3.1. Economic Common Sense of Pollution: There will be very little real progress in solving the pollution problem until we recognise it as an economic problem. Of course, there are non-economic aspects of pollution, but all too often, such secondary matters dominate the discussion.

It is important for clear thinking about the pollution problem to understand a few economic concepts.

One of the most fundamental economic ideas is that of marginalism. The standard economic problem is to find out a level of operation of some activity which would maximise the net gain from that activity, where the net gain means the difference between the benefits and the costs of the activity. With the increase in the level of activity, both benefits and costs will increase but because of diminishing returns, costs will increase faster than benefits. With the attainment of a certain level of activity, any further expansion increases costs more than benefits. At the "optimal" level, "marginal cost"-equals "marginal benefit" from expanding the activity. Further expansion would cost more than its benefit and reduction in the activity would reduce benefits more than it would save costs. At the optimum level the net gain from the activity is said to be maximized.

The application of marginalism to questions of pollution, however,

is not simple. The difficult part lies in estimating the cost and benefit functions. But several important qualitative points should be noted. The first is that the choice facing a rational society is not between clean air and dirty air or between clean water and polluted water, but between various levels of dirt and pollution. The object must be to find out that level of pollution abatement where the costs of further abatement start to exceed the benefits.

Secondly, the optimal combination of pollution control methods is going to be a very complex affair. Steps demanding a 10 percent reduction in pollution from all sources, without considering the related difficulties and costs of reduction, will certainly be an inefficient approach. Where it is less costly to reduce pollution, a greater reduction is wanted to a point where an additional money spent on control anywhere yields the same reduction in pollution levels.

The efficiency of competitive markets depends on the identity of private costs and social costs. If a producer dumps wastes into the air, river or ocean, if he pays nothing for such dumping, and if the disposed wastes have no noticeable effect on anyone else, living or still unborn, then the private and social costs of disposal are identical and nil, and the producer's private decisions are socially efficient. But if these wastes do affect others, then the social costs of waste disposal are not zero. Private and social costs diverge and private profit-maximising decisions are not socially efficient.
The divergence between private and social costs is, thus, one of the fundamental causes of pollution of all types and it arises in any society where decisions are all decentralised.

3.2. Environmental Costs of Economic Growth: It is a useful way to estimate the contributions of different sources to the overall degradation of the environment since pollutant emission is a direct measure of the activity of the source.

Let us call the amount of a given pollutant introduced annually into the environment as the environmental impact, I. We can relate this value I, to the effects of three major factors that influence it, viz.,

\[
\frac{\text{Economic Good}}{\text{Population}} \quad \text{and} \quad \frac{\text{Pollutant}}{\text{Economic good}}, \quad \text{where}
\]

- Population refers to the size of the population in a given year;
- economic good is the amount of a designated good produced during the year and the pollutant refers to the amount of a specific pollutant released into the environment as a result of the production (or consumption) of the good during the year. One can then, estimate the contributions of these factors, viz, the size of the population, production (or consumption) per capita, and the amount of pollutant generated per unit of production (or consumption), which reflects the nature of technology, to the total environmental impact, I.

The pollution control policies of government and private firms are

based on risk analysis and assessment procedures. It involves the assignment of the risks of one action or of alternative actions and a comparison of these to the risks of several alternative actions in order to analyse fully the consequences of proposed policies and actions. Risk analysis is considered to be a valuable tool for policy decisions but William Ramsay points out that it involves many uncertainties in application and that it is neither infallible nor very precise. These uncertainties arise from ignorance about causes and effects, incomplete and inaccurate raw data and value judgements that are practically impossible to quantify.

3.3. Economic Instruments: Economic instruments are designed to achieve environmental goals. It can be defined as an instrument that affects costs and benefits of alternative actions open to economic agents, with the effect of influencing behaviour in a way that is favourable to the environment. Economic instruments typically involve either a financial transfer between polluters and the community in the form of various taxes, charges, financial assistance, user charges for services, product taxes or the creation of new markets (for example, marketable permits).

An appropriate pricing of environmental resources in order to promote an efficient use and allocation of these resources is one of the basic objectives of economic instruments. If the environment is priced correctly, environmental goods and services

can be treated equal to any other production factor in the marketplace and an economically efficient allocation of production factors can be ensured. In the situation of an optimal use of the environment, the marginal pollution reduction costs are equal to the marginal environmental damage costs.

However, environmental goods and services are not marketable. A number of methods have been developed to approach environmental pricing (such as the hedonic pricing and contingent valuation). There is in general, no proper information about the correct environmental prices or marginal damage costs. One approach is to equalise the marginal costs of environmental protection by putting a price per unit on pollution discharged. An efficient situation is thus achieved, because a given amount of pollution is reduced against minimum overall costs. Such environmental prices could be incentive environmental charges. Depending on the circumstances, least cost solution can be reached by tradeable pollution allowances. This cost saving potential is a major characteristic of economic instruments.

Environmental Charges or Taxes, Marketable Permits and Deposit - Refund systems are some of the more important economic instruments. These are examined below:

(i) **Environmental Charges**: These are charged in a straightforward way by putting prices on the use of the environment. In practice, they work out either as emission charges or as product charges. **Emission charges** are charged on the discharge of pollutants into air, water or on the soil and also on the
generation of noise. Emission charges are calculated considering the quantity and quality of the pollutant. User charges, including charges for the recovery of administrative costs have a revenue raising purpose and only those who are connected with the public service are charged. These can be directly related to the amount of pollution discharge. Product charges are levied on products which are harmful to the environment when in production processes or when consumed or disposed off. They can be applied to a product that causes environmental problems either because of their value or of their toxicity or of certain harmful contents, like heavy metals, PVC, EFC, halogenated hydrocarbons, nitrogen and phosphorus.

(ii) Marketable Permits: Marketable permits mean environmental quotas, allowances or ceilings on pollution levels initially allocated by the appropriate authority. These can be traded subject to a set of prescribed rules. Their main advantage is that they can reduce the cost of compliance. The prescribed rules are those necessary to ensure the attainment of the environmental goal.

(iii) Deposit Refund System: In this system a deposit is made on potentially polluting products. A refund is followed by returning the products or their residuals to avoid pollution. This system has the attractive element of rewarding good environmental behaviour. This system is in operation for a long time in the field of beverage containers for economic benefit as the returnable bottles used to be cheaper than the non-returnable bottles. Environmental authorities see environmental benefits also because
substantial parts of household waste consist of packaging. This system can considerably reduce waste volumes. Again this system can contribute to prevention of release of toxic substances into the environment. This instrument may be desirable as part of integrated life cycle management for certain products for proper handling (electric appliances). Deposite refund system is applied in OECD countries to a wide variety of products such as containers, batteries, etc.

Fields of Application of Economic Instruments.

Water Pollution: -

(i) Water pollution is particularly amenable to emission (effluent) and user charges or taxes because effluent discharge from stationary sources are relatively easy to monitor.

(ii) Product charges or taxes may be applied in the case of products that will pollute surface or ground water before, during or after consumption. If the objective of the product charge or tax is to discourage consumption, the quantity of the products consumed should be highly sensitive to prices. The availability of cleaner substitutes could considerably increase the success of product charges or differentiated taxes. Product charges or taxes can also be used as a proxy for emission charges or taxes.

1. Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxemburg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States, Japan, Finland, Australia, Newzeland, are the member countries of OECD - Organisation for Economic Co-operation and Development.


(iii) Marketable permits could be applied to point sources as well as to combination of point sources and non-point sources.

(iv) Deposit refund systems can play an indirect role in water management. Many potentially polluting substances (for example, pesticides) are packed in nonreturnable containers. When the containers are disposed of, the remnants of these substances are released into the environment and might pollute surface and ground water. Such remnants can be properly processed when containers are returned to the producer.

(v) Pollutants which are discharged in large quantities by many dischargers and which are easy to calculate or monitor or for which a common denominator exists can more easily be subjected to emission charges or taxes than the pollutants that occur in great variety and small amounts. Because of the complexity of the latter, a multi-phase approach is necessary, starting with those pollutants that are easiest to handle and lead to substantial improvements.

(vi) The main target groups for economic instruments in the field of water quality policy are industry (chemical, metal, food, pulp and paper, mining, etc.), agriculture and the households.

(vii) With regard to industry, application of emission (effluent) charges or taxes is possible where (a) industry can effectively reduce emissions in response to the charge or tax, (b) technical innovation is likely to be encouraged and (c) when the level of emissions can reasonably be monitored.

(viii) Agricultural pollution from point-sources (such as intensive animal husbandry units) can often be controlled by
regulatory means, like economic instruments in the form of effluent charges or taxes. The effectiveness of these instruments needs careful evaluation in the overall context of agricultural policy.

Air Pollution:

(i) In the field of air pollution control, emission charges or taxes may be considered as a complement or as a substitute for regulation. For administrative reasons, emission charges or taxes are more easily applicable to large volume pollutants and large stationary sources.

(ii) As energy production and use is a major cause of air pollution, energy pricing should take environmental factors into account. This can be done by applying product charges or taxes, in particular, charges on fuels in the form of a surcharge on or a variation of the excise duties on fossil fuels.

(iii) Creating price differentiation between traditional products and cleaner substitutes can be done by a combination of surcharges and discounts on the price of such products in a broadly revenue-neutral way.

(iv) Marketable permits can be considered in order to create market conditions for new and modified installations and regarding air pollution characteristics of some products (e.g. cars).

(v) Deposit refund systems can be applied to products that contain potentially polluting substances in closed circuits (e.g. refrigerators and air conditioners containing CFC's). Such products can be properly scrapped or recycled after return.

(vi) In the case of air pollution, the main target groups for
applying economic instruments are industry, energy and transport. The same constraints applicable to water pollution (mentioned above) should be taken into account for industry. For the energy sector, particular attention should be paid to proper integration of energy and environmental policies through appropriate pricing of energy resources. For the transport sector not only should transport pricing and taxation take into account the environmental factors but also specific economic instruments such as pricing / taxation of fuels reflecting the ultimate environmental damage caused, could be introduced as far as possible. Motor vehicles could also be subjected to environmental charges or taxes. Congestion charges or taxes mainly designed to alleviate traffic problems, could contribute to reducing air pollution. Finally, charging for the use of transport infra-structures (road pricing and other tolls) should also integrate environmental concerns when appropriate.

Waste Management :

(i) The aim of financing (user) charges is the proper collection, processing and storage of waste or the cleaning up of old hazardous waste sites. Incentive charges or taxes can have multiple purposes. The first purpose might be to minimize (voluminous and / or toxic) waste generation in production and consumption processes. Secondly, the purpose might be to discourage production and consumption of (voluminous and/or toxic) waste intensive products and to promote more "friendly" substitutes. Thirdly, the purpose of economic instruments might be to promote recycling which saves depletable resources, including space for waste dumping.
(ii) The emission (disposal) charges or taxes should be based either on the volume and/or the toxicity (or other harmful characteristics) of waste elements. Because of possible evasion, emission charges or taxes can only be applied if it is easy to control the dischargers. In most cases, user charges, i.e., payment for waste collection and the use of waste disposal facilities can be applied.

(iii) The product charges or taxes can be considered in the case of products that will generate waste in the production or consumption phases (e.g. plastic bags). Materials which can not be recycled or reused could be subjected to charges or taxes.

(iv) In those cases where a return of used products to collection or storage sites is important, a deposit refund system can be considered. A product subject to a deposit refund system should exist in large quantity and the necessary collection system should be manageable.

(v) In waste management, main target groups for economic instruments are industry, agriculture, households and the waste handling sector, be it public or private. Economic instruments may be applied to industry either because they produce products that will create waste problems when used or disposed of, or generate voluminous or toxic wastes. Agricultural wastes such as animal manures could also be charged for.

Noise Pollution:

(i) Economic instruments can be used to reinforce direct
regulation, improve enforcement of existing measures and speed up compliance with more stringent noise standards.

(ii) Charges or taxes on noise sources can be considered for aircraft noise, road traffic noise and industrial noise sources.

(iii) Product charges or taxes could be used with respect to appliances. Differentiation of taxes is conceivable with regard to noisy products and low noise-alternatives.

(iv) Other economic instruments considered with respect to other traffic problems could also work in relation to noise. Noise charges or taxes may also be a part of an integrated charging system on motor vehicles comprising pollution and other possible characteristics of vehicles.

(v) Transport, owners of domestic appliances and industry are the main target groups for the application of economic instruments to noise. Manufacturers and users of passenger cars and lorries, airports and railways should be considered in this group. Regarding industry, a variety of sectors are involved, among these are the construction sector as well as many large manufacturers.

3.4. Evidence on Control Costs: Economic efficiency in pollution abatement is related to the degree of control and to the technique used to obtain this abatement. It is often complained that environmental authorities have gone "too far" mandating pollution control because to obtain the last few percentage points of reduc-

tion, the cost far exceeds the social value of this abatement. If true, this excessive control contributes to economic inefficiency because the resources that are employed in pollution control could be more productively utilised elsewhere.

To minimize the cost of abatement, the cost of an incremental improvement in environmental quality within a given area should be equated across all sources of the offending pollutant. In practice this would require to know precisely the contribution of a gram of pollutant from each source of environmental degradation. If such precision in environmental quality modelling is absent, a proxy for the cost of environmental quality improvement is the incremental cost of pollution reduction for each source of pollution. Any set of policies generating equal incremental costs across sources, new and old, is referred to as cost effective.

The incremental cost estimate is actually the average cost per unit of pollution removed over the increment of control in question. If 10 grams of sulphur dioxide are released per kilogram of a product without controls and 8 grams are removed at a cost of 8 monetary units through the imposition of the weakest engineering standard, the incremental cost of this removal is an estimated 1 monetary unit per gram. If a more stringent standard would remove another 1.9 grams at an additional cost of 19 monetary units the estimated incremental cost of removing these 1.9 grams would be 10 monetary units per gram.
3.5. Estimating the Costs of Pollution: The measurement of costs and benefits of pollution abatement is very difficult. Only a small fraction of the costs of pollution can be estimated straightforwardly. Suppose, smog reduces the life of automobile tire by 10 percent. Then, a part of the cost of smog is 10 percent of tire expenditure. In polluted area, extra costs of painting, washing, laundering, etc., should be included in any calculation of the benefits of pollution abatement and yet they are only a part of the relevant costs and often a very small part. Thus, it really is possible to justify a measure like river pollution control only on the basis of costs to individuals or firms of treating water because it is usually less costly to process only the water that is actually used for industrial or municipal purposes and to ignore the river itself.

The costs of pollution which can not be measured so easily are often called "intangible" or "non-economic", although neither term is particularly appropriate. Some of these costs are as tangible as burning eyes or a dead fish, and all such costs are relevant to a valid economic analysis. Those costs are called "non-pecuniary" costs. L.E. Ruff suggests some possible ways of estimating the costs of pollution. One possible way to find the costs is to infer the costs from other prices. In principle, one could estimate the value that people put on clear air and beaches by observing how much more they are willing to pay for property in nonpolluted

areas. Such information could be obtained though at present there is little of it available.

Another possible way to estimate the costs of pollution is to ask people how much they would be willing to pay to reduce pollution. If it was known how much it was worth to everybody, then an estimate of the cost of a marginal amount of pollution could be obtained. The difficulty is that, there is no way of guaranteeing truthful responses. Response to the question, "how much is pollution costing for one" will depend on what one thinks will be done with this information. If anybody thinks he will be compensated for these costs, he will make a generous estimate. If he thinks that he will be charged for the control in proportion to these costs, he will make a small estimate. It thus becomes very important as to how these questions are asked. To estimate the costs of pollution including the so-called 'unmeasurable' costs, a set of questions of the following form could be used: "Would you like to see pollution reduced x percent if the result is a y percent increase in the cost of living?"

Larry E. Ruff now tries to estimate the benefits of pollution abatement. He says that engineers and technicians might work on the question: for each pollution source, how much would it cost to reduce pollution by 10 percent, 20 percent and so on.

Economists know that the cost of reducing total pollution by 10 percent does not mean the total cost of reducing each pollution source by 10 percent. Rather, they will use the equimarginal principle and will try to find that pattern of control for which
an additional unit of money spent on the control of any pollution source yields the same reduction.

3.6. The Benefits of Pollution Control and the Costs Involved:
Most studies of the benefits of pollution control focus on the effects on human health, optical visibility or crop yield. These effects are difficult to estimate because of poor data and the practical limitations on laboratory experimentation. With imprecise monitoring and limited information, epidemiological studies of health effects are subject to criticism. Clinical health studies are limited by ethical considerations and the laboratory experimental results are not easily extrapolated to the general population. Most studies of the impact of air pollution on human health deal only with the relationship between pollution and premature death. Data on morbidity are not usually available, but when available they are subject to substantial potential bias in reporting.

Non-health benefits are also difficult to quantify because the aesthetic values of clean air are not traded in the market place. Increase in visibility may be valuable but this value cannot easily be measured. For example, even if photochemical smog is not dangerous for health, it is generally unpleasant in high concentrations. The impact of pollution on marketable crops is perhaps the only effect that can readily be estimated by conventional techniques.

Even if the relationship between pollution on the one hand and human health, visibility and vegetation on the other are well understood, it would be difficult to estimate the benefits resulting from current pollution control policies. The calculation of the overall benefits requires several other steps. First, the effect of a policy on pollutant must be calculated. Secondly, any reduction in pollutant must be translated into an effect on ambient environmental quality. Thirdly, the population (or agricultural land) exposed to these pollution levels must be identified, since it is unlikely that abatement policies have affected all areas of the country uniformly. Fourthly, the impact of the reduction in ambient pollution levels on health or other phenomena (visibility, crop damage) must be estimated. Fifthly, the value of each incremental improvement in health, other amenities, or crop yields must be estimated. Finally, the total benefits must be calculated by multiplying the estimated improvements in health, amenities or crop yields by the incremental value of these phenomena.

Uncertainty clouds every step of the process enumerated above. Even if one knows how much pollution has been removed, one cannot be sure of its effect on ambient concentrations or the distributions of these concentrations. The major uncertainty in estimating the impact of such changes on mortality or the quality of life is compounded by the difficulty of placing a value on these changes at the margin. Estimates of the value of life are difficult to obtain and they are even more difficult to justify in an emotion-laden public debate. Given these problems, sharp
disagreement about the value of the benefits resulting from enforcing the Environmental Protection Act is hardly surprising.

Can anything be said about the desirability of relaxing or lightening industrial (and utility) controls from the estimates of costs and benefits of environmental control? Unfortunately, it can be said 'no' for two reasons. First, comparisons of total benefits and costs are meaningless for assessing optimality. Secondly, even if these are estimated accurately, the existing costs are not the minimum costs for the current degree of control. If benefits are greater than costs, a relaxation of environmental standards could increase economic welfare. Alternatively, a more efficient strategy of control could increase economic welfare by making controls more stringent.

These conclusions may be clarified from the following diagram. Let us assume that the additional benefits from reduction of pollution from each increment of control from 0 to 100 percent are measured by MB.
The total benefits would be the area under the MB schedule between the vertical axis and the indicated degree of control. The additional costs for each degree of control are given by MC. The total costs of control would be the area under MC between the vertical axis and the chosen control level.

It is assumed that 80 percent is mandated and that total benefits from this level of control greatly exceed total costs. A relaxation of control to 70 percent would increase economic welfare because everywhere to the right of 70 percent removal, the additional (marginal) cost schedule is above the additional (marginal) benefit schedule.

If the efficient cost schedule is substantially below the MC schedule, it would intersect MB to the right of the 70 percent abatement level. It could intersect MB at abatement rates of more than 80 percent. Thus from data on total current costs and benefits, it cannot be concluded that controls are either too stringent or too loose. Marginal costs of efficient controls should be compared with marginal benefits. Such a comparison is extremely difficult.

3.7. The Mechanics of Choosing the Optimal Control: Assuming that the policy makers seek to maximize the net benefits from pollution reduction, the problem becomes one of choosing the policy instrument to achieve this goal. In figures A and B below the marginal benefits resulting from controlling a given pollutant in a given

area are represented by negatively sloped curves. Total benefits are the areas under the marginal benefit curves. In figure A, benefits rise at a declining rate as control gradually increases. Thus, with increasing pollution control, incremental benefits decline slowly.

In figure B, benefits rise with pollution control at a sharply declining rate. This is equivalent to assuming a rather sharp "threshold" effect that finds much benefits for controlling up to Q1 but few additional benefits for controlling past Q2. For example, if the pollutant is a toxic substance generating major health effects above a particular concentration in air or water, and until this concentration is reached, the benefits of control are substantial. Thereafter, they may be much lower. The benefit functions for the pollutants like hydrocarbons, nitrogen, oxides, sulphur oxides and photochemical oxidants are fairly flat—reflecting no threshold effects upon human health, economic damage or aesthetic values. Highly toxic substances are more likely to fit the pattern of curve in figure B of the benefits relationship.

In both figures, the cost function is drawn with sharply rising incremental costs of control as pollution removal approaches 100 percent. This is a reasonable assumption given the engineering realities of control and declining marginal rates of substitution in production and consumption. It may be assumed that, in general, the additional costs of control per unit of pollution will rise at an increasing rate to control discharges more tightly. As pollution control forces substitution for products from polluting industries, the added costs to producers and consumers are likely
The Economics of Alternative Pollution Control Techniques

A. NO THRESHOLD

B. WITH THRESHOLD
to rise. Thus, for any environmental policy promising major reductions in pollution, it is reasonable to assume that costs rise rather steeply in the range of the desired or optimal degree of control.

Obviously, policy makers cannot know precisely the shape and location of the benefits and cost functions such as those in figures A and B. Though benefits are difficult to measure, it can be shown that uncertainties in the measurement of benefits have little impact on the choice of control technique. Uncertainties in the measurement of costs however are more important.

The broken lines in figures A and B represent a hypothetical locus of points, for instance, one standard deviation from the expected marginal cost function, which is shown as a solid line. The greater the uncertainty, the higher is the social cost of errors in setting the control variable.

A pollution fee or a quantitative standard is a control instrument available to regulators. Regulators equate expected marginal benefits with expected marginal costs to maximise welfare. In figures A and B, this equality occur at Qs. If the location and shape of the cost and benefit functions are known to the regulators, the choice of control instrument would be trivial. A pollution fee or tax set at P would lead businessmen to reduce pollution level to Qs as the businessmen would equate the price of polluting with the marginal cost of curtailing it. At Qs regulators could set the quantity standard, with the same result
except for the impact on income distribution.

Pollution taxes would not be collected on the remaining emissions (Qo-Qs) under the standard setting regime, but the pollution level would be the same. Mainly because of this reason businessmen generally prefer standards to pollution fees.

Regulators must worry about the choice of control instrument if there is uncertainty in the assessment of costs and benefits. Let us assume that actual marginal costs exceed their expected levels. If the quantity standard is set at Qs in figures A & B, the regulators have misallocated resources since marginal control costs (shown by MC1 in the figures) will exceed marginal benefits. Thus society will have paid more for pollution reduction between QL and QS (fig A) than it is worth, generating thereby a loss in economic welfare. This loss in economic welfare is represented by the dark and shaded areas labelled 1 in figures A & B. If again the control costs are below their expected value, as shown by MC2, the standard QS will create too much pollution (Qu - Qs) and a loss in welfare as measured by dark and shaded area 2.

If the regulator uses the pollution fee as the control instrument and control costs are precisely as expected, the result is to generate Qs in pollution reduction, the welfare-maximising level. If control costs exceed their expected levels (let MC1), the pollution fee will lead polluters to reduce their control efforts to Q1 when optimally they should have been induced to control to QL. This will generate a welfare loss shown as dark and shaded areas 4. If control costs are MC2, polluters will reduce their
pollution even further to Q2. As a result economic welfare equal to the dark and shaded areas 3 will be sacrificed.

A control instrument that results in the lowest potential welfare losses in the face of uncertainty depends on the shape of the benefit and cost functions. In figure A, the gradual decline in the benefit function, and sharply rising control costs, argues strongly for the use of the pollution tax. Areas 3 and 4 are obviously smaller than the areas 1 and 2. As Spence and Weitzman emphasize, "Standards fix pollution levels but leave clean up costs uncertain; in contrast, fees fix(incremental) clean up costs but leave pollution levels uncertain".

If the slope of the marginal benefit function is gentle, controlling costs and leaving the pollution level uncertain are preferable. Setting the "wrong" standard can be far more costly than setting the wrong pollution fee if incremental control costs are rising sharply. Thus, where there are no threshold effects and control costs are uncertain, pollution fees or taxes are better than quantity standards.

When there are distinct thresholds in the benefits function, the quantity standard is preferred as control instrument. It is better to control pollution directly than to control costs because substantial potential welfare losses can result from the wrong pollution level. It is evident from figure B that for areas 3 and 4, the losses from using a pollution fee are much larger than areas 1 and 2, the potential welfare losses for using the quantity
standard Qs for the same range of uncertainty in control costs.

The choice of control instrument (pollution fees versus standards) is not influenced by the uncertainty in the benefits estimation although it increases the range of potential welfare loss. If there is a range of uncertainty around the marginal benefits schedule as in figure C and D similar to the range with expected marginal control costs, the potential welfare loss for setting the wrong standard or fee is increased without affecting the choice between the two control instruments. If the benefits exceed their expected value MB1 as in figure C, the maximum potential welfare loss from setting the quantity standered at Qs is ACD. On the other hand, the maximum welfare loss from using a pollution fee at P would be GCX or EDF. Similarly, if benefits MB2 are below their expected value as in figure D, the maximum loss from setting a standard is abc, but the maximum loss from using a pollution fee P is bde or gfh. The fee remains superior to the standard where there are no threshold effects in the benefit function and with steeply rising incremental costs, although the potential losses from setting the wrong fee or standard are much larger. Since the cost of being wrong is greater, the case for fee is much stronger than in the certain-benefits case. When there are distinct thresholds in the benefits function and gradually rising incremental costs, this conclusion would be reversed. The regulator would be advised to set the pollution level directly and pay the penalty in uncertain control costs in the certain-benefits case.

It can be said from these considerations that pollution fees are
The Choice of Control Technique with Uncertain Benefits and Costs

FIGURE - C

FIGURE - D
preferred to pollution standard in every case except where strong
threshold effects exist in the relationship between pollution and
human health or other human values. As benefits are not traded,
uncertainty in the benefits function does not affect the choice of
control instrument. Private decision makers are influenced by the
pollution standard, the fee and the cost function but do not
respond to the shape of the benefit function. Though the
regulators must agonize over the magnitude of the benefits, their
anguish is not likely to affect their choice of instruments.

1 Stringency of the Standard: There is a strong consensus among the
firms that have borne the brunt of environmental control outlays,
that environmental standards are too stringent and that the
incremental costs of abatement often exceed the incremental
benefits of the environmental improvement they generate. This
observation does not mean a conclusion that too much is being
controlled. It may reflect the inefficiencies of current control
policies.

2 Inefficiency of the Standards: The method for regulating
environmental discharges is the setting of standards for individ­
ual point sources of pollution. These standards are numerous,
complicated and guided by statutory language that does not obey
and very often avoids economic efficiency. These standards do not
generate pollution reduction at the lowest possible cost. The
inefficiency of the standards resulting from the current maze of

1. R.W. Crandall "Controlling Industrial Pollution", The Brookings
regulation is the principal source of concern to economists who argue for pollution taxes or transferable pollution rights.

Inefficiency from the Wrong Mix of Standards: Choice of the wrong aggregate goal, \( Q_s \), as the basis for promulgating individual point-source standards is the major source of inefficiency in the current standard setting process. In figures A, B, C & D, the marginal cost schedules are drawn under the assumption that emissions are reduced first by sources with the lowest costs of control, with additional reductions coming from slightly higher costs sources or further reductions at higher costs from the first set of sources. Marginal control costs rise with additional reductions as this process continues. The additional cost of abatement at all sources applying controls must be equal at any given control level. If it is not so, a transfer of control of responsibility from the high marginal cost source to the low-cost source would reduce total costs to the society.

The standard setting process misallocates resources even more severely than the results in figures A, B, C & D because the regulators cannot have sufficient information to set individual standards efficiently. Economists argue for a market incentive approach (such as a fee) as a substitute for direct standard-setting regulation because regulators cannot know the costs of abatement at every source. For the standard setting process, the actual cost may be substantially above the marginal cost schedule as shown in figures A, B, C and D. As polluters presumably know

their own marginal abatement costs much better, they are, therefore, more likely to approximate the true marginal cost schedule in their abatement decisions. So pollution fees are likely to generate lower total control costs than a standard-setting regime that obtains the same degree of total pollution abatement.

In figure E, the superiority of fees over standards is shown diagrammatically. The ragged regulatory cost schedule reflects the unevenness of controlling pollution through a set of different standards for new and old sources in a number of different industries. To represent the likely inefficiency in setting these standards, its shape and location are arbitrarily drawn. The shaded area shows that the total economic loss from inefficiency in the choice of control targets and technologies is clearly larger than the social loss caused by choosing a quantity target, $Q_s$, instead of a fee. It suggests that the benefits of market incentives derive more from the proper selection of controls across sources than from the proper choice of an aggregate target under uncertainty.

1 The Opposition to Pollution Taxes: The general predisposition of economists for prices rather than quantities derives from the concern that incremental control costs be equated across sources. This goal can be achieved by other means. Therefore, "pollution tax" system is not required to generate this result.

A more compelling objection, with little empirical support, is that fees require substantially more enforcement outlays than

MARGINAL COSTS OF ACTUAL STANDARDS.
SOCIAL COSTS OF INEFFICIENT POINT SOURCE STANDARDS.
MARGINAL COSTS.
SOCIAL COST OF SETTING WRONG GOAL.
MARGINAL BENEFITS.

FIGURE E: THE SOCIAL COSTS OF INEFFICIENT STANDARDS.
standards. For standards, compliance can be assured by observing the control equipment while fees must be enforced by monitoring emissions. It ignores the possibility of using the equipment-surveillance technique for enforcing fees. For enforcing either a price or quantity mechanism of control, the imperfect monitoring of quantities of pollution, through verification of equipment can be used. Since, under a pollution tax system, the total tax bill is based on quantities of discharge, it would be difficult to argue that monitoring efficiencies make one system superior.

How fees differ fundamentally from standards in their effect on the distribution of wealth is overlooked in the debate over pollution taxes. Quantity standards are, in effect, licenses to pollute at a zero price up to the standard and prohibitions to pollute above the standard. Polluters will prefer such a system over one that imposes a tax equal to the marginal cost of control at the standard. If standards are uniformly set and enforced so that marginal control costs are equal everywhere, production techniques, product prices or pollution levels will not be affected by a shift to a tax--if the tax is precisely equal to the marginal cost of control under the old standards. But polluters will be losers because they must "lease" the air up to the standard by paying taxes rather than obtaining their standard ration at a zero price (Fig.F).

In Fig F, the marginal control costs for an individual polluter are shown by MC, rising at an increasing rate as pollution is reduced. The standard is set at BF unit of pollution per period, thus requiring a reduction of EB units from the "unconstrained"
level. The firm's total control costs are equal to the shaded area MEBA—the area under the marginal control costs function between E and B. These are the only costs of pollution borne by the firm in a standard setting regime. Nothing is paid for the right to pollute BF units per period.

FIGURE F: IMPOSITION OF A POLLUTION TAX

If a fee is imposed, inducing the firm to precisely the same degree of pollution control, the firm will continue to experience control costs of MABE but will also pay pollution taxes equal to BADF which are likely to be substantial.
A movement to pollution taxes from the current standard-setting process is unlikely to enjoy widespread support from the polluting industries, even though substantial efficiency gains can be realised.

Some proponents of environmental policy suggest that regulators use their discretionary power to set standards that will tend to equalise control costs across sources in an industry in order to avoid altering the competitive positions of the firms. This requires equalisation of control costs per unit of output, not of pollution. Fees or taxes would equalise incremental costs per unit of pollution.

Practical Alternative Approaches to the Control Problem: An efficient system of pollution control cannot be implemented without addressing the major problem of transferring property rights from producers to society.

Transferable pollution rights and pollution taxes with two-part tariffs are the two potential approaches to the control problem which would work much better. Each would allow the clean up process to be undertaken far more efficiently. The latter would permit a better expected allocation of resources for pollutants without threshold effects.

Freely Transferable Rights: A system of marketable rights would give a firm the right to emit pollution up to a specified regulatory standard or to sell this right. The firm could reduce its pollution by more stringent controls or by a reduction in its

1. R.W. Crandall, Controlling Industrial Pollution, Pages: 72-79.
output and would be able to offer the pollution right to another potential source of the same pollutant in the same area. It could choose to abandon production altogether and sell its pollution rights as it closes operation in that location.

For pollution rights market, the government should delineate the permissible range of transfers. One type of pollutant could not be traded for another. The total allowable pollution level for each of a myriad of different discharges or emissions should be specified by the initial endowment of pollution rights. Trades should not be made across geographical regions.

Benefits of a Marketable Rights System: A marketable rights system has a number of potential benefits like: (a) efficiency gains, (b) elimination of new source and old-source distinctions, and (c) signals to communities of the real costs of tighter controls.

First, the firms with generous initial allocations (generous standards) would think about sales to those less favoured in the standard setting process in a marketable rights system. Trades will cease when the opportunity cost of rights is equated in all firms in the area—where incremental control costs are equalised. Society would be benefited by lower-overall control costs without any degradation in environmental quality.

It would encourage polluters to improve pollution control techniques which would allow them to sell more of their endowments of pollution rights.
The advantage of this system over the straightforward emissions fees is that the standard setting process is used to generate the initial rights endowment.

Another benefit of regulation by freely transferable rights is the elimination of the current distinction between old and new sources. Standards for new sources are to be more stringent than those for existing sources on the basis of cost per ton of abatement. Businessmen will buy fewer rights for new plants than for older plants of equivalent size, if new plants are easier to control.

Finally, a marketable rights system will reduce the uncertainty for polluters and will help them plan their investment decisions.

Were the state to issue marketable rights, a market would develop for each pollutant and this would generate a price for cleaning up each pollutant. If the public wish even cleaner air or water, they could instruct the state authorities to reduce the quantity of those rights through purchases from current owners.

Objections to Marketable Rights: There are some arguments that these rights cannot be easily specified. Each plant is different, so reduction of emissions in one plant is not equivalent to reducing them in another. The decision to control pollution is affected by geographic location, coproducts, height of stacks, temporal distribution of output and other variables.

Given different transport characteristics and synergistic effects among pollutants, the specification of the spatial distribution of optimal pollution levels is not easy; but this hardly makes
marketable rights unworkable. Market boundaries should be drawn and trades should be allowed within these boundaries but not across them. Alternatively, trades could be allowed at different exchange rates across geographic boundaries.

The second objection to marketability of rights is that it would reduce the pollution control authorities' ability to monitor and enforce the actual levels of pollution. Enforcement of transferable rights system require some certification of the pollution discharged by both the buyer and the seller, before and after the trade.

A third objection to marketable right system is the interaction of pollutants in creating damage. If a social hazard is formed by combining several pollutants, they should not be addressed separately (unless one pollutant is always redundant). This complicates administration, because rights might have to be defined as a set of maximum pollution constraints and no one of which may be exceeded by the polluter.

Finally, if there are few buyers and sellers, the marketable rights approach is unlikely to work. Marketability of regulatory standard harms no one, it simply confers no advantages. A marketable rights system would be valueless only if the rights markets are defined as the confines of the current polluter's plants.

Effectiveness of a pollution rights market has yet to be proved. Hahn and Noll have dealt with this problem. They argue that the design and "initialisation" of the market are crucial. The initial
endowment must be distributed so as not to create monopoly or monopsony power.

A Two-part Pollution Tax: There is no denying the fact that pollution taxes are not likely to be the popular routes to the reform of an environmental policy. But perhaps this type of economic incentive for pollution control should not be so quickly dismissed.

The practical problem regarding fees is that they require payments for pollution rights at a zero price. A solution of the problem is to set two-part fees giving firms an allocation of zero-priced rights up to some specific limit and charging a fee for pollution beyond this initial level.

The initial allocation of zero-priced rights would reflect a political decision, but the setting of the fee would represent best judgement of the regulators as to the appropriate degree of control. The fee and the resulting pollution would give the citizens vital information on the cost of further clean up or the benefits of relaxation. The collection of pollution taxes would provide much more information on control costs than is currently available.

Taxes could be raised, if the resulting pollution levels were deemed too high. The most important benefit of a pollution tax system is that it would lead to efficient pollution reduction, since all firms would be subject to the same incremental cost of pollution in each area for each pollutant, each firm would control pollution until its incremental control costs equated this fee.
Thus, pollution taxes are equivalent to marketable rights.

The other advantage of fees lies in their effect on resource allocation in a world where benefits and costs are imprecisely known. When benefits are not known but the benefit function is rising at a declining rate, fees are likely to be the best choice of a control instrument. Setting the wrong pollution tax is measurably better than setting the wrong standard, if the optimal degree of control cannot be specified and if threshold effects of pollution do not exist.

Finally, the two-part pollution tax answers the unstated political objection to fees: that business will be compelled to incur huge additional costs without being assured of corresponding reductions in other business taxes.