Loyola of Los Angeles Law Review

Volume 5 | Number 2 Article 2

4-1-1972

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*by Thomas D. Crocker**

INTRODUCTION

The student asked, "But is this the way of the real world?"
"I don't know," replied the instructor. "I've never been there."

Investigators of complex systems[1] must be aware of the tension between abstract validity and every day applicability innocently expressed by the above student. It is submitted, however, that many writers dealing with the economics of air pollution control instruments have ignored every day applicability for the internal logical consistency of deductive propositions. When dealing with the student's every day world these writers too often seem unaware that a price has been paid. In particular, their failure to account explicitly for the bounded rationality,[2] uncertainty,[3] and informational, contractual and policing (ICP) costs[4] inherent in all air pollution problems weakens the applicability of their conclusions about the allocative efficiency properties of alternative control instruments.[5]

Attention in this paper will be confined to stationary sources.[6] The assumption is made throughout that human satisfaction or welfare is

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1. The complex system is distinguished by the requirement, particularly in an investigation's early stages, that drastic and even illegitimate simplifications be made for purposes of analytical tractability.

2. By bounded rationality is meant the finite limit to the rate at which for a given expenditure of resources an economic agent is able to assimilate information.

3. Uncertainty refers to the agent's inability to predict future states with zero probability of error, whether that inability be due to incapacity, excessive costs, or irreducible randomness.

4. Informational cost is the cost of finding out what is going on, contractual costs are the costs of carrying out any negotiation or agreement, and policing costs involve seeing that an agreement, once made, is adhered to.

5. In this paper, a control instrument is not an engineering gadget. Instead the reference is to an economic or legal means of bringing about a change in air pollution dosages. A rule that requires the installation of dust collectors in certain industrial processes is a control instrument. The dust collectors are not.

6. Stationary sources are those immobile sources of air pollution which are associated with industrial, commercial and residential activities. COUNTY OF LOS ANGELES, AIR POLLUTION CONTROL DISTRICT, PROFILE OF AIR POLLUTION CONTROL 17 (1971). While these sources were once responsible for generating more than half of the total air pollution discharged into the Los Angeles County atmosphere, they now account

directly related to the minimization of all the costs of air pollution control: damage costs, abatement costs[7] and ICP costs. Accordingly, the preferred or optimal control instrument is one which minimizes the sum of these costs.[8] To this end, and following an assessment of the shortcomings of currently favored control instruments, a non-pecuniary control instrument will be advanced. It will be proposed that the air pollution control agencies define emission "rights" and sell them on a competitive bidding basis.

I. CONTROL INSTRUMENTS CURRENTLY EMPLOYED

The wide variety of instruments available to the would-be controller fall into three general classes:[9] bargaining and negotiations, standards, and charges. Opportunities for direct receptor and emitter[10] bargaining in air pollution situations appear to be quite limited, however, except where small numbers of emitters and receptors are involved.[11]

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for only about 10 percent of such pollution. *Id.* While 10 percent is still a significant figure, the dramatic percentage reduction in pollution emanating from stationary sources in Los Angeles is attributable to two factors: the effectiveness of current stationary source controls and the increase locally in the number of automobiles and their proportionately greater amount of emissions.

7. The damage costs generated by a given quantity of air pollution are identical to what air pollution sufferers would be willing to pay to be rid of the specified quantity. Under a quite broad range of conditions, this willingness to pay is identical to the additional expenditures on health, cleaning, etc., that are caused by air pollution. While the precise amount of damage costs cannot be calculated, certain repair, replacement and cleaning costs have been estimated. For example, the costs to paint steel structures damaged by air pollution are close to $100 million a year. Crop and livestock damage is estimated at $500 million a year; and dyeing of fabrics soiled by air pollution is estimated to be $800 million per year. COUNCIL ON ENVIRONMENTAL QUALITY, FIRST ANNUAL REPORT, ENVIRONMENTAL QUALITY 72 (1970).

Similarly, the abatement or control costs of air pollution are what a producer of waste materials would be willing to pay to use the air as a garbage dump rather than to employ an alternative means of waste disposal. This willingness is reflected by the total investment required to control the major industrial and municipal sources of pollution. The investment necessary through 1975 to control such sources of particular matter, sulfur oxides, hydrocarbons and carbon monoxides in 100 metropolitan areas of the United States is estimated at $2.6 billion. *Id.*

8. These sums would necessarily be weighted rather than simple if distributional considerations are taken into account.

9. For a listing of various available instruments see Gaffney, *Applying Economic Controls,* 21 BULL. OF THE ATOMIC SCIENTISTS 20 (1965); Wright, *Some Aspects of the Use of Corrective Taxes for Controlling Air Pollution Emissions,* 9 NAT. RESOURCES J. 63 (1969).

10. The receptor is the air pollution sufferer. The emitter is the producer of waste materials to which no one finds it worthwhile to lay claim. Air pollution is more or less unique in that the receptor and the emitter are, in part, embodied in the same individual.

11. A case in which emitters and receptors did in fact bargain directly is reviewed

The outlays necessary to bargain directly usually outweigh at least one party's expected gains,[12] and the bargaining that does occur becomes political in nature because attempts are usually made to influence the decisions of some collective body. As such, this article will concern itself only with the instruments which these collective bodies (air pollution control agencies) wield, i.e., "standards" and "charges."

A. Standards

In its various manifestations, the standard has long been the favorite of air pollution control administrators. Local, state and federal air pollution law is replete with discussion of emission, ambient and input standards. The favored combination in practice probably consists of an input standard and an emission standard. The input standard restricts the production materials and equipment an emitter may use while the emission standard limits the quantity of pollutants the emitter may release. This combination is especially well suited to the needs of the control agency if its prime concern is to minimize the effort required of it to do a specific job within a given budget. Once agency approval of equipment and materials specifications is required, agency prediction of emitter behavior is enhanced. The emission standard reinforces this predictability by further inhibiting the potential range of emission variations. Both types of standards are enforced by spot checks and fines for violations.

Control agencies apparently recognize that the use of the above instruments to minimize the sum of damage and control cost is likely to be an extremely expensive undertaking. They have therefore tended to allocate the air resource according to ad hoc administrative notions of fairness and equity. Though by their very nature ad hoc procedures involve some element of arbitrariness,[13] this factor is lessened by interminable control agency and emitter haggling about design, financing, and construction of emitter control facilities. In effect, these negotiations substitute for costly calculation of optimal standards. However, lengthy negotiations consume time, and the result is that in

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in Crocker, *Externalities, Property Rights, and Transaction Costs: An Empirical Study,* 14 J. LAW & ECON. 451 (1971).

12. For a review of some of the difficulties associated with the bargaining approach see Wellisz, *On External Diseconomies and Government-Assisted Invisible Hand,* 31 ECONOMICA 345 (1964).

13. This arbitrariness derives as the result of the varying criteria by which emitter and receptor situations are evaluated. The lack of a definite standard opens the door to capricious and arbitrary determinations.

rapidly changing situations ambient air quality often actually falls. When action is finally taken it sometimes proves to be a response to an environment that no longer exists. In the interim, variances to the presumed control regulations are allowed to proliferate since the willingness of air pollution jurisdictions to grant variances is often a function of more than the evaluative and regulatory lags inherent in the use of input and emission standards. Meanwhile the public, believing something is being accomplished, is too often lulled into quiescence.[14] This public state of mind can readily be maintained if the agency wishes, since most control agencies are given the authority both to report and to control results.[15]

Relative to emitters, the number of receptors is usually large and their interests diffuse.[16] While the control agency must deal with the emitters on a more or less continuing basis since they are the objects of regulation, direction from receptors and their elected representatives is little more than intermittent. This direction is often cursory because of the air pollution problem's technical nature. Finally, a count of officials responsible only for air pollution control would likely find a substantial proportion of them to be engineers intimately versed in the technicalities of emission control. Causal empiricism suggests that a knowledge of a problem's intricacies often results in individual sensitivity to technical errors and thus causes one to proceed cautiously in discrete and carefully ordered steps. The major form of caution exercised by control officials in assessing and preventing damage to receptor interests seems to consist of caveats against proceeding too fast with stringent emitter controls because of the lack of laboratory controlled experimental knowledge about damages. Therefore, if the hypothesis is correct, this cautionary behavior will more likely be exercised on behalf of emitters rather than receptors.

14. The recent spate of private suits to compel public enforcement of public environmental law might imply the termination of this trust in the performance of the regulatory authorities. For a review of these legal actions see Grad & Rockett, *Environmental Litigation—Where the Action Is?*, 10 NAT. RESOURCES J. 752 (1970).

15. Comparisons of ambient air pollutant concentrations over time or space are utterly fruitless unless the sampling procedures and conditions are fully specified. For an interesting review of the many pitfalls see Schneider, *Sampling Problems in Air Pollution Analysis*, 3 ENVIRONMENTAL RESEARCH 452 (1970).

16. A small number of emitters seem to contribute the preponderance of the air pollution from stationary sources in the nation's large cities. *See* Mason, *et al.*, *Sources and Air Pollutant Emission Patterns in Major Metropolitan Areas*, a paper presented at the Air Pollution Control Association Annual Meeting, New York (June 22-26, 1969), where the authors find that in twenty-eight selected large cities, forty-eight percent of the suspended particulates and sixty-seven percent of the sulfur oxides are contributed by the ten largest point sources.

The agency's typical choice of standards as control instruments can generate yet another factor working against receptor interests. As earlier noted, the establishment or at least the enforcement of these standards involves agency-emitter negotiations. Since the number of parties involved in these negotiations is frequently small, there appears little basis for expecting an outcome in which the agency and the emitters act as price-takers. The most probable outcome of such dealings is an arrangement which has at least some of the features of what the economist calls a collusive bilateral monopoly.[17] Since collusion between the regulated and the regulator is a much noted phenomenon,[18] there is no particular reason to expect air pollution control agencies to be exempt from such collusion. Thus, emitter ICP costs in bargaining with control agencies are very likely to be less than the ICP costs of receptors.[19]

B. Charges

Most of the above points concerning standards are well known. What many economists would substitute for standards is the effluent charge,[20] an explicit price to be imposed upon the emitter for the use of the atmosphere.[21] This charge would be set at a designated level (hereinafter referred to as "the optimum") identified with minimization of the sum of emitter control costs and receptor damage costs. As so

17. This structure describes a situation involving only one producer of a particular good (the "monopolist") and only one supplier of an input with which to produce that good (the "monopsonist"). If they agree to combine against the rest of the world, it can be shown that they will increase their joint returns. *See* Stigler, *The Theory of Economic Regulation*, 2 BELL J. ECON. & MANAGEMENT SCI. 3 (1971), wherein the author sets forth an economic-theoretic basis for, and empirical evidence of, collusion between the regulator and the regulated.

18. *Id.*

19. Additional items are readily added to this listing of emitter advantages. For example, the emitter's greater frequency of communication with control officials probably gives him greater insight into their thinking. He thus has an informational advantage in predicting the agency's next move. Furthermore, information is a highly valued input for the control official. Generally, the emitter can more easily provide solidly based technical information. Perhaps all these points are intuitively made clear when one envisions the control official asking himself, "What are the consequences for me if I fail to permit these emissions?" If the emitter can confer benefits upon the agency, the emitter can impose costs by withholding these potential benefits.

20. Pigou first suggested the charge. A. PIGOU, THE ECONOMICS OF WELFARE 192-195 (4th ed. 1932).

21. The applicability of the charge to water pollution problems has also been endorsed. A. KNEESE, THE ECONOMICS OF REGIONAL WATER QUALITY MANAGEMENT (1964).

constituted, the charge has been defended as the economically preferable control instrument in air pollution.[22]

The economic problem in air pollution control thus becomes one of discovering the instrument that best minimizes the cost of achieving and maintaining this optimum. The adherents of the effluent charge cite two types of advantages for the charge when compared to the input or emission standard. First, they correctly argue that the charge economizes the costs of calculations and flows of information necessary for the initial discovery of the optimum pollution level. Second, they also view the charge as being superior in terms of its ability to maintain this optimum. That is, *once it is established,* the optimal effluent charge is thought to have superior incentive properties. Both of these arguments will be considered later. It will be concluded, however, that the informational requirements and incentive properties of the two instrument types are quite similar.

II. Informational Requirements

The construction of an optimal *ad valorem* effluent charge requires knowledge only of the damages caused by an emitter whereas an optimal emissions standard requires knowledge of both the emitter's control costs and the damages he causes. Accordingly, the effluent charge requires less information.[23] Implicit in this argument, however, is the assumption of a world of perfect certainty, a world in which no discrepancy between outcomes predicted by the control agency and those which are realized ever occurs. The control agency is presumed capable of effecting a hypothetical outcome in a world where receptors and emitters make production and consumption plans from which they will never deviate. In this context the control agency would merely be required to make itself aware of these once-and-for-all plans and then produce those adjustments that increase the net value of receptor and emitter output. Additional adjustments would then never be required. Such pervasive intelligence boggles the mind.

If the omniscience, clairvoyance or budget of the control agency

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22. Mills, *Economic Incentives in Air-Pollution Control,* in The Economics of Air Pollution 40 (H. Wolozin ed. 1966).

23. Since an optimal input standard would require knowledge of damage costs and the costs of the input combinations and the control techniques associated with the various emitter production processes, optimal input standards would always require as much information as optimal emission standards. We will therefore disregard input standards when viewing the optimum in terms of the minimization of the sum of damage and control costs.

is regarded as being something less than infinite, it is likely that the agency will at times have to vary its requirements in order to maintain the optimum. For example, a new yardstick would be indicated if the effects of a particular emission were shown to be more (or less) damaging than had been calculated. However, when variation of any sort is permitted in the effluent charge or standards, the issue becomes not one of each instrument's initial informational requirements but the amount and nature of the information each instrument generates. If each instrument generates similar information, then either an optimal charge or optimal emission standard could be calculated. The issue of initial informational requirements accordingly becomes utterly irrelevant. The difference between a price (charge) and a command (standard) is, from the agency's viewpoint, only one of form rather than one of substance.[24] While the emitters directly and explicitly communicate their control costs to the agency in the case of the emission standard, the emitters indirectly communicate their costs in the case of the charge by varying their emissions in response to variations in the charge. In the latter case, the revelation of control costs is implicit in emitter profit or utility maximization which dictates that emissions will cease when the charge exceeds the costs of alternative means of waste disposal.

Notwithstanding that emissions standards and effluent charges are informationally equivalent, relevant informational issues still exist. Each instrument's informational requirements are equivalent in their enormity when one insists upon defining the optimum in terms of the smallest possible sum of damage and control costs. When an air pollution situation calls for a possible change in a standard or charge each variation requires: (1) the collection and transmission of data; (2) a means of transforming the data into a form suitable for analysis; (3) the actual analysis of the data; (4) the communication of the magnitude of the change in the control instrument to emitters and receptors; (5) the observation of the receptor and emitter actions taken in response to the instrument's changed magnitude; and finally, (6) the evaluation of these responses. The larger the number of emitters and receptors and the more intricate and specialized their consumption and production processes, the greater will be the costs of discovering and bringing about the change. The allocation procedures would rest upon a continuing and enormous flow of data, much of

24. Marglin, *Information in Price and Command Systems of Planning*, in PUBLIC ECONOMICS 54-77 (J. Margolis & H. Guitton eds. 1969).

which would be superfluous and often of doubtful reliability due to the fact that most of the information would deal only with past emitter and receptor performance. A control agency decision made today should attempt to govern only what happens tomorrow, not yesterday. That is, to speak of governing or directing emitter and receptor conduct today by decisions that will be made tomorrow is to speak in futility.

Economists have recognized a number of factors greatly complicating the calculation of a charge or standard which minimizes the sum of damage and control costs. Two important complications occur in a multiple emitter context where aggregate receptor damages do not increase at a constant rate with increases in ambient pollution concentrations and where ambient concentration is not the simple sum of all emissions.[25] When damages do not increase at a constant rate with pollution concentrations, each emitter's contribution to damages is dependent not only on his own emissions but also on the emissions of every other emitter. Thus, a change in the emissions of any one emitter can affect the damage contributions of all other emitters even though the emissions of the latter have remained constant. Should one emitter change his emissions, the damage contributions of all other emitters would have to be recalculated. A similar problem arises whenever individual emissions are synergistic. The contribution of one emitter to the ambient air pollutant concentration is in part based on the contribution of a second emitter. However, the contribution of the second emitter is also based in part on the contribution of the first emitter. Once again the contributions of each emitter would have to be recalculated each time a single emission change occurred. Given the lack of any evidence whatsoever that damages change at a constant rate and further given the well known synergistic properties of many air pollutants, there is no question that optimal charges or standards would actually require some complex calculations.

Additional information is required for the standard or charge which minimizes the sum of damage and control costs when the emitter is the possessor of a monopolistic advantage. Buchanan[26] and Wellisz[27]

25. *See* Davis & Whinston, *Externalities, Welfare, and the Theory of Games*, 70 J. POL. ECON. 241 (1962), wherein the authors note (for the first time) these two problems (technically termed nonlinearity and nonadditivity) in a multiple emitter context.

26. Buchanan, *External Diseconomies, Corrective Taxes, and Market Structure*, 59 AM. ECON. REV. 174 (1969).

27. Wellisz, *supra* note 12, at 349.

have shown that when the emissions and level of output of a monopolist are directly related, the loss in social value to the receptor of the monopolist's output following the imposition of emission controls may outweigh the receptor's concomitant gain in air quality.

Further informational problems arise if the unit cost of emission control declines as the size of control facilities increases. There may then appear to be many optimal emission levels. When the charge or standard is calculated by taking the number of emitters as a constant, opportunities for obtaining lower control costs may be foregone by failing to consider the possible control cost reductions occurring when several emitters are merged to employ common control or production facilities. Accordingly, the control cost consequences of a hypothetical emitter merger must be determined.[28] A calculation of the effects of this merger upon the extent of competition in emitter output and input markets would also be required.

The informational problem can be made even more severe by introducing locational considerations. Air pollution differs across space as well as across time. It therefore follows, given the receptors' dislike of air pollution, that they will sort themselves out according to their relative dislikes and according to the air pollution dosages to which they expect to be subject at each location and point in time. Locations will thus differ in market price to correspond with the air pollution dosages that the locations are expected to receive.[29] Disregarding moving costs, whenever the pattern of expected dosages or damages is changed, a new spatial arrangement will result. Therefore, a change in receptor locations can be induced to the extent that a charge or standard implies a change in dosages or damages. This change in location can in turn lead to a further change in damages since the charge or standard might require adjustment to conform with the new damage relations. Accordingly, unless the control agency can predict emitter and receptor locational decisions, there are likely to be as many optimal effluent charges and standards possible as there are combinations of emitter and receptor locations.

III. COSTS AND INCENTIVE EFFECTS OF UNCERTAINTY

The informational difficulties inherent in control agency attempts

28. Davis & Whinston, *On Externalities, Information, and the Government-Assisted Invisible Hand*, 33 ECONOMICA 303, 312 (1966).

29. For some empirical evidence that air pollution does in fact contribute to price differences among locations see Anderson & Crocker, *Air Pollution and Residential Property Values*, 8 URBAN STUDIES 171 (1971).

to apply optimal effluent charges or emission standards explain why control agencies commonly find it worthwhile to resort to those ad hoc emission and input standards arising from the agencies' direct and indirect negotiations with emitters and, to a lesser extent, with receptors. However, there is no apparent reason why emitters or receptors would choose negotiations with the agency in preference to the agency's ludicrous attempts to calculate an optimal charge or standard. Either approach produces substantial uncertainty about emission levels and the extent of damages. Uncertainty is costly. It exerts an influence upon incentives and therefore affects the way individuals behave. Thus, a discussion of control instruments which purports to be a serious evaluation of real alternatives cannot avoid the presence of uncertainty.[30]

Consider the receptor. It may be that he is risk averse in that he attaches a cost to an increasing spread of gains or losses. Even if the receptor is neutral toward risk, the damages he realizes are in fact only the *present* representation of a position he took in the past in response to various sets of what had been expected air pollution dosages. The receptor's damages are generated not only by the sheer presence of a realized pollution dosage but also by the desirability of being prepared to realize any one of several alternative dosages. Flexibility is costly since only one dosage will ultimately be realized at any future point in time. Thus, unpredictable air pollution events as well as air pollution events per se can impose costs.

Where substantial uncertainty is present, the initial bearer of risk can often, at a price, shift his burden to those having a comparative advantage in risk-bearing. The initial bearer can therefore exchange the perhaps small probability of a large loss for the near certainty of a small loss. The established market prices or risk premiums for insurance or contingent claims serve to establish a consensus of expectations about the values of dated assets. The exchange process implies that for the last contingent claim unit exchanged, expectations about future asset values are identical among individuals. However, there seem to be no important real world examples of insurance or contingent claims markets unique to air pollution events. The non-existence of a market implies the non-existence of opportunities for the transfer of air pollution risks. Accordingly, while there are potential exchanges or gains from trade that would improve everybody's position, they are not currently being used to advantage. Thus, different individuals be-

30. Uncertainty and risk are treated as synonyms in this paper.

have as if they face different prices for the same good. This failure to exploit available gains from trade involves an economic loss fundamentally no different than the economic loss involved in readily observable physical air pollution damages. The loss in the case in question again is due not to the air pollution events themselves, but to the unpredictability of these events.

Perhaps the incentive effects of uncertainty upon emitter and receptor behavior are most apparent in the emissions policing problems associated with the optimal effluent charge or standard. To an agency, the discovery of emissions and the stated end of minimizing the sum of receptor damage and emitter control costs can be tasks which are not only contradictory but also repugnant. In particular, the fewer emissions the control agency actually registers and acts upon the easier is its task, but the price attached to each detected emission in order to attain a given level of total emissions must be greater. From the emitter's point of view, the effective price or cost of a given emission unit is the cost of being caught multiplied by the probability of being caught.

If control agency detection and enforcement is less than perfect, the means available to the emitter for reducing the costs of his emissions consist of both finding ways to avoid detection and enforcement as well as actually reducing his emissions. If the price of emissions to those who are unfortunate enough to be detected and penalized is set at that value which minimizes the sum of damage and control costs under *perfect* detection and enforcement, then the total actual emissions will obviously be greater than the total that minimizes the aforementioned sum. This, of course, assumes that emissions vary directly with the effective cost of emitting. Furthermore, because the effective cost to emitters is actually less than the stated price, the emission increase caused by an increase in control costs will be greater than under perfect detection and enforcement and the emission reduction caused by a decrease in control costs will be less.

Should the probability of detection and enforcement be known, the effective cost to emitters can be increased and the cost minimizing level of total emissions can be attained by simply increasing the penalty exacted from those who are detected. However, if relative prices of detection avoidance possibilities differ among emitters, this control agency maneuver would simply serve to increase the difference in effective emission costs between those emitters for whom "cheating" is costly and those for whom it is inexpensive. The effect of a maneuver upon differences in receptor damages would be similar.

In summary, when cheating is possible there is no *a priori* reason whatsoever why the distribution or the magnitude of damage and control costs among individual receptors and emitters or between the classes of receptors and emitters should be identical to that under conditions where no cheating occurs. The level of policing and enforcement effort can therefore have a substantial impact upon the de facto distribution of rights to the atmosphere's use and upon the sum of damage and control costs associated with *any* emission level, including that level which minimizes the sum of damage and control costs under perfect detection and enforcement. Therefore, if detection and enforcement have never been and will never be perfect, how is the optimal pollution level to be determined? Observation of that which has never occurred requires some rules for distinguishing acceptable from unacceptable fictions or "intellectual dodges."

IV. ANOTHER APPROACH

Discrimination between acceptable and unacceptable fictions is aided when the decision criterion for selecting control instruments is changed. If the fictions employed by the control agency to reduce its ICP costs are not communicated to receptors and emitters and if these fictions can be changed at the control agency's convenience,[31] agency attempts to minimize the sum of damage and control costs could well augment emitter and receptor ICP costs and aggravate the uncertainty to which these costs give rise.[32] The preceding two sections have revealed that the uncertainty borne by emitters and receptors is in part determined by the control instrument and the fictions which the control agency chooses

31. In calculating an "optimal" value for an effluent charge or emission standard, "fictions" that would increase the simplicity and surveyability of the data the agency works with would play an important part. This data simplification can be accomplished in two ways: (1) by neglecting certain relevant characteristics and relations, and (2) by aggregating over characteristics or over discrete groupings of a single characteristic common to several individuals. The dangers of neglect are obvious. The conditions under which grouping and aggregation can be validly used are stringent indeed. For a rigorous presentation of these conditions see H. GREEN, AGGREGATION IN ECONOMIC ANALYSIS (1964). It seems likely that the lesser the degree of competence of the control agency in atmospheric, biological, engineering, and economic analysis, the greater will be its willingness to neglect and aggregate characteristics. This introduces the question of how to check, if checking is possible, the validity of the agency's control and damage cost estimates.

32. This is not meant to imply that ICP costs are the source of all uncertainty. The world does seem to possess some irreducible indeterminancy. Its presence only serves to make more tenuous the grounds on which the use of optimal effluent charges and emission standards are customarily justified.

to use.[33] An alternative decision criterion can make the problem of choosing among alternative fictions explicit.

If one makes the not unreasonable assumption that outlays on information, contracting and policing vary with the nature of the fictions used, then only a decision criterion accounting for damage, control and ICP costs can minimize the value of the resources consumed by air pollution and air pollution control. One then asks: Which combinations of fictions and control instruments will fulfill this objective? The advantage of the criterion raised by this question is that it explicitly introduces the ICP costs of a wide variety of control instruments into the decision-maker's problem.

It cannot be denied that a decision-maker who employes a decision criterion minimizing only the sum of damage and control costs recognizes at least his own ICP costs. That is, he at least recognizes that the efforts to minimize the sum of damage and control costs will consume some of his own budget. If the opportunity cost of meeting the budget constraint is "too great", he is likely to consider another control instrument or perhaps employ the same instrument with lesser precision. However, this approach bespeaks of some very poorly defined subjective judgments concerning what constitutes the opportunity costs of staying within one's budget. Furthermore, the approach is unlikely to give an incentive for the consideration of many alternative control instruments. All instruments or values of instruments that minimize the sum of damage and control costs and that can be afforded become equally acceptable. Some further criterion must be introduced for choosing among these equally acceptable instruments.

Finally, if the ICP costs of receptors and emitters cannot be included in the costs to be minimized or in the budget constraint, then, if they are to matter at all, they must somehow be introduced as separate constraints. This requires some premonition as to which levels of receptor and emitter ICP costs are acceptable and which are unacceptable. All this accomplishes, however, is the introduction of yet another problem, the solution of which would likely require the evaluation of another set of fictions.

One fiction which air pollution control administrators have widely adopted is the fanciful concept that there exists an indomitably unique concentration of pollutants in the ambient air. This once-and-for-all choice is generally justified through appeals to the existing literature

33. *See* note 31 *supra* for a discussion of two fictions commonly used.

dealing with the detrimental effects of pollutants upon creatures and artifacts. It is therefore relatively effortless to establish. Its use can be readily justified on economic grounds if there exist substantial discrepancies in emitter and receptor comprehension, perception and expectation of damage and control costs. Fundamentally, the greater these discrepancies are, the less the total value of receptor input and emitter output will be, and the more likely that any arbitrarily, and therefore effortlessly, selected upper bound for pollutant concentrations will serve to increase the total value.[34]

The ability of a control agency to specify and enforce an ambient air standard implies that some legally constituted executive and/or legislative body has seen fit to vest the property rights in the atmosphere in the control agency. The agencies have generally chosen to allocate the selected waste disposal capacity by means of negotiated effluent standards. Economists have often urged that (negotiated) effluent charges be employed instead. In both cases, the agency ideally is supposed to act from the perspective of each and every emitter and receptor in a state where ICP costs are presumed negligible. There exists at least one other alternative: the agency could define emission "rights" and put them up for sale on a competitive bidding basis.[35]

These emission rights would be defined in terms of allowable emission quantities conditioned upon the assumption of specified values or ranges of values by meteorological, temporal and spatial parameters that are presumed to be relevant. For example, a right might state the quantity of sulfur compounds that can be released in the early morning hours when the wind is predominantly from the northwest quadrant at an hourly arithmetic mean velocity of no less than fifteen miles an hour with an adiabatic lapse rate no less than one at a spec-

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34. Formal proof of this statement is available in T. CROCKER, SOME ECONOMICS OF AIR POLLUTION CONTROL 316-321 (1968) (a report to the U.S. Public Health Service); S. TISDELL, THE THEORY OF PRICE UNCERTAINTY, PRODUCTION, AND PROFIT 151-171 (1968). The fundamental notion is simple enough: the greater the differences in prices faced by different individuals for exactly the same good, the greater is the likelihood that *any* arbitrarily selected price which is identical for all parties will increase the total value of output. For an elementary presentation of the reasons why such price discrepancies imply losses of potential valuable output, see T. CROCKER & A. ROGERS III, ENVIRONMENTAL ECONOMICS 54-73 (1971).

35. Proposals for the establishment of explicit property rights in environmental waste disposal capacities are not new. Such a proposal was propounded in Crocker, *The Structuring of Atmospheric Pollution Control Systems*, in THE ECONOMICS OF AIR POLLUTION 61-86 (H. Wolozin ed. 1966). *See also* J. DALES, POLLUTION, PROPERTY, AND PRICES (1968).

ified location.[36] If all this is too complex and costly to define, and if causal empiricism has noted an association between the number of times a butterfly flaps its wings and the ambient air's pollution concentration several hours later, then the agency could define the emission rights in terms of butterfly wing flapping. A price would be established just as a price is established in any other market. The scheme is informationally decentralized and is capable of dealing with large numbers of emitters and receptors at small cost since the agency would not have to specify the behavior patterns of individual emitters and receptors. Furthermore, the evaluative and regulatory lag problem implicit in the effluent standard and charge approaches would be ameliorated. Rather than having adjustments take place after new emissions occur, the bidding process means that the new would-be emitter must purchase the emission immediately prior to undertaking emissions.

However, such a bidding scheme also has severe problems which make its relative advantages somewhat less clear. In particular, all of the previously mentioned receptor informational and contractual cost problems would continue to be present and, if the agency performed no policing, any receptors who did purchase rights would face severe policing problems.

Consider in partial contrast the following scheme. After an ambient air standard whose attributes are defined in terms of a simulated diffusion model is established, emission rights defined in terms of allowable emissions relative to the values assumed by the model's meteorological and topographic parameters could be put up for competitive bidding. If considered desirable, the ambient standard could differ from area to area within a city, but within any one area it would not be subject to any change whatsoever except at regular intervals of substantial duration. Rights would be alienable among

36. There now exist several sophisticated mathematized simulation models of the meteorological transport and diffusion process. Each of these models employs essentially the same parameters, but in a different manner or time-scale. Fundamentally, all describe the spatial and temporal frequency distributions of pollutant dosages and durations from various patterns of emissions sources operating under diverse meteorological and topographical conditions. When programmed for simulations, the models' parameters can be manipulated in a variety of ways to predict the effects of parameter changes upon dispersion patterns. For representative examples of these models see Turner, *A Diffusion Model for an Urban Area*, 3 J. APPLIED METEOROLOGY 83 (1964); Miller & Holzworth, *An Atmospheric Diffusion Model for Metropolitan Areas*, 17 J. AIR POLLUTION CONTROL ASS'N 46 (1967); Koogler, *et. al.*, *A Multivariable Model for Atmospheric Dispersion Predictions*, 17 J. AIR POLLUTION CONTROL ASS'N 211 (1967).

all economic agents and from one location to another. However, any transfer could not result in the ambient standard in that location being exceeded. Thus, the only situation in which a locational transfer could occur would be when an unused assimilative and dispersion capacity at the new location existed. The atmospheric property rights established with this approach would therefore consist of a set of locationally defined time-state emission claims having probabilities associated with each state and discounts associated with each future.

Assume, for simplicity, that there is a fabrication of a uniform ambient air standard and a normalized emission right. The number of rights available to an area therefore would be positively related to the area's dilution and assimilation capacity and, for a given demand over all areas, the price of a right would vary inversely with an area's dilution and assimilation capacity. Those to whom the net benefits of emission are greatest thus would tend to locate in areas having the higher capacities.

The preceding approach closely resembles a zoning scheme in which the atmosphere's dilution and assimilative capacity is the criterion. All the scheme does is specify a range of acceptable use conditions within which the market is to be permitted to arrive at a maximal solution. The ambient standard specifies the maximum rate for waste disposal purposes at which the air input is to be substituted for non-air inputs. Receptors and emitters must then adjust to this rate. The prices for emission rights will contain sufficient information to negate the benefit for the individual agent of knowing directly what other agents are doing. All of the information which would otherwise have to be discovered and analyzed is embodied in the market price of the emission right. Since each economic agent can make his own adjustment to the existing market for rights, a wide variety of differences among individual receptors and emitters can be accommodated. The effect is the same as spatially separating the two groups so that their use decisions can be made independently of each other. Once the standard is established, control agency information on abatement or damage costs is not required. The agency's function would be to police and enforce property rights. In direct contrast to the effluent charge, continuous and expensive monitoring of each emitter in order to determine the total charge he must pay would not be necessary. Random spot checks similar in nature to any other policing function would serve to inhibit most property right violations.

Perhaps the most important feature of the scheme is that the ambient standard introduces certainty about maximum levels of emissions and air pollution dosages. The mutual compatibility of expectations among individual receptors and emitters and between the classes of receptors and emitters means that a major cause of price discrepancies is removed. Receptors are not required to employ inputs of relatively high flexibility in order to be prepared for air pollution contingencies which are ultimately unrealized. If we assume that emitters can predict the price of emission rights with greater accuracy than they can the whims of a control agency, emitter as well as receptor uncertainty would be in fact reduced. The scheme recognizes the existence of a trade-off between the reduction of uncertainty and that minimization of the sum of damage and control costs which occurs in a fictitious, and even whimsical, negligible ICP cost world institutionally constrained by nothing other than a fee simple absolute system of property rights.[37] The key point is that there may be more to be gained for the moment in environmental quality management by reducing uncertainty than by searching for some presently ill-defined and rather unapproachable optimum. Though it is apparent that ICP costs are an important part of the system that determines this optimum, very little is now known about these costs' theoretical properties or their empirical behavior under various control strategies.

The competitive bidding feature is really the only thing which distinguishes the scheme set forth herein from a sophisticated meteorological zoning scheme. This feature, in addition to providing the control agency with at least some of the funds to carry out its policing and enforcement functions, means that holders of emission rights are contributing to the costs of policing and enforcing these rights. Under any straightforward zoning scheme, these funds, if they are to be derived from the air resource's use, would have to be obtained through a property tax. In order to remain allocatively neutral, this tax would have to be strictly proportional across sites to the capitalized value of the emission right embedded in the site. Assessments of this determination's accuracy, if achieved at all, could be achieved only at great expense.

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37. This is not meant to imply that accepted economic theory does not rigorously deal with questions of uncertainty. It does. However, among other conditions, the existence of a market for contingent contracts is required. In contrast, many environmental quality problems appear to be characterized by high ICP costs inhibiting the use of the market as the sole allocation instrument.

V. CONCLUSIONS

Obviously, the zoning scheme set forth herein is not a universal panacea. This paper's main purpose has been to argue that controls, in addition to effluent charges or standards, are required in air pollution control programs if the sum of abatement, damage and ICP costs is to be minimized. A procedure in which a control agency makes invariant and known use decisions to last for a fixed period of time while the market then allocates the air resource among users appears to have several economically desirable properties. Only recently have economists begun to take more than passing notice of the obvious fact that all aspects of voluntary exchanges are not embodied in explicit pecuniary measures.[38] That is, the value of all that is exchanged is not always collapsed into the exchange price. Typically, where alternative future states of nature will have substantial impact upon an asset's value and where the determination of the probability of these states' occurrences is subject to relatively high ICP costs for buyers and sellers, private exchange terms will include a wide variety of both conditional and absolute stipulations. It seems rather farfetched to assert that a regulatory body can perform efficiently without using anything other than a price as represented by an effluent charge or standard, particularly when private markets are unable to do so for a substantial portion of the time. Nonpecuniary controls, to the extent that they reduce emitter and receptor ICP costs, can cause a heretofore non-existent market to come into being. In short, it is not true that such controls always inhibit the operation of markets. They can also create markets.

38. *See* Cheung, *Transactions Costs, Risk Aversion, and the Choice of Contractual Arrangements*, 12 J. LAW & ECON. 23 (1969) wherein the author presents an analysis of Chinese agricultural leasing arrangements.