AIR QUALITY, ENVIRONMENT AND METROPOLITAN COMMUNITY STRUCTURE

by

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In developing an economic-sociological theory of air quality, we begin from the assumption that the underlying causes of air pollution are economic growth and changing social organization. Development of such a model is desirable for at least two reasons. First, the potential hazards of air pollution are so great that a model that predicts air pollution levels for mettopolitan areas is greatly needed. Further refinements of work in this direction, including the model developed below, will enable more accurate predictions to be made. Second, a model that identifies the underlying causes of air pollution will allow us to estimate more accurately the true costs of air pollution abatement and further economic growth. Both aspects of this research will be of interest to planners who are considering the impact of certain economic activities in new towns and growing regions. The results will also be of interest to social scientists sutdying the impact of community structure on environmental quality.

PREVIOUS RESEARCH

Until recently, most research on air quality has focused on a small number of metropolitan communities and used principles of Gaussian diffusion models to estimate pollution within a given area. A coefficient for the vertical diffusion of a suspended matter is computed, and four variables are specified: (1) the strength of various sources of pollution in an urban areas; (2) the linear dimensions of the community under consideration or the size of an area within the community; (3) the "mixing height" or atmospheric depth in which pollutants can diffuse; and (4) the speed of wind spreading pollutants throughout an area. Integral functions are then computed to produce estimated levels of pollution in suspension for an urban area. This model has been validated by correlating Gaussian estimates with measures of air quality from the National Air Sampling Network (NASN) now operating in cities throughout the United States. In Los Angeles, Nashville, and Washington, D.C., for example, Miller and Holzworth (1967) found that estimates from a Gaussian model correlated with NASN data in a range of .83-.88, depending upon the specific pollutant and the community under study. Using computer model for Gaussian diffusions processes in Jacksonville, Florida, Koogler and others (1967) estimated sulfur dioxide counts which showed a .60 correlation with counts of sulfur dioxide from NASN stations. However, this approach does not emphasize variations between metropolitan areas in air quality or the possible interaction between the structural characteristics or urban communities and the environment in which cities are located.

There are some studies in the literature which have already examined the relationship between characteristics of communities and levels of air quality. In one example, population, gasoline sales, industrial fuel consumption, and many other structural features plus mean wind speed are correlated with NASN counts of suspended particulate matter, sulfur dioxide, and nitrogen dioxide in the air around U.S. metropolitan areas during 1960 (McMullen, et. al., 1967). The authors found positive relationships between gasoline sales and lead suspended in the air, between the burning of certain crude oils and vanadium, and between the burning of fossil fuels in homes and atmospheric levels of sulfur dioxide. More refined analysis by Ozolins and others (1966, 1968) have estimated air quality from data on the use of motor vehicles, domestic and industrial fuel consumption, industrial process loss, and fuel used by steam-electric power plants. Here the authors estimated the proportion of fuels or waste from industrial activity expelled into the air from various sources using available business statistics and population figures. These estimates of emissions, combined with data on the location of communities and wind speed, are used in a "rapid survey technique" for estimating air quality in separate communities. For all possible metropolitan areas considered in this research, the correlation between "rapid survey" estimates and air quality estimates from the National Air Sampling Network was .60 for sulfates and .59 for suspended particulate matter. Yet, this technique does not present an analysis of air pollution which is relevant to this research. Instead of developing a theory of community structure and air quality, Ozolins and others have taken a different approach by developing straightforward estimation procedures for ranking cities by air quality. And the research by McMullen and others is not methodologically refined. It specifies simple correlations between variables without examining complex interrelations among structural features of metropolitan areas and the envrionments in which cities are located. Thus, some additional work in this area is needed.

One study which does follow the lines of inquiry which are similar to this research is Welson and Stevens' (1970) work using a multiple regression analysis to examine how variations in metropolitan community structure are related to levels of nitrates and sulfates in suspended particulate matter from NASN data for 57 urban areas. To carry out this research, Welson and Stevens used an index of fuel emissions based on the consumption of coal and fuel oil, the number of people employed in manufacturing, the land area of a city, wind speed,and regional location to predict sulfate levels in 57 metropolitan areas. The multiple correlation coefficient was .69. In predicting nitrate levels in the sample of cities, Welson and Stevens used a measure of wind speed,the percentage of people using public transportation on a regular basis, and the land area of each community as independent variables. The independent variables were found to be significant, and the multiple correlation between the measures of urban structure, environment, and nitrates was .50. Thus, one can see that a relatively simple model has some capacity for estimating air quality.

Welson and Stevens emphasize the use of emissions variables that estimate the total amount of pollutants discharged per unit time from all sources. As we show below, emissions variables are probably redundant in a socioeconomic model of air quality that specifies the underlying causes of air pollution (economic growth and urban environment). Further, the Welson and Stevens study fails to take into account any detailed descriptions of the industrial base.

RESEARCH METHODS

To implement this research, we have constructed forty-one separate indexes for measuring urban structure, environment, and pollution which are listed in Table. 1. These measures include the population residing in the SMSA during 1960, the value added by manufacturing, aggregate metropolitan income, and per capita income. The value added by manufacturing was expected to be the best single predictor of air quality because there are close ties between industrial activity and the expulsion of waste products into the air around cities. We also tried to go further by examining the types of industrial activity or the industrial base of each urban area.[1] To that end, the activities were recorded: steel works, paper manufacturing, the refinement of petroleum, rubber and plastics production, furniture manufacturing, stone clay and glass products, and so on. It is also important for our purposes to have a measure of deliberate attempts at air pollution control for each urban community. Some metropolitan areas engaged in heavy manufacturing may be allocating funds for controlling pollution. Under these circumstances, levels of air pollution may be reduced, even though the structure of an area is conducive to contaminated air. Therefore, we have recorded expenditures

Table 1

Description of Variables

Variable Number	Code	Description
1	SPM	Suspended Particulate Matter
2	NOX	Nitrates
3	SOX	Sulfates
4	FURN	Workforce employed in Furniture, Lumber and Wood (%)
5	FABMET	Workforce employed in Fabricates Metals Industries (%)
6	MACHY	Workforce employed in Machinery except Electrical (%)
7	ELMCY	Workforce employed in Electrical Machinery (%)
8	MOVEH	Workforce employed in Motor Vehicles and Equipment (%)
9	TRNSEQ	Workforce employed in Transportation Equipment except Motor Vehicles (%)
10	MSDUR	Workforce employed in Miscellaneous Durables (%)
11	FOOD	Workforce employed in Food and Kindred Products (%)
12	TEXTIL	Workforce employed in Textile Products (%)
13	APPARL	Workforce employed in Apparel and Fabricated Textiles (%)
14	PRNTING	Workforce employed in Printing and Publishing (%)
15	CHEM	Workforce employed in Chemical and Allied Products (%)
16	MSNDUR	Worforce employed in Other Nondurable Industries (%)
17	STONE	Workforce employed in Stone, Clay and Glass (%)
18	BLSTFU	Workforce employed in Blastfurnaces, Steel Mills, Rolling and Finishing (%)
19	MSPRIR	Workforce employed in Miscellaneous Primary Iron and Steel (%)
20	PRNOFR	Workforce employed in Primary Nonferrous Metals (%)
21	PAPER	Workforce employed in Paper and Allied (%)
22	REFING	Workforce employed in Petroleum Refining (%)
23	PETRCO	Workforce employed in Petroleum and Coal Products (%)
24	RUBBER	Workforce employed in Rubber and Plastic Products (%)
25	WRKFRC	Total Workforce in the SMSA, 1960

Table 1 continued

Variable Number	Code	Description
26	POPUL	Total Population of the SMSA, 1960
27	PDENSE	Population per sqyare mile, 1960
28	AGGINC	Aggregate Income of the SMSA, 1960
29	VAM	Value Added by Manufacture, 1958
30	PRECIP	Mean Annual Rainfall (inches)
31	DEGDAYS	Degree Days, 65 F Base
32	HLYWND	Mean Annual Hourly Wind Velocity
33	PUBTRN	Persons Using Public Transportation to Work
34	APCBDG	Air Pollution Control Budget, 1961
35	NEDUM	Locations in Northeast
36	MWDUM	Locations in Midwest
37	SODUM	Locations in South
38	GASOLN	Gasoline Sales (Gallons) in SMSA, 1960
39	COAL	Coal Consumed in Electrical Power Generation
40	OIL	Fuel Oil Consumed in Electrical Power Generation
41	GAS	Natural Gas Consumed in Electrical Power
42	AREA	Area of the SMSA, (square miles)
43	INCPCP	Income Per Capita, 1960
44	CASPCP	Gasoline Sales Per Capita, 1960

SOURCES: Data on Air Quality were taken from U. S. Department of Health, Education and Welfare, Air Pollution Measurements of the National Air Sampling Network: Analysis of Suspended Particulates, 1957-1961 (Washington: U.S. Government Printing Office, 1962). The percent of the workforce engaged in the various industries was taken from U.S. Bureau of the Census, Census of Population: 1960. Selected Area Reports. Standard Metropolitan Statistical Areas, Final Report PC(3)-10 (Washington: U.S. Government Printing Office, 1963). Population, value added by manufacturing, income and percent using public transportation were taken from U.S. Bureau of the Census, County and City Data Book, 1962 (Washington: U.S. Government Printing Office, 1962). Gasoline sales was taken from U.S. Bureau of the Census, Census of Business, 1958 (Washington; U.S. Government Printing Office, 1958). Gasoline prices across states (used to deflate dollar sales to gallons) are from American Petroleum Institute, Petroleum Facts and Figures, 1959 (New York: American Petroleum Institute, 1959). Data on fuel consumes in electrical power generation were derived from National Coal Association, Steam-Electric Plant Factors, 1960 (Washington: National Coal Association, 1961). Air pollution control budgets are from Jean J. Schueneman, "Air Pollution Problems and Control Programs in the United States" Paper presented at the Annual Meeting of the Air Pollution Control Association, 1962. Reprinted in Air Pollution: Hearings Before a Subcommittee of the Committee on Interstate and Foreign Commerce, House of Representatives, March 18 and 19, 1963 (Washington; U.S. Government Printing Office, 1963), pp. 45-73.

in all cities with budgets for air quality which were at least $5,000. These data provide additional material for developing the economic dimension of intermetropolitan variations in community structure and air quality.

Other important aspects of community structure including the use of public transportation and per capita gasoline sales were also built into this model. We expect a positive relationship between some kinds of air pollution and gasoline sales and a negative relationship between the use of public transportation and atmospheric pollution. Another variable which may have some predictive capability is population density. As the concentration of people in an urban community increases, presumable demands for transportation, electrical power, and fuel oil increase. Furthermore, the close proximity of homes, cars, and industries in more densely settled areas may have some influence on levels of air pollution because each source has a greater chance of being compounded by other nearby sources.

Meteorological data have been compiled because metropolitan structure will interact with weather patterns to determine the urban environment and air pollution levels. Hence, we have measured annual precipitation, degree days, and mean hourly wind velocity. Precipitation probably has a rather circular relationship to air pollution in that it has the effect of "scrubbing" the air of particles while at the same time air pollution may actually "seed" clouds and thereby increase chances for rain, snow, and the like. Wind speed, of course, indicates the amount of ventilation in a city. Degree days, rising with colder temperatures, serve as a scale for fuel demand for heating.

The location of the SMSA is important in several ways. First, climate is partly a regional phenomenon. Also, fuel use patterns tend to vary across regions due to variation in transport cost. Since we have variables at least roughly measuring climate, industrial base, and density, we thought that fuel use patterns should be our main concern in defining the regions for this study. Cities in the Northeast and Midwest tend to use more coal and oil (rich in sulfur) while cities in the West use more natural gas (rich in nitrogen). Southern cities use all three in varying proportions. Following these fuel use patterns (McMullen, et. al., 1967) the Northeast was defined to include SMSA's in those states involved in the Washington-Boston megalopolis plus the northern New England states. The Midwest was defined roughly to be the Mississippi-Ohio river area, north of Arkansas and including Missouri, Iowa, and Minnesota. This definition places West Virginia in the Midwest. The South contains all states south and east of Arkansas, including Virginia. All other states are included in the West.[2] A suspected source of air pollution in most cities is the local power plant or plants. This source was considered important enough to warrant special attention. Accordingly, we use the amount of coal, oil and natural gas consumed in power generation as three of our independent variables.

The dependent variables selected for this study are three common measures of air pollution available from the National Air Sampling Network (U.S. Department of Health, Education and Welfare, 1962): suspended particulate matter (SPM), nitrates (NOX), and sulfates (SOX). Suspended particulate matter consists of tiny particles of solids, including smoke and dust, or liquids such as nitrates and sulfates which remain suspended in the atmosphere as aerosols. SPM is therefore an omnibus measure of pollution, of which nitrates and sulfates are special subtypes. Nitrates are aerosols of nitric and nitrous acid and related compounds which serve as primary ingredients for photochemical smog. Sulfates are aerosols of sulfuric or sulfurous acid which are known to be highly corrosive.

One can see that intercorrelations between independent variables will be prevalent.[3] Region, climate, fuel useage, the industrial base of a community,and so on have pronounced interrelationships which make it impossible to include all variables in each regression equation. The problem is one of choosing the best regression or subset of explanatory variables. Consequently, we appeal to the Efroymson step-wise regression procedure to systematically chosse such a regression (Draper and Smith, 1966, pp. 171-172). This is a statistical search technique which continues to enter new variables into the regression until no further entries can significantly reduce error sum of squares. In addition, variables currently included are tested and removed if their contribution becomes insignificant as other explanatory variables are added. In this way each variable is treated as if it were the last to enter the regression. This removes the bias inherent in other step-wise procedures (Goldberger, 1964, pp. 194-197). Thus, we have a straight-forward tool for building a model of community structure, environment and air quality.

FINDINGS

The results of the step-wise regression analysis are given in Table 2. The multiplicative of log-linear model was chosen as a more satisfying theoretical specification than the additive or linear model in that it emphasized the compounding effects that each variable can have on the others. Although we applied the stepwise procedure to the logarthmic variables, we report the linear form of the final equations in Table 3. Note that in two cases (NOX and SOX) the percent variations explained is higher in the linear model.[4]

With respect to SPM, the omnibus measure of air pollution, we find that value added by manufacture, the percent of the workforce engaged in stone, clay and glass manufacturing, degree days, hourly wind velocity and a mid-west location are significant determinants of air quality. Thus economic activity, measured by value added by manufacturing, and heavy concentrations of stone, clay and glass manufacturing have adverse effects on air quality. The environmental variables, degree days and hourly wind velocity indicate that colder locations, especially in the Midwest, have higher SPM counts while wind disperses suspended particulates. The five variables together explain 42 percent of the total variations in SPM levels among U.S. metropolitan areas.

Nitrate levels are predicted about as well as SPM levels. Gasoline sales, a measure of automobile use, is a significant cause of nitrate pollution,while wind speed and use of public transportation reduce nitrate counts. These results are to be expected, but since no other structural or economic variables entered the final equation, we have verified the importance of automobiles as the primary source of nitrate pollution. We have also demonstrated the importance of a public transportation system in holding down nitrate levels.

In terms of predictions, our model is most successful with sulfates ($\bar{R}^2$ = .657). One can see that chemical manufacturing and blastfurnaces and steel mills are significantly "dirty" industries. Population density is also found to be positively associated with SOX pollution. Wind speed is again found to have a significant cleansing effect. Furthermore, the Northeast and Midwest have high sulfate counts, presumably because cities in these regions tend to use fuels rich in sulfur.

Of almost as much interest as the variables included in the final regression are those indicators of community structure and the environment which were originally thought to be important but were finally omitted from the regressions because they were not significant. These are presented in the form of partial correlations in Table 4. For example, several suspected industries never entered a regression equation: food, miscellaneous primary iron and steel, primary nonferrous metals, petroleum and coal products. Also,fuel used in power generation was never found to be a significant cause of air pollution. Only one demographic variable, population density, entered the final regression equations. Evidently, the total population of an area and the size of its labor force are not as important for environmental quality as more specific measures,especially economic characteristics and transportation patterns. Of the regional dummy variables, only location in the South never entered a regression, presumably because of its heterogeneous fuel use patterns. Finally, the air pollution control budget is not significant. Apparently, in the early 1960's the budgets were too small to have an impact on levels of air pollution. Thus, many urban characteristics which one would intuitively regard as important for air quality are dropped from this model.

Some of the studies discussed in this paper have emphasized the importance of estimates for industrial emissions in gauging air quality in an urban area. Welson and Stevens (1970) use a sulfate emissions variable which is the estimated sum of all sulfur containing fuels consumed within a community multiplied by an emissions factor for each type of fuel, giving the

TABLE 2: Significant Variables Identified by the Efroymson Stepwise Regression Procedure Using a Log Linear Model and Three Separate Measures of Air Quality in U.S. Standard Metropolitan Statistical Areas *

Dependent Variable	Constant Term a	Regression Coefficients b_i											$\bar{R}^2$	F
		VAM	STONE	CHEM	BLSTFU	PDENSE	GASOLN	PUBTRN	HLYWND	DEGDAY	NEDUM	MWDUM		
SPM	4.08 (.401)	.113 (.019)	.077 (.028)						-.289 (.125)	.118 (.040)		.127 (.055)	.416	18.4
NOX	1.05 (.406)						.245 (.042)	-.210 (.081)	-.455 (.177)				.410	12.3
SOX	2.67 (.495)			.129 (.035)	1.92 (.751)	.142 (.053)			-.378 (.182)		.487 (.104)	.343 (.094)	.657	16.6

* Numbers in parenthese are the standard errors of regression coefficients. The .05 level of significance was used here as a criterion for including variables in the regression equation. The coefficient of determination is adjusted for degrees of freedom. The number of cases is 117 for SPM and 50 for NOX and SOX.

TABLE 3: Significant Variables Identified by the Efroymson Stepwise Regression Procedure Using a Linear Model and Three Separate Measures of Air Quality in U.S. Standard Metropolitan Statistical Areas *

Dependent Variable	Constant Term a	Regression Coefficients b_i											$\bar{R}^2$	F
		VAM	STONE	CHEM	BLSTFU	PDENSE	GASOLN	PUBTRN	HLYWND	DEGDAY	NEDUM	MWDUM		
SPM	119. (16.6)	.011 (.002)	605. (285.)						-3.26 (1.76)	.002 (.002)		24.6 (7.29)	.346	13.2
NOX	3.60 (.517)						.002 (.001)	-.054 (.013)	-.116 (.054)				.585	23.9
SOX	9.61 (2.12)			56.2 (11.8)	22.2 (7.67)	.002 (.001)			-.292 (.228)		4.51 (1.15)	3.38 (1.02)	.713	21.2

* Numbers in parenthese are the standard errors of regression coefficients. The .05 level of significance was used here as a criterion for including variables in the regression equation. The coefficient of determination is adjusted for degrees of freedom. The number of cases is 117 for SPM and 50 for NOX and SOX.

percent of fuel finally emitted as sulfate pollution. The sulfate emissions variable so calculated is significant in all but one of their regressions. However, as one might expect, it was significantly correlated (r = .51) with another explanatory variable, manufacturing employment.

We thought that a fuel emissions index might be redundant if it were included in our model, in as much as the measures used in this research express the underlying causes of fuel use and consequent emissions. Fortunately for 36 cities out data overlapped with that used in the Welson and Stevens study. It was therefore possible to include their fuel emissions variable in our list of regressors. It turned out that their measure of emissions did not survive the stepwise regression procedure for either sulfates or nitrates, the only pollutants studied by Welson and Stevens. This is an indication that the contributions of the fuel emissions variables to the observed variance of nitrates and sulfates are taken up by the measures of community structure and the environment.

In order to pursue this result further, we included the fuel emissions measures as additional explanatory variables in the final regression equations for nitrates and sulfates, respectively. The results are presented in Table 5 for the subsample of cities (N = 36) for which our data was consistent with that of Welson and Stevens.

Comparing equations 1 and 2 (NOX) and 4 and 5 (SOX) it can be seen that the addition of the nitrate emissions variable (NEMS) and the sulfate emissions variable (SEMS) respectively causes a reduction in the adjusted coefficient of determination. Further, the standard errors of the original variables are increased. Finally, equations 3 and 6 reveal that our original variables explain 84 percent of the variation of nitrate emissions and 56 percent of the variations of sulfate emissions. We therefore conclude that these fuel emissions variables are redundant for our purposes.

SUMMARY AND DISCUSSION

In view of these findings one can see some potential uses for a model of community structure in explaining air quality. It becomes somewhat easier for example, to predict the costs in terms of increased air pollution of the location of new manufacturing activities in a given area. Benefits of reducted automobile use and reduced congestion in central cities are made more readily available. The findings demonstrate again, for example, the importance of a public transportation system as a means of reducing nitrate pollution.

Of course, research concerning urban structure and environmental pollution is very recent and continued work will be necessary before sophisticated models for analysis and policy are available. Further work needs to be done on other types of air pollution such as hydrocarbons and various metals such as lead and nickel. The components of the model can be expanded to include behavioral aspects such as measures of political power available to various groups and public interest in air pollution problems. Finally, work can be done on time series of air pollution measures.

TABLE 4: The Partial Correlation Coefficients and F Values for Variables Excluded from the Final Regression Equations of each Measure of Pollution in Relations to Metropolitan Community Structure and Features of the Environment throughout the United States, 1960.

SUSPENDED PARTICULATE MATTER			NITRATES			SULFATES		
Variable	Partial Correlation N=117	F Value (F=.05=3.92)	Variable	Partial Correlation N=50	F Value (F=.05=4.045)	Variable	Partial Correlation N=50	F Value (F=.05=4.045)
FURN	-.09	0.82	FURN	-.091	.379	FURN	.059	.203
FABMET	-.02	0.03	FABMET	.083	.315	FABMET	-.168	1.220
MACHY	-.03	0.09	MACHY	.036	.059	MACHY	-.267	3.216
EL MCY	-.12	1.74	EL MCY	.130	.772	EL MCY	-.180	1.411
MO VEH	-.08	0.73	MO VEH	.164	1.245	MO VEH	-.184	1.474
TRNSEQ	-.14	2.27	TRNSEQ	.021	.019	TRNSEQ	-.048	.095
MS DUR	-.14	2.25	MS DUR	-.129	.762	MS DUR	-.232	2.381
FOOD	.02	.04	FOOD	-.198	1.845	FOOD	-.121	.620
TEXTIL	.06	.39	TEXTIL	-.176	1.434	TEXTIL	-.045	.085
APPARL	-.07	.53	APPARL	-.206	1.986	APPARL	-.092	.362
PRNTNG	-.03	.13	PRNTNG	.017	.013	PRNTNG	-.186	1.501
CHEM	.12	1.72	CHEM	-.065	.019	MSNDUR	.114	.552
MSNDUR	-.02	.05	MSNDUR	-.145	.963	STONE	.013	.007
BLSTFU	.19	3.91	STONE	-.134	.817	MSPRIR	.073	.228
MSPRIR	.18	3.54	BLSTFU	.095	.406	PRNOFR	.116	.575
PRNOFR	-.07	.52	MSPRIR	.161	1.205	PAPER	.030	.039
PAPER	-.07	.49	PRNOFR	.168	1.312	PETRCO	-.287	3.775
REFING	.03	.13	PAPER	.036	.059	RUBBER	-.106	.477
PETRCO	-.03	.09	REFING	-.042	.079	WRKFRC	.021	.019
RUBBER	.00	.00	PETRCO	-.093	.391	POPUL	.005	.001
WRKFRC	.00	.00	RUBBER	.136	.845	AGGINC	-.034	.048
POPUL	.01	.00	WRKFRC	.147	.989	VAM	-.053	.118
PDENSE	.04	.14	POPUL	-.092	.381	PRECIP	.111	.521

TABLE 4 continued

SUSPENDED PARTICULATE MATTER

Variable	Partial Correlation N=117	F Value (F=.05=3.92)
AGGINC	-.02	.04
PRECIP	.01	.02
PUBTRN	.02	.06
APCBDG	.13	1.97
NE DUM	-.01	.02
SO DUM	.02	.07
GASOLN	.03	.07
COAL	.05	.25
NATGAS	-.03	.10
AREA	-.03	.08
INCPCP	-.10	1.16
GASPCP	.05	.32
OIL	.05	.25

NITRATES

Variable Variable	Partial Correlation N=50	F Value (F=.05=4.045)
PDENSE	.195	1.777
AGGINC	.105	.500
VAM	.097	.430
PRECIP	-.153	1.077
DEGDAY	.207	2.005
APCBDG	.195	1.772
NE DUM	-.037	.062
MW DUM	.124	.703
COAL	-.026	.010
OIL	-.103	.479
NATGAS	-.219	2.268
AREA	-.207	2.006
INCPC	.265	3.405
GASPC	.092	.381
SO DUM	-.080	.293

SULFATES

Variable	Partial Correlation N=50	F Value (F=.05=.045)
DEGDAY	-.057	.136
PUBTRN	-.055	.126
APCBDG	.062	.164
SO DUM	.214	2.015
GASOLN	-.045	.084
COAL	.213	2.002
OIL	.034	.049
NATGAS	-.170	1.261
INCPCP	-.276	3.462
GASPCP	-.236	2.479
AREA	.005	.001

TABLE 5: A Test of the Significance of Fuel Emissions Variables in Explaining Nitrate and Sulfate Pollutions in U.S. Metropolitan Areas. *

Equation	Dependent Variable	Constant Term	CHEM	BLSTFU	PDENSE	GASOLN	PUBTRN	HLYWND	NEDUM	MWDUM	NEMS	SEMS	$\bar{R}^2$
1	NOX	1.739 (.503)				.237 (.053)	-.234 (.091)	-.702 (.198)					.443
2	NOX	1.102 (.928)				.341 (.124)	-.215 (.094)	-.626 (.214)			-.119 (.128)		.440
3	NEMS	-6.068 (.696)				.875 (.073)	.159 (.126)	.633 (.273)					.845
4	SOX	3.132 (.618)	.105 (.043)	.052 (.021)	.146 (.067)			-.513 (.204)	.524 (.115)	.369 (.109)			.698
5	SOX	3.149 (.627)	.104 (.044)	.049 (.022)	.139 (.069)			-.500 (.210)	.496 (.132)	.329 (.139)		.013 (.028)	.689
6	SEMS	-1.127 (.421)	.089 (.292)	.248 (.143)	.546 (.456)			-1.24 (1.39)	2.19 (.788)	3.08 (.742)			.564

* All variables are expressed as logarithms. The numbers in parenthese are standard errors of regression coefficients. The number of cases is 36.

FOOTNOTES

[1]Our method of describing the industrial base of an SMSA is to find the percentage of workers engaged in various manufacturing industries listed in the Census of Population, 1960, tables 75 and 127.

[2]The northeastern cities were Bridgeport, Hartford, New Britian, New Haven, Stamford, Waterbury, Wilmington, Washington, D.C., Portland, Baltimore, Boston, Worcester, Atlantic City, Jersey City, Newark, Binghampton, Buffalo, New York City, Rochester, Schenectedy, Albany, Troy, Syracuse, Allentown, Erie, Harrisburg, Philadelphia, Pittsburg, Reading, Wilkes-Barre, and Providence. Chicago, Peoria, Rockford, Gary, Evansville, Fort Wayne, Indianapolis, South Bend, Des Moines, Louisville, Detroit, Flint, Lansing, Duluth, Minneapolis, Kansas City, St. Louis, Akron, Canton, Cincinnatti, Cleveland, Columbus, Dayton, Lorain, Springfield, Toledo, Youngstown, Charleston, Madison, and Milwaukee were classified as midwestern communities. The southern cities were Birmingham, Mobile, Montgomery, Jacksonville, Miami, Orlando, Tampa, Atlanta, Jackson, Asheville, Charlotte, Greensboro, Raleigh, Winston-Salem, Charleston, Columbia, Greenville, Chattanooga, Knoxville, Memphis, Nashville, Hampton-Newport News, Norfolk, Richmond, and Roanoke. Finally, Little Rock, Fresno, Los Angeles, Sacramento, San Bernardino, San Diego, San Francisco, Denver, Topeka, Wichita, Lincoln, Omaha, Oklahoma City, Tulsa, Eugene, Portland, Austin, Corpus Christi, Dallas, Ft. Worth, Galveston, Houston, San Antonio, Waco, Seattle, Spokane, and Tacoma were classified as western communities.

[3]A correlation matrix will be sent to interested readers on request.

[4]However, in only one case (NOX) is the percent variations explained significantly higher ($\alpha = .05$) in the linear model. For SPM the logarithmic model was found to be significantly better in terms of percent variation explained. We therefore leave open the question of which model is "correct." For a discussion of this test, see Box and Cox (1964) and Rao and Miller (1971, pp. 107-109).