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AIR POLLUTION CONTROL:
EQUITY CONSIDERATIONS FOR RURAL AND URBAN AMERICA*

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Introduction

This paper deals with one of the many aspects of controlling air pollution--equity. The equity issue discussed concerns the fact that areas with high and low levels of air pollution are subjected to many of the same controls under current legislation. The equity issue is, of course, only one of several imperative questions that should be addressed and fully researched before society embarks on an abatement program of great magnitude. In fact, comparisons between expected cost outlays by firms and individuals to control air pollution, and the cost of allowing the pollution to continue, indicate that it may be less costly for firms and individuals to do nothing.

The following sections report estimates of air pollution damage costs, air pollution levels by city size and cost estimates of controlling air pollution by city size. Comparison of these costs will show that a perfectly discriminating application of measures to abate air pollution--tailoring controls to each city to achieve only the minimum required abatement--will entail less social and private costs than allowing pollution to continue. But indiscriminate controls applied to all vehicles and industries, even those in sparsely settled areas, leads to the disturbing finding that private costs of controlling emissions will exceed costs of allowing them to continue. In effect, the program of control which has been adopted to date is inequitable in the micro sense -- forcing rural residents and their metropolitan cousins to conform to identical controls -- and is also uneconomic in the macro sense -- imposing a greater social and private cost to control air pollution than would occur if we did not control air pollution.

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The Cost of Allowing Air Pollution to Continue

Previous studies have concentrated on the annual national total cost of air pollution, either the cost of cleaning the air or the property and health costs of not cleaning the air. One frequently quoted cost of air pollution damage, \$11 billion [8], originates from an estimate of cleaning costs from the smoke data for Pittsburgh in 1913. The cost was estimated to be \$20 per person per year. In 1958, this figure was updated by the commodity price index and multiplied by the 1958 population to arrive at the \$11 billion mark. Another variation of the Pittsburgh study, however, results in the cost of \$4 billion [9], obtained by multiplying the updated 1958 cost by the urban population. Finally, after updating the damage estimates to 1971 dollars by the consumer price index, the inflated Pittsburgh study estimates are \$15.7 billion for the entire nation and \$5.7 billion for the urban population. Extrapolation of these data to recent years and to cities with less air pollution seems a hazardous procedure at best.

Ridker [7] identified and estimated total costs for a variety of potential effects of air pollution including maintenance costs of residential, commercial and industrial facilities; damage to trees, agricultural crops and livestock; and costs associated with illness and death of humans. The proportion of the cost due to air pollution was \$5.5 billion. When the estimate is updated to 1971 dollars, the figure becomes \$6.8 billion.

More recently Lave and Seskin [3], concentrating on the health costs alone, argued that 25 percent of all respiratory disease is associated with air pollution. They concluded that in 1963, health damages totaling \$2 billion were attributable to air pollution. This study also contains a comprehensive review of previous work dealing with the health costs of air pollution. Thus, researchers and public policy makers have quite a range with which to work in comparing cost aspects of controlling or not controlling air pollution. Damage estimates such as these, updated to 1971 dollars, will be compared with the costs of controlling air pollution in the following section.

The Cost of Controlling Air Pollution

Ideally, the social cost of air pollution would be measured as the net disutility of the population resulting from the polluted air. Our inability to quantify disutility operationally precludes use of this measure. In a recent study, I defined the social cost of air pollution to be the per capita cost, in dollars, of obtaining a given quality of air for each city size [5]. This cost is computed from the air pollution level by size of city, adjusted for industry composition, climatic elements and other factors except city size. Some assumptions underlying this approach are (1) the same level of air pollution causes the same amount of disutility per capita in all city sizes, (2) the cost of controlling air pollution is less than the cost of

allowing it to occur, (3) air pollution can be controlled by known techniques, and (4) cost of these techniques is measurable.

Air Pollution Levels by City Size: Figure 1 shows pollution levels (tons per square mile per year) by size of city (Standard Metropolitan Statistical Area) for industrially emitted pollutants -- sulfur oxides (SO_x) and particulates (P), and the transportation emitted pollutant -- carbon monoxide (CO). The levels of pollution shown in Figure 1 are adjusted for industry composition and climatic elements -- temperature, precipitation and wind velocity. These curves reveal a positive relationship between air pollution levels and city size.^{1/} For instance, the carbon monoxide level increases from 350 tons per square mile per year to over 550 tons per square mile per year as city size increases from 500,000 to 8 million population. However, the increase for particulate matter is much less and perhaps can be explained by the already widespread use of particulate control systems on smokestacks.

Cost of Controlling Sulfur Oxides and Particulates: Once the level of air pollution attributable to city size per se is calculated, e.g., Figure 1, then the social cost can be computed by determining the cost of reducing these air pollution levels to an acceptable level. The costs of controlling the industrially emitted pollutants were taken from Senate Document 91-40 [11], "The Cost of Clean Air." The estimated annual costs of sulfur oxides and particulate controls (maximum) were listed by metropolitan areas for both stationary combustion and selected industrial process sources. A range of estimates is given that includes "low" and "high" costs for fiscal year 1971 through 1974 in addition to sulfur-in-fuel restrictions (1 percent and 1.5 percent) for the metropolitan areas. The cost estimates were based on the assumption that control will be achieved using techniques already available. The range of costs reflects the fact that the costs of air pollution control equipment and installation, operating and maintenance costs vary among plants and regions. An equation using the adjusted pollution levels and the cost estimates of reducing pollution to a given level was then estimated for both the "low" and "high" estimates [See Appendix equations (3_L) and (3_H)].

Constructed from the adjusted levels of SO_x and P from Figure 1 and the coefficients from equations (3_L) and (3_H), Figure 2 shows the social cost per square mile by city size from SO_x and P pollution. Assuming a constant density per square mile of 1,000 for all city sizes, the per capita social cost can be read off the left-hand axis of the curve in Figure 2. The per capita social cost of SO_x and P pollution is relatively low for the majority of cities, e.g., populations less than 2.5 million. The social cost of obtaining different qualities of air can be obtained from the curve by merely shifting the curve down until it intersects the horizontal axis

^{1/} The estimated coefficients and standard errors of the equations used to construct Figures (1), (2), (3), and (4), are presented in the Appendix.

Figure 1
Sulfur Oxides, Particu-
lates and Carbon Monoxide
Levels by City Size

Figure 2
Per Capita Social Cost
and Social Cost per
Square Mile for
Industrially Emitted
Pollutants Sulfur
Oxides and Particulates

at the city size that corresponds to the level of pollution to be tolerated. The curves in Figure 2 reflect the social cost of maximum control (99 percent) in accordance with the Environmental Protection Agency criterion for the pollutants SO_x and P.

Cost of Controlling Carbon Monoxide: The social cost of CO pollution is computed by first estimating the per capita cost to the consumer for the stringent emission-control vehicle that will soon be mandatory, and then calculating the percentage of the urban population that must operate the controlled vehicles to result in a constant level of CO for all city sizes. Finally, this percentage figure for each city times the per capita cost of the emission controlled vehicle yields the per capita social cost of reducing CO in all city sizes.

Table 1
Annual Cost of the Emission Control Vehicles

	With Performance Loss	Constant Performance
Control Package	\$ 8.64	\$ 8.64
No-Lead Fuel Penalty	13.32	13.32
Engine	---	27.00
Fuel Economy Penalty	<u>12.79</u>	<u>19.18</u>
Total	\$34.75	\$68.14

Table 1, containing the annual costs of the emission control vehicle, shows the initial cost of the control package expressed on an annualized basis. The initial cost includes interest charges and the increase in gasoline expenditures resulting from the required higher priced no-lead gasoline for the catalytic converter and the reduction of fuel economy from the decrease in the compression ratio. After absorbing these two cost items, the consumer has a choice -- whether to regain the power and performance realized before the emission controls or whether to accept the losses. The "true" social cost would include the necessary expenditures to return the consumer to the original level of power and performance (i.e., utility). However, most of the driving done (in cities) is at or below half throttle so the loss in performance might not be detectable. Estimates are therefore included in Table 1 for either alternative.

Before the "true" per capita social cost of the control package can be estimated, power and fuel economy losses must be examined. When the combustion ratio of an engine is lowered, there are simultaneous losses in both power and fuel economy, and these percentage losses are of about equal magnitude. If the performance level is to be held constant, the fuel economy loss will be 50 percent higher than the loss in performance. Industry cost estimates fail to adjust for performance loss and indicate a 5 to 30 percent reduction in fuel economy. The estimates of Heron and Felt [2] are used in this study, which give fuel economy losses of 7.8 percent for regular gasoline cars and 13.3 percent for premium gasoline cars. Weighting these two figures by 32 percent premium gasoline cars and 68 percent regular gasoline cars (the approximate current car population mix), the fuel economy loss becomes 9.6 percent, which implies a power loss of 6.4 percent. The consumer must purchase a 6.4 percent larger engine and buy 9.6 percent more fuel to return to his baseline utility level. Assuming the price of lead-free gas is 30 cents per gallon (net of taxes) and fuel consumption is 666 gallons per year, the cost attributable to the fuel economy penalty is \$19.18.

Performance can be increased by either changing the engine size or the gear ratio in the car so that the engine runs faster at a given speed. A 6.4 percent larger engine (for purposes of this study) does not necessarily cost 6.4 percent more for the consumer, nor does one need 6.4 percent more resources to manufacture it. For instance, one could assume that the larger engine will require 6.4 percent additional steel and labor; however, it could conceivably be produced by enlarging the cylinders of the smaller block. To complicate matters even more, the recovery in performance can also be achieved by alternating the gear ratio, which results in an increase in fuel consumption as the engine is now running faster at a given speed. The cost of recovering the power by either method described above or a combination of them is estimated to be \$27 on an annualized basis including interest charges.

The proposed emission controls for CO in 1975, recently suspended until 1976 for the entire country, call for a 90 percent reduction. If city or urban vehicle owners used the controlled vehicles, the CO level attributable to motor vehicles would decline by 90 percent. Selected data indicate that motor vehicles account for roughly 90 percent of the CO emissions in large urban areas. Hence, if operators adopt the emission control package, the net reduction in CO levels is 81 percent for urban areas and is 56 percent for all areas. The social cost of CO control can now be estimated for each city size using the control reduction figure and the estimated annual cost in the following formula:

$$(1) \quad SC_i = (A/C) \times B$$

where

- SC_i = social cost per capita in city size i ;
- A = percentage difference in CO level between the base city and the i^{th} city;
- B = per capita annual cost of the controlled vehicle;
- C = .81, the proportion of control attained with all vehicles using the control package.

The per capita social cost of CO both with and without constant performance is presented in Figure 3. The base city population is 500,000. Alternative city sizes reflecting alternative accepted levels of pollution may be used as the base by merely recalculating A in (1). Diseconomies of size exist from the base size upward. To control CO to a level equal to that present in city sizes of 500,000 the per capita cost in a city of 3 million would be \$19.28 with constant performance and \$9.83 without constant performance. Since taxes must be construed as a social benefit, B in (1) is computed net of any taxes. Later in discussing private outlays to reduce pollution, annual cost estimates will be used that include taxes.

Combined Social Cost of Controlling Sulfur Oxides, Particulates and Carbon Monoxides: Two social costs for each of the industrially and automobile emitted pollutants were estimated. In combining these cost estimates, four possibilities exist and are presented in Figure 4. Again the base city is 500,000. The most complete measures of social cost are shown by curves 1 and 2 which were constructed using the low and high cost estimates for the industrially emitted pollutants and the cost of recovering constant automobile performance. Curves 3 and 4 are included as an alternative if the consumer chooses to accept the performance loss of the engine. The per capita social cost of air pollution for constant engine performance ranges from zero to \$51.23 and zero to \$48.44 for high and low industry costs respectively. The corresponding per capita social costs for an urban area of 3 million, the average size of the sample, are \$24.37 and \$23.57. The curves representing all four combinations of alternative cost estimates show increasing costs throughout the range.

The total social cost of reducing air pollution to levels present in urban areas of 500,000 population and also in areas of 1,000,000 population is computed using the previous results. The 58 urban areas with populations of 500,000 and greater, containing 53 percent of the total U. S. population, contributed a social cost of \$2.53 billion to \$2.64 billion, while the 27 urban areas of population size 1 million or more contributed a social cost of \$2.03 billion to \$2.12 billion. If the higher pollution level present in urban areas of 2 million population is acceptable, then the social cost of reducing air pollution is \$1.33 billion to \$1.40 billion.

Figure 3

Per Capita Social Cost of Carbon Monoxide (base city size = 500,000 population)

Figure 4

Per Capita Social Cost of Air Pollution (base city size = 500,000 population)

Equity Considerations

Since it is difficult to tailor automobile exhaust emission control to the minimum required for each city size, a uniform control program has been proposed. This results in the 38 million rural residents and the 26 million residents in the cities with less than 100,000 population being assessed the same costs as the residents of large urban complexes. The rural and small city populations are, in a sense, being unjustly taxed by being forced to expend the same per capita dollars as the large city population where pollution is a serious problem. The private annual cost of the emission control package is \$74.53 regardless of rural or urban residency and is higher than the per capita social cost in even the largest urban areas (see Figure 4).

The implicit assumption underlying consumer adoption of the emission control package which reduces the utility derived from his automobile, is that the utility gained from cleaner air will at least offset the reduction in utility of the automobile. Since the individual consumer has no perceptible influence on air pollution, lone adoption of the control package would reduce his utility to, say U_1 , with no offsetting rise in utility due to cleaner air. Acting alone and rationally, he would not adopt the control package. Forcing all consumers by law to adopt the control package raises utility through cleaner air. Perhaps utility is raised well above U_0 , the original utility level, for metropolitan consumers and little if any above U_1 for rural customers.

A related issue concerns the basic assumption that the cost of controlling air pollution is less than the cost of allowing it to occur. The total projected cost of controlling air pollution via nondiscriminatory application of controls, \$10.1 billion to \$10.3 billion, is composed of the following components: (1) government expenditures--\$454.5 million [11], (2) industrial expenditures (high and low estimates)--\$942.2 million and \$765.8 million [11], and (3) consumer motor vehicle expenditures--\$8.9 billion. The motor vehicle component of the total cost is based on Table 1 and a projected 120 million automobile equivalents in 1974. As mentioned earlier, the updated damage estimates from the Pittsburgh Study are \$15.7 billion (entire nation) and \$5.7 billion (urban population). The Ridker cost estimate is \$6.8 billion. Only the highly suspect extrapolation of 1913 Pittsburgh data to the entire nation, exceeds the estimated cost projected from this study.

An alternative possibility is to use a perfectly discriminating application of measures to control air pollution to levels found in cities of 100,000 population (a city size considered to have tolerable levels of air pollution). Perfect discrimination in applying control measures results in lower social and private costs (\$3.2 billion) of controlling emitted pollutants than the previously estimated costs of allowing them to continue. The assumption that the cost of controlling air pollution is less than the cost of allowing it to occur can be satisfied only if the abatement program is perfectly discriminatory by city size.

Summary

The proposed method of controlling air pollution imposes a burden on the rural and small town residents. Problems of implementing the proposed plan are already evident as the deadline for U. S. automakers has been suspended for one year. Further, this method of control may prove to be more costly than a policy of "do nothing." However, it is possible that different engine designs and technological advancement not considered in this paper may result in future cost reductions.

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APPENDIX

Structural Form and Estimated Parameters for the Equations Used
in Constructing Figures (1), (2), (3), (4) and (5)
in the Text

- $$\begin{aligned}
 (1) \quad \hat{SO}_x &= -295.6638 + 0.4080*S - 1.8507S^2 + 3.4378R - 3.8242W \\
 &\quad (0.2079) \quad (1.3638) \quad (2.6433) \quad (15.9449) \\
 &\quad + 2.0379T + 5.6520*M \\
 &\quad (1.6755) \quad (2.6794) \qquad R^2 = .5774 \\
 (2) \quad \hat{P} &= 32.1210 + 0.0427S - 0.2454S^2 + 1.5794R - 10.7903W \\
 &\quad (0.0862) \quad (0.5656) \quad (1.0962) \quad (6.6129) \\
 &\quad - 0.1256T + 2.3578*M \\
 &\quad (0.6949) \quad (1.1120) \qquad R^2 = .4372 \\
 (3_L) \quad \hat{C}_L &= -0.5936 + 0.0749**S + 0.0263**SO_x + 0.0217P \\
 &\quad (0.0281) \quad (0.0083) \quad (0.0219) \qquad R^2 = .6541 \\
 (3_H) \quad \hat{C}_H &= -0.7432 + 0.0851**S + 0.0370**SO_x + 0.0314P \\
 &\quad (0.0323) \quad (0.0095) \quad (0.0252) \qquad R^2 = .6790 \\
 (4) \quad \hat{CO} &= -55.4416 + 0.3603*S - 0.4332S^2 + 1.7805R - 4.5093W \\
 &\quad (0.1667) \quad (0.9662) \quad (1.6502) \quad (10.0746) \\
 &\quad + 1.0622T + 2.9983**\hat{G} \\
 &\quad (0.8366) \quad (0.3698) \qquad R^2 = .9424 \\
 (5) \quad \hat{G} &= -0.4366 + 0.5956S - 0.5145**S^2 + 0.0918**S \\
 &\quad (0.0349) \quad (0.2049) \quad (0.0072) \qquad R^2 = .9339
 \end{aligned}$$

where

SO_x = sulfur oxides per square mile
 P = particulates per square mile
 CO = carbon monoxide per square mile
 S = city size (population)
 M = manufacturing index
 R = annual median precipitation (inches)
 W = annual median wind velocity (mph)
 T = annual number of degree days
 C = cost of controlling SO_x and P emissions
 G = gasoline sales per square mile
 D = city density (population per square mile)