DIVISION OF THE HUMANITIES AND SOCIAL SCIENCES

CALIFORNIA INSTITUTE OF TECHNOLOGY

PASADENA, CALIFORNIA 91125

DESIGNING A MARKET FOR TRADABLE EMISSIONS PERMITS

Robert W. Hahn and Roger G. Noll

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ABSTRACT

The economics literature shows that tradable emissions permits have important theoretical advantages over source-specific technical standards as a means for controlling pollution. But efficient, competitive markets in emissions may also be difficult to implement: transactions may be few with high negotiation costs; the market may be highly concentrated. Simple workable versions of the market concept may fail to take account of important complexities in the relationship between the pattern of emissions and the geographical distribution of pollution. This paper examines the feasibility of tradable permits, given these potential problems. Although the empirical part of the paper deals with a specific case--particulate sulfates in the Los Angeles airshed--the methods developed for investigating these issues have general applicability. Moreover, the particular market design that is proposed--an auction process that involves no net revenue collection by the state--has attractive features as a general model.

DESIGNING A MARKET FOR TRADABLE EMISSIONS PERMITS*

Robert W. Hahn and Roger G. Noll
California Institute of Technology

Since the late 1970s, environmental regulators have begun to give serious attention to alternatives to source-specific technical standards as a means for controlling pollution. Indeed, a limited, highly constrained form of one such alternative--tradable emissions permits--began to be implemented for a few air pollutants in some regions. Less constrained methods for implementing tradable permits are actively under consideration; notable examples include the proposals being considered by the Environmental Protection Agency (EPA) for controlling chlorofluorocarbons and by the California Air Resources Board for reducing particulate sulfates in the Los Angeles airshed.

The purpose of this paper is to investigate the practicality of a system of tradable emissions permits. The central issue is not whether a market for emissions permits will work perfectly, but whether it can produce a more efficient combination of emissions and abatement strategies than the traditional regulatory approach. This

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question is examined in the context of a particular pollutant in a specific area, namely the control of sulfur oxides (SO_x) emissions into the atmosphere in Los Angeles. Nevertheless, we believe the analysis to be of general interest. It raises questions that must be answered in order to make a tradable permits system a practical alternative anywhere. It also illustrates the range of institutional arrangements and informational requirements that need to be considered in developing a market for permits.

The tradable permits system examined here is a more radical institutional change than has previously been adopted by regulatory authorities. The "controlled trading options" developed by EPA since the passage of the Clean Air Act amendments of 1977--so-called bubbles, offsets and emissions banks--start with the existing regulatory structure as a baseline, and overlay it with the possibility of of trades.[1] These trading options retain detailed regulatory reviews of each source and of proposed trades. Moreover, traded permits have a somewhat clouded, secondary legal status in comparison to untraded permits.

The approach examined here replaces, rather than supplements, the regulatory methods that are now used to control emissions at their source. It would eliminate distinctions among sources on the basis of age, ownership, industry or method of acquiring permits. It would simply establish a ceiling on total emissions within a geographic area, and it would allow the allocation of emissions among sources in

[1] See Hahn and Noll (1981) for a more complete discussion of this issue.

the area to be determined solely by the market. No regulatory approval of the methods used by any source nor of the distribution of emissions permits among the sources would be required. Policy issues relating to the differential air quality effects of different geographical distributions of emissions permits would be dealt with by the way in which trading regions were defined, and by the rules for trading across regional boundaries, as will be discussed below. The role of the government would be reduced to the following activities:[2] (1) establish ambient air quality standards; (2) determine the total amount of emissions in a geographic area that is consistent with the air quality standard; (3) issue permits and maintain a market for them; and (4) enforce the emissions limits by ascertaining whether each source is emitting pollutants at or below the rate allowed by the quantity of permits it holds, and by imposing noncompliance penalties.

The scholarly literature[3] has examined in detail the theoretical advantages and problems of a system of tradable emissions permits. A competitive market in enforceable emissions permits will achieve a given emissions target at minimum cost and will provide more effective incentives to pursue cost-reducing innovations in abatement technology--advantages that are also characteristic of emissions taxes. In addition, tradable permits have possible political

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[2] Regulators also may wish to use direct regulation, rather than a tradable permits system, to deal with air pollution "episodes" that arise when meteorological conditions are unfavorable. See Hahn and Noll (1981) for a more complete discussion of this problem.

[3] Examples include Dales (1968), Montgomery (1972), Roberts and Spence (1976), and Teitenberg (1980).

advantages in comparison to emissions taxes in that they do not necessarily require that the government collect revenues for allowable emissions (the permits can be given away), and they cause the uncertainties associated with environmental policy to be focused more on the total costs of the policy and less on the equilibrium quantity of emissions. Finally, in comparison to other methods of environmental regulation, a competitive permits market provides fewer barriers to entry for new or expanded pollution sources, and imposes less demanding requirements on regulators.

A major question concerning the practicality of tradable emissions permits is whether a competitive market can be established. Ideally, a market in permits would have a large number of buyers and sellers who actively trade permits, quickly establish a market price for permits that is close to the long-run equilibrium, and take actions that minimize abatement costs and distribute emissions geographically and temporally such that ambient air quality standards are met. In practice, this ideal may not be feasible.

One potential problem is the structure of the permits market. One or a few sources of pollution might account for such a high proportion of emissions that the permits market will be imperfectly competitive, leading to strategic market behavior by the major polluters that prevents the market from allocating permits in a manner that minimizes the total abatement costs. Even if the market is not concentrated, the number of participants may be too few to produce more than very infrequent transactions. This, in turn, could lead to costly bilateral negotiations for effecting trades. Moreover, infrequent trades would produce infrequent and possibly highly variable price signals that undermine the ability of polluters to make efficient choices of levels and methods of abatement. These problems have already arisen in attempts to implement EPA's offset and banking policies.

Another potential problem arises from the geographic specificity of both emissions and damages from pollution. Each receptor is polluted by a somewhat different combination of sources, the emissions from which interact--sometimes nonlinearly--to produce unique effects. To guarantee maximum technical efficiency, ignoring the costs of operating the markets, requires that a separate market be established for pollution at each receptor point. Each firm would have to know the relationship between its emission and pollution at every receptor, and then buy the appropriate amount of pollution permits for each one that it affects. Ignoring this feature of pollution problems and establishing a single permits market for an extensive geographic area could lead to a concentration of emissions from one location that, in turn, would create a localized "hot spot" which is badly out of compliance with ambient pollution standards. Alternatively, creating numerous markets that account for the complexities of the relationship between emissions and pollution could make the costs of organizing an effective market system so high that it is not worth doing. Moreover, a system with numerous interrelated markets may have some markets in which only one or a few polluters participate, leading to inefficiencies resulting from market concentration.

Whether these potential difficulties offset the theoretical advantages of a system of tradable permits is an empirical question, the answer to which depends on technical aspects of the pollution problem that is being addressed and the details of the design of the permits market. Both potential problems--imperfect competition and localized pollution hot spots--arise because of a particular perversity in the cost-minimizing distribution of permits. Hence, to determine whether either problem is likely to be a serious drawback to a specific system of marketable permits requires analyzing the likely operation of the market to see if the hypothetical competitive equilibrium distribution of permits is vulnerable to these perversities. To undertake such an analysis requires two types of information: the abatement cost functions faced by each important source of emissions in the region in question, and a model of the relationship between emissions and pollution that has sufficient geographical resolution that it can predict the effects of alternative patterns of emissions on the pattern of pollution within the area.

The abatement cost functions provide the information necessary to determine the distribution of emissions permits for a specific market system. A pollution source that is operated in an economically rational way will minimize the sum of expenditures on permits and on abatement measures for any given level of operation. Higher permit prices generally will lead to fewer purchases of permits and greater abatement. Hence, knowledge of the abatement cost function for each source provides the information necessary to calculate the demand curve for permits for each source and, by addition, for the entire market. These demand relationships can then be used to estimate the market's allocation of permits among sources for any given total quantity of permits. This is accomplished by using the market demand curve to find the equilibrium price of the given quantity of permits, and then using each source-specific demand curve to estimate the equilibrium distribution of permits. The model of the relationship between emissions and pollution can then be used to predict the distribution of emissions that the market would produce.

Alternative designs of a system of tradable permits can be compared by simulating the operation of each. For example, the definition of the geographic scope of a market--which sources are required to buy which permits--is a design variable that can be used to find the best trade-off between problems of market structure and problems arising from pollution hot spots. As the geographic area in which permits can be freely traded grows more extensive, more sources are incorporated into the market and hence problems of market concentration and infrequent transactions are diminished; however, the likelihood of localized pollution hot spots is increased.

IS IMPLEMENTATION FEASIBLE?

To investigate the viability of marketable permits without actually implementing the alternative requires selecting a specific pollutant, identifying the key implementation problems, and then determining whether a well-designed market will successfully address these issues. As an example, the problem of controlling particulate sulfates in the Los Angeles region was selected. This problem was

chosen because its technical characteristics make it a likely candidate for marketable permits, as is discussed below.

The current approach towards controlling sulfur oxides emissions in Los Angeles relies on source-specific standards, an offset policy, and a modest emissions fee. Large new sources of pollution must adopt the best available technology, and must trade off the uncontrolled portion of their emissions by effecting further reductions at existing sources in the Los Angeles Basin. The owner of an existing source is thus vested with a valuable property right which can be sold in whole or in part to new sources. The owner also has the option of retaining the opportunity for further abatement to facilitate subsequent expansion.

As discussed above, the offset policy is one limited form of a market in transferable permits to emit air pollutants. Its principal drawbacks are that the costs of negotiation are excessive, the number of trades which can be made by new sources is limited, all trades must be approved by several regulatory authorities before they can be consummated, and in any case, sources must satisfy minimum technical standards before and after trades. Negotiation costs are high because new entrants must first identify existing sources of pollution where emissions reductions are feasible, and then try to estimate a reasonable charge for the offset. Moreover, gains from trade are limited to the extent that existing technical standards do not allow marginal abatement costs to be equated across firms.

The question at hand is whether a market for sulfur oxides emissions permits could improve matters. First, the criteria for measuring the success of a market proposal need to be specified. For this specific case a market should satisfy established air quality goals for sulfate particulates in a more cost-effective manner than the current system of source-specific standards, should encourage investment in finding more cost-effective abatement technologies for the future, and should be legally and politically feasible. Legal feasibility means that the market must meet the requirements of relevant constitutional constraints, and be implementable without fundamental changes in the performance objectives of existing statutes. Political feasibility means that the regulatory agency should be capable of administering the program, and that the approach has a reasonable chance of being sufficiently acceptable to industry, the public and regulators that it stands a chance of being enacted by public officials.

To demonstrate feasibility requires a good technical understanding of the problem. The particulate sulfate problem in Los Angeles is caused primarily by the combustion of sulfur-bearing energy sources. Particulate sulfates are a regulatory concern because they reduce visibility, acidify rainwater, and may have harmful health effects. The conversion of sulfur oxides emissions to sulfates in Los Angeles can be thought of as proceeding in three stages. First, sulfur enters the air basin. Virtually all of the sulfur which is emitted in Los Angeles is initially embodied in crude oil. Second, when oil products are refined or burned without controls, some of the sulfur they contain is converted to SO_2 and SO_3 and released to the atmosphere. Finally, the SO_x compounds react to form sulfates through

a series of atmospheric chemical processes.

Cass (1978) has succeeded in constructing an emissions/air quality model for particulate sulfates in Los Angeles. He has shown that the relation between sulfur oxides emissions and sulfate air quality in Los Angeles is approximately linear and, in addition, can be modeled adequately as if it were largely independent of the level of other key pollutants. One feature of Cass's model is that mobile sources are treated as stationary sources by converting them to traffic densities over the airshed. Because the most efficient strategy for reducing sulfur emissions from mobile sources is to reduce the sulfur content of fuels, regulation of mobile sources can be done indirectly by placing the responsibility on refiners. A tradable permits system could then require refiners to add refinery emissions to sulfur oxides emissions from mobile sources to determine the number of permits they must hold.

A major task of the project was to estimate abatement cost functions for the primary sources of sulfur emissions in Los Angeles. Over twenty-five source categories were identified, and abatement costs estimated for each. The published literature, regulatory proceedings, and interviews with representatives of local industry and state and local regulatory personnel were relied upon to generate preliminary cost estimates. The information typically obtained from a particular source was a point estimate: the cost at some historical date of using a particular method to obtain a specific rate of emissions from a particular kind of facility. These were combined to produce a step function for abatement costs for representative facilities in each source category based on 1977 regulatory conditions, with corrections made to put the costs in 1977 dollars. The results of these analyses were submitted as industry studies to the relevant firms operating in Los Angeles, with requests for comments. The additional data received in this manner were used to produce a final cost study, including indications of the amount of disagreement about costs among the sources of information.

A number of factors make these cost estimates upwardly biased as estimators of the costs that would be experienced if a system of tradable permits were instituted. First, for source categories for which no control cost estimates could be found, emissions were assumed to be uncontrollable. Second, production and energy use at emitting facilities were assumed to be independent of the amount of control. In reality, firms with especially high emissions and stiff abatement costs are likely to reduce output or to make more efficient use of energy. Third, although in many cases emissions can be reduced by process changes, firms are reluctant to reveal these possibilities because they are trade secrets that may confer significant competitive advantages in a more stringent regulatory environment. No allowance for these process changes is made in the study, although an effort is now being made to model the possibility of changes in refinery product mix in the oil industry as one means of changing emissions from refineries and refined products.

Because SO_x emissions in Los Angeles result largely from the combustion of petroleum products, the availability of natural gas, which has negligible amounts of sulfur, can significantly affect SO_x

emissions. This, in turn, will affect the demand for permits and, hence, their price. Price regulation has led to excess demand for natural gas since the mid-1960s, and to uncertainties about the availability of gas in the future, even though gas is now scheduled to be deregulated. For this reason, three separate cases were analyzed: one which assumes low availability of natural gas; a second which corresponds to a historical supply year (1973) in which an intermediate supply of gas was available; and a third which assumes a high supply of natural gas. All three cases are based on emissions projections for the early 1980s with 1977 regulations assumed to be in place. In all cases, access to natural gas is assumed to be determined by regulatory allocation priorities, rather than the market. This has an important effect on the results because regulatory allocation priorities are not related to the value of natural gas in terms of either its direct use or the effects of its use on air quality.

With these caveats in mind, the cost data were used to estimate the demand for emissions permits and the distribution of permits that an efficient market would produce.

THE COMPETITIVE MODEL

In all of the models discussed, it is assumed that firms attempt to minimize the sum of abatements costs plus permit costs. In this section, a baseline competitive equilibrium distribution of emissions permits is simulated. Firms are assumed to be price-takers, which is to say they assume that the equilibrium price of a permit is unaffected by their actions. A permit is defined as the right to emit one ton SO_2 equivalent of sulfur oxides per day anywhere in the airshed. After examining this baseline case, it will be compared to a fine-tuned definition of permits that takes account of the geographical locations of sources and receptors, and to a simulated distribution of emissions when the permits are monopsonized.

To simulate the market, it is necessary to specify an air quality target. For the purposes of analysis, four targets are examined, ranging from no further net emission control down to about a 70 percent reduction in emissions. The latter is needed to meet the California sulfate standard. The four cases are summarized in Table 1.

The calculations in the table are based on a linear rollback model of the relationship between emissions and sulfate pollution. The estimates of the emissions/air quality relationship would probably change if a more sophisticated air pollution model were employed, but the rollback model suffices for the purpose of showing how the permit price and abatement costs vary with the choice of an air quality target. Figure 1 illustrates the equilibrium price of a permit to emit one ton/day of SO_x in Los Angeles for the case in which there is a low natural gas supply. All price and cost estimates are given in 1977 dollars.

The decreasing step function in Figure 1 represents the derived demand curve for permits over the range of interest. The curve was drawn as a step function because most of the engineering cost estimates which were used to generate the demand curves were given in this form. The four vertical supply constraints in Figure 1

TABLE 1

SELECTED AIR QUALITY TARGETS FOR THE SOUTH COAST AIR BASIN in tons SO_x/day[a]

TARGET	ALLOWABLE EMISSIONS
1. Achieve California Sulfate Air Quality Standard of 25 micrograms/cubic meter over a 24 hour averaging time.	149
2. Violate California Sulfate Air Quality Standard 3-5% of the time.	238
3. No additional controls with an above average natural gas supply.	335
4. No additional controls with a low natural gas supply.	421

[a]See Hahn (1981b) for the basis of these calculations. Sulfur oxides emissions are measured as tons of SO_2 equivalent.

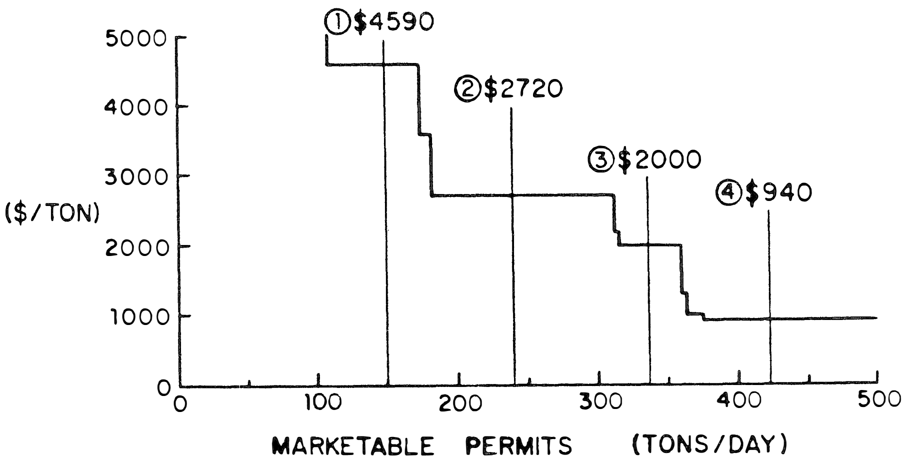

FIGURE 1

The Demand for Permits with Low Availability of Natural Gas

Source: Hahn (1981a)

correspond to the four air quality targets presented in Table 1. The market price of a permit is drawn next to each intersection. Thus, for the first case in which the California sulfate standard is met, the point estimate for the price of a permit is 4,590 dollars. Based on the derived demand for permits, it is also possible to calculate two other potentially interesting numbers. The amount of money which could conceivably change hands in a permit market can be calculated by multiplying the number of permits issued by the equilibrium price. The annual abatement cost for any level of air quality can be computed by integrating the area under the entire demand curve and to the right of the air quality target, and then multiplying by 365. (Because Figure 1 only shows the main part of the curve, and not the curve in its entirety, it is not possible to reconstruct abatement cost numbers from the figure.) The significance of these numbers is discussed below.

The price of an emissions permit is highly sensitive to the availability of natural gas and to the choice of an air quality target. Table 2 shows the equilibrium price of a permit with alternative assumptions about air quality standards and the availability of natural gas. Table 2 exhibits two interesting features. First, it can be seen that the price of a permit can vary by an order of magnitude depending on the assumptions concerning natural gas supply and the air quality target. Second, a comparison of the first two columns indicates that a fairly small change in air quality standards cause a substantial change in the price of a permit. This reflects the fact that the marginal cost of sulfur oxides abatement changes at the upper end of the air quality spectrum.

TABLE 2

PRICE SENSITIVITY ANALYSIS

NATURAL GAS SUPPLY	AIR QUALITY TARGET			
	1	2	3	4
Low	4,590[a]	2,720	2,000	940
Historical	2,720	2,000	940	810
High	1,320	650	470	420

[a]All prices in $ 1977. A permit entitles the user to emit one ton of SO_x for one day.

Source: Hahn (1981a)

The total annual cost of abatement varies considerably both as a function of the natural gas supply and the air quality target. The data are presented in Table 3. The estimates of abatement cost do not include abatement equipment installed prior to 1977. Consequently, the changes in abatement cost between different categories are probably the most meaningful figures. Even without estimates of some abatement equipment in place, abatement costs are in the hundreds of millions, except for the case in which natural gas is in plentiful supply.

The most important point to be derived from Table 3 is that the availability of natural gas has a marked effect on the cost of reducing SO_x emissions. The only difference between the situations of low and high natural gas supply is that the latter substitutes natural gas for 100 million barrels of residual fuel oil. Dividing the difference in abatement costs between the two cases by the difference in the amount of oil used yields an average cost saving per barrel-equivalent of natural gas between 4 and 6 dollars, depending on the air quality target. The cost savings result from the substitution of natural gas for high-sulfur fuel oil, rather than using low-sulfur oil or extensive abatement investments to meet emissions targets.

Another way of illustrating the critical importance of the natural gas supply is to ask what firms would be willing to pay for having natural gas substituted for one barrel of residual fuel oil. Assume that the marginal value of natural gas equals the full marginal cost of burning residual fuel oil. The full cost includes the price of a barrel of oil plus the cost of emitting or abating the associated

TABLE 3

ANNUAL ABATEMENT COSTS
(in millions of 1977 dollars)

NATURAL GAS SUPPLY	AIR QUALITY TARGET			
	1	2	3	4
Low	684	576	487	447
Historical	400	315	280	252
High	112	83	66	53

Source: Hahn (1981a)

sulfur oxides. Performing the calculation for all twelve cases reveals that firms would be willing to pay anywhere from 107 percent to 130 percent of the price of the residual fuel oil for an equivalent BTU amount of natural gas.

In evaluating the desirability of a system of marketable permits, one important issue is the potential savings in the costs of regulation. Of course, most of the opportunities for cost savings are not easily quantified. For example, a system of tradable emission permits will tend to produce lower barriers to entry than the current emission standards approach; however, placing a meaningful dollar estimate on the expected net benefits from such a change is difficult. It is also difficult to know to what extent the marketable permit system will induce innovations in abatement technology over time. Finally, the costs of the regulatory process should be lower under tradable permits, but the magnitude of the savings is uncertain. The following analysis focuses solely on the static efficiency gains which can accrue from using a market mechanism. Moreover, attention will be restricted to that subset of static gains not involving process changes, which could be substantial for industries such as petroleum refiners. Thus, the estimates developed here are best viewed as a lower bound on the actual gains that might result from moving to marketable permits.

For SO_x emissions in Los Angeles, the gains from using an incentive-based approach to maintain the status quo can be expected to be relatively small in comparison to other applications which have been examined. This is because the local pollution control agency has attempted to use cost-effectiveness as a major criterion in promulgating rules.

The specific problem is to examine how the competitive equilibrium under a tradable emissions permit system compares with the current standards approach to regulation. The first step in the analysis is to project the level of expected emissions under standards. This calculation is performed for all three levels of natural gas supply, and two sets of standards. The first set of standards consists of those in place by the end of 1977. The second set consists of those expected to be in place by 1985. The projected emissions for the six cases are shown in Table 4. Note that the projected emissions for the low natural gas scenario under 1977 standards correspond to case 4 in Table 1. The predicted emissions in 1985 are lower than 1977 sulfur oxides emissions because the former standards include more stringent controls on three source categories: petroleum coke calciners, fluid catalytic crackers and residual fuel burning by refiners.

The next step in the analysis is to compare the cost of standards with the competitive equilibrium for an emissions permit market. The difference is the expected annual savings in moving from standards to tradable emissions permits, which is shown in Table 5. The data show that some cost savings are possible, even though regulators have tried to implement cost-effective control strategies.

The last point which the analysis of the competitive case raises is the magnitude of the sums of money which could conceivably change hands if a market were to be implemented in a way that caused

TABLE 4

SULFUR OXIDES EMISSIONS UNDER STANDARDS
(Tons SO_x/Day)

NATURAL GAS	STANDARDS 1977	1985
Low	421	364
Historical	298	250
High	211	167

Source: Hahn (1981a)

TABLE 5

ANNUAL COSTS SAVINGS
WITH AN UNDIFFERENTIATED TRADABLE PERMIT SYSTEM
(in millions of 1977 dollars)

NATURAL GAS	STANDARDS 1977	1985
Low	23	22
Historical	17	15
High	10	8

Source: Hahn (1981a)

all permits to be sold, such as a public auction. Define the total annualized value of the permits as the number issued multiplied by the annual price people are willing to pay to hold a permit for one year. (This price is obtained by multiplying the data in Table 2 by 365.) For the twelve cases examined here, the total annual value of the permits varies between 65 and 250 million dollars, and is generally only slightly smaller than the corresponding annualized abatement costs. This may have considerable political significance. The initial allocation of permits, establishing the baseline from which trades are made, is an implicit allocation of a considerable amount of wealth--indeed, the magnitude of the wealth inherent in the permits is likely to be large in comparison to the efficiency gains from a permits market. Consequently, the principal focus of the political debate over alternative market designs is likely to be wealth distribution, not efficiency.

The preceding analysis deals with the case in which emissions permits are freely tradable throughout the airshed, with no account taken of the differences among sources in the impact of emissions on ambient air quality. In practice, a fine-tuned permits market would be difficult to implement; however, the outcome of such a system, assuming it could be implemented, can be simulated in the same fashion as the case of a competitive market for geographically unspecified permits. This is the subject of the next section.

DOES FINE-TUNING PAY?

Instead of having a single market where permits are undifferentiated, imagine a case where there are several markets corresponding to each of the receptors within an air quality region. Assume further that firms would have to participate in all markets where their individual emissions affect air quality. This is the essence of the "fine-tuning" problem. In practice, a fine-tuned permits market would be difficult to implement; however, the outcome of such a system, assuming it could be implemented, can be simulated in the same fashion as the case of a competitive market for geographically unspecified permits.

The results of the simulations for this case are shown in Table 6. Column (1) lists six alternative levels of total emissions to be allowed in the airshed. Column (2) shows the abatement costs for achieving these levels, assuming a competitive permits market and low availability of natural gas. The low natural gas case was selected because it generates the highest abatement costs and, therefore, is likely to produce the maximal benefits from fine-tuning.

Associated with the competitive distribution of each of the emissions levels in Column (1) is a set of the average concentrations of sulfate particulates during the year at each of the seventeen air quality monitoring sites used in the simulation. Suppose that instead of setting a limit on total emissions, regulators issue permits to pollute at each receptor point equal to the pollution that would result from the competitive equilibrium in the emissions permit market. Each source of emissions would then need to acquire

TABLE 6

ANNUAL ABATEMENT COSTS AND MARKET ARRANGEMENTS

(1) BASELINE EMISSIONS TARGET (TONS/DAY SO_2 EQUIV)	(2) AVERAGE AIR QUALITY (gm/m^3)	(3) COSTS FOR SINGLE MARKET IN EMISSIONS PERMITS	(4) COSTS FOR EQUIVALENT MULTIPLE AIR QUALITY MARKETS	(5) COSTS FOR "ADJUSTED" MULTIPLE AIR QUALITY MARKETS
150	7.0	682	682	682
200	7.8	614	606	594
250	8.4	565	557	545
300	8.9	515	513	505
350	10.1	476	473	464
400	11.1	455	448	436

Note: Assumes "low" natural gas availability.

Source: Hahn (1981a)

separately permits for the pollution its emissions caused at every measuring station. Because geographical location matters in affecting measured air pollution, this approach could produce additional rearrangements of emissions -- and some increase in total emissions -- that resulted in lower abatement costs but did not reduce air quality at any measuring station. Column (3) shows the costs associated with the competitive equilibrium distribution of emissions under this system.

Finally, suppose regulators are concerned only with air quality at the worst measuring station, and that they create permits for each station that allow pollution at every monitoring station to equal the pollution measured at the worst station under the competitive equilibrium distribution of emissions permits in Column (1). This would allow further trades and increases in emissions as long as air quality did not deteriorate at the location with the worst pollution, and did not force some other station to have its air quality deteriorate beyond the level at the worst-case station. The abatement costs associated with the competitive equilibrium distribution of these permits is shown in Column (4).

The result of these simulations is that defining permits in terms of pollution, and geographically differentiating the permits for each monitoring location, has relatively little effect on the efficiency of the market. The differences in annual abatement costs under the three systems vary from zero to four percent of the total, amounts that are surely small compared to the difficulties of trying to implement a more complicated system.

There are two qualifications to the basic result that a finely-tuned system may not be warranted on the basis of cost savings. First, it should be noted that air quality is measured in terms of average annual concentrations. A shorter averaging time could produce a different result. Second, the result speaks to the present. Calculations are based upon the abatement possibilities and emissions inventories of existing firms in their current locations. Changes in the economic structure of the airshed conceivably could alter the pattern of emissions such that a more complicated system would provide substantial benefits. But at present, there does not appear to be a serious loss in efficiency associated with adopting the simplest approach of making emissions permits freely transferable throughout the airshed.

THE EFFECTS OF MARKET POWER

Thus far, the analysis has been restricted to the case in which firms act as price-takers in the permits market. One potential problem with a marketable permits system is that one or a few firms may be able to manipulate the market to their advantage and, in the extreme, destroy its efficiency advantages over standards. This problem cannot be dismissed lightly for the case at hand.

The source producing the highest rate of emissions is an electric utility. Table 7 shows the estimated share of total emissions that it would produce under the competitive market allocation, which ranges between one-fourth to one-half of the permits. Whether this will, in fact, allow the firm to exercise

TABLE 7

MARKET SHARE OF THE LARGEST PERMIT HOLDER UNDER COMPETITION

NATURAL GAS SUPPLY	AIR QUALITY TARGET			
	1	2	3	4
Low	31	43	45	41
Historical	32	43	48	48
High	23	29	40	47

Source: Hahn (1981a)

significant market power is an open question that depends on how the market is organized and operates. For purposes of analysis, we will assume that this sizable market share allows the firm to exercise market power.

The market power of the firm with the largest market share could manifest itself in several ways. It is not even clear without further specification of the details of the design of the market whether a firm with market power will act as a monopolistic seller of permits or as a monopsonistic buyer.[4] Here we will analyze the case of a monopsonistic buyer. We assume that the firm in question initially will be given fewer permits than it is expected to want to hold after the market in permits is opened. This is consistent with present policies that tend to require utilities to adopt abatement methods having higher marginal abatement cost than is common for most other industries. For the numerical simulation discussed below, we assume that the utility will receive no permits initially, and that it will be the only purchaser of permits--that is, the initial distribution of permits is such that the utility will be able to exercise maximal market power. In such a market, the equilibrium price will equal the marginal abatement cost of the sellers of permits, but not of the monopsonistic buyer. In purchasing permits, the monopsonist will take account of the fact that as it increases its purchases of permits, it will drive up their price. Hence, it will buy fewer permits at a lower price than would be the competitive,

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[4] For an analysis of this problem, see Hahn (1981a).

cost-minimizing solution. In other words, the monopsonist will abate too much in relation to other firms, and the latter will have lower marginal abatement costs than the former. To the monopsonist, some additional, uneconomic abatement will be worthwhile because of its depressing effect on the price paid for the permits that it acquires from other firms.

Table 8 shows the simulated market share of the firm holding the most permits, assuming that it achieves the profit-maximizing monopsony. A comparison of Tables 7 and 8 illustrates the additional abatement that the monopsonist will undertake if it has market power. The two tables also reveal one other interesting fact. The market share of the largest firm tends to be high at an intermediate natural gas supply and does not differ much between high and low gas supply. This reflects the fact that at the extremes natural gas is either used sparingly or extensively by almost all industrial sources, while the intermediate case reflects the fact that utilities will be among the last to be allowed to switch to gas from low-sulfur fuel oil under the current scheme for gas allocations.

The decrease in market share is typically accompanied by a decrease in the price of a permit. This can be seen by comparing Table 9 with Table 2. As in the competitive case, the permit price still varies by an order of magnitude over different assumptions about the air quality target and the supply of natural gas.

Although the differences between the competitive and monopsonistic case appear large, whether they cause a major loss of efficiency in achieving abatement targets remains an open question.

TABLE 8

MARKET SHARE OF THE LARGEST PERMIT HOLDER UNDER MARKET POWER

NATURAL GAS SUPPLY	AIR QUALITY TARGET			
	1	2	3	4
Low	20	31	37	41
Historical	32	40	33	44
High	23	25	39	32

Source: Hahn (1981a)

TABLE 9

PERMIT PRICES UNDER MARKET POWER

NATURAL GAS SUPPLY	AIR QUALITY TARGET			
	1	2	3	4
Low	2,720[a]	2,000	1,000	940
Historical	2,720	1,000	650	470
High	1,000	470	420	210

[a]All prices are in $ 1977. A permit entitles the user to emit one ton of SO_x per day.

Source: Hahn (1981a)

The appropriate measure of inefficiency is neither price nor market share, but the differences in total abatement costs under the two situations. If at the competitive equilibrium all firms face a fairly flat marginal abatement cost over a wide range of emissions reductions, a large shift of emissions from the monopsonist to the rest of the firms might entail relatively little loss of efficiency. As can be seen in Figure 1, all of the choices of alternative ambient air quality standards happen to fall within relatively flat portions of the demand curve for permits, and therefore in areas in which the abatement cost function obeys essentially constant marginal costs. Calculations of the efficiency loss of market power were made in each case, and the loss was determined to be relatively small, ranging from zero to ten percent depending upon the particular combination of assumptions about natural gas supplies, ambient air quality standards, and the method used for estimating the abatement cost functions.

Nevertheless, a conclusion that market power will not severely undermine the operation of the market is not warranted at this time. The estimated loss in efficiency due to market power is quite sensitive to small changes in the cost functions. Consequently, considerable thought must be given to the possibility of building in protections against monopsonistic market power into the tradable permits system. These issues are addressed in the following section which focuses on questions of institutional design.

INITIALIZING THE MARKET

The major design criteria for a tradable emissions permit market are: equity in the distribution of permits initially; sufficient early transactions to produce a stable price for permits that is close to the long-run equilibrium to encourage rational long-term investment planning; and attainment of an equilibrium price and distribution of permits that is close enough to the competitive case to assure attainment of air quality objectives at lower costs than can be obtained by alternative regulatory approaches. A major design feature that affects the extent to which a permits market satisfies these criteria is the method for starting up the market.

One way of starting the market is to make an initial allocation of permits, and then to rely on the inefficiencies of this allocation to generate incentives for a market to form. Three methods for initially distributing the permits are considered. One would base permit distribution on emissions as they existed prior to recent attempts to control them, with perhaps some additional provision for firms that have entered the airshed or expanded capacity since that time. The second would base the initial allocation on the emissions allowed under current standards. The third would base the distribution of permits on the projected equilibrium that would result from a competitive, perfectly efficient market in permits. Any other method that is based upon historical emissions performance raises the objection that people who were early to comply with regulation would be punished for cooperating. Any method that is not based on emissions raises the objection that it is arbitrary, and in any case

is more vulnerable to becoming bogged down in a contest between competing claims for redistributing wealth that have nothing to do with air pollution policy.

Basing the initial distribution on the projected competitive equilibrium has a serious defect in terms of efficiency of the permits market. To the extent that the initial distribution succeeded in finding the competitive equilibrium, it would also succeed in avoiding the necessity for any transactions among present sources. Only in the case of new sources or expansions of existing facilities would a demand for trades arise. Thus, a relatively speedy attainment of a stable, competitive price for permits would be least likely under this mechanism. Indeed, much the same problems as confront the current banking and offset policies could be expected: a slow development of the market owing to the difficulties of finding trading partners and negotiating a price.

A second difficulty with the strategy of distributing the permits on the basis of the estimated competitive equilibrium is that it may be more vulnerable to legal challenges and delays. The method for simulating the competitive equilibrium is to minimize estimated abatement costs for the entire airshed, a calculation that is based on numerous estimates of costs for each category of sources at all feasible levels of abatement. This is tantamount to setting new source-specific standards for the entire region. Because the cost estimates on which the equilibrium allocation would be based are admittedly inexact, they are vulnerable to challenge as being insufficiently precise to support a regulatory decision, just as existing source-specific standards are often challenged--and changed or delayed—on the basis of their estimated costs and effectiveness. If any single estimate of costs or efficiency abatement that was used in simulating the competitive equilibrium was successfully challenged, it would undermine the entire initial allocation of permits, and, hence, the implementation of the system.

Other possible candidates for permit distribution are to base initial allocations on an historical level of emissions or current standards. One possibility of the former is the emissions inventory of 1973, while an estimate of the latter is a projection of the 1980 inventory. Both are shown in Table 10. These, too, have unfortunate properties. They appear to stack the deck in favor of monopsonistic behavior by the firm with the largest share of permits. In 1973 and 1980, this firm accounted for 28 and 31 percent of emissions, respectively, as contrasted with a projection of 44 percent under competition, assuming current regulations and historical natural gas availability. Thus, one would expect the largest firm to be a purchaser of permits--and a very large purchaser if the competitive outcome is to be achieved. In either case, it is plausible that in order to achieve the competitive result, the firm with the largest market share must account for nearly all purchases of permits (nearly everyone else would be a seller), and therefore face powerful incentives to engage in monopsonistic purchasing practices.

The dilemma in organizing the permits market is that there is a seeming inconsistency in getting the single largest source of emissions to engage in transactions so as to get the market started

TABLE 10

PAST AND PROJECTED "MARKET SHARES" OF SULFUR OXIDES EMISSIONS BY SOURCE TYPE FOR THE SOUTH COAST AIR BASIN OF CALIFORNIA[1]

1973 Emissions		1980 Projection Low Natural Gas Scenario	
Source Type	% of Total Emissions[2]	Source Type	% of Total Emissions
Utility	28	Utility	31
Mobile Sources	16	Mobile Sources	27
Utility	11	Utility	10
Oil Company	8	Oil Company	4
Steel Company	7	Coke Calcining Company	4
Oil Company	3	Oil Company	4
Coke Calcining Company	3	Steel Company	3
Oil Company	3	Oil Company	3
Oil Company	2	Oil Company	2
Oil Company	2	Oil Company	2

[1]These figures are based on the 1974 definition of the South Coast Air Basin which was subsequently revised.

[2]Emissions are rounded to the nearest percent.

Source: Calculations by R. Hahn based on Cass (1978) and data used to compile Cass (1979).

quickly on a course that provides stable price signals to firms making abatement and location decisions, and in preventing the market from being manipulated. Several possibilities emerge for attacking this problem.

One approach is to use different methods for the largest emissions source and other sources for making the initial distribution of permits, allocating to the potential monopsonist something like the competitive equilibrium estimate while using the historical basis for allocating permits to others. This would probably produce a situation in which the largest source was not a participant in the early stages of the market; however the remaining sources would have an incentive to engage in trades, and would be more likely to produce a competitive outcome.

A second approach is to make a distinction between the most important sources as a group and the remaining sources, allocating permits initially so that all of the former are equally interested in acquiring more permits, while all of the latter want to sell. Thus, each of the half-dozen most important sources of emissions could be allocated a number of emissions permits that falls short of the estimated competitive equilibrium by the same absolute amount, while the other firms could be given permits that exceeded their estimated equilibrium amount by some proportion that is consistent with the first allocation. In such a situation, the largest source of emissions would hold the largest number of permits, but would not account for an especially large fraction of the transactions on its side of the market.

A third approach is to allocate only some fraction of the permits on the basis of historical or projected emissions, and let the state auction the rest. All firms could, say, be allocated 80 or 90 percent of their projected equilibrium emissions, and the remaining permits would be sold. This has the objection that, like an emissions tax, the state ends up collecting revenues, so that the costs of the system to polluters exceed their abatement costs; however if the fraction of permits sold were small enough, the efficiency gains to industry in rationalizing abatement control strategies would offset the revenues lost to the auction.

A final possible approach is to use an auction process that redistributes auction revenues to the firms that participate in the market. In order to produce an efficient outcome, the method for determining the rebate to a firm must not depend on its actions in the auction. One possible auction process that generates no net revenue and that has attractive incentive properties is as follows. Each firm would receive a provisional initial allocation, based upon one of the criteria discussed above (historical emissions, current standards, expected competitive equilibrium). All sources would be required to offer their entire allocation for sale. Each firm would then report its demand curve for permits, and the sum of the demand curves would be used to calculate the market-clearing price for the fixed total quantity of permits for the entire market. This price would then be used to calculate the final allocation of permits to each firm, according to its demand curve. Firms would make a gross payment to the state equal to the market price times their final allocation, and would receive a gross revenue from the state equal to the market price times the initial allocation. The net financial effect on each firm would be the market price times the difference between its initial and final allocation; the net financial effect on all firms taken together would be zero.

Initialization methods that use an auction process have two significant advantages over methods that simply define the initial distribution of permits and then wait for normal market forces to cause trades. The first advantage is that all firms are placed on the same side of the market initially--as demanders for state-issued permits. This reduces the likelihood that a large pollution source will be able to exercise market power, for the latter depends on the share of firms' excess demand (or supply) in relation to others on the same side of the market. The second advantage is that all firms participate in the establishment of the auction price, not just the firms that are sufficiently out of equilibrium after the initial allocation of permits that they have a strong enough incentive to orchestrate an early transaction. An auction avoids the transaction costs and other problems of bilateral negotiations for consummating the first exchanges, and maximizes the amount of information conveyed by the initial price signal.

The preceding discussion of these organizational issues has value beyond a particular concern about market power in the context of this case study. While an imperfectly competitive market for permits may not be a common problem, all potential applications of tradable permits involve the selection of an institution for allocating the

permits in a manner that satisfies equity constraints and still promotes an efficient market. Whereas the nature of the problems to be overcome in facing a trade-off between these objectives will differ from case to case, conflicts between efficiency and the political perception of equity are likely to be common. The substantial differences in regulatory standards among industries and between new and old sources are manifestations of the same kinds of conflicts in the current system. Thus, specification of the properties of different methods for distributing permits and organizing trades is an important general issue for making feasible the adoption of tradable permits.

GENERALIZING THE BASIC APPROACH

Even if the formation of a tradable emissions permit market is found to be an attractive policy option for one particular pollutant in a specific locale, the issue still remains as to the generalizability of the result. Will a detailed air quality model always be required for each application? Will new cost estimates need to be developed for each case? In short, will regulators need to undertake an in-depth analysis similar to the one discussed here in order to ascertain whether a market solution is appropriate for a particular problem?

Certainly, some analysis will always be required in thinking about making the transition from "command and control" regulation to a market approach; however, it is likely that as experience with incentive-based options such as markets increases, the level of analysis needed for potential new applications will decrease.

Specifically, what are the critical components with which a regulator should concern himself before considering a market scheme? One is the approximate costs of regulation incurred by the agency and by industry. A second would be the agency's monitoring and enforcement capability. A third important element would be knowledge about the sources of emissions, and a fourth would be an understanding of the relationship between source emissions and measures of environmental quality.

The first point to observe about this list of requirements is that in a general way it is common to the development of a rational environmental policy of any kind. A regulator needs to have some idea of the relationship between emissions and pollution in order to develop a set of standards, tradable emissions permits, or effluent taxes that accomplishes the objectives of environmental policy. Moreover, regulators need to know the pre-regulation pattern of emissions and the abatement opportunities available to each major source in order to set standards or taxes that will achieve environmental objectives in a cost-effective manner. Finally, all policies must be consistent with the ability of the regulator to monitor emissions and pollution, and to enforce any method of achieving its goal.

Nevertheless, the informational requirements may differ in their details for implementing a system of tradable permits. One reason is that a positive case needs to be made to convince political actors--regulators, regulated businesses, environmentalists, and the

public at large--that a change in regulatory methods is worth trying. This is the source of the belief that the initial implementation of a tradable permits system will require a well-documented study of its likely performance, but that subsequent implementations will require less information if the initial program succeeds.

Even so, a market approach may still require a different combination of analysis and data than other approaches. The reason is that the important regulatory decisions in implementing and maintaining a market system are somewhat different, leading to different evidentiary requirements if a regulatory authority's decisions are to withstand legal and political attacks. A case in point would be the establishment of a baseline emissions inventory upon which to make the initial distribution of permits. Because potentially large implicit wealth transfers are involved, participants in the process to set up a tradable permits system could be expected to take an active interest in establishing a baseline, leading an agency to make a greater commitment of resources to this issue than would otherwise be the case. By the same token, agency expenditures for identifying best control technologies could be reduced, because the agency would no longer need to establish legally defensible source-specific standards. In a world with tradable permits, the key regulatory decisions are the initial allocation of the permits, the establishment of total emissions limits, and the determination of an ambient air quality standard. Regulatory resources would tend to be redirected towards these issues, and away from studying problems of specific sources.

As a practical matter, a market approach is likely to retain some standards. In the case reported here, for example, attention was focused entirely on the effect of SO_x emissions on particulate sulfates because the Los Angeles airshed is in compliance with standards for SO_2 concentrations. As discussed above, SO_2 emissions undergo chemical reactions and transportation in the atmosphere to become sulfates. Thus, at any given location, SO_2 pollution is more likely to be the result of a nearby source of SO_2 emissions, whereas particulate sulfates are more likely to be the result of emissions from numerous sources, including some at a relatively great distance. In Los Angeles, compliance with SO_2 standards generally only requires that major emissions sources install tall enough smokestacks so that by the time SO_2 reaches the ground it has been adequately dispersed in the atmosphere to satisfy maximum atmospheric concentrations. The adoption of an emissions market for sulfur in Los Angeles as a means for controlling sulfate pollution would most assuredly be done in the context of a continued requirement of an adequate stack height for major stationary sources of SO_2 emissions. This observation has quite general applicability, for it is commonly the case that a single source of emissions produces several different kinds of pollution: a nearby effect for which it is the only source, and more distant effects that involve interactions with other sources. Markets are well suited for dealing with the latter case, but only within the context of maximum permissible concentrations at the point of emissions in order to avoid exceeding the limits for localized effects. At the extreme, for cases in which localized effects are the

binding constraint on emissions for most of the important sources, a tradable permits system could have limited value.

Another situation in which tradable permits may be less attractive is in the case of very complex pollution problems in which several types of emissions interact to form a variety of pollutants, often in nonlinear and even nonmonotonic ways. An example of a complex, nonmonotonic pollution problem is photochemical smog. Smog is the product of chemical reactions involving, among other things, numerous hydrocarbon compounds and oxides of nitrogen (NO_x). For different combinations of emissions in the atmosphere, smog can be either increased or decreased by increasing emissions of NO_x. More generally, the specific kinds and geographic distribution of numerous emissions can be very important in determining the severity of pollution, given a constant level of total emissions for NO_x and hydrocarbons. While this may be successfully attacked by a set of markets for several categories of emissions, perhaps with considerable geographic fine tuning, it is also possible that a pure market solution will not be practical. Indeed, regulators could well find that they must retain a requirement of prior approval of major transactions of permits for smog components in order to provide the opportunity to investigate their consequences for air quality. Nevertheless, although the problem of determining the feasibility of tradable permits for dealing with smog is far more difficult than the SO_x feasibility problem, the method of this paper is still applicable, with the answer depending on empirical issues relating to the details of the emissions/air quality relationship and the abatement cost functions of emissions sources.

With the preceding caveats in mind, the research to date on the Los Angeles sulfate problem indicates that tradable emissions permits are a promising alternative to command and control regulation. For the case of particulate sulfates in Los Angeles, none of the major sources of market imperfections appear to be so intractable that they cannot be overcome by an intelligently designed market institution. Hence, because of the other beneficial incentive effects of the system, tradable permits for sulfur oxides emissions in Los Angeles appear attractive. Moreover, the analytical issues associated with researching the question of the feasibility of a permits market have also proved to be tractable, suggesting that the same methods might be fruitfully applied to other pollution problems.

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