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POLLUTION AND RESOURCE ALLOCATION*

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'Everything I like is either illegal or immoral, pollutes the environment, or increases the population'.

[R. A. Lewin, *Bioscience*, 19, 1969, p. 584].

Our economic perspective of the pollution problem characterizes that problem as involving a conflict between the consumption of two broad classes of goods—physical (or produced) commodities and the direct consumption of 'clean environment'. After considering the relative merits of market and political decision-making processes used to achieve appropriate social choices between the consumption of physical goods and 'clean environment', we focus on the alternative policy options for pollution control. The main conclusion we reach is that, in general, fiscal instruments (taxes and subsidies) are a more efficient means of controlling pollution than the widespread use of regulations or other legal instruments.

Introduction

An ever-increasing popular and technical literature has been concerned with persuading us that mankind is on the brink of ecological disaster. However seriously one ultimately takes this threat, it seems difficult to contemplate the pressures of population growth, the rapid exploitation of known reserves of exhaustible resources, and the apparently perceptible deterioration in the quality of the natural environment without some disquiet. And judging by the attention devoted to these matters in the economics literature, the economics profession at large regards them as enormously important.

The purpose of this paper is to submit to examination just one of these problems—that of environmental quality disruption. From the start, however, it has been obvious that the task of providing a comprehensive coverage of all aspects of even this one problem would be quite impossible except in terms of largely meaningless generalizations. The environmental quality problem as a whole is just so complex that policy discussion requires some way, initially, of breaking it down into manageable components, which can ultimately be brought together again to form a consistent total perspective. In this spirit, we have chosen to focus on only one (albeit a particularly important) aspect of environmental quality disruption—the so-called problem of pollution.

* This paper has evolved from a more wide-ranging paper which was presented to the Annual Conference of the Australian Society of Agricultural Economists held at the Australian National University in February 1973. Order of authorship for the present paper was decided by tossing several coins.

In doing so, it is probably desirable to indicate, at the very outset, just where we see the pollution problem as such fitting into the wider context. Basically, we regard the general problem of environmental quality disruption in a growing economy as a compound of three related, but distinguishable, phenomena—increasing pollution, increasing congestion, and an increasing demand for recreational and other services provided directly by a clean environment. It is clear that these can be viewed as quite distinct matters—at least at the conceptual level. Congestion may worsen, without any change in pollution levels or the demand for clean environment *per se*. Likewise, technological changes may influence pollution levels without affecting congestion or preferences for environmental services. And tastes for environmental services may alter while congestion and pollution levels stay constant.

In practice, though, the distinction may be extraordinarily difficult to maintain. An increase in population size, or income per head, will generally involve a simultaneous increase in pollution levels and demand for environmental services; an increase in pollution levels may increase the observed demand for environmental services (e.g. trips to national parks), even when the underlying preferences for environmental services remain unchanged. (In the latter case, we observe a move along the demand curve rather than a shift in it). Needless to say, it may be difficult (and, incidentally, quite wrong in some cases) to deal with these effects separately. Nevertheless, some such distinction seems necessary if the topic is to become manageable, and we shall endeavour to emphasize, wherever it seems relevant in the discussion, the essential interdependence of the various dimensions of the total problem, without actually concerning ourselves with questions of congestion or conservation as such.

Our primary objective has been to provide a broad conceptual economic framework, within which the pollution problem might be analysed and appropriate means of reducing the impact of pollution on society's well-being discussed. The need for such a framework seems to us to be extreme. Although much has been written on the pollution question—particularly, recently—most proceeds on a relatively *ad hoc* basis, and many of the more fundamental questions are skated over or completely ignored. We have, by way of contrast, attempted to start at first base with the question 'what *is* the economic dimension of the pollution issue'? and to proceed logically from there to identify that aspect of the issue which makes it a social problem, and through this to the ultimate question of what we should do about pollution.

In no sense is this paper to be considered as a review of the literature. It is both less than, and (we hope) more than, that.[1] It is less, because there are many issues aired in the literature which we have ignored (and possibly even a number that we have overlooked). It is *more,* because it involves an attempt to re-think the fundamental questions and to present the answers (in so far as we have found any) in a novel and hopefully stimulating form. In this way, our aim is that the framework set out here should prove useful to those who are familiar with

[1] We must, nonetheless, admit that our thinking has been influenced by the contributions of Dales [7], Ayres and Kneese [1], Parish [10] and Coase [6]. This is by no means a complete list, and we indicate other important sources as we make use of their ideas.

much of the relevant literature, as well as to those who are not; and to those who are economists as well as to those who are not.

Regrettably perhaps, this paper has no explicitly agricultural orientation. The reason for this is simply that we considered that the conceptual exercise we have undertaken here needed to be conducted first. The extremely interesting question of how the pollution problem bears on the rural sector—and indeed the more general question of the optimal location of polluting industries, which we hardly do justice to here—must remain for a logically and temporally subsequent discussion.

The plan of the paper is as follows. In section I we attempt to derive an economic perspective of the pollution problem. In section II, we are concerned to discuss the extent to which the *economic* problem of pollution requires political intervention because the market fails to solve it—and further, the extent to which the political mechanism can be expected to achieve what the market cannot. Section III presents a discussion of alternative pollution control procedures available to governments and attempts to outline appropriate criteria for policy choice. Section IV presents the conclusions.

I

Pollution as an Economic Problem

The fundamental economic problem, or at least the problem with which economists have traditionally concerned themselves most, is that of maximizing society's welfare in the face of various constraints—constraints imposed both by the natural world, and by man's limited knowledge of the ways in which the natural world can be manipulated to achieve society's ends.

One of the most basic constraints prevailing (although one which, until recently, has received little explicit attention from economists) is that implied by the law of Conservation of Mass. This law insists that processes of production and consumption can, via chemical and physical change, modify *but never destroy* the matter used in those processes. In other words, except to the extent that re-use is feasible (and economical), production-consumption activities inevitably involve the conversion of productive inputs (including oxygen from the atmosphere) into an equivalent mass of non-productive residuals that must somehow be disposed of.

It perhaps needs to be emphasized in this connection that it is *consumption,* and not production, which is the ultimate objective of economic activity: production processes exist, not as ends in themselves, but merely to satisfy individuals' demands for physical consumption goods. Thus, while production activities no doubt typically generate a larger volume of more objectionable waste products than consumption activities do, nevertheless all disposals can ultimately be seen as arising from a multi-stage process in which naturally occurring matter is transformed, firstly into a form in which it is amenable to consumption, and then via the consumption process itself into some other form in which it is generally not consumable. It is consumption therefore which provides the rationale for all economic activity—and hence society's demand for physical consumption goods which is ultimately responsible for the need for residuals disposal.

Once this point is admitted, it is clear that that view of the pollution problem, quite common in popular discussion, which seeks to categorize individuals into two mutually exclusive classes—the wicked polluters on the one hand, and the deserving polluted on the other—and sees the pollution problem as arising out of the moral degeneracy of the former group, is in fact hopelessly misguided. It is, more seriously, dangerously confusing. The truth of the matter is that *all* consumers contribute to pollution by the very act of consumption: firms pollute, not because they derive fiendish delight from doing so, *but because the individual consumers of their products pay them to.*[2] In this sense, it is not a case of 'them' against 'us', but us against ourselves—and it saves a lot of misplaced indignation to realize that this is so.

Until quite recently, residuals disposal does not seem to have been widely regarded as posing a serious problem—in economic, or any other, terms. That this is so is presumably attributable to the fact that such disposals had not interfered at all significantly with other production and consumption activities which individuals wished to pursue. Disposal is, of course, effected simply by the discharge (either deliberately or as the result of natural processes) of the unwanted residuals into the atmosphere (as gases or waste energy), into the waterways (as sewage, or as industrial residuals suspended or dissolved in water), or onto the land (as rubbish, scrap, junk, garbage and so on). And over some range, the basic assimilative capacity of these media can handle such discharge. That is to say, the environment at large is capable of transporting, dissipating, diluting, degrading or storing to some extent all types of residual generated by man's production/consumption activities, though its capacity to do so may be affected by natural phenomena (temperature, wind-speed and stream flow variations, for example) or by deliberate human intervention (such as augmenting stream flows, treating residuals before discharge, or such relatively simple things as building higher chimney-stacks).[3] Up to a point, the natural qualities of the environment thus provide us with a means of disposing of residuals in an essentially costless fashion. Beyond that point, however, there begins to emerge a conflict between man's use of the environment as a sink for residuals disposal, and such other uses for it as he may have.

Once recognized, the precise nature and extent of this conflict needs to be specified. And this is not necessarily a trivial exercise, in part because the nature of the 'other uses' of the environment are not clearly or completely specified, but also because hard facts, and even convincing theories, are in short supply. However, it is clear that an almost endless list of potential or actual damage caused by residuals could now be compiled, ranging from potential threats to man's existence, through scarcely less potentially devastating (though less specific) threats of ecological instability, right down to relatively minor damage to buildings and the like. In other words, apart from providing a sink for residuals, the natural environment provides a variety of other services which con-

[2] We are not suggesting that consumers *actually* pay firms to pollute. But operating in a world where legal and other constraints are imperfect, it is demands for products and their consumption which lead to pollution.

[3] We might also observe that the natural processes are not always rapid, and occasionally they may in fact be detrimental to human well-being (e.g. the 'natural' production of ozone and nitrogen dioxide from motor vehicle exhausts).

tribute directly to individuals' satisfactions, and over a substantial—and practically relevant range, the use of the environment as a sink conflicts with these other uses. If we term these other uses, somewhat loosely, as elements in the demand for a 'clean environment', the conflict to which we are referring can be characterized as a conflict between the consumption of two broad classes of goods—physical (or produced) commodities, which necessarily involve the creation of residuals, and the direct consumption of 'clean environment'.

Of course, this is something of a simplification, since some commodities may require 'clean environment' not only as a disposable medium, but also as an input in their production processes. (For example, some chemical processes may require *pure* water for the appropriate chemical reactions to occur). This complicates, but does not alter, the basic problem: it implies simply that some goods may be highly complementary in production with the good, 'clean environment', and presumably some others highly substitutable. It is convenient at this stage however, to retain our conceptually simple two-good model.

Once pollution is recognized as the manifestation of an inevitable conflict between two types of consumption activity, the *reconciliation* of that conflict emerges as the central problem for society. A choice has to be made between the consumption of physical commodities and the consumption of clean environment, and the crucial question is how that choice might best be made.

Under at least one fashionable conception of economics, such choices are viewed as being the central subject matter of the discipline, and, it must be admitted, it is rather comforting for the economist to be able to point out that for him the pollution problem emerges as one amenable to quite standard economic reasoning. This is not, in any sense, to belittle the magnitude or importance of the pollution problem, nor even necessarily to claim that the economist's techniques are adequate for the task in hand, but merely to point out that, looked upon in this way, it is apparent that there is nothing inherently more difficult about the pollution problem than many others to which the economist has applied his doubtful expertise.

II

Pollution as a Problem of Social Choice

To recognize a social problem as a question of choice does not necessarily identify it as one requiring an explicitly *social* choice—i.e. one demanding the explicit application of public policy.

Many—indeed perhaps most—social choices are not made explicitly as such. Rather, they emerge as the summation of the outcomes of a large number of decentralized market decisions. And we know that there is nothing inherently inefficient about such decentralization of decision-making; indeed, quite standard and widely applied theorems of welfare economics state that in many cases the resulting choices are the best conceivable ones. In such cases, co-ordination of decisions is achieved neatly, and at least cost, by the market mechanism.

On the other hand, it is equally clear that some choices are not appropriately left to the co-ordinating forces of the market or, at least,

it is not obvious that market solutions represent the best or least-cost solutions. In these circumstances the social choices may be made, or may require to be made, *explicitly as* social choices through a political mechanism of some sort.

But it is not immediately apparent that choices made in a political context will better represent 'the aggregate desires of society': the question of whether the political mechanism makes better choices than the market mechanism depends on a number of things, including the precise form of the political decision-making process, and the nature of the commodity over which the choice is being exercised. For example, the very characteristics which disrupt the smooth working of the market mechanism may also preclude efficient choices being exercised through the political mechanism.

Thus, in focussing on the pollution 'problem' from a policy viewpoint, we might ask two sorts of questions—firstly, what are the characteristics of pollution that are likely to make it difficult for the market to make a satisfactory allocation of resources to the output of 'clean environment'; and secondly what are the characteristics of the political mechanism as an allocator of resources to alternative uses, and to what extent is its performance in this context likely to be superior to (or different from) the market's?

Market Failure

In the case of pollution problems, what appears likely to result in failure of decentralized market processes to ensure an ideal choice between the competing uses of the environment is the fact that such problems are characterized by externality. Externalities are often said to arise whenever the well-being of one economic unit is affected by the activities of other units—that is, whenever utility and/or production functions exhibit interdependencies.[4] However, from the viewpoint of identifying the existence of externality with the failure of the market mechanism to make appropriate (allocative) choices rather more is required than mere interdependence. Clearly many activities involve interdependencies, but not all of them involve market failure problems. Indeed the very *existence* of markets depends upon the existence of interdependencies, for it is the function of markets to internalize the interdependencies. In simple terms an example of what we have in mind is the observation that our welfare is increased by the productive activities of others, but at the margin we pay for their products what they are worth to us, so that the marginal social contribution of their activities is matched by the payments they receive. It is only when appropriate compensation is not forthcoming—when interdependencies are not internalized—that externalities exist. More precisely externalities exist whenever decision-makers do not take into account relevant costs or benefits of their actions, *which benefits and costs, if they were taken into account would result in different, and socially preferable, choices being made.*

The application of these notions to the economic problem of residuals disposal is, however, perhaps not so obvious as it might at first seem. Certainly to the extent that externalities do exist they can be associated

[4] The externality problem is examined in detail in Coase [6] and Buchanan and Stubblebine [4].

with interdependencies between the production/consumption of physical goods (which involves residuals disposal) and the consumption of 'clean environment'. By the same token, what exists is not a single interdependence, but a compound of inter-related interdependencies which we could classify according to environmental media involved (atmosphere, lithosphere or hydrosphere) and/or according to ultimately affected 'parties' (humans, animals, plants or inanimate objects). However, we cannot immediately conclude that we are faced with problems of externality, for up to a point the market permits, and indeed positively encourages, adjustments by individual economic units which resolve or mitigate the conflict of demands. For example, individuals may make their demands for a clean environment effective by changing their residential location, or by installing air cleaning or conditioning devices in their homes, and will do so if this constitutes their least-cost response to the interdependencies. Moreover, to take another related example, those individuals who demand pollution-free food or water provide a stimulus through the profit motive to others to produce commodities which will satisfy these demands, as witnessed by the availability of bottled 'pure' water and of 'uncontaminated' foods.[5]

What is characteristic of these adjustments is that they involve attempts to internalize the interdependencies at the point where residuals appear as an unwanted input into other production/consumption activities, rather than at the point where the residuals arise as an inevitable output (by-product) of the production or consumption of physical goods. The extent of such adjustments is of course limited in the first place by technical feasibility considerations, and ultimately by their economic viability, and if adjustments above and beyond these seem to be economically desirable the emphasis must be shifted to tackling residuals disposals at source, where they occur simultaneously with the production and consumption of physical goods. However it is at this point that market inefficiencies—genuine externality problems—are most likely to emerge since adjustments of this sort inevitably involve cooperative agreements among the relevant individuals in circumstances where such cooperation seems likely to break down.

In the market context, and given the common-property nature of most dimensions of the natural environment, any changes in residuals outputs which are desirable will be achieved only by the 'polluted' parties offering compensation to the 'polluter' for any adjustments he makes.[6] Any such adjustments can be regarded as socially desirable if the marginal damage suffered by the polluted individuals exceeds the marginal cost to the polluter of changing his output, and indeed such adjustments could only occur through voluntary action in so far as these implied net benefits exist. However, it is unlikely that the cooperative agreements—the bribes—will be appropriately arranged because the benefits of such agreements are non-excludable—that is, the benefits of

[5] We should perhaps emphasize two points relating to cases where the market does provide apparently efficient solutions. First, market processes may be slow in responding to the emergence of previously unrecognized conflicts; and, secondly, the market solutions may sometimes be grossly inequitable. Either of these observations might be sufficient to justify public intervention.

[6] The compensation or 'bribes' referred to here is in an economic sense no different from prices paid for goods and services in the market.

reduced pollution arising from a bribe offered to the polluter by one individual accrue to all affected individuals even though they have made no contribution to the cost of reducing the pollution level. Each individual thus obtains a 'free-ride' (cost-free benefits) at others' expense and, of course, has an incentive to obtain as substantial a free-ride as is possible. If the numbers of individuals involved is large, as will typically be the case in pollution problems, then each individual will be aware that any attempt on his part to obtain a free-ride will have a negligible impact on the final negotiated outcome. He is thereby given a very definite incentive to understate his true preferences. Thus, the market is doomed in these circumstances to produce an inefficient allocation of resources between physical commodities and clean environment—and this despite the presumed existence of benefits to everyone from a successful internalization of the relevant interdependencies.

If the government is to succeed where the market fails, it must be able to overcome the difficulties inherent in the non-excludability problem associated with tackling residuals disposal at source. To this end, of course, governments have available to them a wide variety of policy instruments ranging from their ability to manipulate the legal system within which the market operates, through to their ability to manipulate the market process via the imposition of taxes and subsidies. However, before turning to a discussion of the instruments available, and their relative success in achieving an efficient allocation of resources between physical goods and clean environment, we shall consider the second of our two general questions—is there any reason for believing that explicit social choices, made through the political mechanism, will result in better choices than those achieved by the market?

Political Failure

It is typically presumed in economic policy discussions that where the market proves to be an inefficient coordinator of decisions, the government should step in to remedy the market's failings. As a value-judgement, such a view would presumably meet with widespread approval, but it is an altogether different matter to establish the positive proposition that where the government does intervene, its decisions *will be* superior to those made in the market: political mechanisms themselves may be imperfect in coordinating decisions. Certainly the real-world political framework appears to bear little relationship to the omniscient, infinitely benevolent government implied in much of the policy literature, and in this sense the answer to the question 'can the government do better than the market?' is not at all obvious.

In fact, the performance of the government in economic policy matters has been subjected to a certain amount of analysis in the recent past.[7] Unfortunately most of the theoretical issues are nowhere near to being resolved so that any attempt on our part to deduce conclusions about the likely performance of the government with respect to pollution control must necessarily be tentative. Nonetheless, given the importance of the pollution problem (as well as the importance of the issues to be raised for policy discussion of all sorts) an attempt to indicate

[7] The major contributions are the work of Downs [8] Tullock [13], and Buchanan and Tullock [5].

some of the more important features of the political mechanism's operation seems worthwhile.

There is one sense in which the usual presumption that government intervention will be oriented towards improving the allocation of resources is understandable. When we say that the market fails to allocate resources efficiently, what we generally mean is that there is a possible change in allocation which would make some individuals better off and none worse off: if this is so then there would appear to be benefits to elected governments (in terms of improvements in their popularity, or probability of being re-elected) from improving the allocation of resources where the market decisions are inefficient. Indeed, if it were true that all government decisions required unanimous support from the electorate then this observation would have substantial relevance. At least one assumes that no-one would give their support to policies which made them worse off, so that overall those changes in policy which occur would involve improvements in resource allocation in the normal Paretian sense.

However, once we recognize that governments need only strive for majority, and not unanimous support, then we must also recognize that both the motivation and ability of governments to seek improvements in resource allocation are likely to be weak for at least two important reasons:

(a) Given that the politicians who compose political parties are motivated, roughly speaking, by much the same aims as most 'ordinary' individuals, and hence that they are not likely to be more than usually altruistic, it would seem likely that political parties would aim to improve the efficiency of the allocation of resources only in so far as political processes (and especially interparty competition) constrains them to do so. In fact, however, a party can be elected or ensure continuing support by *redistributing income* in favour of electorally important or dominant coalitions of individuals in society. For this reason we would expect that political competition is at least as likely to take the form of 'bribing' such groups of individuals (floating voters, farmers, the unions, businessmen and so on) by offers of specific tax concessions or subsidies, as it is to involve pressures to improve the allocation of resources. Ultimately, under majority rule, even a policy platform offering a perfectly efficient allocation of resources can be defeated by another platform offering redistribution of income from a minority to a majority of voters.[8]

(b) To the extent that incentives do exist for governments to attempt to improve on the allocation of resources determined by the market mechanism, they are constrained by the information that is made available to them about individuals' preferences. The information made available to the government through voting behaviour is likely to be deficient for a number of reasons. In the first place, since an individual voter recognizes that his vote is unlikely to be decisive, he will (quite rationally) tend to seek little information

[8] Strictly speaking, of course, redistributions need only be aimed at potential floating voters, or groups which carry enough influence to affect the outcome of elections.

about the benefits of publicly provided services, or at least will not obtain as much information about them as he would about equivalent goods or services available in the private market. In the second place, voters have only one vote with which to express their preferences over competing packages of policies (policy platforms): they are not in a position to reveal their preferences over specific projects, nor the intensity with which those preferences are held. For these sorts of reasons the ballot-box is likely to be a poor source of information for government, and they will be obliged to rely fairly heavily on less direct sources of information provided by lobbies, formal surveys and enquiries, letters to members, and so on. However, while these sources may provide some information, the quality of that information is unknown. It may, for example, reflect peculiarities in the cost-sharing (tax) arrangements: anyone will demand more of a publicly provided service if it will cost them little or nothing.

Considerations of this sort certainly confirm what was perhaps intuitively obvious anyway: that the government is not at all likely to make the most efficient choice between physical goods and clean environment. It also gives us reason for treating with considerably more caution than is usually done the presumption that the government will nonetheless *improve* on the market's results. The government has, of course, a number of advantages over the market: through its coercive powers (through taxation) the government can force everyone to contribute to the cost of pollution control, and in this sense has a means of coping with the 'free-rider' (non-excludability) problem that is the prime cause of the market's failure. Moreover, by responding to the desires of a *coalition* of individuals the government obtains a degree of co-operation which (as explained earlier) would be missing in the market where each individual attempts to free-ride at others' expense. Clearly, the more homogeneous the preferences of the individuals in society the more likely it is that preferences of the dominant coalition will be fairly representative of those of society as a whole, and hence that the government's response will be substantially better than the market's. Unfortunately, we have little reason for supposing that the pollution issue is one on which there is a great deal of agreement. At least, that is, we regard the pollution question as involving more intense divisions of opinion than many other current issues, and hence we suspect that the performance of the political mechanism is likely to be correspondingly poorer: we cannot be certain, though, whether this is likely to involve too much, or too little pollution control.

This catalogue of difficulties inherent in the political mechanism convinces us that we should not expect too much of the government as a decision-maker in relation to pollution control. This is not to say that the government cannot be expected to improve at all on the market, and clearly the better informed it is, the greater are its chances of achieving a significant improvement. The economist's role would, then, appear to be to attempt to inform the government about its main policy options in controlling pollution, and the considerations which are likely to be crucial in choosing between them. It is to an outline of this task that we now turn our attention.

III

Methods of Pollution Control

In so far as the market fails to establish an efficient allocation of resources between the output of physical commodities and the output of clean environment, the government is faced with the problem of choosing between a large number of instruments for modifying the behaviour of economic units. Since our major concern is with general conceptual issues, it seems useful to begin by attempting to classify the instruments available into broad categories. One such classification which immediately suggests itself is that which distinguishes those instruments which involve the use of the government's legal powers from those which involve the use of its fiscal powers.

This particular classification is one that has been quite widely used in economic analysis, apparently in the belief that it provides a clear distinction between the use of direct controls and the use of fiscal instruments. However, in an important sense this particular distinction is misleading, for the legal powers available to the government are of two quite distinct sorts, only one of which corresponds to the 'direct controls' mentioned above.

One form of legal power available to the government is that which allows it to establish *liability rules.* That is, the government may establish whether or not those whose activities impose damage on others are 'liable' for the damages caused. Once such liability rules are established, and the means of enforcing them (i.e. the legal system) provided, it may be left to voluntary activity to determine the extent to which individuals are prepared to allow their rights to be abridged in exchange for some form of compensation.

The second form of legal action involves the government establishing *structural rules,* such as regulations and prohibitions, which *directly* limit the permissible behaviour of individuals and/or firms. In one sense, these structural rules are not unlike the liability rules since both establish particular patterns of property rights. However, while the liability rules form a base from which negotiations may freely proceed between damaged and damaging parties, the structural rules provide a non-negotiable upper limit to the extent that one party may inflict damage upon another.

It is clear, then, that there are three distinguishable policy types available to government—the establishment of liability rules, the establishment of structural rules, or the use of fiscal instruments—and at the most general level the issue to be tackled is the question whether there are reasons for favouring one policy type over the others in attempting to achieve an efficient level of pollution control. For purposes of analysis, the subsequent discussion is broken into two sections. The first considers briefly the way that changing liability rules might help to relieve the pollution problem, while the second contains a more extensive discussion of regulations (i.e. structural rules) and fiscal instruments in controlling pollution.

Liability Rules, Property Rights and Pollution Control

There is a clear connection between the establishment of liability rules (i.e. the definition of property rights) and the successful operation of

the market system. The process of exchange which characterizes market transactions essentially involves the exchange of property rights over the services of assets owned by the transacting parties. This of course is most obvious in the case of a barter process, but the only substantive difference in modern market systems is that money is interposed as the medium through which the exchange of property rights is effected. These 'property rights' embody the relevant liability rules, if the exchange system (the market mechanism) is to function efficiently it must be possible to define *and* enforce all such rights. If we cannot enforce a property right over the benefits of our activities others will benefit without having to exchange some of their property to obtain the services of ours. This is, of course, precisely the problem generally referred to as the 'free-rider' problem arising from non-excludability, and in a fundamental sense this problem arises directly from an inability to enforce property rights.

The relationship between these observations and the possibility of using changes in liability rules as a solution for the pollution problem lies predominantly in the fact that much of the natural environment is not subject to private property rights. In most respects the air mantle, waterways and open access lands are common property resources, equally available for use by all; and even in those cases where there are liability rules relating to damages caused through use of 'the environment', the large numbers of economic units involved, and the diffuse nature of the damage each imposes on other users of the environment often makes the enforcement of property rights technically and economically infeasible. These facts have inspired the belief that changing liability rules—defining or redefining property rights—would provide one way of improving the allocation of resources to pollution control.

The proposals for an 'Environmental Bill of Rights', awarding a property right to a clean environment to individuals in society, are a case in point. Already modest beginnings with such Bills have been made in some states of the U.S.A. and their major purpose seems to be to make the burden of proof in environmental suits (under nuisance and property laws) less demanding. If these Bills of Right achieve their purpose, they will provide some incentive to polluters to control the damage they cause, or to offer compensation to affected individuals, although the extent to which this is so depends crucially upon the success of prosecutions under the Bills, the cost of prosecutions, and the size of damages awarded.

The qualifications introduced in the last sentence are obviously of critical importance, for the point of relying on this (or any other) sort of re-allocation of property rights to solve the choice problem is not merely to provide a legal and institutional framework within which retribution can be exacted *ex post* for damages suffered: the essential purpose of defining (or re-defining) property rights is to establish a basis from which negotiations between polluter and polluted could emerge to internalize relevant interdependencies through voluntary action. What is required, then, is not simply the clear definition of rights, but also the means of policing and enforcing such rights. So long as it is difficult to perceive infringements of rights or to prove damages, and while large numbers of economic units are involved, the negotiation and policing of agreements between damaging and damaged parties will remain economi-

cally infeasible. But even if Environmental Bills of Rights are successful in reducing the problems of enforcement, there is yet another problem to be faced—that is, they may give rise to a level of pollution which is inefficiently low. This is so because precisely the reasoning which induces individuals to *understate* their preferences for pollution control when the firm has a *de facto* right to pollute, will induce individuals to *overstate* their requirements for compensation when the firm is liable for damages caused. In this case, the choice between physical goods and clean environment will be distorted in favour of the latter, and it is by no means obvious that a distortion in that direction is to be preferred.

It certainly seems to us that whatever purpose manipulation of property rights may serve, it is unlikely that it will provide a simple solution to the pollution problem. The crucial points may, perhaps, be summarized as follows. If the market fails to achieve an efficient allocation of resources, then it may fail whatever the allocation of property rights, because market failure can often be taken to imply that enforcement of private property rights is infeasible or uneconomic; and, moreover, if the enforcement problems *can* be mitigated (by, for example, reducing the burden of proof in environment suits) we may find ourselves faced with a choice between inefficiently high and inefficiently low levels of pollution!

Perhaps, after all, Environmental Bills of Right and similar legal instruments should be seen as embodying a statement of society's views on the most *equitable* liability rules. *Effective* enforcement of property rights, and hence the establishment of major improvements in the allocation of resources between clean environment and physical consumption, will, in most cases, require the government to intervene more *directly* in market processes, through the use of its regulatory and fiscal powers.

Fiscal Instruments and Regulations in Pollution Control

Accepting that the establishment of efficient pollution control measures will require the government to intervene more or less directly in the market, using its fiscal or its regulatory powers, what issues are likely to be decisive in choosing the appropriate policy-mix?

This question, which constitutes the subject matter of this section, is not easily answered. In part, the difficulties arise from the fact that the criteria needed to judge the relative merits of the available options are difficult to specify with precision, but, in addition, the policy options which have been grouped into the categories 'fiscal instruments' and 'regulatory powers'[9] may themselves be employed in many different ways. For example, in a purely *technical* sense it is possible to distinguish three basic methods of controlling pollution: reduction in the volume and/or improvement in the quality, location, or time pattern of residuals generation; treatment of residuals after generation and/or improvement of the assimilative capacity of the environment; or application of protective measures at the point where damage is inflicted upon the ultimate receptors. To each of these technical methods of control there corres-

[9] The term 'fiscal instruments' refers to both taxes and subsidies, while 'regulatory powers' includes the power to prohibit or ban an activity. In the analysis which follows we generally use taxes as representative of all fiscal instruments, and regulations as a term covering all direct controls.

ponds an array of taxes, subsidies, or regulations which may be employed to achieve some given degree of control. For example, if we are concerned primarily with controlling the volume and/or quality of residuals generated in productive activities, we may choose to relate taxes, subsidies or regulations to one or more of the following dimensions of the production-consumption process:

(i) pollution 'nuisance' or damage, defined in terms of the relevant argument(s) which enter individuals' utility functions, or firms' production functions;
(ii) the emissions which are produced as a by-product in the production of goods;
(iii) the goods with which emissions are jointly produced;
(iv) the inputs used in production processes generating pollution.

Rather than attempting (and necessarily failing) to do justice to the infinite variety of alternative policies and policy-mixes available, we have concentrated on the general issue of whether there are reasons systematically favouring the use of fiscal instruments over 'equivalent' regulations, or vice-versa. By way of justification we might offer two observations. Firstly, much of the detailed investigation of the various parameters to which taxes and regulations may be applied is available elsewhere;[10] and secondly discussion at this more general level may substantially reduce the difficulties which need to be resolved at the more specific level of choice. However, whichever level of choice we are concerned to examine, an essential first-step is the specification of the criteria in terms of which choice should be made, and it is to this task that we initially turn.

The Criteria

In the most general sense, the basic objective is to choose, from the available set of policy options, a policy (or policy mix) which will achieve global efficiency in the allocation of resources to alternative uses—which 'uses' explicitly include the output 'clean environment'. However, in order to make some progress towards evaluating the relative merits of alternative policy options it seems appropriate to break up the general efficiency goal into several specific aspects, which we can indicate by raising the following set of questions:

(i) does the policy achieve an efficient 'quantity' of pollution (clean environment), both in the period in which it is initially imposed, and over time?
(ii) does the policy achieve the established level of pollution control at least social cost in terms of other goods and services foregone?
(iii) how does the policy distribute cost between the various parties in the pollution conflict?
(iv) what, for any given level of policy success, are the informational requirements of the policy?
(v) what are the measurement and monitoring costs associated with the chosen policy?

[10] See, for instance, Brennan, Walsh and Chisholm [3], Parish [10] and Zerbe [14].

These questions involve, to a certain extent, distinct dimensions of pollution control techniques. The first two relate to aspects of the standard Paretian efficiency goal.[11] The third, in contrast, is basically concerned with the incidence of the various policy options. While incidence questions might typically be thought of as being concerned with the *distributional* impact of the adopted policy, it is important to recognize that distributional effects may not be allocatively neutral: the incidence of the policy may directly influence the quantity of pollution control applied.

The last two of the questions raised relate to administrative matters: they merit explicit attention here precisely because they are of such importance. To achieve Pareto optimality "regardless of cost" is clearly a contradiction in terms—and as has been emphasized in the externality literature (at least from Coase [6] onwards) questions of administrative cost, in the widest sense, may be crucial in determining the appropriate choice between policy tools. Because of their importance, particular attention is given to information and measurement costs in the comparison of fiscal instruments and regulatory controls which follows.

Fiscal Instruments versus Regulations

The primary difference between the use of regulations and the use of fiscal instruments to achieve a given end is that the former seeks to achieve the objective by directly manipulating relative *quantities,* while the latter operates on relative *prices.* While we shall have reason to suggest that this difference is of crucial importance in determining whether one or the other policy-type is generally to be preferred as the instrument for establishing an efficient level of pollution control, it may be as well to indicate at this point that at the conceptual level the difference between fiscal instruments and regulations is not as great as is commonly suggested.

In an analytical sense, the difference between, say, a tax on the production of a commodity, and a law regulating its output level might be looked on as follows: a regulation involves an *implicit* tax, with a rate structure that is subject to a large, discrete change at some point—usually zero up to that point, and some other, positive and *finite,* rate thereafter.[12] A tax, on the other hand, usually applies at a non-zero rate over the whole range of output, although it too could have discrete changes in the rate structure. The non-zero tax rate implicit in the regulation is, of course, associated with the cost of violating the regulation, and is determined by the probability of being detected and convicted, and the penalty imposed on conviction.

In fact, if the practice of courts or legislatures in framing penalties is to attempt to estimate the true cost to the rest of society involved in the contravention of the law, and then shore up this 'cost' to allow

[11] The Paretian efficiency goal refers to the attainment of a so-called Pareto optimal allocation of resources i.e. an allocation such that there exists no further changes which allow someone to be made better-off without making someone else worse-off.

[12] The fact that the implicit rate is almost always finite is important, for it is this fact which ensures that there will be some possibility of firms failing to meet the regulations. This implicit tax rate is, as we suggest later, a function of the probability of violations of the regulation being detected and prosecuted, and the fine imposed on conviction.

for inadequacies in enforcement procedures, the expected cost to each firm of contravening the law would seem to be exactly the same as that faced by the firm under a tax calculated according to marginal social damage caused (i.e. the 'ideal' Pigovian tax). Of course, one could argue, possibly quite forcibly, that generally held notions of retributive justice ('making the punishment fit the crime') may tend to militate against offenders being fined more than the estimated value of damages caused, so that due allowance for the probability of being detected is not made. However, there are often other costs associated with the act of law-breaking arising from the disapproval of society (psychic costs, or loss of goodwill, for example). Such costs (if applying) raise the effective tax rate implicit in the regulation, and may offset the failure of the courts to take full account of the deficiencies in enforcement procedures.

Clearly, taxes and regulations can, in principle, be made to operate in precisely the same way, and the differences between them at the conceptual level are much smaller than is often suggested. Nonetheless, important differences do exist associated with information requirements, measurement costs, and allocative effects generally.

Information Requirements.

One of the crucial differences between the use of taxes and regulations for achieving a relatively efficient level of pollution abatement is associated with their information requirements. Surprisingly, this is a fact which has received less attention than it warrants, and such observations as have been made are often dangerously misleading.

To achieve a relatively efficient degree of pollution control through a policy of 'pure' regulation, the government would need to know:

(a) what is the optimum aggregate level of pollution abatement for each of the various types of waste emissions;
(b) how these aggregates should be allocated among individual polluting units; and
(c) the level of penalties necessary to ensure compliance with the regulations.

The information needed to make correct decisions is clearly enormous: ideally what we need to know to establish the regulations is the marginal social damage function (the demand curve for pollution abatement) and the marginal social cost of abatement function (the supply curve of pollution abatement) not merely for each type of waste emission, but also for each individual polluting unit. Estimation of the demand curves requires obtaining individuals' evaluations of different levels of environmental quality, while estimation of the supply curves involves estimating the cost of goods and services foregone to achieve different levels of pollution abatement. And we need to know *both* because we wish to know the optimum *quantity* of pollution abatement.

Pollution taxes, on the other hand, would appear to be inherently less demanding informationally than regulations designed to achieve the same efficient level of pollution abatement. The point is that if we could estimate the demand curves for pollution abatement, we could face firms with a tax schedule corresponding to the marginal social

damage at each level of their activity, and firms themselves would adjust their activities to the efficient level. In short, in order to impose the appropriate tax, we need only know the demand curve, whereas for regulations we need both the demand and supply curves. Of course, with the tax scheme we would not know what the optimum pollution level is: the optimum will emerge from firms' adjustments.

The difficulties associated with obtaining the necessary information to set appropriate rates of tax should not, of course, be underestimated; and the costs of failing to obtain all the required information may be extreme.[13] Nonetheless, it does seem clear that whatever the difficulties involved in meeting the informational demands of establishing efficient pollution taxes may be, they are substantially less than those involved in establishing equally efficient regulations. Since, in practice, we will have to contend with very incomplete information, expendable uncertainties should not be introduced: the expected error in 'guessing' an optimal tax structure is likely to be less than that involved in 'guessing' an optimal quantity.

Measurement Requirements

An important aspect of the administration of pollution control policies lies in the business of measuring and monitoring individuals' use of the various recipient media for the discharge of wastes. It is tempting for policy-administrators to focus only on that dimension of measurement cost which accrues to the government; but individual firms might also be obliged to incur measurement costs under certain policy options. Thus two aspects of the measurement problem are relevant:

(a) what is the total amount of measurement required?
(b) how is the responsibility for measurement apportioned between government and individual firms?

In the absence of empirical detail it is not possible to know precisely how measurement costs vary between industries, between regulations and taxes, and according to which parameters within the production-consumption process are measured.[14] Some general observations can, however, be made.

With a pollution tax it would appear to be necessary for each firm's activities to be continuously monitored in order to establish total tax liability. A regulation, on the other hand, is normally enforced by monitoring the activities of some (randomly selected) firms at occasional (randomly selected) time intervals. Thus under a regulation, it seems, at first glance, that measurement costs will be smaller. We do not believe

[13] For example, a tax on emissions into the atmosphere may induce firms to substitute water for air as the recipient medium for waste products—and the resulting state of the world may well be worse than formerly.

[14] It seems fairly clear, however, that measurement costs will generally be lower when the target of the tax or regulation is physical inputs or outputs of goods, rather than waste emissions or actual pollution damage. Against these lower measurement costs must be set the fact that it is relatively inefficient to control pollution by imposing taxes on physical inputs or outputs. We simply do not have the formidable amount of information that would be required to specify the particular mix and level of taxes on physical inputs and/or outputs that would result in precisely the same allocation of resources as would efficient taxes on pollution damage itself.

this to be true. Although the *government* is not required to do as much measuring as in the tax case, firms themselves will be required to measure their own emissions in order to ensure obedience to the law. If the effective tax rate implied under the regulation is the same as that under a tax, the incentive to measure will be the same. Total measurement costs are therefore likely to be at least as large for a regulation as for an equivalent tax, but the government has the prime responsibility for measurement in the tax case—and the firm in the regulation case.

Allocative Effects

We have argued that, conceptually at least, it is possible to frame penalties such that the expected cost to a firm of contravening a regulation is the same as that which would be faced by the firm under an ideal pollution tax designed to achieve the same resultant output of residuals. The implications for resource allocation are, however, likely to differ in some respects.

In the first place, the outcome under a regulation—which is enforced by a system of occasional random checks—will depend partly upon the attitudes to risk of individual firms. If firms are risk averse, there will be less pollution under a regulation than under an 'equivalent' continuously monitored tax.

In the second place, the tax normally involves payment over intramarginal as well as marginal units—the regulation applies only to marginal units. Thus, if a firm produces one hundred units of pollution on the basis of a pollution tax applying at an average rate of t dollars, it pays a total tax of 100.t dollars. If the same firm faces a pollution quota of one hundred units, and adheres to it (which it will if the expected cost of exceeding the quota is equal to, or more than, t dollars per unit excess) then it pays nothing at all.[15] Although this phenomenon is customarily referred to as an 'income effect', this may be misleading because it is also sometimes suggested that, since firms will prefer regulations to allocatively equivalent taxes, one might get more pollution control (via more general political acceptability for pollution control) if regulations are used.[16] Moreover, it is also frequently noted that firms have a greater incentive to invest in pollution-reducing technology under taxes than under equivalent regulations because any given reduction in pollution is worth more to them in the tax case. In this sense, taxes and regulations are *not* allocatively equivalent, even when they result in the initial period in the same level of pollution output. Thus, it is clear that the so-called 'income effects' mentioned here are not really income effects at all.

Summary

Taken together, the information, measurement and allocative aspects of the tax versus regulation comparison suggest that a fairly clear case exists for generally favouring the use of fiscal instruments over the use of regulatory powers as a means of achieving a relatively efficient level of pollution control. Of course, even at this very general level

[15] Except, of course, the foregone profits which applies equally to the tax.

[16] Firms would have an even higher preference for subsidies on pollution abatement, but given that subsidies would probably be financed via general taxes it seems likely they would be less politically acceptable to the general public.

of analysis the arguments are not entirely conclusive. For example, we have already noted that the 'income effects' associated with regulations make their use more attractive to polluting units than equivalent taxes, and hence may make the use of regulations more politically acceptable. Moreover, if we consider particular cases of pollution we may find circumstances in which uncertainty is so pervasive, and the potential social costs of failing to take appropriate action so large, that the immediate imposition of stringent regulations appears to be essential.

It is interesting to note, too, that this general preference for taxes over regulations also suggests that a somewhat distinct group of policies which have been the focus of increasing attention in recent years are not as attractive as they initially appear. These policies, which might collectively be referred to as 'environmental standards' approaches, involve a mixture of policy-types—partly imposing regulations (i.e. the imposition of aggregate standards of residuals disposal), and partly using the pricing mechanism (i.e. emissions taxes in the Baumol and Oates [2] scheme, and transferable quotas in Dales' [7] proposal). Baumol and Oates in particular have argued that these 'standards' approaches are informationally less demanding than pure tax approaches. Our earlier arguments, however, clearly suggest that this proposition is subject to serious doubt.

The essential point is that in order to establish relatively efficient aggregate standards we must obtain estimates of *both* the aggregate demand and supply schedules for pollution control, whereas a pure tax scheme would involve estimation of only the demand schedule. However, we must also accept that the 'transferable quota' approach does have some countervailing advantages. Using a pure tax scheme, we need to know not merely the aggregate marginal social damage function, but rather the social damage function for each individual polluting unit: but using tranferable quotas, once the aggregate standard is determined, the allocation of quotas among individual units is achieved efficiently by the market mechanism.[17] In contrast, the iterative procedure involved in the Baumol and Oates schemes (i.e. adjusting uniform emissions taxes until the desired aggregate standard is established) appears positively clumsy.

Certainly, it seems to us, the appropriate choice between taxes and standards is much less obvious than Baumol and Oates would have us believe, and their particular proposal appears to be less attractive than the transferable quota approach suggested by Dales. But it would be misleading to leave the overall debate with an implicit suggestion that the adoption of either taxes or standards for the attainment of efficient levels of pollution abatement would be a fairly simple matter. It should be clear from our previous remarks that the information and measurement requirements for both policy types are very large; and policies in this area are likely to be determined in circumstances of substantial ignorance and uncertainty. In this case, it may be best to persuade

[17] The operation of a transferable quota scheme requires that waste emissions be measured in terms of some standardized 'pollution index'. With respect to water pollution, Biological Oxygen Demand (BOD) could be adopted as the unit of measurement for pollution quotas, for example. It should be noted, too, that the measurement costs required to ensure that firms do not exceed their quota levels may be high, as we have previously suggested.

governments to adopt only modest policies, and to treat broad classes of goods or inputs in uniform fashion even though we may suspect that different inputs or production processes have different 'pollution productivities'. Exceptions to this uniformity rule could then be allowed in cases where it can be clearly shown that particular inputs or processes have much higher (or lower) than average 'pollution productivity', or in particular geographical areas where pollution is more serious, and/or the demand for abatement higher than average. To adopt a series of 'finely-tuned' policies in circumstances where information is incomplete, or prohibitively expensive is to ignore the very high social costs involved in making a wrong decision.[18]

IV

Conclusions

To attempt to provide a concise summary of the contents of this paper, given its size, and the wide-ranging nature of its contents, would be an impossible task. Instead, in conclusion, we might simply emphasize *some* of the major issues that we have raised.

We have argued that, as an economic problem, 'pollution' must be seen as involving a conflict between various possible uses of the environment, forcing us to choose between, on the one hand, consumption of physical (or produced) commodities, and on the other, consumption of a 'clean environment'. However, to argue that a choice needs to be made is not to argue that the choice need necessarily be made through the political mechanism. Making choices is, after all, what organized markets are all about, and even accepting that substantial 'market failure' is likely, we cannot state with certainty that where political decision-making processes are utilized to resolve the conflicts the results will be substantially better than those generated by voluntary action. Nonetheless, whatever we may think about the relative virtues of market and political decision-making processes, substantial political intervention is inevitable.

All of the alternative policy options for pollution control require that the demand curve for 'clean environment' be estimated. In addition, some policy options also require estimation of the supply curve of 'clean environment'. It is essentially this observation which leads us to argue that, in general, the use of taxes and subsidies is likely to be preferable to widespread use of regulations or other legal instruments. On the other hand, there does appear to be some virtue in the proposal for using transferable quotas in the context of an 'environmental standards' approach, and a mixture of 'pure' taxation policies, and the use of this quota scheme may prove to be the most useful form of pollution control.

Finally, we believe that the information and measurement requirements involved in the implementation of appropriate pollution control policies will often be extremely costly. This suggests that attempts to implement *finely tuned* policies for pollution control are unwarranted. In other words, it is our view that the use of the political decision-making

[18] Some of the issues relevant to this assertion are considered in an unpublished manuscript by H. G. Brennan and T. McGuire, 'Optimal Policy Choice under Uncertainty'.

process to impose discriminatory control on pollution sources can, in general, only be justified in circumstances of clear market failure and where a fairly high demand for pollution abatement exists. A general policy of reducing pollution levels might be better achieved by general and reasonably uniform taxes on all pollution sources.

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