definitely, such an approach would not even be second best." On the other hand, Baumol and Oates (1988) argue that the transaction cost example rests heavily on the number of economic agents involved. If there are many involved, properly designed economic instruments could still be more efficient.
6. One reason may be that a change from a regulatory to an incentive-based system redistributes wealth. In particular, such schemes would generally be unfavourable to firms that currently hold existing free-of-charge emission permits. The same would also occur, however, in many instances, if regulatory mechanisms change.
7. The OECD has carried out case studies for several sectors. Sectoral studies completed so far relate to agriculture (OECD, 1989*d*), energy (IEA, 1989), transport (ECMT, 1989) and water resources (OECD, 1989*e*).
8. According to Jorgenson and Wilcoxen, the effects of pollution control are significantly magnified by its impact on capital service prices, and thus repercussions through capital markets would seem to be a major explanation of the difference in results.
9. Several attempts have been made to construct measures of welfare, which are more comprehensive than GDP estimates. Eisner (1988) surveys the U.S. literature on Extended Accounts. Such measures impute values for household work, leisure, etc. Concerning environmental disamenity, social costs of economic activity are subtracted, which are not internalised as private cost. In the accounts proposed by Nordhaus and Tobin, for example, disamenities of urban life include pollution, litter, congestion, noise, insecurity, buildings and advertisements offensive to taste, etc.

10. The literature on satellite accounts shows that there are several controversial issues, especially as regards the selection of discount, depreciation and depletion rates or the valuation of intangibles such as biological diversity. Nobody has yet suggested an adequate treatment of global problems that may result in uncertain damage far in the future.

11. See, for instance, Krutilla & Fisher **(1975)**, Henry **(1974)** and Arrow and Fisher **(1974)** for an elaboration.

12. The so-called mutual compensation principle was suggested as follows: "...the polluting country pays a 'pollution tax' related to the cost of damage estimated by the polluted country while the polluted country pays a 'treatment tax' related to the cost of pollution control as estimated by the polluting country. The purpose of the 'pollution tax' is to induce the polluting country to take suitable pollution control measures and the 'treatment tax' is intended to encourage the polluted country to accept the cost of residual damage... Like all economic instruments, it (the system) is based on the assumption that countries try to minimise the total costs due to pollution..." (OECD, **1976)**.

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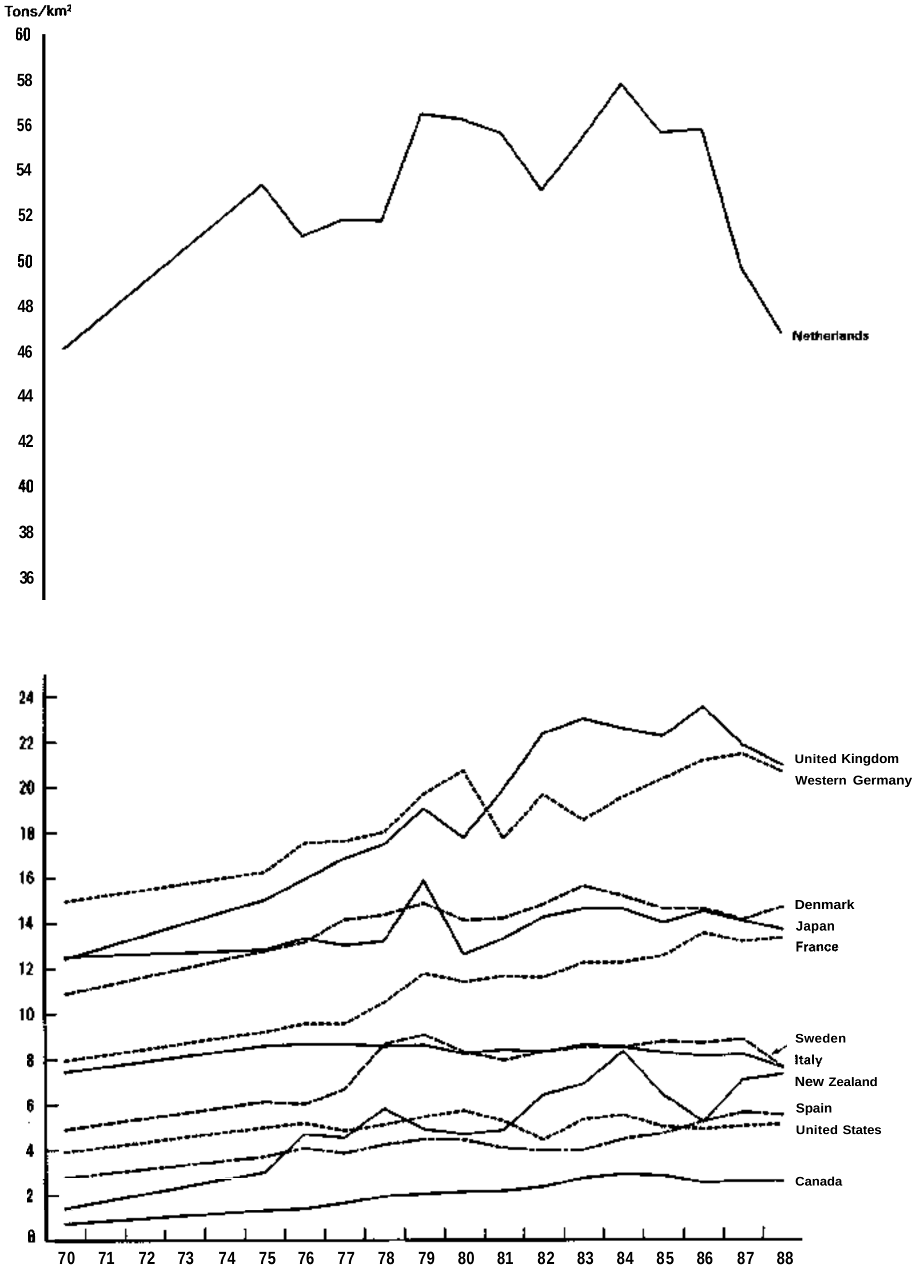
Table A1. Categories and effects of air pollutants

Pollutant	Direct effects	Indirect effects
Traditional air pollutants		
Carbon monoxide (CO)	Interferes with absorption of oxygen that can cause adverse health effects on central nervous system, exacerbating heart diseases	
Nitrous oxides (NOx)	Effects on respiratory system (irritation, oedema and emphysema), in particular in combination with other atmospheric irritants	Forms nitric acid through chemical processes in the atmosphere and thereby a cause of acid rain and fog
	Detrimental effects on dyes, fabrics, rub ber	
	Adverse effect on vegetation (more pronounced when occurring with high SOx concentration)	Together with hydro-carbon forms photochemical pronounced when occurring with high oxidants that have adverse effects on vegetation (living conditions, crop yields)
Sulphur oxides (SOx)	Adverse effects on respiratory system	Forms sulphuric acid when dissolved in water, which affects both close vegetation and buildings as well as formation of acid rain
Hydro-carbons (HC)	Class of volatile organic-compounds (VOC), which is toxic to humans in high concentrations (aldehydes, benzene, organic acids)	Together with NOx, HC forms photochemical oxidants (ozone in the lower atmosphere) that have adverse effects on vegetation (living conditions, crop yields)
	Adverse effects on plants	
Lead (Pb)	Damages various processes in body functions, such as kidney, liver, reproductive system, blood formation, basic cellular processes and brain functions (at high concentration levels)	
Particulate matter (aerosols)	Toxic or carry toxic substances absorbed onto its surface	
	Reduces visibility ("smog")	
	Soiling of fabrics and buildings	
Other air pollutants		
Chlorofluorocarbons (CFCs)		Class of chemical compounds that destroy ozone in the upper atmosphere when exposed for solar radiation. Also a greenhouse gas (see below)
Carbon dioxide (CO_2) Methane (CH_4)		"Greenhouse gases" that absorb infrared radiation and thus may increase the temperature in the lower atmosphere.

Source: OECD (1991).

CHART A

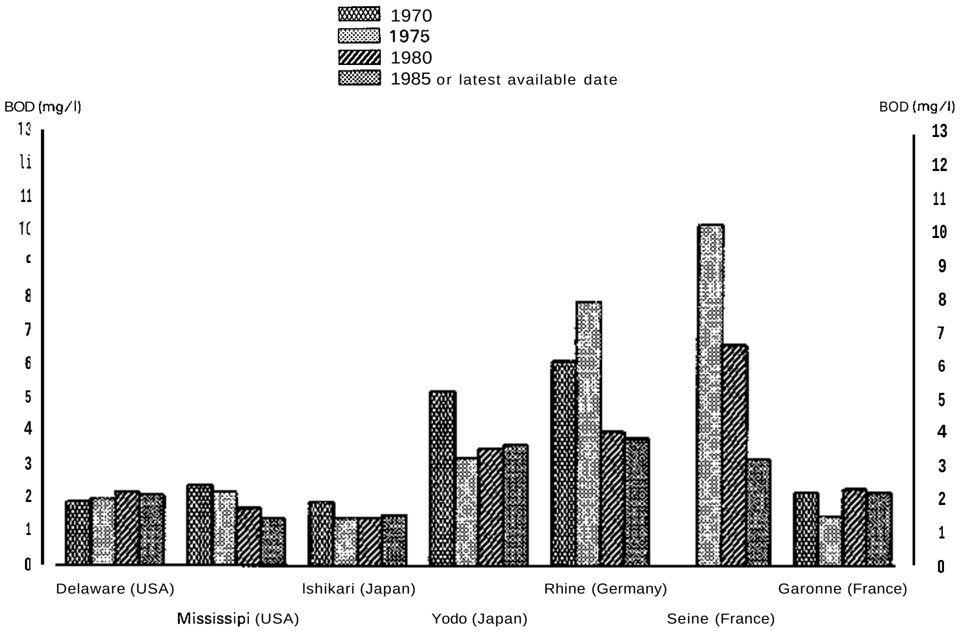
APPLICATION OF NITROGENOUS FERTILISERS ON ARABLE LAND

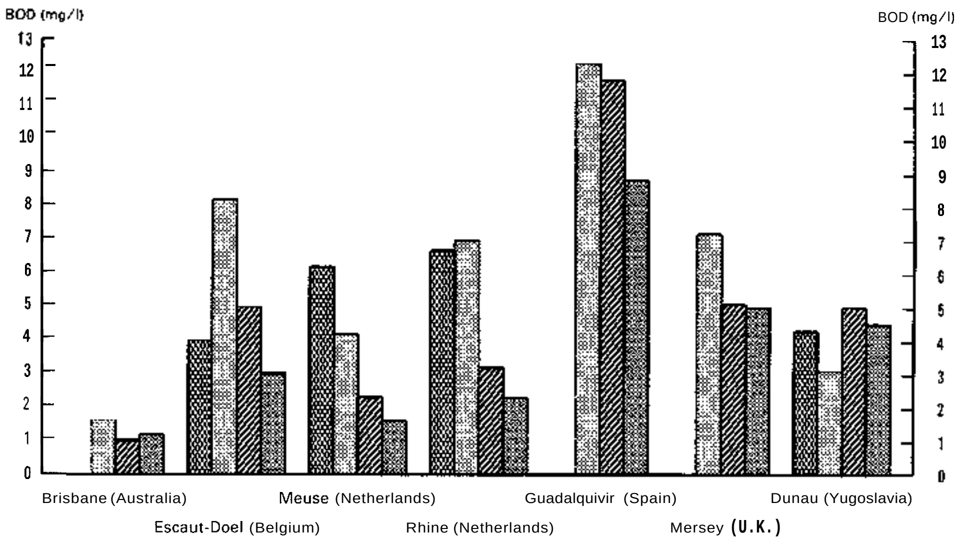


Source: OECD (1989)

CHART B

WATER QUALITY OF SELECTED RIVERS (1)





1. Biological oxigen demand, (BOD) at mouth or downstream frontier. High BOD indicates low water qualify.

Source: OECD (1989)