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SOLVING THE AIR POLLUTION PROBLEM: A SOCIAL SCIENTIST'S PERSPECTIVE†

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The purposes of this article are to present a social scientist's explanation of why there is an air pollution problem and to indicate areas where one social scientist would look for solutions to the problem. I must admit at the outset that I am an economist and hence favor the economists' solutions. However, I have tried to fairly represent the six disciplines of the social sciences which are most concerned with the problem. These disciplines are: Sociology, Psychology, Political Sciences, Law, Economics, and Urban Planning.

WHAT IS THE AIR POLLUTION PROBLEM?

Society would prefer a clean air environment to a polluted one. However, attaining clean air requires the expenditure of resources and society has other uses for these resources. In the United States the resource allocation process is left to the market mechanism except when society is not satisfied with the result. In such cases society through government interferes with the market.

What, then, is the air pollution problem? Briefly stated, it is that society appears to be demanding a better air quality than it is currently getting in the market. That is, society is willing to allocate more resources to the production of clean air than the market is now allocating to that goal. Having said this, let me retract somewhat from this stand. Air quality is not a problem of universal concern throughout the country. People in many parts of the country are not now suffering from sufficiently poor quality air to justify additional expenditures on control. In other areas the air may be of relatively poor quality but the people of the area may prefer to continue breathing this level of air quality rather than take resources away from other activities which they regard as more important. In other words, the choice of quality of air is a local choice which depends upon the local meteorological conditions, mix of pollutants released, technology and cost of controls, *and* the local preferences for clean air relative to other social goals.

Throughout the remainder of this article I assume society's desire

†While the opinions contained in this article are my own, I have gained much from the six papers written for the Social Sciences Task Force of Project Clean Air. Project Clean Air is the University of California's applied research program on air pollution control. I also wish to thank William Brown, Thomas Crocker, Ralph d'Arge, and an anonymous referee for their helpful comments on earlier versions of this paper.

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is for a reallocation of resources toward the production of better air quality. In making this assumption I am implicitly placing the reader in one of the several heavily polluted airsheds in the country where the argument for increased control can more easily be made.

WHY THE PROBLEM REMAINS

There is a combination of factors which contribute to the lack of a solution to the problem. Many of these factors are technological in nature. Concern here will be exclusively with the institutional factors which cause a misallocation of resources away from air pollution control.

A. Lack of Effective Polluter Action

A rational firm tries to produce its goods at the lowest possible cost to itself. One way this can be done is to release unwanted by-products into the environment. In this way the firm saves itself the cost of collecting these by-products and removing them from the site of production. The release of these wastes into the atmosphere causes others to suffer losses (poor health, loss of view of the mountains, etc.) for which they are not compensated by the firm. There is little incentive in the private market for a firm to reduce the losses it imposes on others. The net result is a situation where the firm is paying less than the true cost of its production (where the true cost of production includes the firm's out-of-pocket costs *and* the losses it imposes on others). The lower costs are reflected in the lower price charged for the firm's products. This causes the firm to produce and sell more than would be the case if it paid the full costs, and thus more pollution than is desirable is produced and released.

Of course it is in the interest of each firm to resist any government control actions which would increase its out-of-pocket costs of production. Furthermore, some industries are more adversely affected by control efforts than others. These industries tend, by coincidence, also to be ones having few firms and large sales volumes. Examples include the automobile manufacturers, the oil companies, and the electric power utilities. This combination of general resistance to control efforts by all firms and strong resistance by the relatively few but politically powerful firms most adversely affected, results in strong anti-control lobbies at all levels of government.

The individual suffers from pollution. He is also a polluter. He uses a car which emits pollutants. He burns trash in his backyard or does so indirectly through local government as his agent. The reasons he does not take action to reduce his pollution of the atmosphere are in part the same as those cited for the firm. Pollution control costs money and there is little incentive to spend the money. In addition, the individual perceives the problem as very large and he perceives his contribution to the problem as being too small to have any effect on the quality of the air he breathes. This combination of cost without any perceivable personal benefits, results in a passive non-cooperative attitude toward control efforts. The typical reactions I get when I ask friends about air pollution control are: "I'm not going to do anything unless everybody else does too"; and "Somebody (the government) ought to do something about it."

B. Lack of Effective Public Action

The damages caused by air pollution accrue to all individuals living in the area of the release. Likewise, the benefits of improved air quality accrue to all individuals in the controlled area. Thus, successful efforts to control pollution by some individuals would cause others who do not join the effort to reap part of the benefits. This provides a strong incentive to refuse to help in attaining control of air pollution because each individual knows he will benefit from a successful effort without any expenditure of his own efforts or resources. This is a classic example of the "free rider" principle.

At the same time each individual compares his power to affect governmental control decisions with that of the anti-control faction. In this comparison he feels impotent. The result of this combination of free rider problems and a perceived lack of political power has been a relatively weak (or non-existent) pro-control lobby.

C. Lack of Effective Government Control Action

While it is true that government agencies now in operation have slowed the increase in air pollution levels and in some cases may even have reduced pollution levels, people still complain of dirty air. The combination of a strong anti-control lobby and a weak pro-control lobby have understandably resulted in a relatively weak control effort. This weak control effort may be due in part to poor management by control agency officials, but a greater share of the blame can be placed upon the organizational structure of the control effort. Public opinion has forced the passage of bills to control pollution. However, there is more than one way to subvert control efforts. Thus we find that agencies already in existence lack adequate control authority because of diversified control responsibilities. For example, in California the Air Resources Board has control responsibility over automobile emissions and county Air Pollution Control Districts have control responsibility over stationary sources in their counties.

In the Los Angeles Air Basin there are parts of six counties, each with a different jurisdictional organization and regulations for air pollution control.

A second factor which leads to lack of effective control is the limited amount of resources provided control agencies to do their job. It is a typical political maneuver to approve a program, but to provide the program with little or no funding so that it cannot really do the job it was assigned to do. With this tactic the politician can point to his stand against air pollution when questioned by the electorate and yet not alienate the anti-control lobby which may support his re-election.

A third factor which leads to a lack of effective control is the difficulty in enforcing controls under current forms of regulation. Standards are usually enforced by a permit or certificate issued to the firm. The cost of administering such a system is very large, and in light of the limited resources available to control agencies this is a critical consideration. Furthermore, the inspection process very often interferes with the normal operation of the plant. Non-compliance is "... enforced by criminal process, probably the most cumbersome coercive tool we have. The violator is protected by all the constitutional protections which apply to any criminal trial. He can demand a trial by jury and unanimous verdict (and this against the heavy burden of proof faced by the prosecution)."[1]

Finally, control agency officials are sensitive to political pressures (either explicit or implied) from the anti-control lobby (and conceivably from the pro-control lobby). The agency is dependent on political entities such as state legislatures for annual appropriations. Its officials are very aware of any action which might offend the political powers which control the resources needed for their control program. This can result in lax administration of control regulations or large variances for large and politically powerful firms. The firms themselves use this fact in their relationship with the control agency. The typical threat is that controls imposed by the agency would cost too much and the firm would have to close its plant and move. If this were true, the plant must be marginal and it is likely the firm would either rebuild or move shortly even without additional air pollution controls being placed on it. In fact, as Faltermeyer points out, "... in Los Angeles, not a single industrial establishment, large or small, old or new, has been forced to move away or go out of

1. Krier, *Air Pollution and Legation Institutions,* 3 Project Clean Air, Task Force Assessments: The Contribution of the Social Sciences to the Solution of the Air Pollution Problem 5-29 (P. Downing ed., Air Pollution Research Center, Univ. of Cal., Riverside, Sep. 1, 1970) [hereinafter cited as Task Force Assessments].

business because of the cost of complying with air pollution regulations."[2]

Thus we find strong pressures placed on government agencies to go slow on control efforts and weak pressures placed on them for stringent controls. The result is obvious. One of the jobs of the social sciences is to find ways of counteracting this anti-control bias in our legal, governmental, and socio-economic structure.

D. Growing Public Interest

In recent years the public interest in improving environmental quality has grown rapidly. It is now a leading political issue. This increasing interest stems from a combination of economic and sociological factors. For many families in the middle, upper-middle, and upper income classes in America, income has increased to the point where the acquisition of additional material goods no longer serves as the primary personal goal. As Molotch and Follet put it, ". . . among those Americans who have lived with their basic 'needs' of food, clothing and shelter satisfied there is emerging a new consciousness of alternative goals . . . among them would be a physical environment which is healthful and aesthetically pleasing."[3] Coupling this with the growing availability of leisure time adds power to the observation.

THE NATURE OF THE SOLUTION

There are two main aspects to the nature of the solution: technology and resource allocation.

A. Development and Adaptation of Technology

Some people claim that most of the technology necessary to "solve" the air pollution problem is already available.[4] While it is true that substantial improvements in air quality could be made if existing control devices were universally installed, many technical problems yet remain. In the next few years much work is needed on the development of devices which do an adequate pollutant removal job inexpensively and reliably. In the long run growing population will dictate very high levels of control. The attainment of current and future air quality goals is not going to be technologically easy. With all the research that has been completed to date it seems unlikely that a technological panacea will be discovered. Society cannot af-

2. E. Faltermayer, Redoing America 73 (1968).
3. Molotch and Follett, *Air Pollution: A Sociological Perspective,* in 3 Task Force Assessments, *supra* note 1, at 2-11.
4. E. Faltermayer, *supra* note 2, at 85.

ford to wait and hope that such a panacea will appear. We must more adequately tackle the job of adapting and implementing the technology now available.

B. Reallocation of Resources

At the present time the United States economy is using its resources to produce goods and the secondary effects of this production on the environment are substantially ignored. As has been pointed out above, there is good reason for this attitude among individuals and firms. The legal and social structure is such that some form of government action is necessary to force individuals and firms to consider in their resource use decisions the effect of their actions on the environment and hence overcome the anti-control bias. The goal is to reallocate the use of the nation's resources away from pollution and towards control. This goal assumes that we now have too much pollution, an assumption which seems reasonable in light of the growing public concern with the quality of the environment. Determining the extent to which this reallocation is necessary and how it can be most effectively arranged are the subjects dealt with in the remainder of this paper.

THE LEVEL OF CONTROL

The level of control which is socially desirable is a function of the cost of control, the technological effectiveness of control measures, and the damages averted by lowering pollution levels. These are the elements of the traditional benefit/cost analysis. The decision rule is to expand air pollution control to the point where the additional cost of one more unit of control (marginal cost) is just equal to the value of the additional damages averted (marginal benefit). This equality defines the point where total net benefits (total benefits less total costs) is a maximum and hence the optimal allocation of resources to air pollution control.[5] Our task is to quantify these costs and benefits. While the quantification of benefits is conceptually easy, in practice current methodological tools can quantify only some of the benefits. Many others remain unquantified or in some cases quantified in terms that are not commensurate with the dollar measure used for costs. This leads me to propose a variant of benefit/cost analysis which takes these quantification problems into account. An important point which must be stressed is that the methodology suggested here leads one to conclude that due to the

5. Sewell, Davis, Scott, and Ross, *A Guide to Benefit-Cost Analysis,* in Readings in Resource Management and Conservation 544 (I. Burton & R. Kates ed. 1965).

cost of control and the low levels of damages at high control levels there will be some non-zero level of pollution desired by society.

A. Policy Trade-Off Analysis

A policy trade-off analysis is an effort to produce all the relevant considerations both pro and con for each set of alternative air pollution control policies the governmental decision-makers could choose. The end product of this effort would be a listing of the full implications of each policy alternative in a way which would make clear the trade-offs between competing social goals. The decision-makers would then have before them all the technical and socio-economic information they "need" for effective policy deliberations.[6] The governmental decision-makers would have to make the difficult decisions of how much to weight each positive and negative aspect of the various alternatives in order to select the best alternatives for the people they represent.

Implicit in the whole policy trade-off analysis framework is the assumption that the decision-makers represent geographical areas which bear most of the important effects of their decisions. In most air pollution control cases, this would require that control responsibility be assigned to a level of government which encompasses the entire airshed rather than some random part of it. This jurisdictional problem is typical of many intergovernmental relations problems. A local government can zone its land so that the polluting industries are on the downwind side of its jurisdiction. Thus, it solves its air pollution problems but creates problems for the residents of the downwind area. Since these people live under a different governmental jurisdiction, they cannot force the decision-maker to consider the effects of his decisions on them without having a higher authority to which they can appeal. In this regard local authorities are in much the same position as the individual or firm in that the system we now have does not force local decision-makers to consider the effects of their decisions on others outside their jurisdiction.

Also implicit in this policy trade-off analysis framework is the assumption that the decision-maker is someone (or some legislative body) who fairly and fully weighs all aspects of the air pollution control problem along with all other competing public and private uses of resources. The likelihood of finding an individual with such vision or of setting up a legislative body which perfectly adjudicates

6. Since information is costly to obtain, the public agency must determine how much to spend on information gathering. In general the agency should collect information to the point where additional information (greater accuracy, etc.) would cost more to obtain than it would benefit the decision-maker in terms of enabling him to make a better decision.

among competing uses of the airshed's resources is obviously remote. In the absence of such perfection some less satisfactory decision-maker or decision-making body must be used. One might spend a great deal of time discussing how to design an institutional framework which can fairly represent all aspects of the decision (all competitors for the resources) but this is not the purpose of this paper. Rather, it is assumed that some such institution can be formed so as to counteract anti-control bias in current institutions, and that the decision-makers are influenced by the information this analysis can provide.

It is obvious that no one discipline can provide enough information for a thorough policy trade-off analysis. It should be equally obvious that social scientists as well as physical and biological scientists and engineers are needed in this effort. As an example of how the various aspects of this analysis fit together we will discuss the possible choices facing a decision-maker who must determine the level and type of controls to require in an airshed. There are five main parts to this analysis: the cost of the various alternatives, the effect of each alternative on air quality, the benefits of the resultant improvement in air quality in terms of damages avoided (quantified in money terms whenever possible), the administrative costs and problems (including public acceptance) of each alternative, and finally, who pays for the control operations.

The cost of any air pollution control device includes the cost of the equipment, the cost of its installation, its effect on operating costs, and the cost of proper maintenance. All these costs can be put into annual figures which are a function of the life expectancy of the source on which they are installed as well as the life expectancy of the devices themselves. Each device will have an expected reduction (or increase) in each of the five main pollutants emitted: HC, CO, SO_2, particulates, and NO_X. As we learn more about aldihydes and other emissions from mobile and stationary sources, they could be included in the analysis. These expected reductions will be a function of the type of source, controls already installed, and the source's age and condition. In addition, there is uncertainty about both costs and emission reductions for new devices not yet in production.[7] Thus some confidence intervals should be placed on both costs and effects. Applying the cost estimates to the population of various sources in the airshed yields estimates of the total annual cost of alternative devices applied to various types of sources. Similarly, corresponding estimates of emission reductions (in pounds per day) can be derived.

7. I am defining "new devices" as any new add-on device or process shift which may be developed or proposed in the future.

One can then set various levels of annual expenditures and determine the maximum possible emissions reduction attainable for that sum. Immediately, however, one is faced with three problems. One is that it is not obvious how much weight to give to a pound of reduction in HC versus a pound of reduction (or increase) in CO, SO_2, particulates, or NO_X. To solve this problem a translation of reductions into improvements in air quality is desirable. The second problem is that each alternative may have different administrative problems and costs which should not be ignored. Third, the reductions occur over a period of years. Some weight must be given to reductions in future years. This can be done by calculating the reductions (or improvements in air quality) for each future year, discounting each to the present and summing the results. The output of this part of the policy trade-off analysis is a listing of control alternatives, their costs, and their emissions reductions.[8]

The air quality improvement estimates are themselves a major research project. They require detailed knowledge of the meteorology of the airshed, information on the type and speed of chemical and photochemical reactions, location, timing, amount, and type of pollutants emitted, and much more. Some recent progress is evidenced by the work of Neiburger, and Behar.[9] A full understanding of all the complexities of air quality relationships is a long way away. In the meantime we must act on the information that is available. In this case some rough approximations will have to suffice.

Combining the cost data and effectiveness data in terms of air quality, we can produce a listing of alternative policy choices, their costs, and the resultant air quality of each alternative. It remains to estimate the benefits (damages averted, etc.) resulting from the various levels of air quality improvement. The health effects of air pollutants are often mentioned but very little is actually understood. It is obvious, however, that some people have serious impairments to their health as a result of, or aggravated by, air pollutants. Among diseases aggravated by air pollution are emphysema, other respiratory diseases, and heart disease.[10]

In addition to the pathological effects of pollutants, there appear

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8. The first steps toward such an analysis for the California airsheds can be found in Downing and Stoddard, *Benefit/Cost Analysis of Air Pollution Control Devices for Used Cars,* 3 Project Clean Air, Research Reports (Air Pollution Research Center, Univ. of Cal., Riverside, Sep. 1, 1970) [hereinafter cited as Research Reports].

9. Neiburger, *Mathematical Model of the Diffusion and Reaction of Pollutants Emitted Over an Urban Area,* and Behar, *Simulation Model of Air Pollution Photochemistry,* 4 Research Reports, *supra* note 8.

10. For a discussion of the health effects of air pollution and the benefits of its control, *see* Lave and Seskin, *Air Pollution and Human Health,* 69 Science 723 (Aug. 21, 1970).

to be effects on the psychological well-being and behavior of individuals. These psychological effects include greater irritability, depression, slowed reaction time, and reduced productivity. Furthermore, these effects are manifested at much lower levels of pollutants than are pathological effects.[11] Some recent evidence which may reflect the psychological aspects of air pollution was produced in a study by Ury, Goldsmith and Perkins. They found that there is a positive and highly significant relationship between high oxidant levels and increased occurrence of traffic accidents.[12]

In addition to the health and psychological effects of air pollutants, there is a preponderance of evidence concerned with the physical damages of air pollutants. Damages to agricultural crops in California in 1969 were estimated to be $44 million. In addition, there is well-documented evidence of damage to forests, recreational areas, and ornamental plantings.[13] In other airsheds pollutants may cause increased paint wear, corrosion of metals, dirtying of clothes and buildings, etc. The property damage of air pollution alone is estimated at approximately $12 billion per year.[14]

Some estimates of the implications of the various levels of improved air quality associated with each policy alternative can be obtained from the estimated health effects, psychological effects, and physical damages averted by each air quality improvement. These estimates should be put in dollar terms whenever possible in order to make them commensurate with the cost estimates. If this is impossible, damages stated in physical terms should be used. In some cases only informed opinion is available on damages. This should also be included in damage estimates in order to give the decision-maker as much information as possible on which to base his decisions. A problem remains with the weighting of various bits of information on increases or decreases in air quality parameters and hence the benefits of control. In cases where implicit trade-offs provide a weighting system (for example, the health effects of 10 lbs. of HC vs. 100 lbs. of CO), the weighting should be made explicit. In the many cases where such weights are not available, there appears to be no alternative but to make the trade-offs explicit and ask the decision-maker to apply his subjective weighting. But even the principle of

11. Reynolds, *Psychological and Behavioral Effects,* 3 Task Force Assessments, *supra* note 1.

12. Ury, Goldsmith and Perkins, *Possible Association of Motor Vehicle Accidents with Pollutant Levels in Los Angeles,* 4 Research Reports, *supra* note 8.

13. Taylor, *Agriculture and Air Pollution,* 1 Cal. Air Environment (Air Pollution Research Center, Univ. of Cal., Riverside, Apr.-June 1970) and Miller, *Air Pollution and the Forests of California,* 1 Cal. Air Environment (Oct.-Dec. 1969).

14. E. Faltermayer, *supra* note 2, at 86.

more information has some limitations since at some point the cost of obtaining additional information exceeds the additional benefits which this information provides.[15]

There are two remaining issues about which the decision-maker should have information. One is the administrative problems and cost of each policy alternative and the other is the issue of who pays for air pollution controls. These will be discussed in some detail in the following three sections.

With all this information the decision-maker must choose that combination of policies which he feels most closely represents the best compromise between pro-control and anti-control interests. He must also consider the social goal of cleaner air in light of other social goals which are competing for the nation's resources. This adjudication among alternatives provides an answer to the question of what is the desired level of control. Without this thorough analysis, air quality standards cannot approximate the socially optimal level of control. The air quality standards which are currently in effect are based on health effects and technological feasibility. They have not been set on the basis of such an analysis as is suggested here and therefore cannot (except by chance) approximate the most desirable level of air quality for an airshed. This may in part explain why these "standards" are treated as goals toward which control administrators should strive rather than standards which must not be violated.

CONTROL INSTRUMENTS AND METHODS OF CONTROL

There are five basic forms of control instruments which are either in use or which could be used for air pollution control. They are: prescriptive regulations, effluent standards, air quality standards, pricing and taxing systems, and property rights restructuring. It is unlikely that the use of any one form of control to the exclusion of the others will succeed in attaining the quality of air the public desires. Each form has advantages and disadvantages. Therefore, it is likely that some combination of forms will prove to be the best regulatory system. Two such combination systems will be discussed in this section following the discussion of each control instrument.

A. *Prescriptive Regulations*

These regulations state that a specified action must or must not be taken. The requirement that all used automobiles sold in the State of California have an exhaust breather device installed and in good op-

15. Anderson and Crocker, *The Economics of Air Pollution: Literature Assessment,* in 3 Task Force Assessments, *supra* note 1.

erating condition is an example of such a regulation. The major advantage of this form of regulation is its relative ease of enforcement. A service station mechanic can inspect the automobile in a few minutes and issue a certificate of compliance. This involves very little time lost by the purchaser and by the Motor Vehicle Department who only has to check to make sure the certificate is valid. The major disadvantage of prescriptive regulations is that they are inflexible. If a new device were developed which controlled hydrocarbon emissions more effectively for less money and with no increase in the emission of other pollutants, its substitution for the breather device in future installations would require legislative action. And such action is likely to be slow in coming because of the vested interests of those who benefit from the old regulations.

B. Effluent Standards

These regulations state that a particular source of pollution must control its emission of identified pollutants to a specified level. The specification can be in terms of parts per million parts of effluent releases (ppm) or some measure of the total amount of pollutants released, such as the grams per mile standards for automobiles. The total release form (if properly measured) is preferable since the ppm standards stimulate dilution rather than control. Thus, the California effluent standards for 1970 automobiles state that an automobile cannot emit more than 2.2 grams per mile of hydrocarbons. The major advantages of the effluent standard are its relative ease of enforcement (at least in theory) and its freedom from specification of how the standard is to be met. Enforcement is theoretically easy since all that is necessary is a periodic check to insure that the emitter is not violating the standard. However, there are two problems with enforcement. One is the difficulty of measuring the effluent. Access to the effluent must be obtained and generally this can only be done with the emitter's knowledge. Having obtained access, there is still the problem of how to measure the pollutants accurately and inexpensively, a problem which in many cases has not been solved. The second difficulty is that there are large numbers of emitters which must be monitored. With present technology this becomes a time consuming, expensive, and difficult task. The effluent standard is stated in a way which allows each polluter to determine the best method for him to meet the standard. For one firm this may be by installing a control device such as a stack gas scrubber while for another it may be by using different fuel. A third firm might find a change in its production process to be the least expensive method of meeting the same standard. Some find the standard difficult and expensive to meet. They often apply for and are granted a variance on the grounds of hardship. Other emitters find the standard easy to meet at little or no expense. Yet they are not asked to meet stricter standards. To put it another way, some firms find pollution control expensive while others find it relatively cheap. The same level of pollution control can be obtained for a smaller cost to society if the latter were to control emissions to a greater degree than the former, rather than having both control to the same degree.

C. Air Quality Standards

These regulations state a specific level for pollutants in the air which cannot be exceeded. In California, for example, the air cannot exceed 0.10 ppm oxident for one hour. The major advantage of this form of regulation is that it explicitly recognizes the goal of air pollution control, improvement in the quality of the ambient air. The standards are typically based on consideration of technical feasibility and health effects. The major disadvantage of air quality standards is that they do not solve the problem of which polluters are to control how much of their emissions. Such standards put a large burden upon control agencies who must determine the best way to meet the standards. Air quality standards do not stand by themselves. They must be supplemented by other forms of regulation. Thus, air quality standards are often treated as goals to be strived for, rather than legal constraints which must be met.

D. Pricing or Taxing Regulations

These regulations impose a charge or tax for the release of pollutants into the atmosphere. The charge would vary with the type of pollutant released, the amount released, and the time of release. The basic principle is that if a polluter releases pollutants which cause damage he must pay society to compensate for these damages. If he releases less pollutants and thus causes less damages, he will have to pay less. Thus the charge provides an incentive for private action to reduce pollution in order to avoid or diminish the charge. A subsidy may be employed in the same way. In this case the higher a firm's control efforts, the higher the subsidy it receives. There are two major problems with subsidies which do not occur with charges. First, it is difficult to determine if a firm would install the control device even without the subsidy. If all control efforts are subsidized, then public expenditures will be larger than necessary to obtain that level of control. Second, a subsidy may offend the public's sense of equity in that you are paying people to do what their social conscience should require them to do. (See Section VI.)

The charge system's major advantage is that it provides for maximum flexibility in individual emission control efforts. Each emitter balances savings in pollution charges against his cost of control. He minimizes the sum of his control costs and pollution charges by equating the marginal savings of pollution charges with the marginal cost of additional control necessary to bring about the reduction in charges. This level of control is likely to be different for each polluter even if the emitters are engaged in the same activity (*e.g.*, power production). The overall level of control will be determined by the level of the charges. The major disadvantages of this system are administrative problems and the related measurement problems of applying the charges. In order to apply equitably a charge system which has some sophistication in terms of variations with quantities of pollutants released and their time of release, some fairly accurate and periodic (continuous?) measurement of emissions must be made by the regulating authority. This must be done for every emitter. As in the case of the effluent standard, the measurement problem may be, in some cases, impossible with the instrumentation now available. In addition, the computing of charges and their collection can add substantially to administrative costs.

E. Property Rights Restructuring

This action would vest the right to use the air to either the recipient of the pollution or some central authority rather than the polluter as is now the case.[16] The major advantage of this action is that it would provide a bias toward control in the legal system which can be used to offset the bias toward pollution which now exists. Currently a party who has been damaged by air pollution must prove in court that emitter A damaged him. He must establish that he was damaged and that emitter A did it and not emitter B. This is almost always an impossible task. Under restructuring, emitter A could not pollute if it damaged anyone excessively and the burden of proof would be on him rather than on the pollution recipient. Although little work has been done on the possibility and results of the restructuring of property rights, one presumed disadvantage is that it still would not provide a marketable property right in the same sense as land ownership is a marketable property right. Instead, it substitutes untransferable rights with a bias against pollution for the

16. Krier, *supra* note 1, and Anderson and Crocker, *supra* note 15.

current untransferable rights with a bias toward pollution. To get around this problem various licenses or permit systems have been suggested.[17] Permits to pollute the air would be sold at auction by the air pollution control agency. The total sum of pollution to be allowed in the airshed (as determined by some government agency) would determine the total number of permits to be sold. Both the public and emitters (manufacturers, etc.) could bid for the permits. The public, as represented by conservation groups and perhaps governmental agencies, would purchase permits so as to deny them to the emitters and thereby reduce pollution, while the emitters would buy them in order to avoid control costs (or perhaps in order to operate). This system would provide each side with equal access to the air resource and could work well in theory. The problem, however, is that the public would again try to act as free riders. If I think a conservation group will buy up pollution rights, I can enjoy the cleaner air without compensating the group. Much additional study is needed on the subject of property rights restructuring.

F. Combinations of Control Instruments

It should be obvious from the summary above that each control instrument has its advantages and disadvantages and no one instrument will do the job perfectly. While it is probably also true that no combination of control instruments will be perfect, deficiencies in one instrument can be offset by strengths in another. Thus, a combination system is likely to be the best control method.

The control system currently used in California's Air Pollution Control Districts is a combination of prescriptive regulations and effluent standards with air quality standards used as a goal rather than a standard. The setting of regulations and standards appears to be based on technological feasibility and some notion of how much the emitter should have to pay for his control effort. No effort is apparently made to relate the various controls and their costs to each other, let alone to their effect on air quality. In part this is due to the fragmented control effort. If the use of this combination is to be continued, I would recommend the following modifications. First, one air basin-wide control agency should be set up with control over all sources of air pollution. Second, air quality standards should be set which reflect the cost of control *and* the benefits of control either in terms of air quality improvements, physical and health dam-

17. The permit system concept was suggested originally in Crocker, *The Structuring of Atmospheric Pollution Control Systems*, in The Economics of Air Pollution 61 (H. Wolozin ed. 1966), and further developed in J. Dales, Pollution, Property and Prices (1968).

ages avoided, or a monetized estimate of damages avoided. Third, alternative sets of regulations and standards as well as enforcement procedures should be compared to determine which set will meet the air quality standards at the least cost to society. Obviously the second and third steps are not completely independent. Care should be taken to relate control efforts to effects on air quality parameters rather than gross tonnages of pollutants not released.

An alternative to the above system would combine air quality standards, pricing, and effluent standards. Again a regional air quality control organization would be instituted and air quality standards would be set. In determining how the air quality standards are to be met, emitters would be divided into two (or more) groups. Small emitters and emitters with difficult pollution measurement problems would be regulated by carefully enforced effluent standards (with some prescriptive regulations used for especially difficult cases). Large emitters would be regulated through prices. The total emissions allowable if the air quality standards are to be met would be similarly divided. The pricing system's rates and the effluent standards would be determined by their portion of the allowable emissions. If, in the judgment of the decision-makers, the pricing structure produces too much or too little abatement the rates can be adjusted accordingly. This system would provide maximum flexibility in control for the emitters who need it most, such as manufacturers and power plants while avoiding the administrative and enforcement problems inherent in applying the pricing system to a multitude of small polluters such as individual automobiles. Enforcement for small polluters would consist of periodic checks to insure that their effluents meet the standards. The large emitters would be, in the process of determining their charges, more or less continuously monitored with self-enforcement in order to avoid additional charges.

CRITERIA FOR SELECTION AMONG CONTROL POLICY ALTERNATIVES

Only a few of the many possible combinations of control instruments have been discussed. In fact most of these alternatives have not been evaluated in the broad context that is suggested here. Research needs to be done on the comparative merits of control policy alternatives. In this evaluation the following criteria might be used. The control policy must be effective in attaining the control goals. It must be easily enforceable. It must be acceptable to the public (and to the politicians and lobbyists who control its passage). It must be efficient in the sense of reaching control goals with the least possible disruption of economic activity and also in the sense of being inexpensive to administer and enforce. It must be equitable in the sense of likes being treated alike and emitters who are not alike being treated differently on some rational and consistent basis. And finally it must be flexible so as to cover changing situations.

There is probably no control policy alternative which meets all of these criteria perfectly. Some trade-off among criteria will be necessary. But at least all of these criteria ought to be considered.

WHO PAYS?

One of the most important issues which must be faced in air pollution control efforts and the one around which most of the control controversies center is who pays for control. Surprisingly, economists have little they can say on this subject even though it would seem to be at the heart of that discipline. Instead, they say that resource allocations will be different depending upon who pays but there is no way to judge, using economic criteria, which is the better allocation. Instead the issue becomes one of equity (and, in our system, politics). There appear to be three alternatives as to who pays: the polluter, the recipient of the pollution, and the general public through government. Again it is likely that some combination of alternatives will be used to finance air pollution control.

The argument in favor of charging the polluter is that he causes the pollution with his action and should have to pay for its control. It is his fault. In the case of polluting firms it is typical that the firm will not pay the full cost of the controls or process changes it is required to install. Instead it will pass part of this cost on to its consumers in the form of higher prices while absorbing the remainder in the form of lower profits and decreased sales. In this way the firm and the users of its output pay for the reductions in pollution caused by the firm's production. This appears to be an equitable solution. But even there the government makes some indirect contribution to financing the firm's control efforts. The cost of control can be written off as an expense for tax purposes thus reducing accounting profits and income tax. For a large corporation this amounts to a 48% reduction in its out-of-pocket costs of control.

One major argument against having the firm pay all the cost of control is that the firm may be on the brink of economic disaster (or "this plant is already losing money") and any additional cost will cause it to close and move elsewhere. If this were to happen, it would cause an economic hardship on the community. Employment would be cut. Retail sales would be down. Property tax collections would be reduced without a corresponding reduction in the local government's expenses. This is the typical threat mentioned above. Perhaps the most rational counterargument for this is that if the firm (plant) is really on the brink, not causing it to pay for air pollution controls will only postpone the closing for a short time. If the damages of its pollution are large, perhaps the community as a whole would be better off without the employment *and* the pollution. Some communities now realize continued growth is not always good. In fact the State of Oregon now operates under a quasi-official policy of not trying to attract new people to the state. Also this closing could free resources in the community for the development of "clean" industries or firms more willing or able to control their pollution.

There is also an argument in favor of having the recipients of pollution pay for its control. When pollution is controlled the recipients benefit from less pollution. It seems only right that they should pay for the benefits which they receive. This appears to be a less convincing argument on ethical grounds. However, it does have political appeal since it allows for a small charge to each of many recipients rather than a large charge to a relatively small number of polluters. The political advantages of this should be obvious.

One of the real problems of this approach is to determine who the recipients are and how much each should pay. Theoretically all recipients who benefit from control should pay. But the dividing line is always fuzzy on such things. For example, should a person who lives outside the affected area but works within it pay? Perhaps so, but what if he only comes into the affected area once a week or once a month? The decision on how much each recipient should pay is equally unclear. We could adopt the benefit principle and say that each recipient should pay in proportion to the benefits he receives. But then some meaningful measure of benefits must be derived. The measurement of such benefits has been one of the most difficult tasks economists have undertaken and the techniques available are imprecise and incomplete. For example, suppose that two people received the same level of improvement in air quality. One of the two people is in good health but the other suffers from emphysema. Improved air quality is more important to the emphysema sufferer and we would conclude from the benefits received principle that he should pay more for control. In this example society says to the individual, "Don't get sick or we will charge you more for air pollution control." This hardly seems like the most equitable position to take.

With these conflicts and problems the natural reaction is to turn to government for a solution. The problem of air quality is important to all members of our society. Therefore, the argument goes, all members should help financially with its solution. So government supports research and control efforts and sometimes subsidizes pollution control efforts of individual polluters. This financial help may consist of direct grants to municipalities or investment credits or property tax exclusions for privately installed control devices.

As with the other alternatives there are problems with government financing. Such financial support will most often come from the general fund. The taxes which supply revenue to the general fund are not very good indicators of the taxpayer's ability to pay. This is increasingly true as you analyze tax burdens among income groups in successively more local jurisdictions. Income purchases and property value are also generally poor reflectors of the benefits received from control. Thus, this form of financing does not fare well on equity grounds. Further, subsidies typically take a form which reduces the cost of control devices but does not affect the cost of other alternatives such as process adjustments and fuel conversion. This provides a bias toward devices and a possible misallocation of resources. Also, it is likely that some polluters will receive subsidies on devices which they would have installed anyway. This means that not all of the government's subsidy is stimulating control efforts, thus involving waste of very scarce control resources.

We can say that the question of who pays has no one "best" solution, and like the control policy alternatives, compromises must be made between competing goals. These competing goals in this case are equity, political expediency, and sufficiency of revenue.

RESEARCH NEEDS

I hope that the above discussion has convinced you that social scientists can make significant contributions to our knowledge of how to control air pollution. I urge that social scientists be included in the continuing policy formulation process by being placed on the various advisory committees and panels of the air pollution control organizations.

However, it is obvious from an analysis of knowledge in the social sciences that there are important gaps which should be filled through research. Most of the research I suggest here is of an applied nature. Any such research must be cross-disciplinary in its approach. What is needed is an approach to the solution which unifies technological developments and public policy alternatives. The following are the parts of this unifying approach in which I feel social science research can be particularly useful.

A. Policy Implementation Studies

Study is needed to determine the most effective means of implementing the policies of the decision-makers. Indeed it is desirable to consider alternative policies with respect to the problems which may be encountered in their implementation as well as their theoretical effects.

B. Attaining Public Acceptance of Policies

With rapidly changing technology, the public is exposed to new ideas constantly. These ideas sometimes attain acceptability and sometimes they do not. Study is needed to determine the current public acceptance of alternative policies, how this acceptance (or lack of it) is changing, and how the change might be directed toward acceptance of the policies deemed best by the decision-maker.

C. Air Quality Standards

Air quality standards as they are presently formulated are based mostly on technical considerations (that is, what is technologically feasible) and to some extent on health considerations. It appears that a major reassessment of these standards is warranted. These standards should be set on the basis of technical feasibility, social goals, costs of attainment, health effects, and psychological effects. This extension of standards criteria, especially into psychological effects, can have a profound effect on the type of solution we might expect.

D. Interrelation with Other Urban Problems

Proposed solutions to the air pollution problem may create other social problems. The relationship between proposed air pollution control policies and urban problems such as the income of the urban poor, the urban social structure, the transportation of people and goods, and the political structure must be carefully analyzed.

E. Cost-Effectiveness Analysis of Alternative Control Devices

In order to determine the advantages and disadvantages of alternative policy actions it is necessary to develop estimates of the cost of alternative control devices. These estimates can then be combined with estimates of the effectiveness of these devices in controlling air pollution in order to determine their relative effectiveness per dollar of expenditure. This needs to be done for both stationary and mobile sources of air pollution.

F. Policy Trade-Off Analysis for an Airshed

The goal of this research is to develop a model of an airshed which interrelates its physical, economic, and social characteristics and to use this model to simulate the effect of alternative air pollution control policies. The end product of this effort will be a listing of the full implications of each policy alternative in a way which will make clear the trade-offs between competing social goals of each. The decision-makers will then have before them for the first time all the technical information they should have in order to be most effective in their policy deliberations. They will have to make the difficult decisions concerning how much to weight each positive and negative aspect of the alternatives in order to select the best alternative for the people they represent.