Volume Title: Economic Analysis of Environmental Problems

Volume Author/Editor: Edwin S. Mills, ed.

Volume Publisher: NBER

Volume ISBN: 0-87014-267-4

Volume URL: http://www.nber.org/books/mill75-1

Publication Date: 1975

Chapter Title: The Instruments for Environmental Policy

Chapter Author: Wallace Oates, William Baumol

Chapter URL: http://www.nber.org/chapters/c2834

Chapter pages in book: (p. 95 - 132)

The Instruments for Environmental Policy

Wallace E. Oates, Princeton University and
William J. Baumol, New York University
and Princeton University

In their part of the continuing dialogue on environmental policy, economists have quite naturally stressed the role of policy tools operating through the pricing system. The case for heavy reliance on effluent charges to internalize the social costs of individual decisions is, at least in principle, a very compelling one. However, a cursory survey of potential policy instruments reveals the existence of a wide spectrum of methods for environmental control ranging from outright prohibition of polluting activities to milder forms of moral suasion involving voluntary compliance.

In spite of the economist's predilection for a central role for direct price incentives, we suspect that even he recognizes that a comprehensive and effective (and even the "optimal") environmental policy probably involves a mix of policy tools with the use of something more than only effluent fees. The purpose of this paper is a preliminary exploration of the potential and limitations of the various policy tools available for environmental protection; our concern here is what we can say in a systematic way about the particular circumstances under which one type of policy is more appropriate than another and how various policy tools can interact effectively. We stress the word preliminary, because this paper is, in effect, an interim report on a study of environmental policy.

In the first section, we enumerate and classify the available policy instruments. In the following three sections, we present a simple concep-

NOTE: We are grateful to the National Science Foundation whose support has greatly facilitated our work on environmental policy.

tual framework for the analysis of environmental policies and a discussion of what *in principle* would appear to be the appropriate roles for the various policy tools. We turn in the fifth section to an empirical examination of the effectiveness of the different environmental policies. Our work here is in its early stages; we have at this point some admittedly fragmentary and piecemeal evidence on the efficacy of available policy instruments. In some cases, we have had to rely upon evidence that is indirect, occasionally derived from experiences other than environmental programs, to obtain some insight into the likely effectiveness of a particular policy tool.

Policy Tools for Environmental Protection

Before examining the various active policy options available for the control of environmental quality, we want to acknowledge the case for a policy of no public intervention: we could rely wholly on the market mechanism as an instrument for the regulation of externalities, unimpeded by public programs designed to protect the environment. In fact, as Ronald Coase has shown in his classic article, it is actually possible, under certain conditions, to achieve an efficient pattern of resource use through private negotiation that internalizes all social costs or benefits. This can, at least in principle, result from the incentive for parties suffering damage from the activities of others to make payments to induce a reduction in these activities.

The difficulties besetting the Coase solution are well known, particularly the free rider problem and the role of transaction costs. The main point we wish to make here is that the Coase argument is plausible only for the small group case, for only here is the number of participants sufficiently small for each to recognize the importance of his own role in the bargaining process.[1] Note, moreover, that this requires small numbers on *both sides* of the transaction; even if the polluter is a single decision-maker, a Coase solution is unlikely if the damaged parties constitute a large, diverse group for whom organization and bargaining is costly. A quick survey of our major environmental problems—air pollution in metropolitan areas, the emissions of many industries and municipalities into our waterways—indicates that these typically involve large numbers.

1. Even in the small group case, the use of certain bargaining strategies or institutional impediments to side payments may prevent efficient outcomes.

This would suggest that the Coase solution is of limited relevance to the major issues of environmental policy.[2]

Turning to the remaining policy alternatives, we present in the following list a classification of policy tools that is admittedly somewhat arbitrary. We will examine four classes of policy instruments. The first category includes measures that base themselves on economic incentives, either in the form of taxation of environmentally destructive activities or, alternatively, of subsidization of desired actions. Under the second heading, we group programs of direct controls consisting of quotas or limitations on polluting activities, of outright prohibition, and of technical specifications (e.g., required installation of waste treatment devices). Third, we consider social pressure with no legal enforcement powers so that compliance on the part of individual decision makers remains voluntary. Finally, the fourth set of programs consists of an actual transfer of certain activities from the private to the public sector.

Tools for environmental policy:

1. Price Incentives[3]
   a) Taxes
   b) Subsidies
2. Direct Controls
   a) Rationing
   b) Prohibition
   c) Technical Specifications
3. Moral Suasion: Voluntary Compliance
4. Public Production

We stress at the outset that, while the list seems simple enough, it does conceal the vast number of ways in which these policy tools may be employed. Taxes, for example, may vary with time and/or place, may apply to particular inputs, or, alternatively, outputs or byproducts of productive activities, and so forth. Similarly, direct controls on polluting activi-

2. In certain instances, no intervention may, of course, be optimal for totally different reasons: not because the market will resolve the externalities itself, but because in that particular case the damage happens to be small while the social cost of regulation is large. Here we fail to intervene not because the disease will cure itself, but because the cure is worse.

3. The auctioning of pollution rights could be added here. However, considering the major environmental problems before us, the practicality of this proposal seems to us rather limited.

ties can take an enormous variety of forms, involving the courts or special regulatory agencies, permitting and sometimes encouraging citizen lawsuits, and so forth. This list is neither exhaustive nor composed of mutually exclusive policy measures. Programs of taxes and regulations, for example, can be combined to control waste emissions; we will, in fact, consider such policy mixes shortly.

Forms of Environmental Damage

In this section, we consider, in general terms, the various forms that insults to the environment may take. More specifically, we are interested in different types of environmental damage functions. As we will argue later, the damage function that characterizes a particular type of polluting activity may be of central importance in determining the policy instrument appropriate for its control.

The first distinction is between the situation in which the current level of environmental quality is a function of the *current* level of the polluting activity and the case where it depends on the history of *past* levels of the activity. The state of purity of the air over a metropolitan area, for example, depends largely on the quantities of pollutants currently being emitted into the atmosphere. This we will call a *flow* damage function.

Alternatively, past levels of activity may build up a stock of pollutant. Therefore, the extent of environmental damage depends on the history of the activity. This we call a *stock* damage function. Such damage functions are typically associated with nondegradable pollutants, such as mercury and DDT. The pollutant accumulates over time and thus constitutes an ever increasing environmental threat. The stock and flow damage functions are pure, polar cases. In reality there is a spectrum of damage functions in which historic levels of polluting activity assume varying degrees of importance in determining the present level of environmental quality.[4] However, the distinction is a useful one for certain policy purposes.

Of equal importance is the particular form of the damage function. Economists are familiar with cost functions which exhibit monotonically increasing marginal costs; a familiar example in the literature is the case

4. For an interesting theoretical study using a more general damage function which incorporates both stock and flow elements, see C. G. Plourde.

of crowding on highways. Once costs of congestion set in, the time loss to road users resulting from the presence of an additional vehicle rises rapidly with the number of vehicles. Many environmental phenomena, however, appear to involve more complex damage functions; some exhibit important discontinuities or threshold effects. When, for example, waste loads in a river become sufficiently heavy, the "oxygen sag" may become so pronounced that the assimilative capacity of the stream is exceeded. The dissolved-oxygen content may in such cases fall to zero, giving rise to anaerobic conditions. In such cases, the cost of exceeding the threshold level of the activity may be exceedingly high. There may, moreover, exist a series of thresholds so that the damage function can be exceedingly complex. In addition, the precise form of the damage function itself may be problematic, thus injecting an important element of uncertainty into the situation.

The uncertainty element in the damage function is not a haphazard affair, but arises out of the very nature of the relationship. It is essential to recognize that damage functions are multivariate relationships, functions of a vector of variables many of them entirely outside the control of the policy maker. The effects of a given injection of pollutants into the air depend on atmospheric conditions. The damage caused by a waste emission into a stream is determined largely by the level of the water flow: it may be relatively harmless when poured into a stream that is near its crest, but very dangerous when put into the same stream when depleted by drought. Externalities in urban affairs will be more or less serious depending on the state of racial tension, the level of narcotics use, and a variety of other crucial influences.

Expressed somewhat more formally, the function describing the determination of environmental quality at time s, q_s, may be written

$$q_s = f(m_s, E_s), \tag{1}$$

where m_s is the level of waste emissions and E_s is a vector whose components are environmental conditions, such as the direction and velocity of the wind, the quantity of rainfall, and so forth. The important thing about E_s is that it includes variables over which we have little, if any, control. The exogenous variables describing the vector, E_s, are themselves likely to be random variables, or at least subject to influences which can best be treated as random.

The environmental damage function may be defined as

$$z_s = g(q_s) = h(m_s, E_s). \tag{2}$$

While q_s indicates the state of environmental quality (e.g., the sulfur dioxide content of the atmosphere or the dissolved oxygen level of a waterway), z_s denotes the social cost associated with the value of q_s. For example, higher levels of sulfur dioxide in the air people breath appear to induce a higher incidence of respiratory illnesses and mortality (see Lave and Seskin); the costs associated with these repercussions are represented by z_s.[5]

The introduction of uncontrolled determinants of environmental quality and the associated uncertainty creates some difficult policy problems. For example, environmental control policy may have a combination of several objectives such as (a) the achievement *on average* of a level of environmental quality, q_s, such that the cost of environmental insults is acceptable; and (b) prevention of the attainment of some threshold level of q_s at which there is discontinuity in the damage function, thus causing social costs to soar to unacceptably high levels.

If the values for the components of E_s were known precisely for all future periods, we could set values of m_s for each period s so as to achieve these objectives, and we would look for the least cost methods of holding emissions to these specified levels. Unfortunately, we frequently do not know the values of E_s in advance. Normally however, we can make some predictions about them. In fact, we almost have a kind of probability distribution for variables such as weather conditions. Often the dispersion of the distribution becomes much smaller as the pertinent point in time approaches (e.g., we have a better idea about tomorrow's weather than next week's weather).

Even so, the policy maker cannot control most of the variables in the vector, E, and even his ability to foresee their values remains highly limited. The science of meteorology has not yet reached a stage at which forecasts can be made with a high degree of certainty. Meteorologists are unable to determine the timing of next year's or even next month's atmospheric inversions or rainfall patterns so that plans for the intermittent crises that are likely to result may be made in advance. This phenomenon can be extremely important in the selection of policy tools. It may be that, because of limited attention to this issue in the economics

5. More realistically, we can regard q_s and m_s as vectors whose components represent, respectively, various measures of environmental quality and levels of discharges of different types of wastes. This, however, seems to add little to the analysis. Note that z_s is a scalar, not a vector, for it represents the social cost, measured in terms of a numeraire, of the level of environmental deterioration (q_s) generated jointly by m_s and E_s.

literature, we have tended to overlook the merits of policy instruments usually favored outside the profession.

Matching Policy Tools with Environmental Conditions

Before proceeding to a more detailed empirical analysis of policy tools, we want to consider under what circumstances one policy tool is likely to be more appropriate than another. As a frame of reference, let us assume a set of standards or targets for environmental quality with an eye toward devising an effective environmental policy to realize these standards.[6]

In the case of stock damage functions with costs directly related to the accumulated quantity of the pollutant, a positive level of the polluting activity implies that the *level* of environmental damage will increase continually over time. The stock of pollutants will increase over time with the flow of emissions from one period to the next. Environmental quality will thus continue to deteriorate. Any damage thresholds may eventually be exceeded, and clearly the target level of environmental quality will not be achieved. In these cases there would appear to be a strong case for outright prohibition of polluting activities, for simply reducing the level of the activity will serve only to slow the cumulative process of environmental deterioration.[7] Outright prohibition would, therefore, seem to be an appropriate policy measure where damage functions are of the stock form. The recent ban on the use of DDT in the United States is a case in point.

Where, in contrast, environmental quality depends primarily on the current level of polluting activities, prohibition may be excessively costly. Achievement of the target level of environmental quality requires adjustment of the current levels of activities to those consistent with the target.

6. We could specify alternative types of objective functions. For example, we could assume standard utility and cost functions and, following the usual maximization procedures, derive our first order optimality conditions requiring that environmental quality be improved (or polluting activities curtailed) to the point where benefits and costs are equal at the margin. The major problem here is the difficulty of measuring benefits and costs. On this issue, see, for example, Baumol and Oates. Most of the discussion in the present paper applies, incidentally, to both of these approaches to environmental policy.

7. It might be desirable to curtail the flow of emissions gradually over time if the costs of rapid adjustment are high. This raises the interesting problem of the optimal path of reduction in the rate of flow, a problem which we note but which goes beyond the scope of this paper.

These required levels, in many cases at least, can be expected to be nonzero. A variety of the policy instruments included in our earlier list may then be appropriate to influence levels of polluting activities.

What *in principle* can we say about the relative effectiveness of these policy instruments? The efficiency-enhancing properties of taxes (effluent charges) are widely recognized and need little discussion here.[8] In terms of our objective, the realization of a set of specified standards of environmental quality, we have shown elsewhere (Baumol and Oates) that, assuming cost-minimizing (not necessarily profit-maximizing) behavior by producers, effluent charges are the least-cost method of attaining the target: the proper effluent fee will generate, through private decisions, the set of activity levels which imposes the lowest costs on society. Any other set of quotas determined by regulatory authorities and consistent with the specified environmental standards will thus involve a higher opportunity cost.

This would appear to establish a presumption at the conceptual level in favor of price incentives over regulatory rationing, and to make a system of fees an ideal standard with which others should be compared and judged as more or less imperfect substitutes. However, the proof of the superiority of the tax instrument involves a number of simplifying assumptions (and typically utilizes a static analytic model); there are several other critical considerations without which it is impossible to understand fully the inclination toward other policy instruments on the part of many noneconomists who are demonstrably well informed and well intentioned.

Once we enumerate these elements, their relevance is obvious. We will show that on economic grounds they may often call for measures other than the tax instruments that receive primary attention in the economic literature. This list includes the following.[9]

8. See, for example, Kneese and Bower, and Upton.

9. We might consider adding to this list the "political acceptability" of the program. This is not without an important economic dimension. Suppose we are given two programs *A* and *B* the first of which is shown capable of yielding an allocation of resources slightly better than that which would be produced by the latter. However, suppose that *B* can be "sold" to a legislature with little expenditure of time and effort, while the enactment of *A*, if it can be secured at all, would require a highly costly and time consuming campaign. In such a case, *purely economic considerations* may favor the advocacy of *B* in preference to *A*, if we are willing to take the predisposition of the legislature as a datum in exactly the same way we take the production function for a particular product as given for the problem of determination of outputs.

1. Administrative and enforcement costs (playing a role analogous to transactions costs elsewhere in theoretical analysis).

2. Exclusion or scale problems, which may make it difficult for the private sector to provide activities appropriate for the protection of the environment. (If one wishes, this can be classified as a special case of the problem of high administrative costs, the costs of collecting payment for an environmental service or of assembling the large quantity of capital needed to supply it efficiently.)

3. Time costs. Here we include not only the interval necessary to design a program and put it into effect, but also the period of adjustment of activities to the program.

4. Problems of uncertainty.

Let us now explore how these considerations, in the context of the objective of allocative efficiency, influence the choice among the basic types of policies listed in "Tools for Environmental Policy."

Pollution taxes

Beginning once more with the tax measures we see that, in addition to their desirable allocative properties, effluent charges possess a further major attraction: their enforcement mechanism is relatively automatic. Unlike direct controls, they do not suffer from the uncertainties of detection, of the decision to prosecute, or of the outcome of the judicial hearing including the possibility of penalties that are ludicrously lenient. Like death, taxes have indeed proved reasonably certain. Few are the cases of tax authorities who neglect to send the taxpayer his bill, and that is the essence of the enforcement mechanism implicit in the tax measures. They require no crusading district attorney or regulatory agency for their effectiveness.

However, once we leave this point, we are left with considerations in terms of which tax measures generally score rather poorly. We will defer the issue of time costs to a later point where its role will be more clear. It is true that *enforcement* costs are likely to be relatively low, although like any other taxes we can be confident that they will provide work for a host of tax attorneys employed to seek out possible loopholes. Perhaps more important in many cases are high monitoring or metering costs. One of the major reasons additional local telephone calls are supplied at zero charge to subscribers in small communities is the high cost of devices that record such calls, and the same is apparently true of communities in which water usage is not metered universally. This is particularly to the point when we recognize that allocative efficiency requires tax charges to vary by season of the year, time of day, or with unpredictable changes in environmental conditions (e.g., the charge on smoke emissions should presumably rise sharply during an atmospheric "inversion" that produces a serious deterioration in air quality). Moreover, in many cases there is no one simple variable whose magnitude should be monitored. Waste emissions into waterways should ideally be taxed according to their BOD level, their content of a variety of nondegradable pollutants, their temperature, and perhaps their sheer volume. Obviously, the greater the number of these critical attributes, the more costly will be the monitoring program required by an effective tax policy. This, of course, increases the complexity of other types of regulatory programs as well.[10]

A special problem may arise from the structure of the polluting industry. Under pure competition, fees will, in principle, work ideally; in addition, it is easy to show that they tend to retain their least-cost properties in any industry in which firms minimize cost per unit of output. However, under oligopoly or monopoly, management's interests may conflict with such a goal, and taxes on polluting activities may fail to do their job with full effectiveness. If an industry routinely shifts virtually all of the cost of such fees without attempting to reduce waste emissions in order to lower its tax payments, much of the intended effect of the tax program will be lost.

From all this we do not conclude that economists have been ill-advised in their support of tax measures. On the contrary, we continue to believe strongly that in many applications they will in the long run prove to be the most effective instrument at the disposal of society. However, it is clear that certain environmental and industrial characteristics can impair

10. The technology of monitoring industrial waste emissions appears still to be in its infancy; metering devices which provide reliable measures of the composition and quantities of effluents at modest cost are (to our knowledge) not yet available. Environmental officials in New Jersey, for example, rely heavily on periodic samples of emissions which they subject to laboratory tests, which involve costly procedures. However, there is a considerable research effort underway to design effective and inexpensive metering mechanisms. This may well reduce substantially the administrative costs of programs whose effectiveness depends on measurement of individual waste discharges. In this connection, William Vickrey has stressed, in conversation with us, the dependence of the cost of metering on the degree of accuracy we demand of it. In many cases, high standards of accuracy may not be defensible. As Vickrey points out, a ten-hour inspection of an automobile will undoubtedly provide a more reliable and complete description of its exhaust characteristics than a half-hour test, but it is surely plausible that the former exceeds the standard of "optimal imperfection" in information gathering!

their effectiveness. This, as we will suggest shortly, may point to the desirability of a mixed policy of fees and controls.

Subsidies

An obvious alternative to taxes is the use of subsidies to induce reductions in the levels of these activities; what can be accomplished with the stick should also be possible with the carrot. Kneese and Bower, for example, have argued that "Strictly from the point of view of resource allocation, it would make no difference whether an effluent charge was levied on the discharger, or a payment was made to him for not discharging wastes" (p. 57). However, in addition to some extremely important differences at the operational level between taxes and subsidies, Bramhall and Mills have pointed out a fundamental asymmetry between the effects of fees and payments. While it is true that the price of engaging in a polluting activity can be made the same with the use of either a tax or subsidy, the latter involves a payment to the firm while taxes impose a cost on the firm. As a result, the firm's profit levels under the two programs differ by a constant. We have shown formally that, in long-run competitive equilibrium, subsidies (relative to fees) will result in a larger number of firms, a larger output for the industry, and a lower price for the commodity whose production generates pollution. Moreover, it is plausible the net effect will be an *increase* in total industry emissions over what they would be in absence of *any* intervention. Subsidies tend to induce excessive output. Thus, at least at a formal level, taxes are to be preferred.[11]

Direct controls

Direct controls often seem to score poorly on most of our criteria, in spite of their appeal to a curiously heterogeneous group composed largely of activists, lawyers, and businessmen. They are usually costly to administer,

11. Subsidies may be desirable if there is reason to suspect that direct controls constitute the only alternative that is feasible politically. Two reasons for this are obvious to the economist: a) direct controls are likely to allocate pollution quotas among polluters in an arbitrary manner while taxes *or* subsidies will do this in a manner that works automatically in the direction of cost minimization; b) a direct control that prohibits a polluter from, say, emitting more than x tons of sulfur dioxide per year, under threat of punishment, offers that polluter absolutely no incentive to reduce his emissions one iota below x even though the private cost of that reduction to him is negligible compared to its social benefits. Thus, subsidies may sometimes be preferable to direct controls even though both of them produce misallocations.

because they involve all the heavy costs of enforcement without avoiding entirely the costs of monitoring in whose complete absence violations simply cannot be detected. We have already noted their tendency to produce a misallocation of resources. Moreover, experience suggests that their enforcement is often apt to be erratic and unreliable, for it depends largely on the vigor and vigilance of the responsible public agency, the severity of the courts, and the unpredictable course of the public's concern with environmental issues.

Yet direct controls do possess one major attraction: *if enforcement is effective,* they can induce, with little uncertainty, the prescribed alterations in polluting activities. We cannot expect controls to achieve environmental objectives at the least cost, but they may be able to *guarantee* substantial reductions in damages to the environment, a consideration that may be of particular importance where threats to environmental quality are grave and time is short. This points up two limitations of effluent charges: first, the response of polluters to a given level of fees is hard to predict accurately, and second, the period of adjustment to new levels of activities may be uncertain. If sufficient time is available to adjust fees until the desired response is obtained, the case for effluent charges becomes a very compelling one. However, environmental conditions may under certain situations alter so swiftly that fees simply may not be able to produce the necessary changes in behavior quickly (or predictably) enough. Where, for example, the air over a metropolitan area becomes highly contaminated because of extremely unfavorable weather conditions, direct controls (perhaps involving the prohibition of incineration or limiting the use of motor vehicles) may be necessary to avoid a real catastrophe.

There *may* be a further role for direct controls in industries dominated by a few large firms whose market power enables them to pass forward taxes on polluting activities without much incentive to undertake major adjustments in production techniques to reduce environmental damage.[12] This is frankly a difficult case to evaluate. Perhaps the best example is the ongoing attempt to impose technical standards for exhaust discharges on new automobiles. Because of the highly concentrated character of the auto industry, it is not clear that taxes on motor vehicles (perhaps graduated according to the level of exhaust emissions) would have much effect

12. Of course, it is normally desirable that some portion of the tax be passed forward in the form of price increases, as a means to discourage demand for the polluting output. The issue is that an oligopoly whose objectives are complex may not always minimize the costs of producing its vector of outputs.

on automobile design or usage.[13] A more promising approach may consist of legislated emission standards that will compel alterations in the design of engines so as to reduce the pollution content of vehicle discharges. However, the use of standards also involves difficult problems: witness the protracted "bargaining" between auto-industry representatives and federal legislators over the level of the standards and the timing of their implementation. Moreover, there is always the danger of adopting standards approaching complete "purity" that impose enormous costs; the reduction of polluting activities typically involves marginal costs that increase rapidly as the required reductions in waste discharges approach 100 per cent. The setting of emission standards without adequate regard for the costs involved may produce some highly inefficient results.

Hybrid programs

Even those policy makers who have come to recognize the merits of a system of charges as an effective instrument of control seem normally unwilling to rely exclusively on this measure. Rather they typically prefer a mixed system of the sort in which each polluter is assigned quotas or ceilings which his emissions are in any event never to be permitted to exceed. Taxes are then to be used to induce polluters to do better than these minimum standards and to do so in a relatively efficient manner.

While this may at first appear to be a strange mongrel, some of the preceding discussion suggests that, under certain circumstances, such a mix of policies may have real merit. If taxes are sufficiently high to cut emissions well below the quota levels, the efficiency properties of the tax measure will be preserved. Moreover, it retains the advantage of the pure fiscal method in forcing recognition of the very rapidly rising cost of further purification as the level of environmental damage is reduced toward zero. It is all too easy to set quotas at irresponsibly demanding levels, paying no attention to the heavy costs they impose. But it is hard not to take notice when tax rates must be raised astronomically to achieve still further improvements in environmental quality.

On the other hand, the quota portion of the program can make two important contributions, safety and increased speed of adjustment and implementation. Suppose, for example, there is a threshold in the damage

13. As Roger Noll points out, the case for effluent fees is the weakest "when regulators must deal with firms with considerable market power, and, at the other extreme, individuals with very little freedom of choice arising either from a lack of economic power, lack of knowledge, or lack of viable technical options" (pp. 34–5).

function so that a form of environmental abuse imposes a serious threat, but only beyond some point that is fairly well known. In this case, a hybrid policy can make considerable sense, since the quotas it utilizes can be employed to make reasonably certain that damages never get beyond the danger point. Taxes can be unreliable for this purpose, since, as noted earlier, the tax elasticities of pollution output are generally not well known and these fees may not induce changes in activity levels with sufficient rapidity. Thus, reliance on tax incentives alone may impose unacceptable risks, which can be prevented by a set of direct controls that set ceilings on levels of polluting activities.

Controls can, moreover, introduce additional flexibility into an environmental program. In terms of our illustrative case, urban air pollution, we noted that authorities may be able to invoke temporary prohibition, or at least limitations, on polluting activities when environmental deterioration suddenly reaches extremely serious levels.

Hybrid programs of taxes and controls thus represent a very attractive policy package. The tax component of the program functions to maintain the desired levels of environmental quality under "normal" conditions at a relatively low cost and also avoids the imposition of uneconomically demanding controls. The controls constitute standby measures to deal with adverse environmental conditions that arise infrequently, but suddenly, and which would result in serious environmental damage with normal levels of waste emissions.[14] Such a mixed program should not involve notably higher administrative costs than a pure tax policy, since much of the monitoring structure used for the latter should also be available for enforcement of the controls. In sum, where threshold problems constitute a serious environmental threat and where levels of polluting activities may require substantial alteration on short notice, which is not a rare set of circumstances, a hybrid program using both fees and controls may be preferable to a pure tax-subsidy program.

Moral suasion: voluntary compliance

We come next to the cases in which it seems appropriate to rely on appeals to conscience and voluntary compliance. As economists, we tend to be somewhat skeptical about the efficacy of long-run programs which

14. In this volume, Lave and Seskin report evidence that the mortality danger of air pollution crises may have been exaggerated. Nevertheless, it remains true that, during periods of stagnant air, the social cost of a given emission level will be high, because a great proportion of the polluting element remains over the city for a protracted period.

require costly acts of individuals but offer no compensation aside from a sense of satisfaction or the avoidance of a guilty conscience. In fact, the appeal to conscience can often be a dangerous snare. It can serve to lure public support from programs with real potential for the effective protection of the environment. Later, we will provide some evidence that suggests this to be a real possibility.

There is nevertheless an important role for voluntary programs. In particular, in an unanticipated emergency there simply may be no other recourse: the *time cost* of most other instruments of control may be too high to permit their utilization under such circumstances. A sudden and dangerous deterioration of air quality allows no time for the imposition of a tax or for the drawing up and adoption of other types of regulatory legislation. There may be no time for emergency controls, particularly if they have not previously been instituted in standby form, but there can be an immediate appeal to the general public to avoid the use of automobiles and incinerators until the emergency is passed. Moreover, as we shall indicate in a later section, there is evidence to indicate that the public is likely to respond quickly and effectively to such an appeal. Perhaps social pressures and a sense of urgency lie behind the efficacy of moral suasion in such cases.[15]

Casual observation suggests that the sense of high moral purpose is likely to slip away rather rapidly and thus implies little potential for long-term programs that rest on no firmer base than the public conscience. However, that is no reason to reject this instrument where it can prove effective, particularly since no effective alternative may be available. We suspect that we have not yet experienced the last of the unforeseen emergencies and, in extremis, time cost is likely to swamp all other costs in the choice of policy instruments.

Public provision of environmental services

The direct public "production" of environmental quality may be justified in two types of situations. The first is the case where the current

15. There is another precondition for the efficacy of moral suasion, even in an emergency. We can usually expect a few individuals not to respond to a public appeal. Thus, voluntarism cannot be relied upon in a case where universal cooperation is essential, as during a wartime blackout where a single unshielded light can endanger everyone. However, in most environmental emergencies as long as a substantial proportion of the persons in question are willing to comply with a request for cooperation, a voluntary program is likely to be effective. For example if, during a crisis of atmospheric quality, an appeal to the public may lead to a temporary reduction in automotive traffic of some 70 or 80 per cent, that may well be sufficient to achieve the desired result.

quality of the environment is deemed unsatisfactory (i.e., falls below the specified standard) as a result of "natural" causes and where this cannot be corrected through market processes because the particular environmental service is a public good. It is hard to find a perfect illustration, but natural disasters such as periodic droughts or flooding come close. Here the problem is not one of restricting polluting activities on the part of the individual; it is one of providing facilities such as dams and reservoirs to prevent these catastrophies. The private sector of the economy may handle such situations adequately if the commodity needed to avert the disaster is not a public good—that is, if exclusion is possible (or, more accurately, not too costly) and consumption is rival. However, where exclusion is difficult and/or consumption is joint, as in the case of protection from flood damage, the public sector may have to take direct responsibility for the provision of the good.

The second type of situation in which direct public participation *may* be appropriate is that involving large economies of scale and outlays. An example may be the case of a large waste treatment facility used by a multitude of individual decision makers. The reduced cost of treatment of effluents made possible by a jointly used plan may not be realized if left to the private sector.

This example, incidentally, suggests a further type of environmental service that the public sector must provide, namely the planning and direction of systems for the control of environmental quality. The need of reaeration devices, for instance, depends upon water flows (influenced by reservoir facilities), the levels of waste emissions (determined in part by current fees or regulations), and so forth. The point is that the control of water quality in a river basin or atmospheric conditions in an air shed requires systematic planning to integrate effectively the use of quality-control techniques. Kneese and Bower stress the need for river basin authorities to plan and coordinate a program of water-quality management. Urban areas require similar types of authorities to develop integrated air quality programs. Thus, public agencies must not only directly provide certain physical facilities, but must also exercise the management function of coordinating the variety of activities and control techniques that serve jointly to determine environmental quality. Such agencies need not be federal, but must be sufficiently large so that their jurisdiction includes those activities that influence environmental conditions in a given area. This implies jurisdictions sufficiently large to encompass systems of waterways and areas whose atmospheric conditions are dependent on the same activities.

Optimal Mixed Programs: A Simple Model

The logic of the argument in the preceding section for the use of hybrid programs in the presence of random exogenous influences can be more clearly outlined with the aid of a simple illustrative model. Such a model can indicate not only the potential desirability of such a hybrid as against a tax measure or a program using direct controls alone, it can also illustrate conceptually how one might go about selecting the optimal mix of policy instruments.

A relationship apparently used frequently in the engineering literature to describe the time path of environmental quality is (in a much simplified form)[16]

$$q_s = k_s q_{(s-1)} + m_s, \tag{3}$$

where:

q_s is a measure of environmental quality during period s,
k_s is a random exogenous variable (call it "average wind velocity") during time s, and
m_s is the aggregate level of waste emissions in period s.

In the presence of a tax program, the level of waste discharges will presumably be determined in part by the tax. Let us define

m_{is} = waste emissions of firm i in period s,
$c_i(m_{is}, \ldots)$ = the total cost function of firm i, and
t = tax per unit of waste emission.

Then, if the firm minimizes its costs, we will presumably have in equilibrium

$$\frac{\partial c_i}{\partial m_{is}} = -t. \tag{4}$$

That is, the firm will adjust waste discharges to the point where at the

16. Other forms of this relationship are obviously possible. For example, k_s and $q_{(s-1)}$ may be additive rather than multiplicative. The facts will presumably vary from case to case, but within wide limits the choice of functional form does not affect the substance of our discussion.

margin the cost increase resulting from a unit reduction of emissions (e.g., the marginal cost of recycling) is equal to the unit emission charge. Using the cost function for the firm and its cost-minimizing emission condition, (4), we can derive a relationship expressing the level of waste discharges of the ith firm as a function of the unit emission tax:

$$m_{is} = h_i(t_s). \tag{5}$$

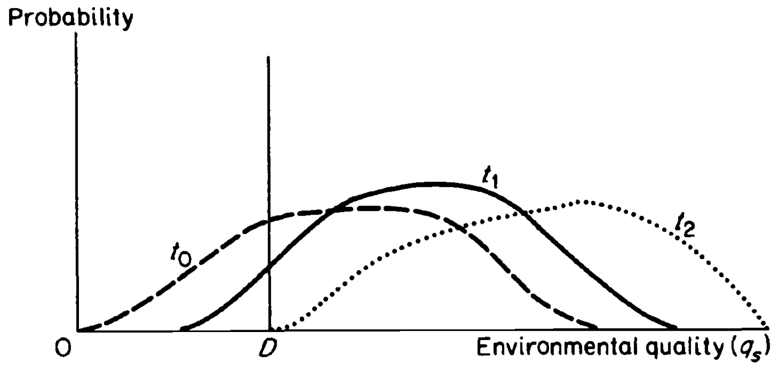
Aggregating over all i firms, we get an aggregate waste-emission function

$$m_s = h(t_s) = \sum h_i(t_s). \tag{6}$$

From equation (6), we can thus determine the total level of waste discharges into the environment in period s associated with each value of t, the effluent fee.

Next, suppose we know the probability distribution of k_s, our random and exogenous environmental variable ("average wind velocity") in equation (3). For some known value of environmental quality in period $(s - 1)$, we can then determine the distribution function of environmental quality in time s associated with each value of the emission tax, t. Figure 1 depicts some probability distributions corresponding to different tax rates.

Figure 1



We see that a reduction in the emission tax from t_1 to t_0 shifts the distribution leftward. Once a lower tax rate is instituted, higher levels of waste emissions become profitable, thereby increasing the likelihood of a period of relatively low environmental quality.

Assume, moreover, that the environmental authority cannot readily change t in response to current environmental conditions so that t is essentially fixed for the period under analysis.[17] Let there also be some accepted "danger standard" (i.e., a minimum acceptable level of environmental quality). We designate this danger standard as D in Figure 1 and assume that the environmental authority is committed to maintaining the level of environmental quality above D at *all* points in time.

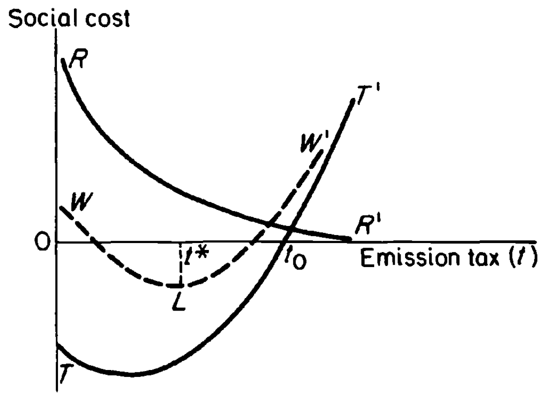
How can the authority achieve this objective at the least cost to society? One method of guaranteeing that q_s will never fall below D is to set the tax rate so high that waste emissions can never, regardless of exogenous environmental influences, reach a value sufficiently high to induce environmental quality to deteriorate to a level less than D.[18] In terms of Figure 1, this would require an emissions tax of t_2, which shifts the environmental probability distribution rightward until its horizontal intercept coincides with D. However, as we suggested earlier, this method of achieving the objective may be an excessively costly one, because it is likely to require unnecessarily expensive reductions in waste discharges during "normal" periods when the environment is capable of absorbing these emissions without serious difficulty. It may be less costly to set a lower emission tax (less than t_2 in Figure 1) and to supplement this with periodic introductions of controls to achieve additional reductions in waste discharges during times of adverse environmental conditions (periods of "stagnant air").

In Figure 2, we illustrate an approach to the determination of the optimal mix of emission taxes and direct controls. Let the curve TT' measure the *total* net social cost associated with each value of t. There are two components of this social cost. The first is the added costs of production that higher taxes impose by inducing methods of production consistent with reduced levels of waste emissions. This cost naturally tends to rise with tax rates and the associated lower levels of waste discharges. However, we must subtract from this "production" cost a negative cost (or social gain) which indicates the social benefits from a higher level of environmental quality. Over some range of values for t (up to t_0 in Figure 2), we might expect the sum of these costs to be negative, that is, the social benefits from improved environmental quality may well exceed the in-

17. Alternatively, we can assume that the response of waste emissions to changes in t is not sufficiently rapid for the tax adjustments in period s to influence significantly waste discharges during that period.

18. It may, of course, be impossible to achieve such a guarantee with any finite tax rate, no matter how high.

Figure 2



creased costs of production. However, as tax rates rise and waste discharges decline, the *marginal* net social cost will typically rise. The marginal production cost of reductions in waste emissions (equated in value to t) will obviously increase, while we might expect diminishing social gain from positive increments in environmental quality.[19] The TT' curve will, therefore, typically begin to rise at some point and, for values of t in excess of t_0 in Figure 2, the net social cost of the tax program becomes positive.

We recall that the environmental authority is committed to the maintenance of a level of environmental quality no lower than the danger point, D. We will thus assume that, whatever the level of the emission tax, environmental officials will introduce direct controls whenever necessary to maintain q above D. One relationship is immediately clear: the higher the emission tax, the less frequently will environmental quality threaten to fall below D and hence the less often (and less "intensely") will the use of direct controls be required. Controls, like taxes, impose increased costs of production by forcing reductions in waste emissions. Therefore, the more frequent and extensive the use of direct controls,

19. We have drawn TT' with a "smooth" shape (a continuous first derivative), but there could easily be flat portions of TT' corresponding to ranges of values of t over which the level of waste emissions remains unchanged. Note, however, that even in this instance TT' would still exhibit the general shape depicted in Figure 2 and, most important, would still possess a well defined minimum for some value (or continuous range of values) of t.

the greater the increment in production costs they will generate. We depict this relationship in Figure 2 by the curve RR', which indicates that the higher the tax rate the less the reliance and, hence, the lower the costs associated with the periodic use of direct controls to maintain q above D.[20]

When we sum TT' and RR' vertically, we obtain the net social cost (WW') associated with each level of the emission tax (t) *supplemented* by a program of direct controls which prevents environmental quality from ever falling below the danger point (D). In Figure 2, we see that the lowest point (L) on the WW' curve corresponds to the cost-minimizing or optimal tax rate (t^*) and determines residually the optimal use of direct controls.[21]

We stress that the treatment in this section is purely illustrative. It indicates an approach to the determination of the optimal mix of emission taxes and direct controls. A rigorous solution to this problem requires an explicit recognition of the stochastic element in the curves in Figure 2. The social costs generated by a given tax program depend in part on the values taken by our random exogenous environmental variable ("wind velocity"), so that the curves in this diagram must be regarded in some sense as "averages." More formally, the solution involves the minimization of a stochastic social cost function subject to the constraint that $q \geq D$. Elsewhere we will show how this can be formulated as a nonlinear programming problem, whose solution yields the optimal mix of effluent taxes and direct controls.

Environmental Policy Tools in Practice

In this section, we want to present some preliminary evidence on the effectiveness of the various tools of environmental policy. Since evidence in the form of systematic, quantifiable results is scarce, we have had to resort in some instances to case studies suggesting only in qualitative

20. Unlike the tax-cost function (TT'), the social cost of direct controls does not include a *variable* component related to the benefits from varying levels of environmental quality. Direct controls in this model are used solely to maintain q above D. We can treat the social benefits derived from the guarantee that environmental quality never falls below D as a constant (independent of the level of t), and we can, if we wish, add this constant to RR' (or to TT' for that matter). The essential point is that we can expect RR' to be a function that decreases monotonically in relation to t.

21. Note that the curve WW' may possess a number of local minima. It need not increase monotonically to the right of L.

terms the nature of the response to the programs. Many of the findings, however, do seem roughly consistent with the preceding discussion.

Price incentives

While economic theory suggests an important role for price incentives, particularly effluent fees, for environmental control, we really have limited experience with their use. The opposition to proposals for effluent charges has been strong, in some measure, we suspect, because people realize they will be effective and wish to avoid the inevitable costs of environmental protection.[22] Nevertheless, there has been some use of charges, and what evidence is available suggests that effluent fees have in fact been quite successful in reducing polluting activities.

The most striking and important case appears to be the control of water quality in West Germany's Ruhr Valley. The site of one of the world's greatest concentrations of heavy industry, the rivers of the Ruhr Valley could easily have become among the most polluted rivers in Europe. However, since the organization of the first *Genossenschaft* (river authority) in 1904 along the Emscher River, the Germans have been successfully treating wastes in cooperatives financed by effluent charges on their members. There are presently eight *Genossenschaften*. Together they form a closed water-control system which has maintained a remarkably high quality of water. In all but one of the rivers in the system, the waters are suitable for fishlife and swimming. Together, the eight cooperatives collect approximately $60 million a year, mainly from effluent charges levied on their nearly 500 public and private members. The level of charges is based largely on a set of standards for maintaining water quality, although the formulas themselves are rather complicated. As Kneese and Bower point out, the fee formulas do not correspond perfectly to the economist's version of effluent fees ("they violate the principle of marginal cost pricing," p. 251).[23] Nevertheless, the charges, in conjunction with an integrated system of planning and design for the entire river basin, "is a pioneering achievement of the highest order" (Kneese and Bower, p. 253).

There has been a scattered use of effluent fees for environmental protection in North America, and these, to our knowledge, exclusively for

22. For an excellent survey and evaluation of the most frequent arguments directed against programs of effluent fees, see Freeman and Haveman.

23. For a more detailed discussion of the Ruhr experience, see Kneese and Bower, Chapter 12.

the control of water quality. However, this evidence does again point to the effectiveness of fees in curtailing waste emissions. Kneese and Bower cite three instances in which the levying of local sewer charges induced striking reductions in waste discharges.[24] C. E. Fisher reports similar responses to a local sewerage tax in Cincinnati, Ohio. Fees were established in 1953 with the proviso that a rebate would be given to anyone who met a specified set of standards by a certain date. Subsequently, some 23 major companies invested $5 million in pollution control in less than two years to meet these standards.

There also exist three more systematic studies of industrial responsiveness to sewerage fees. Löf and Kneese have estimated the cost function for a hypothetical, but typical, sugar beet processing plant in which cost is treated as a function of BOD removal from waste water. Their results suggest, assuming the firm stays in business, that a very modest effluent charge would induce the elimination of roughly 70 per cent of the BOD contained in the waste water of their typical plant. Likewise, a recent regression study by D. E. Ethridge of poultry processing plants in different cities imposing sewerage fees indicates substantial price responsiveness on the part of these firms. In a total of 27 observations from five plants, Ethridge found that "The surcharge on BOD does significantly affect the total pounds of BOD treated by the city; the elasticity of pounds of BOD discharged per 1,000 birds with respect to the surcharge on BOD is estimated to be −0.5 at the mean surcharge" (p. 352).

The most ambitious and comprehensive study of the effects of municipal surcharges on industrial wastes in U.S. cities is the work of Ralph Elliott and James Seagraves. Elliott and Seagraves have collected time-series data on surcharges, waste emissions, and industrial water usage for 34 U.S. cities. They have put these data to a variety of tests and their findings indicate that industrial BOD emissions and water consumption do indeed appear to respond negatively to the level of surcharges on emissions. In one of their tests, for example, they have pooled their cross-section and time-series observations and, using ordinary least squares, obtained the following estimated equations:

$$\begin{aligned} T = 13.1 - \underset{(8.5)}{14.6S} - \underset{(79.3)}{120.0G} + \underset{(22.6)}{36.2P} \qquad (7) \\ R^2 = .17 \qquad N = 190, \end{aligned}$$

24. These involved sewerage fees in Otsego, Michigan, in Springfield, Missouri, and in Winnipeg, Canada. See Kneese and Bower, pp. 168–70.

$$W = 2.2 - \underset{(2.9)}{5.2S} - \underset{(24.7)}{36.8N} + \underset{(7.2)}{8.6P} + \underset{(26.0)}{75.1F} \tag{8}$$

$$R^2 = .32 \qquad N = 179,$$

where;

T = pounds of BOD per $1,000 of value added in manufacturing;
S = surcharge per pound of BOD in 1970 dollars;
G = price of water (per 1,000 gallons) in 1970 dollars;
P = the real wage rate (per hour) in 1970 dollars;
N = net cost of additional water (per 1,000 gallons) in 1970 dollars;
F = proportion of value added in manufacturing in the city contributed by food and kindred products.

The coefficients on the surcharge variable (S) possess the expected negative sign and are statistically significant using a one-tail test at a .05 level of confidence. Using typical values for the variables, the authors estimate the elasticity of industrial BOD emissions with respect to the level of the surcharge to be -0.8, and the surcharge elasticity of water consumption at -0.6.[25] We are thus beginning to accumulate some evidence indicating that effluent fees can in fact be quite effective in reducing levels of industrial waste discharges into waterways.

In contrast, our experience with charges on waste emissions into the atmosphere is virtually nil. However, there is one recent and impressive study by James Griffin of the potential welfare gains from the use of emission fees to curtail discharges of sulfur dioxide into the air. Using engineering cost data, Griffin has assembled a detailed econometric model of the electric utility industry.[26] The model allows for desulfurization of fuel and coal, substitution among fuels, substitution between fuel and capital (using more capital allows more energy to be derived from a unit of fuel), and for the substitution away from "electricity-intensive" products by consumers and industry. Griffin then ran a series of nine alternative simulations involving differing effluent fees and other assumptions

25. The explanatory power (R^2) of the Elliott-Seagraves' equations is not extremely high. Among other things, this reflects the difficulties of accounting for varying industrial composition among cities and for intercity differences in the fraction of waste emissions that enter the municipal treatment system. Ethridge's equations, which use observations on only a single industry (poultry-processing), have much higher R^2 (of about .5).

26. In 1970 "power plants contributed 54% of the nation's sulfur dioxide emissions" (p. 2).

based on the estimates provided by the Environmental Protection Agency of the social damage generated by emissions of sulfur dioxide. In all the simulations, substantial net welfare gains appeared. The results were somewhat sensitive to assumptions concerning the availability and cost of fuel gas desulfurization processes about which there is some uncertainty. However, with such techniques available at plausible costs, Griffin's average annual welfare gains ranged from $6.5 to $7.7 billion, and these estimates do not allow for possible shifts to nuclear power sources.

The evidence thus does suggest that effluent fees can be an effective tool in reducing levels of waste emissions. This, of course, is hardly surprising. We expect firms and individuals to adjust their patterns of activity in response to changes in relative costs. It has often been observed that in less developed countries, where wages are relatively low, more labor intensive techniques of production are typically adopted than in higher wage countries. Moreover, in a regression study of the capital labor ratios across the states in the U.S. for 16 different manufacturing industries, Matityahu Marcus found that factor proportions did indeed vary systematically in the expected direction with the relative price of capital in terms of labor. There does seem to be sufficient substitutability in relevant production and consumption activities for modest effluent charges to induce pronounced reductions in waste emissions.[27]

What would be even more interesting is some measure of the relative costs of other control techniques (for example, the imposition of uniform percentage reductions in the waste discharges of all polluters). Evidence on this is scarce. However, one such study has been made, a study of the costs of achieving specified levels of dissolved oxygen in the Delaware River Estuary.[28] A programming model was constructed using oxygen balance equations for 30 interconnected segments of the estuary. The next step was to specify five sets of objectives and then to compare the costs of achieving each of these objectives under alternative control policies. Although effluent charges were not included specifically as a policy alternative in the original study, Edwin Johnson headed a subsequent study using the same model and data. This made possible the comparison of four alternative programs for reaching specified levels of dissolved oxygen in the estuary. The results for two D.O. objectives are presented

27. For a useful summary of estimates of price elasticities for polluting activities, see the paper by Robert Kohn.

28. Federal Water Pollution Control Administration, *Delaware Estuary Comprehensive Study: Preliminary Report and Findings* (1966); a useful summary of this study is available in Kneese, Rolfe, and Harned, Appendix C.

in Table 1, where LC is the least-cost programming solution, UT is a program of uniform treatment requiring an equal percentage reduction in discharges by all polluters, SECH is a program consisting of a single effluent charge per unit of waste emission for all dischargers, and ZECH is a zoned charge in which the effluent fee is varied in different areas along the estuary. As indicated by Table 1, the substantial cost savings of a program of effluent fees relative to that of uniform treatment is quite striking. Moreover, it should be noted that the least-cost programming solution involves a great deal more in the way of technical information and detailed controls than do the programs of fees. The reduced costs from the use of fees instead of quotas thus appear to be potentially quite sizable.

TABLE 1

Cost of Treatment Under Alternative Programs

D.O. Objective (ppm)	*Program*			
	LC	*UT*	*SECH*	*ZECH*
		(million dollars per year)		
2	1.6	5.0	2.4	2.4
3–4	7.0	20.0	12.0	8.6

Source: Kneese, Rolfe, and Harned, p. 272.

As we mentioned in the preceding section, effluent fees are, in theory, a more efficient device for achieving standards of environmental quality than subsidies. Fees appear, moreover, to possess a number of practical advantages as well. The design of an effective and equitable system of subsidies is itself a difficult problem. If a polluter is to be paid for reducing his waste emissions, it then becomes in his interest to establish a high level of waste discharges initially; those who pollute little receive the smallest payments.

In practice, subsidies have been used far more extensively in the United States than fees. The federal government has relied heavily on a program of subsidization of the construction of municipal waste treatment plants and on tax credits to business for the installation of pollution control equipment. The serious deficiencies in the first program are now a matter of record in the 1969 Report of the General Accounting Office. The failure to curtail industrial pollution; the subsidization of plant construction but not operating expenses (resulting in many instances of incredibly ineffective use of the facilities); and the inappropriate location of many plants have resulted in the continued deterioration of many major U.S. waterways despite an expenditure of over $5 billion.[29]

Although we have been unable to find any direct evidence on the tax credit program, there is a simple reason to expect it to have little effect. As Kneese and Bower (pp. 175–78) point out, a firm is unlikely to purchase costly pollution control equipment which adds nothing to its revenues; the absorption of k per cent (where $k < 100$) of the cost by the government cannot turn its acquisition into a profitable undertaking.

Thus both theory and experience point to the superiority of effluent charges over subsidies as a policy tool for environmental protection. Finally, we might also mention that, from the standpoint of the public budget, fees provide a source of revenues, which might be used for public investments for environmental improvements, while subsidies require the expenditure of public funds.

Direct controls

As James Krier points out, "Far and away the most popular response by American governments to problems of pollution—and indeed, to *all* environmental problems—has been regulation . . ." (p. 300). Three general types of regulatory policies for environmental control: quotas, prohibition, and the requirement of specified technical standards are stated in the list of tools for environmental control. However, this classification does not indicate the vast number of ways in which these direct controls may be implemented. The directive for polluters to cease certain activities or to install certain types of treatment equipment may come from an empowered regulatory authority, may result from a court order, or might be forced by the citizenry itself through a referendum. Even this is an oversimplification. There are, for example, several methods by which action through the Courts may be initiated (see Krier). Our category of "direct controls" thus encompasses an extremely broad range of policy options. It is beyond the scope of this paper to examine in detail, for instance, the potential of various forms of litigation for effective environmental policy. We shall rather examine somewhat more generally the success or failure of each of these approaches with particular attention to the circumstances which appear to bear on their effectiveness.

The record of regulatory policies in environmental control is not very impressive. This stems at least as much from administrative deficiencies

29. For further documentation of the ineffectiveness and abuses under this subsidy program, see Marx, and Zwick, and Benstock.

in the application of regulatory provisions as in the establishment of the provisions themselves. A successful regulatory policy generally requires at least three components.

(1) A set of rules that, if practiced, will provide the desired outcome. In this case, satisfactory levels of environmental quality achieved at something reasonably close to the least cost.

(2) An enforcement agency with sufficient resources to monitor behavior.

(3) Sufficient power (the ability to impose penalties) to compel adherence to the regulations.

The design of an efficient set of rules is itself an extremely difficult problem. As mentioned earlier, effluent charges have important efficiency enhancing properties. Moreover, the specification of an efficient set of regulatory provisions will generally require at least as much, and frequently more, technical information than the determination of schedules of fees.[30] In addition, experience suggests that substantial transaction costs in terms of resources devoted to bargaining (as noted earlier in the case of the continuing controversy over auto emission standards) may be involved in the rule selection process.

Even an effective set of regulations can only achieve its objective if it is observed. Unfortunately, the history of environmental regulation in the United States is not encouraging on this count. Regulatory agencies have frequently been understaffed and unable, or unwilling, to enforce antipollution provisions. An interesting historical example is the River and Harbors Act of 1899 which prohibits the discharge of dangerous substances into navigable waterways without a permit from the Army Corps of Engineers. As of 1970, only a handful of the more than 40,000 known dischargers had valid permits. Moreover, the newspapers abound with accounts of huge plants which have paid trivial sums (sometimes a few hundred dollars) for serious violations of pollution regulations. Many of the provisions simply have not given the agencies the power they require for enforcement.

Action through the courts has also not proved very effective. Environmental lawsuits, where a plaintiff can be found, have often stretched over years or even decades without resolution. However, even if judicial proceedings were prompt, it is difficult to envision how suits by individual plaintiffs for damages could lead to an efficient environmental policy.

30. In an interesting paper, Karl Göran-Mäler has shown recently that the determination of an efficient set of effluent standards (or quotas) among activities requires at least as much information as that necessary to solve for an optimal set of effluent charges.

Kneese and Bower, while acknowledging the potential of some support from the judicial process, conclude simply that ". . . efficient water quality management cannot be achieved through the courts" (p. 88).

Nevertheless, where enforcment is effective, and it surely has been in a significant number of cases, direct controls can lead to substantial reductions in polluting activities. A variety of regulations in various metropolitan areas have generated large reductions in waste discharges into the atmosphere. The banning of backyard incineration and of the use of sulfur bearing fuels over several months of the year led to significant reductions during the 1950's in smoke, dust, and sulfur oxide discharges into the air shed over the Los Angeles basin. Likewise, tough new regulations in Pittsburgh during the 1940's, requiring the switch from coal fuels to natural gas for heating purposes, resulted in notable improvements in air quality. Strong regulations combined with aggressive enforcement *can* clearly raise the level of environmental quality.[31] The difficulties, of course, are that the improvements may come at an unnecessarily high cost, or, alternatively, may come not at all, if the regulations are themselves inadequate or are ineffectively enforced.

Moral suasion and voluntary compliance

We suggested earlier that, while moral suasion is likely to be an ineffective policy tool over longer periods of time, it may prove quite useful in times of emergency. An interesting illustration of this pattern of response involves voluntary blood donations. In September of 1970, New York City hospitals were facing a blood crisis in which reserves of blood had fallen to a level insufficient for a single day of operation. The response to a citywide plea for donations was described as "fantastic" (*New York Post*, September 4, 1970, p. 3); donors stood in line up to 90 minutes to give blood. The statements by some of the donors were themselves interesting:

"I've never given blood before, but they need it now. That's good enough reason for me."

"I was paying a sort of personal guilt complex."

"It's the least I could do for the city."

31. Direct controls in the form of "technical specifications" for polluting activities may be the only feasible policy instrument, where the monitoring of waste emissions is impractical (or, more accurately, "excessively costly"). For example, if difficulties in metering sulfur dioxide emissions into the atmosphere were to preclude a program of effluent fees (or quotas, for that matter), it might well make sense to place requirements on the quality of fuel used, on the technical characteristics of fuel burners, etc.

And yet within a few months (*New York Times,* January 4, 1971, p. 61), the metropolitan area's blood stocks were again down to less than one day's supply. It was also noted that many donors who promised to give blood had not fulfilled their pledges.[32]

A somewhat similar fate seems to have characterized voluntary recycling programs. Individuals and firms greeted these proposals with substantial enthusiasm and massive public relations efforts. Many manufacturers agreed to recycle waste containers collected and delivered by nonprofit volunteer groups. While the initial response was an energetic one, it seems to have tailed off significantly. "Many (of the groups) disbanded because of a lack of markets or waning volunteer interest" (*New York Times,* May 7, 1972, p. 1 and p. 57). The Glass Manufacturers Institute announced that used bottles and jars returned by the public were being recycled at a rate of 912 million a year, but this represents only 2.6 per cent of the 36 billion glass containers produced each year. Similar reports from the Aluminum Association and the American Iron and Steel Institute indicated recycling rates of 3.7 per cent and 2.7 per cent respectively for metallic containers. The reason for the failure of these programs to achieve greater success is, according to several reports, "that recycling so far is not paying its own way" (*New York Times,* May 7, 1972, p. 1). Experience with recycling programs also points to a danger we mentioned earlier: that these types of programs will be instituted instead of programs with direct individual incentives for compliance. There are a wealth of examples of businesses providing active support for voluntary recycling as parts of campaigns *against* fees or regulations on containers. The *New York Times* (May 7, 1972, p. 57), for instance, cites a recent case in Minneapolis in which the Theodore Hamm Brewing Company and Coca-Cola Midwest, Inc. announced that they would sponsor "the most comprehensive, full-time recycling center in the country." This pledge, however, was directed against a proposed ordinance to prohibit local usage of cans for soft drinks and beer.

A final example of some interest involves a recent attempt by General Motors to market relatively inexpensive auto-emission control kits in Phoenix, Arizona. The GM emission control device could be used on most 1955 to 1967 model cars and could reduce emissions of hydrocarbons, carbon monoxide, and nitrogen oxides by roughly 30 to 50 per cent. The cost of the kits, including installation fees, was about $15 to $20.

32. Other cases we are currently investigating are the formation of car pools both in emergency and "normal" periods to cut down on auto emissions, and the extent of voluntary reductions in usage of electricity during periods of power crises.

Despite an aggressive marketing campaign, only 528 kits were sold. From this experience, GM has concluded that only a mandatory retrofit program for pre-1968 cars, based upon appropriate state or local regulation, can assure the wide participation of car owners that would be necessary to achieve a significant effect on the atmosphere. The Chrysler Corporation has had a similar experience. In 1970 Chrysler built 22,000 used car emission control kits. More than half remain in its current inventory. In fact after 1970 Chrysler had experienced "negative" sales. About 900 more kits were returned than shipped.

The role of moral suasion and voluntary compliance thus appears to promise little as a regular instrument of environmental policy. Its place (in which it may often be quite effective) is in times of crisis where immediate response is essential.

Concluding Remarks

Our intent in this paper has been a preliminary exploration of the potential of available tools for environmental policy. There is, as we have indicated, a wide variety of options at the policy level with differing instruments being appropriate depending upon the characteristics of the particular polluting activity and the associated environmental circumstances. The "optimal" policy package would no doubt include a combination of many approaches including the prohibition of certain activities, technical specifications for others, the imposition of fees, etc. We hope that the analysis has provided some insight into the types of situations in which certain policy instruments promise to be more effective than others.

Our own feeling, like that of most economists, is that environmental policy in the United States has failed to make sufficient use of the pricing system. Policies relying excessively on direct controls have not proved very effective in reversing processes of environmental deterioration and, where they have, we would guess the objective has often been achieved at unnecessarily high cost. Moreover, to the extent that environmental authorities have used price incentives, they have typically adopted subsidies rather than fees. These subsidy programs have often been ill-designed, providing incentives only for the use of certain inputs in waste treatment activities and by absorbing only part of the cost so that investments in pollution reducing equipment continue to be unprofitable. We still have much to learn at the policy level about the proper use of price incentives in environmental policy.

What emerges from all this is the conclusion that there is considerable validity to the standard economic analysis of environmental policy. There is good reason for the economist to continue to emphasize the virtues of automatic fiscal measures whose relative ease of enforcement, efficiency enhancing properties, and other special qualities are too often unrecognized by those who design and administer policy.

On the other hand, we economists have often failed to recognize the legitimate role of direct controls and moral suasion, each of which may have an important part to play in an effective environmental program. These policy tools may have substantial claims in terms of their efficiency, particularly under circumstances in which the course of events is heavily influenced by variables whose values are highly unpredictable and outside the policy-maker's control. In environmental economics we can be quite certain that the unexpected will occur with some frequency. Where the time costs of delay are very high and the dangers of inaction are great, the policy-maker's kit of tools must include some instruments that are very flexible and which can elicit a rapid response. A tightening of emission quotas or an appeal to conscience can produce, and has produced, its effects in periods far more brief than those needed to modify tax rules, and before any such change can lead to noteworthy consequences. Where intermediate targets, such as emission levels, may have to be changed frequently and at unforeseen times, fiscal instruments may often be relatively inefficient and ineffective.

In sum, as in most areas of policy design, there is much to be said for the use of a variety of policy instruments, each with its appropriate function. Obviously this does not mean that just any hybrid policy will do, or that direct controls are always desirable. Indeed, there are many examples in which their use has provided models of mismanagement and inefficiency. Rather, it implies that we must seek to define particular mixes of policy that promise to achieve our environmental objectives at a relatively low cost.

References

1. Baumol, W. and W. Oates. "The Use of Standards and Prices for Protection of the Environment," *The Swedish Journal of Economics* 73 (March 1971), pp. 42–54.
2. Bramhall, D. and E. Mills. "A Note on the Asymmetry Between Fees and Payments," *Water Resources Research* 2 (Third Quarter 1966), pp. 615–616.

3. Coase, R. "The Problem of Social Cost," *Journal of Law and Economics* 3 (October 1960), pp. 1–44.
4. Comptroller General of the United States. *Examination into the Effectiveness of the Construction Grant Program for Abating, Controlling, and Preventing Water Pollution.* Washington, D.C.: Government Printing Office, 1969.
5. Elliott, R. and J. Seagraves. "The Effects of Sewer Surcharges on the Level of Industrial Wastes and the Use of Water by Industry," *Water Resources Research Institute* Report No. 70 (August 1972).
6. Ethridge, D. "User Charges as a Means for Pollution Control: The Case of Sewer Surcharges," *The Bell Journal of Economics and Management Science* 3 (Spring 1972), pp. 346–354.
7. Fisher, C. "Cincinnati Industry Reduces Sewer-Surcharges," *Sewage and Industrial Wastes* 28 (September 1956), pp. 1186–1187.
8. Freeman, A. M. and R. Haveman. "Residual Charges for Pollution Control; A Policy Evaluation," *Science* 177 (July 28, 1972), pp. 322–329.
9. Griffin, J. "An Econometric Evaluation of Sulphur Taxes," *Journal of Political Economy* (forthcoming).
10. Johnson, E. "A Study in the Economics of Water Quality Management," *Water Resources Research* 3, No. 2 (1967).
11. Kneese, A. and B. Bower. *Managing Water Quality: Economics, Technology, Institutions.* Baltimore: Johns Hopkins, 1968.
12. Kneese, A., S. Rolfe, and J. Harned, eds. *Managing the Environment: International Economic Cooperation for Pollution Control.* New York: Praeger, 1971.
13. Kohn, R. "Price Elasticities of Demand and Air Pollution Control," *Review of Economics and Statistics* 54 (November 1972), pp. 392–400.
14. Krier, J. *Environmental Law and Policy.* New York: Bobbs-Merrill, 1971.
15. Lave, L. and E. Seskin. "Acute Relationships Among Daily Mortality, Air Pollution, and Climate," *Economic Analysis of Environmental Problems,* edited by Edwin S. Mills. New York: National Bureau of Economic Research, 1974.
16. Löf, G. and A. Kneese. *The Economics of Water Utilization in the Beet Sugar Industry.* Baltimore: Johns Hopkins, 1968.
17. Mäler, K. G. "Effluent Charges versus Effluent Standards," Working Paper (May 20, 1972).
18. Marcus, M. "Capital-Labor Substitution Among States: Some Empirical Evidence," *Review of Economics and Statistics* 46 (November 1964), pp. 434–438.
19. Marx, W. *Man and His Environment: Waste.* New York: Harper and Row, 1971.
20. Noll, R. "Institutions and Techniques for Managing Environmental Quality," 1970. Mimeographed.
21. Plourde, C. "A Model of Waste Accumulation and Disposal," *Canadian Journal of Economics* 5 (February 1972), pp. 119–125.

22. Upton, C. "Optimal Taxing of Water Pollution," *Water Resources Research* 4 (October 1968), pp. 865–875.
23. Zwick, D. and M. Benstock. *Water Wasteland*. New York: Grossman, 1971.

COMMENT

Charles Upton, The University of Chicago

The authors consider a variety of policy instruments for regulating environmental quality. For a variety of reasons which they—and I—find compelling, they reject proposals such as subsidies and moral suasion and suggest instead a mixture of pollution taxes and direct controls. They conclude that although "environmental policy in the United States has failed . . . to make sufficient use of the pricing system . . . economists have too often failed to recognize the legitimate role of direct controls . . . which may have an important part to play in an effective environmental program."

According to Oates and Baumol, an important reason for using direct controls is the stochastic nature of environmental quality. Since a fixed tax will result in periods of low environmental quality, direct controls should—again, according to the authors—be employed on those occasions. Yet this argument is an invalid comparison between controls which can be varied and a tax structure which cannot. Their argument essentially rests on the quite strong assumption that pollution taxes cannot be changed to deal with "emergencies," but the level of direct controls can be changed.

But one can change the level of taxes. Indeed, one should. For example, air quality in urban areas is usually lower in winter than in summer, suggesting the use of a two-part emissions tariff, and not a uniform emissions tax throughout the year supplemented by direct controls during the winter and summer months.

The notion of a differential tax can be further extended to other cases. For example, air quality drops during "thermal inversions" and so presumably does the optimal level of emissions. Oates and Baumol call for direct controls under such circumstances. But a temporary rise in the emission tax—of sufficient magnitude—could achieve the same reduction in emissions as direct controls. To be sure, one could not impose a "thermal inversion surcharge" until it could be determined that an inversion had occurred. Hypothetically if this took one day, taxes would not be useful on the first day. But then one could not impose emergency controls until it was determined that an inversion had occurred.[1]

In sum, it is important to distinguish between cases in which one knows that a parametric shift in the environmental quality has or will occur and those which are unpredictable. In the first case, either taxes or controls can be used; the well-known efficiency properties of taxes to which the authors allude suggest that taxes are appropriate. In the second case, there is no emergency policy which will be able to affect emissions.

As the authors admit, their argument rests on the assumption that the taxes cannot be changed as rapidly as direct controls can be imposed. However, they do not address the question of how one could institute controls and have them effective if it is impossible to use taxes.[2]

Integral to Oates and Baumol's discussion of the uncertainty issue is their analysis of the environmental authority's objective, which they take to be meeting some prescribed standard of environmental quality. The true objective of the authority is to maximize the value of environmental quality net of emission treatment costs. Since this rule may prove difficult to implement, it may sometimes be useful to adopt as a proxy an objective of meeting a prescribed environmental quality standard.[3] However, if the shifts in the parameters such as wind conditions that affect environmental quality are truly stochastic and emission levels cannot be changed in response, it may be impossible to meet any standard with certainty.

Even if it is possible to change emissions to meet a given environmental quality standard, optimal social policy may be to accept variations

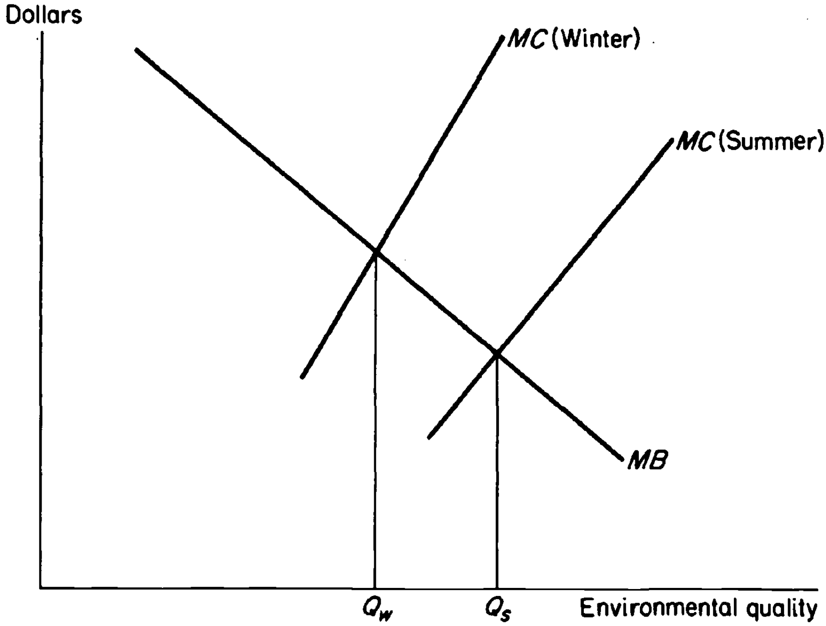
1. One could however announce a tax schedule which would be applied whenever inversions occur, even though there might be a delay in determining that an inversion had occurred. But unless one assumes that firms have superior ability to recognize the start of an inversion, this plan will not make the tax any more effective since firms will respond only when they believe an inversion has begun.

2. Two caveats on this point. First, firms will set the short run marginal cost of reducing pollution equal to the tax. So if only a short-run reduction in emissions is desired, one may require a tax higher than the one which would be required if a permanent reduction in emissions was desired (assuming, of course, that the short-run marginal cost of reducing emissions is higher than the long-run marginal cost).

Second, there is another problem if the regulatory authority is unsure of the effects any given tax or control schemes will have on emissions. This is a difficult problem which has no simple solution. However, this is not the problem taken up in the paper.

3. To be more precise, it is sometimes useful to analyze pollution control as the dual tasks of meeting a quality standard at minimum cost and determining the optimal standard.

Figure 1



in environmental quality. For a simple example, consider again the case of winter and summer months. One factor behind the difference is the wintertime demand for heating. If we interpret this as meaning that the marginal cost curve for environmental quality shifts to the left in winter months and if, for simplicity, we assume that the marginal benefit curve is the same for both seasons, it is optimal to have seasonal changes in environmental quality standards. As Figure 1 illustrates, the optimal level of environmental quality is Q_w in the winter and Q_s in the summer.

Another difficulty with emission taxes raised by Oates and Baumol lies in their application to oligopolies. Since the authors attach only minor importance to this issue and since an oligopoly is an ill-defined concept, my comments will be brief. First, note that in the simple case of a profit-maximizing monopolist, emission taxes are more efficient than direct controls. An emission tax will induce any profit-maximizing firm to reduce emissions and substitute hitherto more costly factors of production, thus minimizing the total social cost of producing output. Direct controls probably will not do that. To be sure, a monopoly will not necessarily pass along the full cost of emission control to the consumer (as would a competitive firm), but this will be true whether the costs arise from direct controls or control via emission taxes. So, on balance, the differences lie in favor of emission taxes.

Two additional cases are those of the regulated industry and an oligopoly which has objectives other than maximizing profits. However, there is a question of their relevance: to what extent does regulation matter and do oligopolies exist? But these are old issues and there seems little point in repeating the arguments here.

Another regulatory device which Oates and Baumol do not consider is nonintervention. Indeed they begin their paper by specifically ruling out this possibility, claiming that the transactions costs involved in the provision of environmental quality by private action make such a solution impossible. The transactions costs involved in private action do not constitute an absolute barrier to the provision of public goods by private action; they mean public goods might thereby be undersupplied. Although little is known about the economics of political processes, it is possible that political control of environmental quality could mean an oversupply of environmental quality. If so, a policy of nonintervention which results in an undersupply of environmental quality may well be preferable to a policy of government intervention which provides an oversupply. The expected cost of an undersupply must be weighted against the costs of a possible oversupply and inefficient production of environmental quality possible with a nonmarket solution.[4]

It is even more difficult to reject *a priori* a policy of nonintervention by the federal government when one considers the possibility of local control. Regional differences in factor endowments suggest that there should be regional differences in the provision of environmental quality. Indeed, even were there no differences in factor endowments, differences in individual tastes would argue for cities providing different levels of environmental quality.

Surely, almost all of the externalities from, for example, Pittsburgh's air pollution are internalized within Pennsylvania, and there would seem little necessity for federal intervention to set air quality standards. To be sure, there are some cases like the Chicago SMSA where problems cross state lines. However, the number of negotiators required to inter-

4. Or to put it another way: most economists would agree *a priori* that there is some inefficiency in a water pollution control act which called for zero effluents, and it is conceivable that the social welfare would be lower than it would be under a policy which permitted unlimited discharges of pollutants.

nalize interstate externalities is sufficiently small (the governors of Illinois and Indiana) that the Coase solution seems appropriate.

Thus, it is difficult to rule out a policy of nonintervention at the federal level. Although a case can be made for economies of scale implicit in federal control,[5] these gains must be weighted against the welfare loss from the provision of uniform levels of environmental quality (which seems implicit in federal control).

5. A common example of these economies is the possible cost to the automobile industry of dealing with fifty state automobile emission standards.