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Some Economics of Air Pollution Control

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SOME ECONOMICS OF AIR POLLUTION CONTROL*

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I am looking from my office, where a stingy
Ray of sunlight struggles feebly twixt the buildings tall,
And the fetid air and gritty of the dusty, dirty city,
Through the open window floating,
Spreads its foulness over all.

Until recently, one of the favorite exercises of anyone who ever taught courses in elementary microeconomic theory was the use of air as a means of pointing out the distinction between an economic good and a free good. Since it was supposedly available in sufficient quality and quantity to satiate every individual's breathing needs and since it supposedly had no valuable alternative uses, the air resource was thought to fulfill nicely the concept of a free good—a good which was of no concern to economists.

With some reflection, it appears the economist's well-worn example of air as a free good constitutes a misinterpretation of the layman's phrase "as free as the air." What the economist thought the layman meant was that more air was available than the sum, whether weighted or unweighted, of individual wants at the smallest conceivable positive price. But what the layman actually meant is that air was, for the most part, free for the taking: there were no operative constraints, economic or otherwise, placed upon the manner in which the individual could use the air.[1] Reasoning inductively, the economist felt that since no apparent or recognizable price was attached to

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1. This statement is somewhat of an exaggeration, for as early as 1306, English courts were enforcing statutes designed to curb the air fouling caused by the employment of animal fats in the production processes of candlestick makers. At the same time, efforts were being made in London to limit the burning of soft coal. In 1661, one John Evelyn in a pamphlet entitled *Fumi-Fugium; or the Inconvenience of the Aer and Smoake of London Dissipated* reports that some offenders were even executed. I am indebted to Paul G. Neimann for these examples.

the use of the air, the air must be a free good; but the layman, reasoning intuitively, was sufficiently perceptive to note that since the air was everybody's and therefore nobody's property, he could use it and alter it in any way he desired.

Air actually hasn't been a free good since the first caveman made a metal tool, for the air, or rather the oxygen which makes up one-fifth of the air's volume, caused this tool to deteriorate with time's passage. Since the prevention of this deterioration would have required the use of positively priced inputs such as the labor and the materials required for the construction of an air-tight casing, the simple presence of air does and always has necessitated taking into account the efficient use of resources having valuable uses elsewhere.

However, the above is not to say that the air in which the caveman found himself immersed had properties posing problems similar to those we today face. Except when volcanic eruptions occurred and perhaps in the farthest reaches of his caverns, the natural makeup of the atmosphere was such as to not endanger the caveman's life or the life forms upon which he was dependent for his livelihood. The modern air pollution problem results from the fact that the contemporary world has accentuated the air's artifact destroying properties and has injected a new dimension by altering the air's makeup in a manner causing it to have deleterious physical effects upon biological entities. The efficient cause of this phenomenon is the desire of man to employ the air's waste disposal abilities as one of his major means of ridding himself of those side-products having a nonpositive value of specific production and consumption processes.

Use by the individual of the air's waste disposal abilities takes place so long as the present value of his incremental private recovery and/or retention costs is greater than the present value of his incremental private recovery and/or rentention benefits for all existing potential pollutant emissions and for all expected potential pollutant emissions whose recovery possibilities can be influenced by his present and/or contemplated actions. The problem faced by those responsible for the evolution and the application of air pollution control policy is to make the consequences of the collection of individual decisions about the present values of private recovery costs and benefits conform with what are thought to be socially desirable consequences. In short, the job of the formulator of air pollution control policy is to bring about that correspondence between individual and collective welfare—however defined—which is lacking because the individual cannot or will not be operationally cognizant of the connection between certain of his means of achieving and maintaining his objectives and the achievement and maintenance of certain objectives for the collection of individuals. Rather than viewing each individual as an isolated unit in an impervious cell, having contacts with other individuals only through a mutually satisfactory and voluntary reciprocal decision process, the air pollution control policy formulator must attempt to devise decision rules resulting in operations on the air resource-use decisions of individuals which will serve to achieve and maintain a correspondence between individual and collective welfare. The achievement and maintenance of this correspondence requires changes in the institutional environment in which individual pollutant air resource-use decisions are made.

I
VIEWS OF THE AIR POLLUTION PROBLEM'S NATURE

Any view of the means by which any air pollution problem is to be ameliorated will be colored by and must begin from a premise about the place which the use of the air's disposal abilities holds in man's desired scheme of things. In the materials dealing with air pollution with which most people are familiar, a more or less quasi-philosophical and macrocosmic view of the problem is taken: the economic aspect of man and the biological aspect of man are considered to be competitive. That is, an increase in the degree to which one holds sway must necessarily reduce the interval over which the other is operative. Supposedly, there exists an entirely separate and readily identifiable part of each and every individual, the essence of which is economic, while there exists another part, the essence of which is biological: the essence of any air pollution problem is to be found in a conflict between *homo oeconomicus* and *homo sapiens*. Only the former or economic part emits pollutant materials into the atmosphere while the latter biological part attaches a high value—even an infinite value—to something called "clean" air. The basic thesis is that in the modern industrial world economic man has acquired too much power at the expense of biological man and that this is the root cause of the air pollution and other problems of environmental quality with which we are faced. From this thesis there easily follows the assertion that in order to maintain some sort of unspecified balance between the two, it becomes necessary to control the rampant nature of economic man. Or, less daintily, we are presented with the rather crude and ugly scene of economic man greedily tearing off and consuming pieces of his own flesh, thereby defeating the ultimate purpose the economic part of man's nature is expected to serve: biological survival.[2]

The specific policy proposals following from this competition thesis are rarely heavily endowed with clarity. The constant emphasis upon the association between increases in the standard of living (real per capital incomes?) and increases in the physical quantities of pollutant materials placed in the environment might be taken to mean in terms of policy that increases in the standard of living should be allowed only insofar as there are commensurate increases in the environment's absolute physical capacity to handle increased pollution loads. Or, if biological survival is taken to be the end, then air pollution might be serving a positive purpose by ensuring that existing members of the species with relatively weak respiratory systems do not pass this trait on to their descendants. On the other hand, simple charity and brotherhood, as well as the interests of society in preserving those members of the species wtih mixes of those traits considered at the moment to be highly desirable, might imply the avoidance of any and all acts tending to reduce the mathematical expectation of any single *homo sapien* member's chances of survival. Other possible policy interpretations come easily to mind.

It may or may not be true that higher levels of real per capita income and biological survival are incompatible. Certainly, whatever the concept of biological survival espoused, no substantive evidence exists. Nevertheless, it is clear that, though increases in real per capita incomes and lack of atmospheric pollution loadings have perhaps historically often tended to be associated, this does not mean that they are necessarily directly related. In fact, the economist's view of man's nature would make it appear that actual pollution loadings and real per capita incomes are inversely related, even though poten-

2. Examples of this approach are not at all difficult to find. In its Air Conservation 3 (American Association for the Advancement of Science, 1965), the Air Conservation Commission states that "to tamper with the processes which create air pollution is to tamper with human civilization, but to ignore it is to ignore a threat to human survival." Or, in the words of the Environmental Pollution Panel of the President's Science Advisory Committee, "The production of pollutants and an increasing need for pollution management are an inevitable concommitant of a technological society with a high standard of living. Pollution problems will increase in importance as our technology and standard of living continue to grow." See Restoring the Quality of Our Environment 1 (The White House, Nov., 1965).

tial pollution loadings and real per capita incomes are probably directly related.[3]

In the economist's context, the most basic consideration is the old and probably somewhat tiresome caveat that human wants are for all practical purposes unlimited while the means with which to satisfy these wants are limited. The issue is therefore fundamentally one of choice: not choice in the sense of an infinite set of either/or alternatives, but choice in the sense of the optimum degree of thirst-fulfillment for a whole ordered hierarchy of wants.[4]

Few would deny that the highest place in this hierarchy belongs to the basic and fundamental biological wants: the subsistence needs for food, clothing, and shelter. The needs and objectives of economic activity having the highest priority for nearly every individual and every society are the provision of the means for the satisfaction of these elementary wants in a manner which will best ensure the preservation of those attributes of the human species that existing individuals consider to be highly desirable. As wants of the highest priority are satisfied, attempts are then made to satisfy the wants initially relegated to the next highest priority until such time as those wants having the lower priority, given the available means, are satisfied. But this does not mean that all wants to which the highest priority is initially attached are completely satiated, for, as the individual or collection of individuals making up the society partially fulfill their wants in the highest priorities, the satisfaction to be obtained from wants in the lower priorities will increase in relative value. That is, at some point in the fulfillment of those wants to which the individual initially attaches the highest priority, the fulfillment of those wants in all lower priorities will take on greater significance; or, as needs are partially fulfilled, the hierarchy of wants will change. That need to which the highest priority was initially given, will, after it has been partially satisfied, drop down to a lower position in the ordering and another want formerly of a lower order will now become of the highest order.

3. By *potential* pollutant loading is meant that pollutant load which would be placed in the atmosphere in circumstances where the air's waste disposal abilities can be treated as a free good. Basically, for any given state of technology, the concept involves that set of circumstances in which it never is worthwhile for any single emitter to give explicit attention to the engineering efficiency with which certain physical components of the inputs associated with the emitter's production processes are recovered and/or retained.

4. Marshall, *Principles of Economics* 86-91 (8th ed., MacMillan and Co., Ltd., 1920).

Given the validity of the preceding statements, the basis upon which most choices are made is that attribute of an alternative having a lower priority in an initial primary ordering. Or, to put the matter in a slightly different way, for any pair of alternatives from which one can choose, with each alternative having several different attributes or features, that attribute or feature upon which choice will be based is that having a lesser relevance in a primary ordering. Thus if I've already had my fill of extravagant foods, when I must choose between and among restaurants I will select that restaurant having its waitresses in the briefest costumes or that restaurant which is most pleasantly decorated. Or, if I must choose between two otherwise equally satisfactory homesites, I will select that site which is not downwind from a smoky factory. However, if the choice is one of starving in an idyllic setting or having wholesome food and adequate shelter while living near the smoky factory in which I earn the money to buy this food and build this shelter, I will choose to live near the factory. Thus, over some set of orderings of my wants I will always select that set of alternatives which best satisfies my basic so-called biological needs; but after some positive degree of satisfaction of these needs has been achieved and is being maintained, I will then reorder my wants so that cleaner air receives higher priority than does additional food, clothing, and shelter. Only after I have begun to feed my body will I feed my soul; and soul feeding, as is cleaner air, is a superior economic good: that is, a good which varies directly with real income or with the extent to which I have been able and expect to continue to be able to satisfy those needs having a higher priority in my primary orderings.

Some rather impressionistic evidence is available to support the contention that a relative absence of air pollution is a superior economic good. Consider the following two examples which, though they involve the public goods or free rider problem often associated with interviewing techniques,[5] at least do not provide any grounds

5. Samuelson, *The Pure Theory of Public Expenditure,* 36 Review of Economics and Statistics 387-89 (1954); and Samuelson, *Diagrammatic Exposition of a Theory of Public Expenditure,* 37 Review of Economics and Statistics 350-56 (1955). If the interviewee will not be subject to air pollution controls during the course of his normal activities, if he actually desires cleaner air, and if he is given reason to think that the intensity of desire for cleaner air he expresses in his answers will be directly related to the degree of clean air ultimately provided, he will have an incentive to overstate the intensity of his desire. The reason for this is that unless he must bear some visible direct or indirect burden of the control costs, his answer, or rather the

for rejection of the superior goods hypothesis. First, a sociological study conducted by the U.S. Public Health Service in Clarkston, Washington, a city near which a kraft pulp mill with its associated odor, dust, and fume problems is located, found that 44 per cent of the local managers, proprietors, and professional people—a group one would expect to have a greater frequency of relatively high incomes and wealth—were "aware" of an air pollution problem and were seriously "concerned" about its effect upon their health and their real properties. However, only 32 per cent of the clerical and skilled laborers, and only 19 per cent of the semi-skilled and unskilled workers expressed a similar awareness and concern.[6]

In spite of the number of sociological studies which might be marshalled for the support of the superior good hypothesis, this hypothesis is perhaps most dramatically supported by the following statement made in response to a mail questionnaire survey concerning air pollution's health effects in Polk County, Florida, and carried out by the Florida State Board of Health. The rather ambivalent statement was made by a lady who had apparently signed a privately sponsored petition intended to protest the local air pollution problem thought to be caused by the emission of gaseous and particulate fluorides from phosphatic fertilizer manufacturing processes.

> I am sorry about this matter. I was misinformed. My husband has worked for one of the phosphate plants for 21 years. The mine has been our bread and butter. We have not been harmed in any way mentioned above. Thank you.
>
> P.S. The dust does get pretty bad.[7]

From the preceding it would appear that, if anything, increases in per capita incomes intensify man's wish for cleaner air. That is, the higher are per capita incomes, the more man be willing to forego in physical and value terms in order to achieve and maintain a given state of atmospheric cleanliness. Furthermore, once a fairly high level of per capita income is achieved and can reasonably be expected to be maintained, it is likely that the rate of increase in the demand

results of his answer, are to him essentially costless, i.e., he can appropriate the benefits flowing from the provision of cleaner air without having to compensate anyone for the costs of such provisions.

6. Medelia, *et. al.*, *Community Perception of Air Quality: An Opinion Survey in Clarkston, Washington* 45-55 (U.S. Public Health Service Publ. No. 999-AP-10, 1965).

7. Florida Air Pollution Control Commission, *Minutes, Sept. 16, 1966,* 2 Florida State Board of Health, 1966. (Mimeographed.)

for cleaner air will be greater than the rate of increase in per capita incomes. In short, if the state of the air's cleanliness in any locale is to be made responsive to the wishes of the citizenry, then a higher state of cleanliness can be attained when the citizenry's real per capita incomes are relatively high than when they are low. Even though potential air pollutant loadings might be less with low real per capita income levels, actual air pollutant loadings per unit of potential loadings will be higher because relatively clean air will fall back to a lower position in the citizenry's priority orderings. Stripped of all extraneous and complicating factors, higher per capita incomes and cleaner air tend to be complementary rather than competitive.

II
COMPLICATING FACTORS

Unfortunately, the real world does not allow one to strip away and forget about the aforementioned complicating factors. Even though the citizenry as it attains higher real per capita incomes may be willing to bear substantial costs in order to have cleaner air available, it often appears to lack the economically efficient organizational means necessary to the implementation of these desires. Not possessing these organizational means, it must observe deterioration of its environment as per capita incomes increase because potential pollutant loadings become synonymous—nearly so anyway—with actual pollutant headings. The reason for the difficulty of finding an economically efficient organizational means for the implementation of these desires is basically due to a single attribute of the air resource: its indivisibility.

If this indivisibility did not exist, and, in the absence of de jure monopolistic elements and imperfections, one would expect trade between and among emitters and receptors in pollutant loading (emission) rights to take place, and the maximization of the present value of the difference between total emitter cost-savings and total receptor damage costs to occur. The total receptor damage cost function relates the returns the receptor is forced to forego because of air pollutant fumigations over some given interval of time to the pollutant materials released into the atmosphere by the emitter. Similarly, the total emitter cost-savings function relates the costs the emitter can avoid by releasing pollutant materials into the atmosphere to the volume he does release over the same given interval of time. The marginal form of the total receptor damage cost function thus shows the additional compensation receptors must receive in order to be indifferent as between being subjected to or not being subjected to an additional unit, however measured, of pollutant fumigations. In the same sense, the marginal form of the emitter cost-savings function shows the additional compensation emitters must receive in order to make them indifferent as between releasing or not releasing into the atmosphere an additional unit of pollutant materials. Thus, according to the initial distribution of rights to the use of the atmosphere, the marginal damage cost function can be regarded as either a supply function or a demand function. If all use rights are legally the receptors', then the marginal damage cost function is the supply function faced by emitters for the release of pollutant materials into the atmosphere. The marginal cost-savings function is then the emitters' demand function for such releases. But if all use rights are legally or effectively the emitters', then the marginal cost-savings function is the supply function faced by receptors for the rights not to have greater atmospheric pollutant loadings, while the marginal damage cost function is the receptors' demand function for these rights.[8]

Most contemporary writers on pollution problems and most modern property law starts from the premise that rights to the use of the air resource belong only to the receptor.[9] Thus, according to this

8. Since the gaseous medium in which pollutants are transported from one location to another is for all practical purposes of entirely natural origin, the economically efficient organizational means of allocating the air resource is that means providing the same allocative result as would occur when a single party owned and made all effective decisions about the mix and quantity of productive factors to be placed in the locale blanketed by the gaseous medium. Less breathlessly, the economically efficient allocative result is that result which maximizes the air resource's rent.

9. In a personal communication dated June 7, 1966, Carl F. Murphy of the Temple University School of Law made the basis for this premise eminently clear for the writer. In Murphy's words, "That type of title which dominates United States real property rights is the fee simple absolute, under which the individual is assumed to have an absolute interest in something which the law calls real and which includes soil, whatever is below the soil, the use of run-off water and waters circulating through the soil, the use of stream waters flowing through the close, the atmosphere above the close, and as much of the air space as can be used or is needed for security. All of this is encompassed by Coke when he says that the fee simple absolute extends from Heaven to Hell." Since it is the receptor air space which is being invaded and since the existing locations of receptors are generally considered to be inviolate and not subject to variation, the law and public opinion generally tend to view the emitter as the "guilty" party. The continuing reiteration of the argument that an ambient air or an emitter standard, or an effluent charge provide the emitter with a "license to pollute" is sufficient evidence of this.

premise, the receptors' marginal damage cost function is the supply function the emitters face for the rights to the use of the air's waste disposal abilities, while the emitters' marginal cost-savings function is their demand function for these same rights. In these circumstances, one might expect the market to do a fairly adequate job of allocating the air's two value dimensions according to the criteria of economic efficiency. Receptors and emitters would be expected to exchange emission rights until such time as the difference, however measured, between emitter total cost-savings and receptor damage costs, however specified, was maximized. Emitters would be willing to pay receptors for the right to release pollutants until additional payments became greater than initial control costs. Receptors would find such payments to their liking until such time as an additional payment would fail to cover the additional damage costs to be imposed. Receptors must include in their cost calculations (and in their output decisions) the opportunity costs of refusing payments for increases in emissions. In doing so, the receptor is including in his cost calculations the effects of his actions upon the emitter; and he is doing so in the same manner the emitter would if the emitter was simultaneously the emitter and the receptor.[10]

But things haven't been working this way because the individual receptor's theoretical property rights are imperfectly enforceable, *i.e.*, for the most part they are inoperative. The reasons, both of which flow from the air resource's indivisibility feature, are two. First is the public goods aspect of the air pollution problem. The real reflection of this aspect is to be found in the fact that at present individual receptors in most cases have no way to compensate emitters so as to make it worthwhile for the emitters to reduce pollutant loadings. That is, the individual receptor is rarely able to dig up enough money on his own to make it worthwhile for the emitter to cut down emissions. Furthermore, even if the individual receptor is able to pay emitters enough to get them to stop invading his supposed property rights, he has no way of preventing the benefits of his "bribe" from accruing to fellow receptors. There will be no cooperation among receptors to whose advantage it is not to cooperate with each other. That is, it is worth the while of the individual receptor not to play the "bribe the emitter game" because any one receptor's needs cannot be satisfied apart from other receptors' needs.

10. The basic points in this paragraph were initially made by Coase, *The Problem of Social Cast,* 3 Journal of Law and Economics 1-44 (1960).

No receptor has an incentive to try to enforce his supposed property rights, for he will maximize his share of net returns from the air resource by doing nothing while others do everything. But the very universality among receptors of this lack of incentive actually prevents anything being done: no action at all against emitters is taken.

If receptors could enforce their theoretical property rights costlessly, large numbers of them would find it worth their while to do so, in spite of the public goods nature of whatever successes any individual receptor may expect to achieve. In reality, however, the financial and political resources of the individual receptor relative to the emitter are rarely such as to enable him to carry out this enforcement. Given, therefore, that the political, legal, and financial resources of a group are somehow directly related to the group's size, there are then some positive benefits accruing to the individual receptor when he joins coalitions of his fellow receptors. He is clearly able to bring public nuisance suits only when he is a member of such coalitions,[11] and if the law allows receptors to sue jointly he can better afford private nuisance suits. Finally, he is far better able to bring political and legal pressures to bear upon the emitters.[12]

But even though receptor coalitions may enable receptors to exert some positive degree of control over the uses to which emitters put the air resource, there is little likelihood that the distribution of the

11. At least one state, Florida, allows a private citizen to bring suit in the name of the State of Florida to enjoin a public nuisance even though he suffered no unique or special damages. Cf. Fla. Comp. Gen. Laws 1927, Sec. 5029; Fla. Rev. Gen. Stat. 1920, Sec. 3223; and Fla. Laws 1917, c. 7367, Sec. 2. Several Florida courts, including the Florida Supreme Court, have confirmed these measures' legality. Cf. National Container Corporation v. State ex rel. Stockton, 189 So. 4 (1939); Gulf Theatres, Inc. v. State ex rel. Ferguson, 182 So. 842 (1938); and Merry-Go-Round, Inc. v. State ex rel. Jones, 186 So. 538 (1939). These cases and statutes open up some interesting possibilities for receptor harassment of emitters on a nearly continuous basis. Nevertheless, though Florida has had some severe air pollution problems, little if any harassment along those lines has occurred.

12. Traditionally, one of the most difficult things for a receptor to do in a court suit in which he is suing for damages is to show just how much damage the emitter did him. Any reasonable hope of success usually requires calling in expert witnesses whose testimony is not inexpensive. Thus the individual receptor has generally stood little chance. However, a Federal Court has recently ruled that Florida law states when a party causes damage in uncertain amounts, all doubts must be resolved against this party. That is, if an emitter causes any part of a receptor's loss, the emitter is responsible for the entire loss and must compensate the receptor accordingly. Cf. Roe v. Armour, 370 F 2d 829 (1967). Though the receptor must still show by the preponderance of evidence that the emitter caused some damage, the emitter when he asserts that the harm was done by "an Act of God" must prove by the preponderance of the evidence that he, the emitter, did not cause any of the harm.

cost (among receptor coalition members) of achieving and maintaining this degree of control will closely approximate that of the uninhibited perfect market described by the economist's marginalist criteria. Certainly, as long as the distribution of receptor political and legal power does not correspond to what the distribution of purchasing power would be under a perfect economic market, then opportunity exists for the receptors to impose negative externalities upon one another. So long as one assumes an individual will vote and/or apply political pressure for a measure which benefits him, will vote against a measure which removes existing or potential benefits from him, and will abstain from voting on a measure which neither benefits nor imposes costs upon him, then any proposed measure which is adopted and for which less than complete unanimity prevails must make somebody worse off as it is making somebody else better off. Unless complete unanimity about the measures to be adopted prevails, adoption of the measures and configurations of receptor outlays (and the rights to the use of the air resource which the measures imply) must be *Pareto suboptimal*[13] because at least one individual is being forced to participate in a transaction he would otherwise prefer to avoid. In other words, without unanimity at least one individual must make an exchange he would not make and would not have to make in a perfect market because in a perfect market he would obtain negative net benefits from the exchange. Old negative externalities are unlikely to be negated optimally in receptor coalitions and/or new negative externalities substituted for the old negative externalities found in the uninhibited imperfect market. Presumedly, the individual receptor would consider the possibility that a coalition might give his fellow receptors an opportunity to impose costs upon him as a disadvantage of entering the coalition.

To the extent the public goods and lack of unanimity incentives not to enter coalitions outweigh in receptor minds the receptor benefits available from these coalitions, the emitters can treat the air's waste disposal abilities as common property freely available to all wishing to use them. "The . . . [operational] divorce of scarcity

13. In the contemporary manner of putting things, a Pareto optimum exists when it is not possible for any reorganization of institutional forms or any further shifting and movement of economic goods and the rights to the use of these goods to result in a situation in which at least one individual is made better off without anyone else being made worse off. In short, a Pareto optimum exists when there are no further gains from trade.

from effective ownership"[14] brings about a situation in which "the conservative dictum that everybody's property is nobody's property"[15] appears to be fulfilled: the resource is exploited until the social surplus or rent which would otherwise accrue to its owners is totally dissipated. Each and every emitter voluntarily continues to release pollutant materials over any one interval of time until the present value of the marginal costs of the non-air productive factors employed by him are equal to the present value of the marginal value products he obtains from these same non-air productive factors. Since no price is attached to the emitter's use of the air resource itself, there is no own-cost accruing to the emitter by further exploitation of the resource. He thus continues to exploit it so long as any surplus remains.

Even when the air is saturated with pollutant materials or when only a given volume of air (an ambient air standard) is available for waste disposal purposes, the present value of the resource's future availability is zero to the individual emitter. If for some reason, idealistic or otherwise, the individual emitter sets the time at which he will reach a given volume of emissions farther into the future, he will simply accentuate whatever costs other emitters are imposing upon him. The other emitters, in addition to making this emitter's uses more costly, would, by dissipating the resource's rent, remove much or all of his possible future returns or cost-savings. Thus each emitter in order to minimize the costs that other emitters impose upon him must immediately take as much of the resource as his non-air productive factors allow him to get.[16] Prescriptive rights or a queue are substituted for an auction or market system as a means of allocating the air's waste disposal abilities. Only if speed is the sole variable of which marginal value productivity is a function will the order of priority for users established under the queue correspond to the order of priority established under an auction system based on marginal value productivity.

14. Bator, *The Anatomy of Market Failure,* 72 Quarterly Journal of Economics 363-65 (1968).

15. Gordon, *Theory of a Common-Property Resource: The Bionomic Equilibrium of the Fishing Industry,* 62 The Journal of Political Economy 135 (1954).

16. There does exist a quite minor exception to this case. If for all possible positive levels of use in the present the rent from the air resource is insufficient to cover the average costs of the non-air factors, then the resource would not at present be exploited. Every potential user would find it advisable to wait for the moment when the surplus was sufficient to cover the costs of his non-air factors. But when this moment arrived, the individual user would still have to move as fast as he could in order to obtain his share.

III
SOME IMPLICATIONS FOR AIR POLLUTION CONTROL

The presence of a common property situation in which the members of one group impose uneconomic negative externalities upon the members of another group immediately suggests the possibility of internalizing the externalities by assigning ownership of the medium through which the externality is imposed to a single entity. This entity would be instructed to and legally required to maximize the social surplus or rent to be obtained from the air resource by maximizing the present value of the difference between emitter cost-savings and receptor damage costs.

The preceding suggestion for merger is the major offering of many proposals for the control of externalities. However, those who offer these proposals are a long way from going just about as far as they must go. The specification of only the objective toward which an air pollution control authority is to strive and the provision of the legal and political authorization for the authority's existence entirely neglects the devices or criteria the authority is to employ for making its decisions about which allocations of the air resource over any given interval of time will serve to maximize the air resource's rent.

Any control device which is to be workable in a context in which there has been a serious common property problem requires that the schedules of benefits and costs facing emitters and receptors be revised so that collectively preferred courses of action will have greater private net benefits than do collectively less preferred courses of action. Any revision in the benefit and cost schedules associated with a given quantity and mix of resources must involve some changes in actual, though not necessarily theoretical, property rights. Any proposal for a control policy must therefore give careful attention to the courses of action likely to be selected by emitters and receptors after the policy's initial application as well as the courses of action selected prior to the policy's initial application, *i.e.*, before any revisions in property rights and their associated private benefit and cost schedules.

Those control policies resulting in revised emitter and receptor operative property rights which have garnered the greatest favor among those dealing with and writing about air pollution and similar problems of environmental quality are the imposition of emitter standards and emitter charges.[17] In the engineer's or administrator's environment, the choice between the standard and the charge seems to be a direct function of the individual's acquaintance with the elements of economics. The greater his acquaintance, the greater the likelihood he will favor the charge over the standard, even though the question of just what the charge should be and the criteria to be used for figuring out the degree of effort to be employed in determining it is generally carefully sidestepped.[18] However, since an economically efficient emitter charge at a point in time necessarily implies an economically efficient quantity of emissions at that same point in time—and vice versa—the basis for selection between the two—if one insists that such a selection be made—must rest upon the degree to which each will tend to maintain maximization of the air resource's rent.[19]

17. Though it really is only a special case of a standard, whether emitter or ambient air, the idea of area specialization in which the air and/or water resources of a given locale would be devoted exclusively to emitter uses or exclusively to receptor uses has attracted a substantial number of cautious adherents. See Committee on Pollution, Waste Management and Control 48 (Publication 1400, National Academy of Sciences-National Research Council, 1966); and Gaffney, *Welfare Economics and the Environment* in Jarrett, ed., Environmental Quality in a Growing Economy 88-101 (Resources for the Future, 1966). However, the economic validity of this specialization proposal requires the fulfillment of at least one of two rather special assumptions. The first is that the emitter use and the receptor use be entirely incompatible in a physical sense. That is, the smallest possible presence of the emitter use completely shuts out any presence of the receptor use; or the smallest possible presence of the receptor use wholly thwarts and frustrates any possibility of the emitter use. If this first assumption is fulfilled, the economic analysis of the pollution problem cannot be considered to be too difficult for all one needs to do is select that use producing the greatest net benefits. Strictly dichotomous situations present no real difficulties to economic decision-making.

The second necessary assumption—that assumption which must be fulfilled if the first is not fulfilled—requires that whenever two or more uses of a given space are in some degree physically competitive, the net returns from one use must outweigh the net returns from any and all other uses for each and every conceivable scale of all uses. This is certainly a rather stringent requirement one suspects could be fulfilled if and only if categories of use were defined in a rather broad and loose manner.

18. See The Environmental Pollution Panel, *op cit.* 17-18. Abundant material relating to the establishment of air pollution control standards is available in the monthly issues of the Air Pollution Control Association Journal.

19. Kneese, *The Economics of Regional Water Quality Management* 82-85 (The Johns Hopkins Press, 1964), argues that in a static world a charge is generally to be preferred to a standard because it requires less information and because it offers the emitter an incentive to take action down to a zero level of emissions. But, with respect to the first supposed advantage, Kneese assumes that a standard specifying the required state of the receiving medium has already been (arbitrarily?) established. The charge is then simply set at that level causing the collection of emitters to meet

Even if an economically efficient charge or an economically efficient standard is costlessly selected initially, there are two ways for those measures which serve initially to achieve economic efficiency not to be able to maintain this efficiency. The first and most obvious of these ways is due to change influencing emitter and receptor costs and returns over which neither receptors, emitters, nor an air pollution control authority can have substantial influence. Yet, if the control authority has any pretensions about maximizing the economic surplus to be derived from the air resource, it cannot ignore the possibility of the need to adjust its policy to such changes. The problem enters in determining whether the "need" to adjust is economically justified. Whether it will be or not is basically a question of the extent to which any additional benefits accruing to the improved allocation implied in the needed adjustment outweigh the additional costs of obtaining the information necessary for making the adjustment.[20]

An investigation of the economic aspects of any air pollution problem requires the acquisition of substantial amounts of information about receptor and emitter technical coefficients of production, managerial efficiencies, ages, types, and qualities of specialized factors of production, expected output prices and input costs, etc. ad infinitum, and the reaction paths of these parameters to changes in the levels, however measured, of actual and expected emissions and pollutant

the already established standard. Basically, therefore, the prior establishment of the standard avoids the necessity of knowing emitter control costs, while the imposition of the charge causes the collection of emitters to meet the standard by the least cost means. However, as is well known, unit cost minimization would be equivalent to net benefit maximization only when receptor marginal damage costs are a constant.

As for the second supposed advantage, one might note that just as the charge, no matter how far from being optimal, gives the emitter an incentive to take action down to a zero level of emissions, it also allows him to pay the charge up to the level of his maximum potential emissions. There is no reason to think that any benefits associated with the former would occur with greater frequency and in greater magnitude than would any costs associated with the latter. In summary then, the only inherent advantage in a comparative static world for the charge relative to the standard is some sort of psychological advantage: people are perhaps more likely to allow a price to be adjusted in accordance with changing conditions than they are a standard which because it was set by "scientists," supposedly has the immutable truths of the physical world embedded in it.

20. For more on this point, see Demsetz, *The Exchange and Enforcement of Property Rights,* 7 Journal of Law and Economics 11-26 (1964); and Crocker, *The Structuring of Atmospheric Pollution Control Systems,* in Wolozin, ed., The Economics of Air Pollution 76-79 (Norton, 1966).

fumigations. The estimation of all these parameters is costly.[21] If the costs of acquiring information negate the benefits from adjusting the previously optimal standard or charge, then—abstracting from information costs—this standard or charge is no longer optimal, even though it is optimal, given its previous existence, when information costs are included. However, without having adequate information, there is no a priori reason to think that the standard or charge which was formerly optimal continues to approximate an optimum better than a standard or charge set at any arbitrary level. Economic objectivity is of no assistance in selecting among arbitrary alternatives. Or, if one insists upon estimation of all the relevant parameters despite information costs, his scientific objectivity can be purchased only at a substantial sacrifice in economic objectivity.[22]

The second way in which control measures initially serving to achieve economic efficiency may not be able to maintain this efficiency is due to the aforementioned nearly universal assumption that it is the receptor's property rights being invaded: the natural origin of rights to the use of the air resource is considered to be zero effects upon receptors. Thus, any constraints to be placed upon users of the air resource are to be placed upon emitters, the initial perpetrators of the negative externality. Whether the emitter constraint be a standard or a charge, that to which the constraint's merits are held to be relative is the absence of the standard or the charge.

21. The benefits of this estimation might not be as great as they superficially appear either. The accuracy or precision with which one is able to make many parameter estimates is often directly dependent upon the accuracy or precision with which estimates of other parameters have been made. The greater is the number of parameters to be estimated and the greater the number of these parameters whose estimates are dependent upon each other, the greater is the risk of erring badly in the final determination of the optimal adjustment to make. The accuracy with which a parameter is estimated that is a function of another already estimated parameter cannot in fact be any greater than the estimate for the already estimated parameter.

22. The assumption implicit in this paragraph that the natural scientists have a good understanding of the systemic effects of air pollutants upon the economically relevant attributes of various physical and biological entities makes this discussion rather irrelevant. Most so-called scientific knowledge of air pollution effects consists of seemingly endless descriptions of symptoms. Anyone failing to agree with this assertion might try asking his nearest chemist friend (bio or otherwise) the following question: "If the magnitudes and proportions of all other factors which may influence a particular entity are given and if the relations between and among these factors and the entity are thoroughly understood, can you tell me the magnitude of the effect of a given concentration of a particular pollutant material over a given interval of time upon any economically relevant attribute of that entity?" In nearly every single case, the reply will be a somewhat dismayed but nevertheless straightforward "No!"

The major point upon which the discussion about the merits of emitter constraints turns is the importance of barriers to trade between and among the offended and the offenders. Those who consider the barriers erected by the public goods and common property problems to be low and even nonexistent have been called the "modern-old" group, while those who consider the barriers to be high and even insurmountable have been called the "modern" group.[23] The former have placed a great deal of emphasis upon the entirely correct point that externalities can be traded, but, due perhaps to the drastic implifying assumptions necessary for the rigorous development of their ideas, they have generally neglected the point that some means for trading must be made available, or, if available and not used, some constraints must be added to and/or deleted from the system to make it worthwhile to all contending parties for trading to take place. In contrast, the "modern" group has emphasized the need for some continuing exogenous application of constraints in the form of emitter charges and/or standards. However, this emphasis has often blinded them to the fact that such application because of the trading opportunities, *i.e.*, gains from trade, which it brings into existence can itself generate externalities. Thus despite the appearance the emitter charge or standard gives of being a simple and direct form of air pollution control, it is actually a very complex means operating perhaps primarily on emission volumes but with important and usually unintended effects on the areal and temporal distributions, numbers, and even the types of emitters and receptors. These secondary reactions are likely to cut very deeply into the economic gains thought to justify the standard's or charge's initial imposition.

These secondary reactions produce a type of uncertainty not so much like that usually classified under a complete lack of probabilistic knowledge regarding the interactions between present and future production possibilities, states of technology, random acts of nature, and market conditions, but rather that type usually included under strategy or game problems in which all participants have brains they are not unwilling to use. With the latter type of uncertainty, the prospects faced by any one emitter or receptor are determined not only by that state of the ambient air the individual

23. The "modern" and "modern-old" distinction is from Wellisz, *On External Diseconomies and the Government-Assisted Invisible Hand* 31 Economica 345-362 (1964).

attempts to exploit to his advantage, but also by the other air users who are the individual's opponents and who try to turn the world to his disadvantage while simultaneously trying to turn it to their advantage. In this latter sense, emitters and receptors may attempt a wide variety of maneuvers to reduce the uncertainties surrounding their expectations about their repercussoins upon one another. Before the imposition of the emitter charge or standard, recepter net revenues were, among other things, dependent upon the emitter's production and emission decisions. But, unless trade in externaltiies took place so that the emitter would have to regard foregone receptor payments as an opportunity cost, the emitter's production and emission decisions were in no way influenced by the receptor. However, with the imposition of an emitter charge or standard whose severity varies directly with the level of receptor damages, this one-way interdependency is no longer the case. Just as the emitter must now recognize that his production and emission decisions influence receptor production decisions, receptor production decisions will have an influence upon emitter production and emission decisions. Two possible features possibly leading to nonoptimality are associated with this reciprocal interdependency.

The first of these features is due to the necessity of knowing what the receptor and emitter input mixes and magnitudes would be with an optimal charge, *i.e.*, a charge maximizing the present value of the difference between emitter cost-savings and receptor damage costs. Before this charge can be determined, one must have knowledge of the receptor and emitter input mixes and magnitudes underlying the marginal receptor damage function and the marginal emitter cost-savings function one is trying to equate. This knowledge, however, requires substantial insight into the configurations over a fairly long time horizon of the actions and reactions of emitters and receptors. In the absence of this knowledge, some other base would have to be employed. Likely candidates are the input mixes and magnitudes prevailing before the control's imposition, that prevailing for emitters when no receptors are present, or that prevailing for receptors when no emitters are present.[24]

The receptor response to the reduced level of emissions supposedly resulting from the imposition of a nonoptimal charge or standard upon emitters can assume any one of the following forms: (1)

24. These last two possibilities mean, of course, that conceptually each party is to be allowed to treat the air resources as a free good—an approach wholly contradictory to the whole purpose of control.

they could employ the same mixes and magnitudes of the same inputs as before; (2) they could use different quantities of the same inputs but in the same proportions; (3) they could use different quantities of the same inputs in different proportions; (4) they could use different inputs; or (5) they could change the time interval over which any of the previous four possibilities will be allowed to be operative. That possibility selected by any receptor will be that which he feels will make the greatest contribution to the present value of his expected net returns. There is no a priori reason to think that the possibility selected will not have a greater rather than a lesser or unchanged susceptibility to pollution damages. To the extent that any of the latter four of the aforementioned five possibilities brings about at the new level of emissions an increase in receptor revenues greater than any increase in receptor damage costs, and to the extent the emitter charge is adjusted directly to the level of receptor damages, the charge the emitter must pay for each unit of pollutant materials he releases must continually increase over time. Ultimately, emissions could conceivably approach zero.

The preceding assumes that receptors try to maximize their net revenues over relatively short time intervals. However, if they are willing to bear short-term losses in order to acquire what they think to be long-term gains, the second nonoptimality feature associated with reciprocal interdependency enters. In order to increase the level of charges which the emitter must pay or to increase the severity of the standard to which the emitter must conform, the receptor may employ inputs more susceptible than previously to pollution damages even though the increase in his damage costs is greater than the increase in his short-term revenues. If the equipment installations and the production process changes the emitter must make to control his emissions involve high capital and low operating costs, receptors are likely to find such a strategy particularly appealing. Of course, the emitter might recognize what is happening and increase rather than decrease his emissions. General staying power and the amount of liquid resources each party can draw upon are more likely to determine the ultimate outcome than is any notion of economic efficiency.[25] And, if one wishes, additional wonderfully complex complications can be introduced readily and probably realistically. Circum-

25. Though it is easily shown that in a static world receptors would be better off and emitters no worse off when receptors are partially compensated for the damages they suffer, it is also worth noting that such compensation makes receptor exaggeration of damages less costly.

stances in which one receptor pays another to employ a greater quantity of pollution susceptible inputs or one emitter pays another to increase his emissions are easily imaginable.[26] Because an additional unit of receptor damages must necessarily be the joint responsibility of all emitters, individual emitters whose emissions are substantially lower than other emitters but whose incremental control expenses are quite high might find it worthwhile to pay emitters whose emissions have been relatively high but whose incremental control expenses are relatively low to reduce their emissions. Under all these circumstances, that information could afford to obtain about emitter cost-savings and receptor damage costs would be seriously biased. That is, the observations would bear only a highly superficial resemblance to those which would be obtained where one is able to simulate and/or stimulate a highly competitive market in emission rights.

CONCLUSIONS

In contrast to the theme of much of the rhetoric heard about the subject of air pollution, economic theory and quite incomplete empirical evidence give some indication that increased real per capita incomes and improved environmental quality are directly related. However, the near absence of enforceable property rights underlying most air pollution problems makes the actual implementation of the relation difficult at best. Though it has often been pointed out that some gains from trade exist when externalities are present, it is often unrecognized that some means or incentive to trade or some device which simulates trade must be provided if these potential gains from trade are to be realized. That is, some revisions of the benefit and cost schedules associated with operative property rights must occur. In addition, the gains from trade these revisions bring about must serve to maintain economic efficiency as well as attain it.

Those devices proposed for the control of air pollution which have received the greatest public attention are the emitter charge

26. The public goods or "free rider" problem would here be less severe than usual, for it would be to the advantage of any one individual in the emitter or receptor group to pay his brother to act as he does. That is, the more individuals in the group who adhere to the same strategy, the greater the net benefits accruing to any given degree of effort by an individual member of the group. For the individual receptor who exaggerates his damages and bears the short-term costs of doing so, the more the receptors who similarly exaggerate their damages, the greater the long-term net benefits the individual receives for any given level of foregone short-term net returns. In short, the receptor gets more for his money when other receptors help him defeat the would-be befoulers of undefiled atmospheric vapors.

and the emitter standard. Obtaining the requisite information for the establishment and maintenance of either an optimal emitter charge or an optimal emitter standard is likely to be an extremely expensive process, even when that information is available. Given that information is not itself a free good and that one cannot afford to obtain continuously the information necessary to maintain the emitter charge or standard at optimum levels, there is no way of knowing with certainty whether that charge which initially brought about an optimal allocation of the air resource will continue to maintain that optimum. A control device which only results in an optimum at a single point in time does not have much to recommend it over any other control device.

If the emitter charge or standard is to be based on receptor damage costs (what else might they be based upon?), then the ability and likely motivation of receptors and emitters to carry out physical and/or temporal input substitutions, whether strategically or nonstrategically, can bring about severe distortions in receptor damage costs and/or emitter cost-savings. Though the extent to which the conditions generating these distortions are present in reality is open to question, their possible variety is so great that it is highly unlikely the emitter charge or standard is universally applicable. To the extent that the conditions for these distortions do exist, some control must be exercised over the actions of receptors as well as emitters. That is, the opportunity for emitters and receptors to treat the air resource or the chance to impose costs upon one another as (nearly) free goods must be removed. Among the possibilities for accomplishing this is the ambient air standard combined with an emitter charge. Though this smacks of cost minimization rather than net benefit maximization, an ambient air standard, as opposed to an emitter standard which specifies the volume of pollutant materials an individual emitter may release over some given time interval, specifies the required state of the receiving medium. If the ambient air standard is once and for all selected prior to and independently of the emitter charge, the distortion phenomena could be avoided. Emitters and receptors would take the ambient air standard as a given and would select their input mixes and magnitudes without reference to the expected actions and/or reactions of each other. The emitter charge to be combined with the ambient air standard would be redundant when and where only one emitter is present. But when two or more emitters are present, it would serve to insure that each unit, however measured, of air available for waste disposal purposes would go to the emitter placing the highest value upon it. That is, it would go to the emitter who would have to sacrifice the most if he didn't have the unit available. By establishing the ambient air standard, informational efficiency in the sense of unbiased cost-savings and damage cost estimates is obtained at perhaps some cost in the fulfillment over time of the static optimality conditions. But at least the possibility of the sheer waste (an utter lack of any private benefits that are not more than negated by private losses elsewhere) of scarce resources involved when emitters and receptors must of necessity try to outsmart each other would be avoided.

In short then, the welfare losses possibly resulting from the application of a combination of the ambient air standard and the emitter charge are failures to fulfill the static optimality conditions all the time. But thse welfare losses plus the welfare losses associated with reciprocal interdependency are possible with the imposition of only the emitter charge or standard that is to vary directly with the level of receptor damage costs. In many if not most air pollution problems, the extent to which the former control device deviates from the maximization of the air resource's rent is likely to be less than with the latter control device—particularly when one includes political and legal maneuverings among the means with which emitters and receptors may influence the level of the latter control device.