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Did Federal Regulations Clean the Air? An Econometric Analysis of the Clean Air Act Amendments on Air Quality

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Since the middle of the last century, air quality has steadily improved in the United States. As the U.S. moved through the 20th century, cleaner fuels replaced coal and wood as sources of heating in the home, and improvements in vehicle technology contributed to cleaner air. It is widely assumed that not until passage of the Clean Air Act Amendments in 1970 (which federalized air pollution control), did air pollution begin a dramatic decline. Goklany (2000) undertook the first real empirical analysis of this conventional wisdom. Analyzing both air quality and emissions data for the six major pollutants tracked by the EPA: carbon monoxide, sulfur dioxide, nitrogen oxide, ozone, lead and particulate matter, he found that the decline in these pollutants began before federalization.[1]

Apart from Goklany's study, there has been little systematic or empirical testing of the effects of federal regulations on national air quality. In spite of this deficit, legislators and politicians continue to claim success from regulatory regimes that they helped to create. One reason for this certainty gap is the lack of consistent data on national air quality, particularly for the period before federalization.

This study tests econometrically the assertion that federalization led to an improvement in air quality. This study is not a definitive assessment of the effects of federal regulation on national air quality, but aims to test the available data in the hopes that further empirical research will be undertaken in this area. In particular, more research with state level and local data will enable us to draw a clearer picture of what factors affect air pollution. And

[1] Goklany, Indur M. Cleaning the Air: The Real Story of the War on Air Pollution, Cato Institute, 1999.

might allow us to understand how regulatory regimes perform at the local level.

My results suggest that regulations sometimes, but not always, affect air quality. The amount of petroleum consumed also has an effect on air pollution levels. Of great significance, is that the number of enforcement actions taken by the EPA has no effect on the pollution level for carbon monoxide or sulfur dioxide. It has a small positive effect on the level of lead.

This may indicate that regulations play a role in changing behavior, leading to a decrease in pollution levels. Industries and individuals may adjust their behavior to comply with a new law, but they do not necessarily improve compliance in response to enforcement actions. Similarly, the amount of money spent on enforcing regulations does not always result in changed behavior.

History of Air Pollution Control

Until 1970, air pollution was under the regulation of the individual states. Starting in the mid 1950s states and localities began to design air pollution programs to clean the air in their communities. In 1955, states received some federal assistance under the Air Pollution Control Act. The act also reaffirmed that state and local governments had fundamental responsibility for air pollution control. [2]

Federal aid and assistance was also granted to the states with the passage of the Clean Air Act in 1963. The act gave a greater role to the federal government, though states and localities still remained primarily responsible.[3] With the passage of this act, the National Ambient Air Quality Standards (NAAQS) were defined. Further amendments in 1965 led to the Motor Vehicle Air Pollution Control Act that authorized the government to set emissions standards for cars. Two years later, the Air Quality Act was passed requiring the states to implement air quality standards. States were to develop their own standards and plans for implementation. The act was widely considered a failure. None of the state plans passed. Though, empirically, pollution levels had already begun their decline.[4]

[2] Godish, Thad "Air Quality", Lewis Publishers, 1999 p.245
[3] Godish p.245
[4] Goklany, p.57

The onset of the environmental movement in the late 1960s contributed to American's increased interest in combating perceived environmental problems.[5] Public support for federal legislation was strong. Another impetus for federalization was to eliminate confusion stemming from each state having its own emission standards. [6]

In December 1970, the Clean Air Act Amendments were passed. The federal government now assumed authority in the form of the newly established Environmental Protection Agency for setting the NAAQS. Emissions and motor vehicle standards were also defined. And the federal government assumed regulatory control over stationary sources of air pollution. The Amendments also gave the EPA enforcement authority over polluters and enabled citizens to file suits.

Over the next two decades, the Clean Air Act was amended twice more. In 1977, amendments were passed to tighten existing standards and make "midstream adjustments." A provision of the 1977 Amendments was the regulation of ozone destroying chemicals. Also, a grandfather clause was introduced for older power plants, exempting them from the new pollution standards.

The 1990 Amendments focused on acid rain and introduced a new program to reduce levels of sulfur dioxide and nitrogen oxide.

A favorite tool of the newly created EPA was enforcement. Created through the consolidation of pollution programs in several agencies the EPA needed to rally around a common mission. This meant spending a great deal of resources pursuing violators. During its first two months of operation the EPA "brought five times as many enforcement actions as the agencies it has inherited brought during any similar period."[7] The EPA's first administrator, lawyer, William Ruckleshaus, emphasized enforcement: an approach that continued through the mid-1990s.

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[5] Godish p. 237
[6] Goklany, p.29
[7] Adler, quoting Marc Landy in the Environmental Protection Agency: Asking the Wrong Questions

The EPA's approach did lead to bureaucratic expansion and ensured five reorganizations of the EPA's enforcement office.[8]

After decades of pursuing high-profile polluters and pointing to increased enforcements as a measure of mission success, questions began to be raised about the efficacy of the enforcement approach. Adler has noted that pursuing big cases does not necessarily result in improved environmental quality.[9]

To that end, the Clinton Administration instituted a "Reinventing Environmental Regulation" component of the National Performance Review. And the administration also created the Office of Environmental Compliance Assistance (OECA) to focus on the aim of enforcement rather than bean-counting.[10]

In 1995, EPA began exploring alternative ways to encourage compliance including the introduction of an environmental audit policy. At the same time a move towards measuring performance began to take hold, highlighting the need for more specific measures of environmental health.

Under the Bush administration, this shift in focus from enforcement to devising incentives to encourage compliance has continued.

<u>Data Quality and Limitations</u>

For this study I use air quality data collected and published by the EPA. I am concerned with air quality data and not emissions data. Air quality data or monitoring data measure ambient concentrations of pollutants in the atmopshere. They measure the outcome, or result of those factors that affect air quality.

Emissions data measure output or the quantity of pollutants released in the air in a year, and are estimated from the amounts of material consumed or produced by activities that emit pollutants.

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[8] Adler, p 42
[9] Adler, p.42
[10] Adler, p. 43

Data tracking the presence of the six major pollutants in the atmosphere can be found in some form dating back to the late 1950s. However, air quality data before the 1970s are sparse and not geographically representative. Air quality data are measured at monitoring stations which are located throughout the country. These monitoring stations are operated by state environmental agencies who report hourly and daily measurements of pollutant concentration to the EPA's central database[11]. The EPA computes a yearly summary for each monitoring station.

Data collection techniques as well as monitoring stations changed often during the pre-federalization period. An attempt was made to build a data set for the pre-1970 period using the EPA's raw data. However, I was unable to find a consistent set of monitors extending from pre-1970 to 2000. This makes construction of a time series for econometric testing, difficult. The EPA has air quality data on its website from 1982 to the present. In order to test the effects of the 1970s regulations, I linked together existing time series from EPA's annual Air Quality reports and from Earth Report 2000. By chaining the series together and using a weighted average I was able to construct a series of average annual pollutant concentrations from 1970 to 2000.

Pre-1970s data would strengthen the findings because it would enable testing of the effects of regulations before and after federalization. Another limitation of an analysis of national air quality is that it fails to take into account local conditions affecting pollution levels such as weather, geographic factors, and local industry. Local data are likely to produce a clearer picture of what factors affect air pollution levels. The intent of this study is to test a model measuring the effects of federal regulations on air pollution, nationally. It is hoped that further analysis with local data will be undertaken.

Data Series

The data for this study are defined as follows:

Carbon Monoxide 1970-2000, annual average of the second maximum 8 hour reading, parts per million

[11] EPA website http://www.epa.gov/air/data/info.html, September 2004

Lead 1976-2000, annual average of the maximum quarterly reading, micrograms per cubic milliliter

Sulfur Dioxide 1976-2000, annual average of the arithmetic mean, parts per million

Ozone 1974-2000, annual average of the second maximum one-hour reading, parts per million

Nitrogen Dioxide 1974-2000 annual average of the arithmetic mean, parts per million

I was unable to link together a time series for Particulate Matter. Particulate Matter has been measured differently over the decades. Initially, the EPA tracked Total Suspended Particulates (TSP). In 1987, the EPA switched to tracking PM-10 (particulate matter less than 10 microns in diameter). This made chaining the two series impossible.

Because the data set is small, there are limitations to an econometric analysis. The EPA only makes yearly averages available. Thus I could not obtain quarterly or monthly data without constructing a series from the raw data series. Ultimately, a regression analysis only proved meaningful for three of the remaining pollutants: carbon monoxide, sulfur dioxide and lead. Nitrogen dioxide's decline is shallow, with a nearly flat slope, making it unsuitable for a regression analysis. In the case of ozone, difficulties arose with variable selection. Ozone is created by the reaction of Volatile Organic Compounds (VOCs) in the presence of sunlight. Weather and geographic factors play a large role in its creation. In this case, we are concerned with national data, modeling for local weather conditions proved outside the scope of this analysis.

The econometric analysis was undertaken using Intercooled STATA version 8.2.

Since the data used in this analysis are a time series, it is necessary to test each data series for stationarity. A Dickey Fuller test was run for each variable and where necessary, the series were first-differenced to correct for the presence of a unit root thus making the time series stable. However, first-differencing has the drawback of sacrificing a data point, thus reducing by one the sample size for each of the pollutants.

Modeling the Impacts on Air Pollution

Each of the pollutants in this study is caused by a variety of individual factors. In modeling each pollutant, I sought to specify variables that would most closely capture those factors leading to the increase or decrease of the individual pollutant. I describe each variable for each of the three regressions below

Variable Selection for the Model

These variables were selected according to their importance in describing changes in the level of pollution in the atmosphere. A brief definition of each independent variable precedes a discussion of the results.

1975 Catalytic Converters (CATALYTIC75)
A requirement of the 1970 Clean Air Act Amendments was that all newly manufactured motor vehicles be equipped with catalytic converters by 1975. The effect of this is to reduce emission levels of carbon monoxide and is likely to lead to a lessening of CO levels in the air. Catalyic75 is coded as a dummy variable to pick up for the effects of the rule on carbon monoxide levels.

1977 Clean Air Act Amendments (REGS1977)
The 1977 amendments to the Clean Air Act tightened previous requirements and established sanctions against states that did not comply. REGS1977 is coded as a dummy variable. It is expected that the amendments have the effect of leading to improved air quality.

1977 Clean Air Act Amendments –Sulfur Dioxide (SOX78)
This variable captures the effects of the 1977 Clean Air Act regulations for sulfur dioxide. Because the data series for sulfur dioxide begin in 1976 and first differencing causes the first data point to be sacrificed, using REGS1977 is not possible. Thus, SOX78 is coded as a dummy variable to pick up for the effects of the earlier regulations.

1979 Lead Phaseout (LEAD79)
The phase-out of leaded gasoline began in 1974 with retailers offering unleaded gasoline. In 1979 refineries were required to not produce gasoline averaging more than 0.5 grams of lead per gallon, pooled for leaded and

unleaded gasoline. LEAD79 is a dummy variable coded to capture the effects of the initial stages of the lead phaseout.

1985 Lead Phaseout (LEAD85)
The standard for leaded gasoline was reduced to 0.5 grams of lead per gallon for leaded gasoline. LEAD85 is a dummy variable coded to capture the effects of the reduced standard.

1988 Lead Phaseout (LEAD88)
In 1988 all refineries were required to comply with a standard of 0.1 grams of lead per gallon on leaded gasoline. This variable is a dummy variable coded to capture the effect of the reduced standard.

1990 Clean Air Act Amendments (REGS1990)
As with the previous variables, REGS1990 is also coded as a dummy variable. It is expected that the 1990 amendments have the effect of leading to improved air quality.

1995 Acid Rain Standards (ACIDRAIN95)
The 1990 Clean Air Act Amendments states that by 1995, sulfur dioxide and nitrogen dioxide would be further regulated as a means of reducing acid rain. This variable is coded to pick up the effects of the implementation of the new standard.

1996 Lean Ban (LEADBAN96)
In 1996 the phase-out of lead in gasoline was completed with the final ban on lead additives in motor vehicles.

Enforcement Actions (DOJREFERRALS)
One of the results of the 1970 Clean Air Act Amendments was the establishment of federal enforcement authority over polluters as well as the creation of citizen suits. Enforcement actions are defined as the number of civil referrals made by the EPA to the Department of Justice under the Clean Air Act. This variable captures the effects of EPA enforcement. As enforcement actions increase, it is expected that air quality will improve.

Ratio of EPA regulatory budget to staff (BUDGET)
Expansion of the EPA's regulatory budget does not tell us how the money was spent. Assuming that increased staff and not improvements in office

capital determine how many new citations are made each year, this variable measures the ratio of the EPA's annual regulatory budget to its staff.

Natural log of real Gross Domestic Product (lnGDPPC)

It has been established that as society grows richer, its environment tends to improve. (Grossman and Kreuger, 1991). Wealthier societies tend to value a cleaner environment after other societal needs have been largely met, and will invest more of its resources towards achieving this goal. The Environmental Kuznets Curve (EKC) hypothesizes that at low incomes environmental impact per dollar GDP increases with increasing GDP per capita, while at high incomes it declines. The economic literature suggests that some air pollutants such as sulfur dioxide and carbon monoxide follow the EKC (Yandle, Bhattarai and Vijayaraghavan, 2004).

This variable is expressed as the natural log of real gross domestic product per capita. It is expected that as GDP per capita increases, air quality will improve. The natural log is an elasticity measure. It measures the impact a change in GDP has on the level of pollution.

Natural log of cumulative patents (lnCUMPAT)

Technological progress is thought to have an effect on air quality. In order to capture the effects of improved technology on the environment, I define this variable as the cumulative number of patents issued annually. I was unable to get a breakdown of patents issued for technology related to pollution. Thus, this variable is a proxy because it captures all technology. The natural log is an elasticity measure which measures the impact a change in technology has on the level of pollution.

Vehicle Miles Travelled (VMT)

Carbon monoxide is mainly created by tailpipe emissions. As the number of vehicle miles traveled increases, it is expected that the level of carbon monoxide in the atmosphere will increase. As vehicle technology improves, emissions should fall and air quality should improve. Lead emissions are also related to the usage of leaded gasoline. As the number of vehicle miles increases I expect the amount of lead in the atmosphere to increase.

Petroleum Consumed (PETROLC)

The amount of petroleum consumed is a major contributor to sulfur dioxide emissions. As petroleum consumption increases, it is expected that the level of sulfur dioxide will increase. The variable is expressed in quadrillion British thermal units (Btus) of petroleum consumed per year.

Kilowatt Hours Generated (KWH)

Electricity generation, which is reliant upon coal combustion, is a significant contributor to sulfur dioxide in the atmosphere. It is expected that as kilowatts consumed increases, the level of sulfur dioxide in the air will also increase. The variable is expressed as billions of kilowatt hours generated per year.

Descriptive Statistics

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
lnCO	30	-0.053647	0.040565	-0.166835	0.030123
Lead	24	-0.061875	0.0995467	-0.371	0.046
SOX	24	-0.0004	0.000427	-0.0014	0.000169
lnCUMPAT	31	13.76503	0.090348	11.0732	14.88001
Catalytic75	31	0.8387097	0.3738783	0	1
REGS1977	31	0.774193	0.425023	0	1
SOX78	31	0.7419355	0.4448027	0	1
LEAD85	31	0.516129	0.508000	0	1
LEAD88	31	0.4193548	0.5016103	0	1
REGS1990	31	0.354838	0.486373	0	1
ACIDRAIN95	31	0.1935484	0.4016097	0	1
LEADBAN96	31	0.1612903	0.3738783	0	1
DOJREFERRALS	31	73.22581	46.70097	0	1
lnGDPPC	30	-0.328496	1.9113096	-10.45709	0.067513
PETROLC	24	0.1341667	1.177816	-2.92	1.94
VMT	30	5.47e+10	2.92e+10	-3.26e+10	1.05e+11
BUDGET	30	2281.972	23490.87	-42658.12	61213.63
KWH	30	7.57e+10	5.68e+10	-5.4e+10	2.68e+11

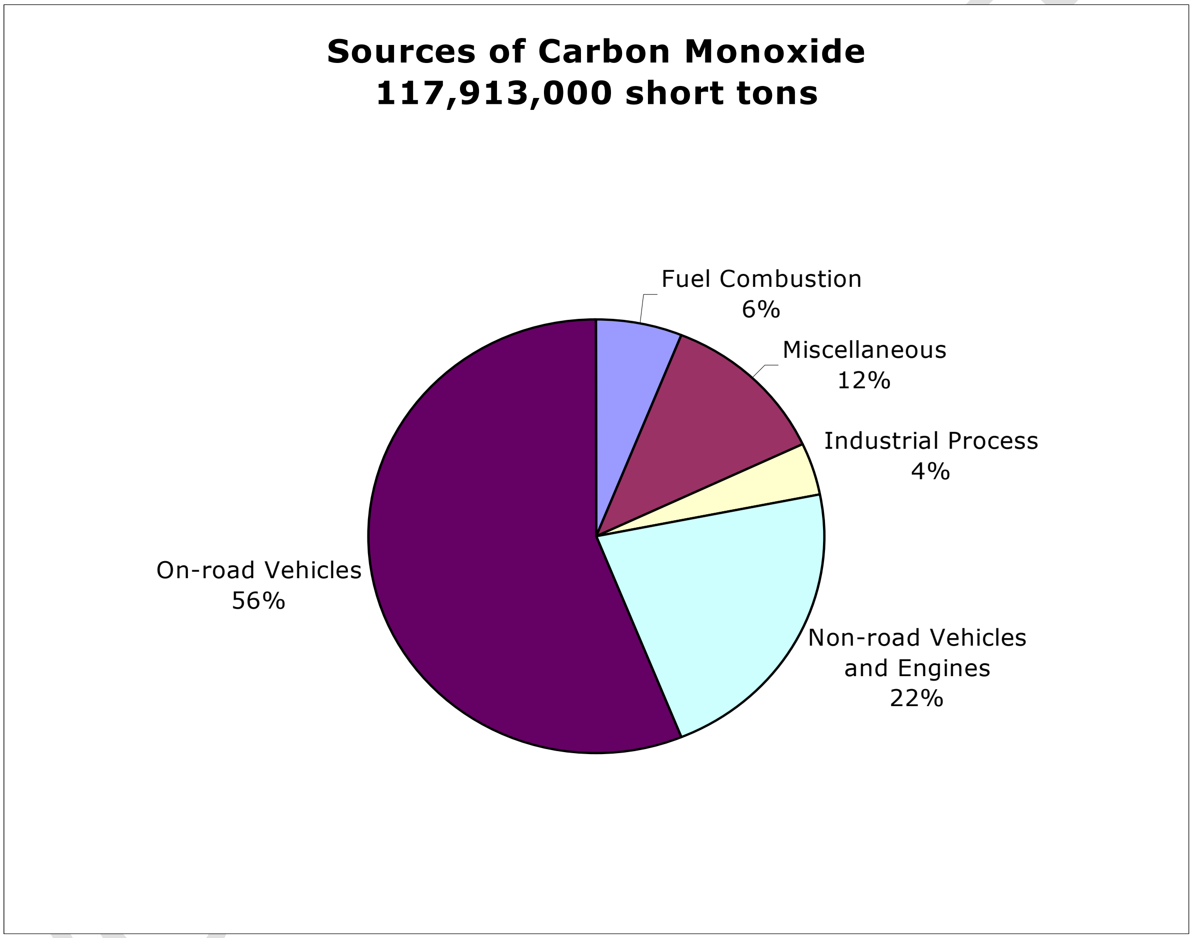
Discussion of each regression model

1. Carbon Monoxide

Carbon monoxide (CO) was one of the first pollutants recognized as hazardous to human health.[12] In the 1960s, attempts to control emissions of carbon monoxide from vehicles began on the state level. Caused by incomplete combustion of fuel, two-thirds of CO is emitted from vehicle

[12] Goklany, p.14

tailpipes (mobile sources). The remainder of CO comes from stationary sources, such as metals processing and chemicals manufacturing. Small amounts of CO are emitted from a variety of sources including residential wood burning and forest fires.



Source: EPA website

Data before the 1970s is not complete, but piecing together what is available shows a definite decline in CO before passage of the 1970 Amendments.[13] And the decline in levels of CO is most dramatic during the early 1970s, before the amendments could really take effect.

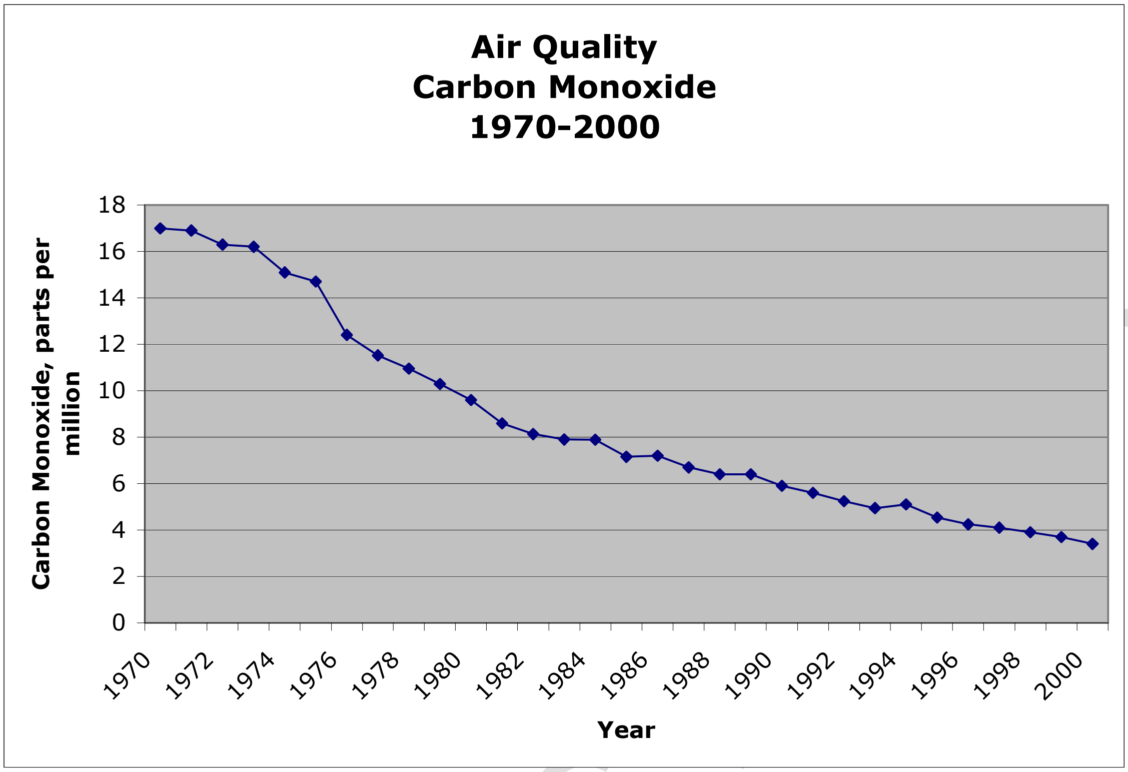
[13] Goklany, p.57

The Clean Air Act gives state and local governments primary responsibility for regulating pollution from power plants, factories, and other "stationary sources". The EPA has primary responsibility for "mobile source" pollution control.

One requirement of the 1970 Amendments was that by 1975 most new cars were to be equipped with catalytic converters designed to convert carbon monoxide into carbon dioxide. Catalysts reduce carbon monoxide emission by up to 80 percent, an effect that is likely to reduce carbon monoxide levels in the air.

Since CO emissions from automobiles increase dramatically in colder weather, the 1990 Clean Air Act called for cars and trucks manufactured after 1994 to meet a carbon monoxide standard at 20°F. Cities with high CO levels were required to use only oxygenated gasoline during the winter. The 1990 Act also expanded requirements for inspection and maintenance standards.

The level of carbon monoxide in the atmosphere has decreased dramatically over the past several decades. The graph below shows the decline in the annual average of the second highest 8-hour concentration of carbon monoxide at each monitoring location. Between 1970 and 2000, the level of carbon monoxide in the atmosphere declined by 80 percent, with the most dramatic decline occurring in the 1970s and 1980s. Between 1970 and 1980, CO emissions decreased by 43 percent. In the 1980s the decline was by 31 percent. And in the decade of the 1990s, CO declined by 39 percent.



Sources: EPA Air Quality reports, Environmental Quality, Earth Report 2000

Is this decline due to federal regulations? In order to test this, I specified a linear relationship between a decrease in carbon monoxide and the presence of the 1970 Amendments (as captured by the introduction of the catalytic converter in 1975), the 1977 and 1990 Clean Air act Amendments, the number of clean air act civil referrals to the Department of Justice, the amount of money spent by the EPA on their regulatory budget as a ratio of the number of employees, the natural log of GDP per capita, and the number of vehicle miles traveled.

The model is as follows:

$$Y = \alpha + \beta_1 \text{ Catalytic75} + \beta_2 \text{ REGS1977} + \beta_3 \text{ REGS1990} + \beta_4 \text{ BUDGET} + \beta_5 \text{ DOJREFERRALS} + \beta_6 \ln\text{CUMPAT} + \beta_7 \ln\text{GDPPC} + \beta_8 \text{ VMT} + \varepsilon$$

Where:

Y = Air Quality, the natural log of the annual average of carbon monoxide, parts per million

α = constant

Catalytic75 = 0 where the catalytic converter is not mandated.
= 1 where the catalytic converter is mandated.

REGS1977 = 0 where the 1977 Clean Air Act Amendments are not in place.
= 1 where the 1977 Clean Air Act Amendments are in place.

REGS1990 = 0 where the 1990 Clean Air Act Amendments are not in place.
= 1 where the 1990 Clean Air Act Amendments are in place.

BUDGET = ratio of EPA regulatory budget to staff in real dollars.

DOJREFERRALS = yearly number of civil referrals from the EPA to the Department of Justice under the Clean Air Act.

Lncumpat = natural log of cumulative patents issued per year.

LnGDPPC = natural log of real GDP per capita per year.

VMT = vehicle miles traveled annually.

ε = error

Ordinary Least Squares Regression Results
N= 30

LnCO	**Coefficient**	**Standard Error**	**t-statistic**	**p-value**
Catalytic75	-.078538	.0413539	-1.90	0.071
REGS1977	.0134679	.0438553	0.31	0.762
REGS1990	-0.0085	.0288416	-0.29	0.771
DOJREFERRALS	.0003138	.0003227	0.97	0.342
lnGDPPC	.0038856	.0043216	0.90	0.379
VMT	2.34e-13	2.85e-13	0.82	0.420
lncumpat	0.0086998	0.0309944	0.28	0.782
BUDGET	1.84e-11	2.79e-11	0.28	0.782
Constant	-0.1511574	0.3843731	-0.39	0.698

R-squared = 0.2699

Durbin Watson d-statistic (8, 30) = 2.822

Bruesch-Pagan/Cook-Weisberg test for heteroskedasticity
Ho: Constant Variance

Chi2 (1) = 0.08
Prob > chi2 = 0.7769

Discussion of Results

The regression results show that none of the variables are significant in explaining changes in air quality. With a t-statistic of –1.90, the regulation that mandated the catalytic converter is very close to being statistically significant, and the sign on the coefficient indicates that the 1975 regulation mandating the catalytic converter had a positive impact on improvement air quality. For every year the regulation for the catalytic converter is in effect, there is a seven percent decline in carbon monoxide.

The results indicate that subsequent regulations are insignificant. The number of civil referrals to the DOJ, and the amount of money spent by the

EPA on the regulatory budget are also insignificant in explaining changes in the level of carbon monoxide in the air. Similarly, increased GDP per capita and the increase in the number of vehicle miles traveled do not have any explanatory power.

An R-squared of .269 indicates that the variables explain about 26.9% of the variation in carbon monoxide levels.

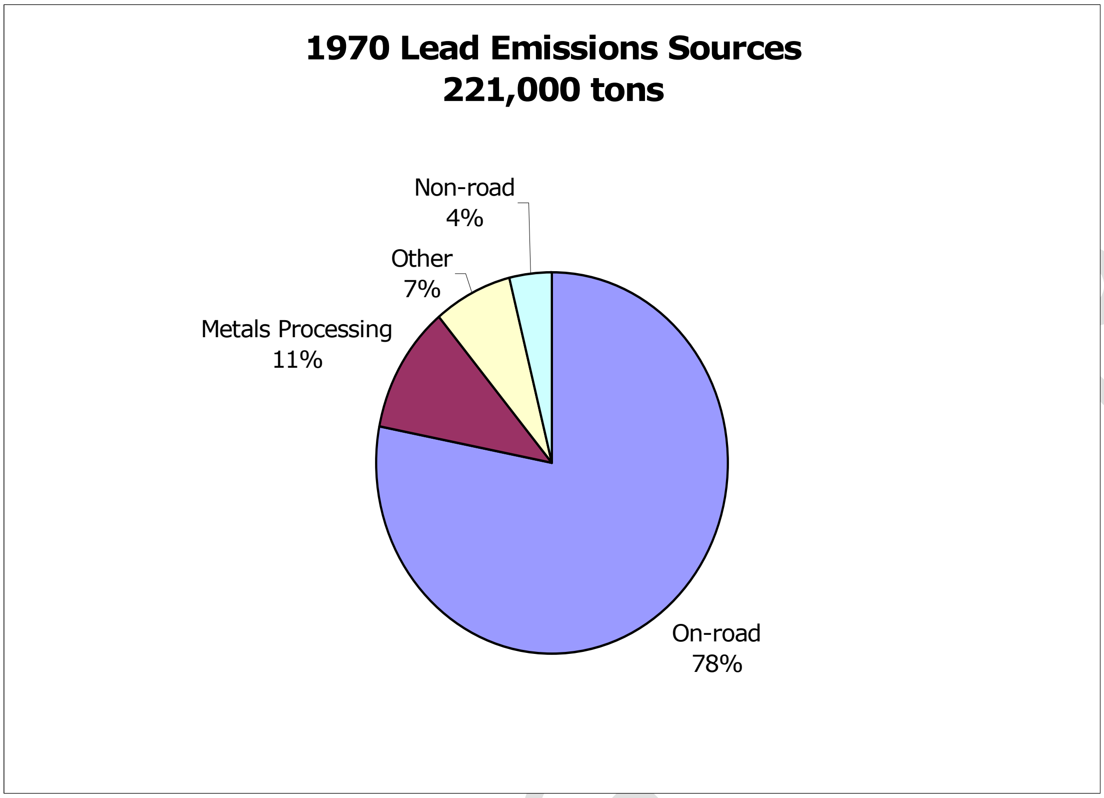
Tests for autocorrelation and heteroskedasticity were performed and indicate that the model meets the Gauss Markov assumptions for Best Linear Unbiased Estimator.

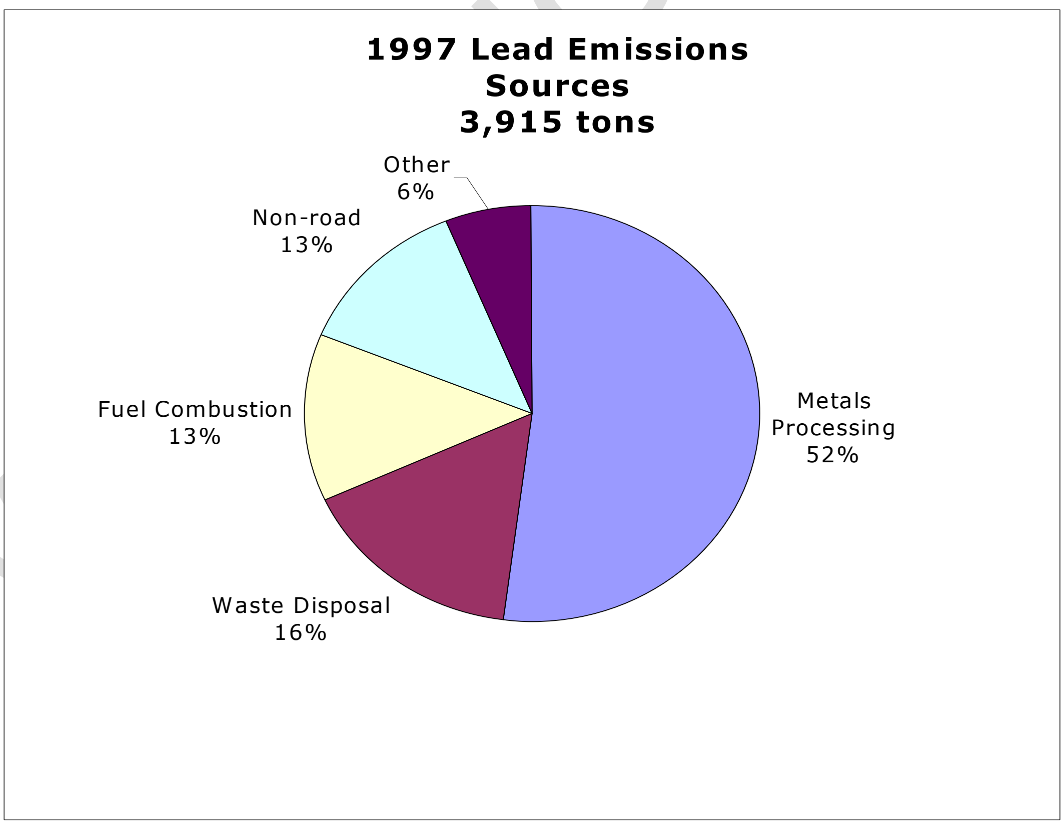
2. Lead

Levels of lead in the atmosphere began a rapid decline in the early 1970s. Since the 1920s, refineries had added lead to gasoline as a means of boosting the octane rating and reducing "engine knock". Before the EPA began to regulate lead in gasoline, nearly all gasoline contained 2.4 grams per gallon. Lead's hazard to human health had long since been established, and leaded gasoline also has the effect of destroying the effectiveness of catalytic converters in cars. Since catalytic converters were necessary for meeting new standards for carbon monoxide emissions, lead became a target for regulation. The gradual phase-out of lead in gasoline began in 1974 with the introduction of leaded and non-leaded gasoline at service stations.

In 1979, refineries were prohibited from producing gasoline averaging more than 0.5 grams of lead per gallon per quarter for both leaded and unleaded gasoline. Further restrictions were issued in 1982. In 1985 the standard for leaded gasoline was reduced to 0.5 grams. Three years later refineries had to comply with a 0.1 grams per gallon standard. The elimination of lead from gasoline was signed into law on January 1, 1996, effectively banning lead from fuel.

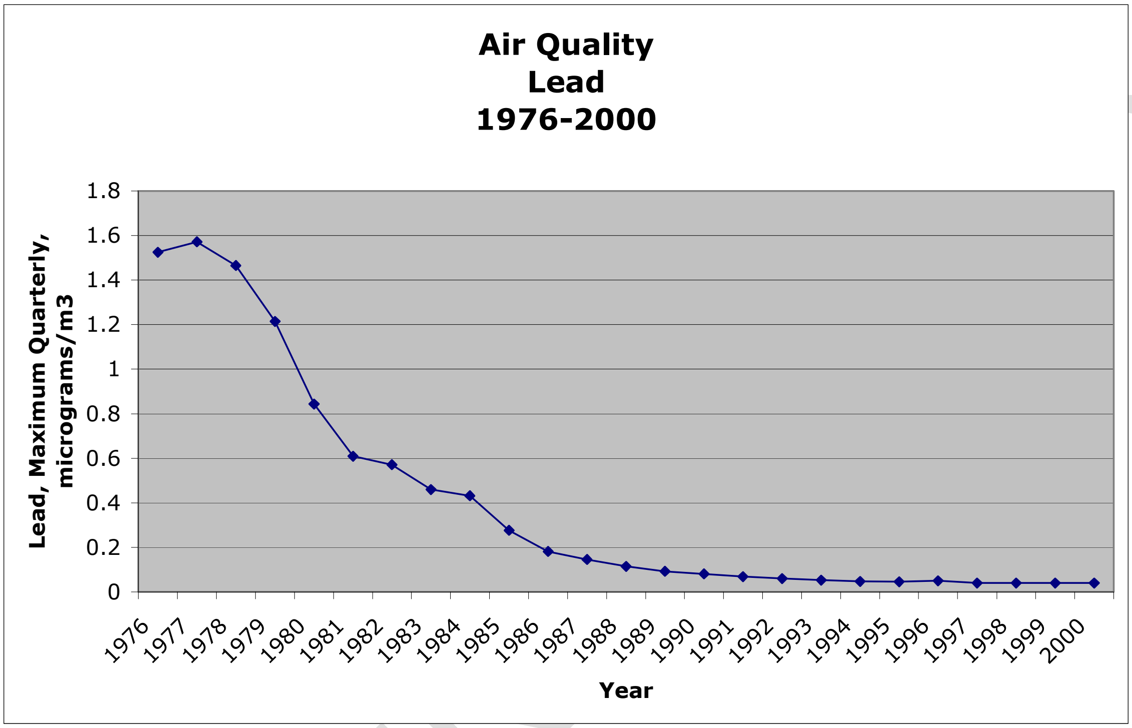
Today the major source of lead in the air is from battery manufacturing and lead smelters.





Source: EPA website

The decline of lead in the atmosphere was rapid and dramatic in the 1970s and 1980s. Between 1976 and 1985 lead levels in the air declined by 86 percent. Between 1990 and 1996 levels decreased by 38 percent.



Source: EPA Air Quality reports, Environmental Quality, Earth Report 2000

How much of this is related to regulations? And what is attributable to other factors? A model was specified to test this. I hypothesize that lead levels are affected by the presence of the 1979, 1985, 1988 lead reduction standards, the 1996 ban on lead additives in gasoline, the number of civil referrals from the EPA to the DOJ, the growth of the regulatory budget of the EPA, increased GDP per capita, the increase in the amount of vehicle miles travelled, and the advancement of technology.

The follow model was specified:

$$Y = \alpha + \beta_1 \text{ LEAD79} + \beta_2 \text{ LEAD85} + \beta_3 \text{ LEAD88} + \beta_4 \text{ LEADBAN96} + \beta_5 \text{ DOJREFERRALS} + \beta_6 \text{ BUDGET} + \beta_7 \text{ lnGDPPC} + \beta_8 \text{ VMT} + \beta_9 \text{ lnCUMPAT} + \varepsilon$$

Where:

Y = Air Quality for Lead, measured as annual average of the maximum quarterly reading, micrograms per cubic milliliter

α = constant

LEAD79 = 0 where standard is not in effect.
= 1 where standard is in effect.

LEAD85 = 0 where standard is not in effect.
= 1 where standard is in effect.

LEAD88 = 0 where standard is not in effect.
= 1 where standard is in effect.

LEADBAN96 = 0 where standard is not in effect.
= 1 where standard is in effect.

BUDGET = ratio of EPA regulatory budget to staff in real dollars.

DOJREFERRALS = yearly number of civil referrals from the EPA to the Department of Justice under the Clean Air Act.

LnGDPPC = natural log of real annual Gross Domestic Product per capita.

VMT = total vehicle miles traveled per year.

Lncumpat = natural log of cumulative number of patents issued each year.

ε = error

Ordinary Least Squares Results
(n= 24)

LEAD	**Coefficient**	**Standard Error**	**t-statistic**	**p-value**
LEAD79	-0.1728316	0.0734953	-2.35	0.034
LEAD85	0.0055838	0.0636587	0.09	0.931

LEAD88	-0.0009734	0.0595838	-0.02	0.987
LEADBAN96	-0.0533116	0.0552581	-0.96	0.351
DOJREFERRALS	-0.0010504	0.0005422	-1.94	0.073
BUDGET	1.00e-06	7.51e-07	1.34	0.203
LnGDPPC	0.0000964	0.0068629	0.01	0.989
VMT	7.43e-13	7.62e-13	0.98	0.346
LnCUMPAT	0.2071338	0.117504	1.76	0.101
Constant	-2.774593	1.567357	-1.77	0.098

R-squared = 0.7785
Durbin-Watson d-statistic (10, 24) = 2.531743

Breusch-Pagan/Cook-Weisberg test for heteroskedasticity
Ho: Constant variance

Chi2 (1) = 3.76
Prob > chi2 = 0.0524

Discussion of Results

The 1979 regulations played a part in reducing levels of lead in the air. With a t-statistic of –2.35. For every year the 1979 regulation is in effect there is a 17% decrease in levels of lead. Subsequent reductions in 1985, 1988 and the ban of lead in 1996 are not significant in reducing lead levels. Though the signs on the coefficients for LEAD88 and LEADBAN96 indicate they are related to an improvement in air quality for lead. This may be due to the fact that by the mid to late 1980s, the most dramatic reductions in lead had already occurred. By the time the final ban took effect, most of the impact of the initial regulations had already taken effect.

Civil referrals to the DOJ are barely significant with a t-statistic of –1.94. A t-statistic of -1.96 would enable us to accept the result without qualification. The coefficient on this variable indicates that for every unit increase in regulations there is a 0.1 percent decrease in lead levels, indicating that enforcement actions have a small positive effect on improved air quality for lead.

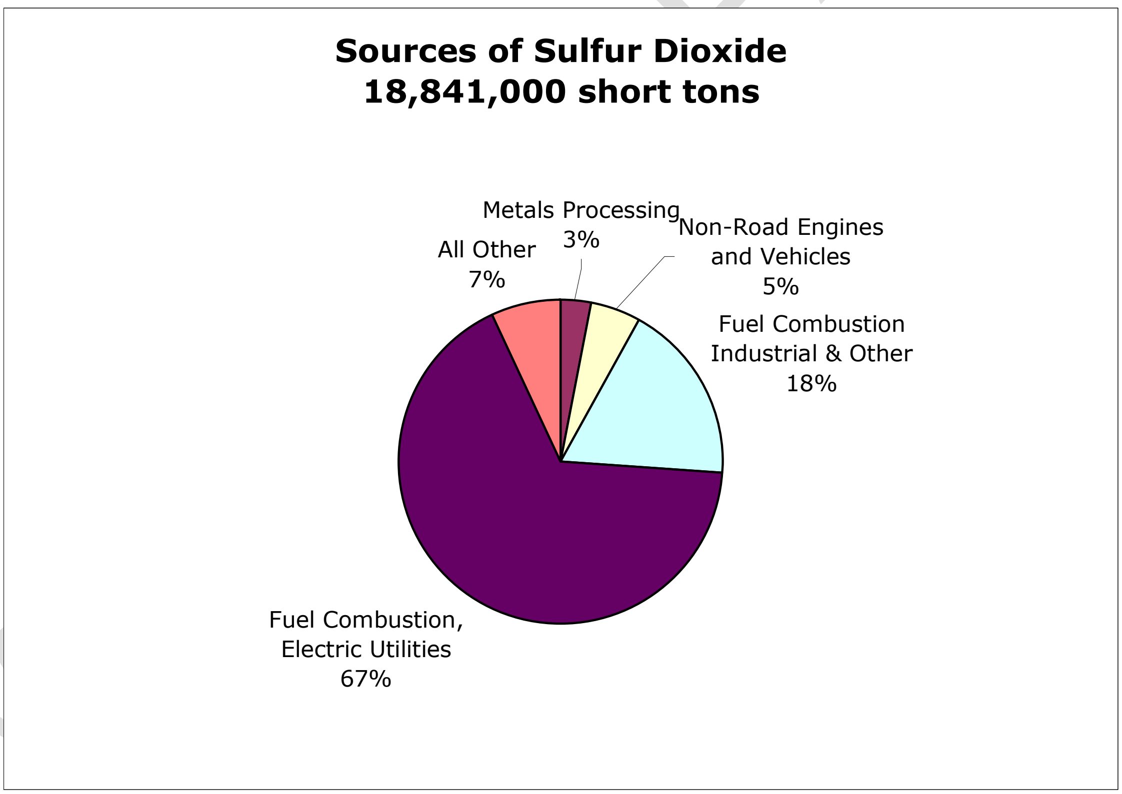
Variables for technology, GDP, vehicle miles traveled and the ratio of the regulatory budget to staff are not significant.

An R-squared of 0.778 indicates that the variables explain 77.8 percent of the variation in levels of lead.

Tests for serial correlation and heteroskedasticity show that the model meets the Gauss Markov assumptions for Best Linear Unbiased Estimation.

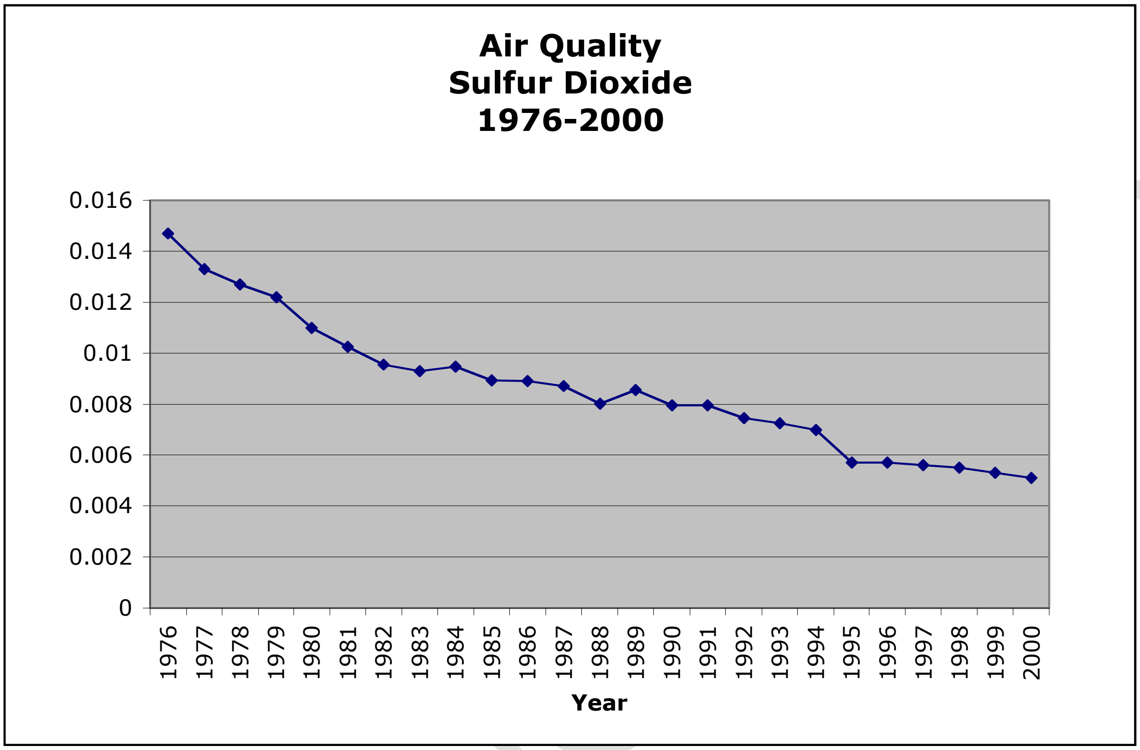
<u>Sulfur Dioxide</u>

Sulfur dioxide is primarily created through the combustion of fuel, coal and oil in particular. It is also caused by the extraction of gasoline from oil, and metals from ore. Regulation of sulfur dioxide was the focus of the 1990 Clean Air Act amendments that stipulated stricter controls on stationary sources as a means of reducing acid rain.



Source: EPA website

Levels of sulfur dioxide declined by 40 percent between 1976 and 1986. Between 1987 and 1997 levels fell by 55 percent. During the post acid rain regulations of 1995, they declined by 10 percent as shown below.



Sources: EPA Air Quality reports, Environmental Quality, Earth Report 2000

I hypothesize that sulfur dioxide levels are affected by the presence of federal Clean Air regulations as captured by SOX78, REGS1990 and ACIDRAN95, the number of civil referrals made by the EPA to the DOJ, the growth of the EPA's regulatory budget as a ratio of its staff, the natural log of GDP per capita, the amount of petroleum consumed, the number of kilowatt hours generated and the improvement in technology as measured by the natural log of cumulative patents.

The following model was specified:

$$Y = \alpha + \beta_1 SOX78 + \beta_2\ REGS1990 + \beta_3\ ACIDRAIN95 + \beta_4\ DOJREFERRALS + \beta_5 + BUDGET\ \beta_6 + \beta_7 lnGDPPC + \beta_8\ PETROLC + \beta_9\ KWH + \beta_{10} lnCUMPAT + \varepsilon$$

Where:

Y = Air Quality of sulfur dioxide, as measured by the annual arithmetic mean, parts per million.

SOX78 = 0 where 1977 Clean Air Act amendments are not in place.
= 1 where 1977 Clean Air Act amendment are in place.

REGS1990 = 0 where 1990 Clean Air Act Amendments are not in place.
= 1 where 1990 Clean Air Act Amendments are in place.

ACIDRAIN95 = 0 where 1995 Acid Rain regulations are not in place.
= 1 where 1995 Acid Rain regulations are in place.

BUDGET = ratio of EPA regulatory budget to staff in real dollars.

DOJREFERRALS = yearly number of civil referrals from the EPA to the Department of Justice under the Clean Air Act.

LnGDPPC = natural log of real Gross Domestic Product per capita.

PETROLC = annual amount of petroleum consumed expressed in British thermal units.

KWH = Kilowatt Hours generated per year.

LnCUMPAT = natural log of cumulative patents issued per year.

ε = error

<u>Ordinary Least Squares Results</u>
(n=24)

SOX	**Coefficient**	**Standard Error**	**t-statistic**	**p-value**
SOX78	0.0010664	0.000532	2.00	0.065
REGS1990	-0.0003429	0.0003252	-1.05	0.310
ACIDRAIN95	-0.000285	0.0002288	-1.25	0.233
DOJREFERRALS	8.45e-07	2.76e-06	0.31	0.764

BUDGET	-5.21e-10	3.67e-09	-0.14	0.889
LnGDPPC	-3.83e-06	0.0000363	-0.11	0.917
PETROLC	0.0001951	0.0000809	2.41	0.030
KWH	-5.08e-16	1.37e-15	-0.37	0.717
LnCUMPAT	0.0006071	0.0004665	1.30	0.214
constant	-0.0098543	0.0061325	-1.61	0.130

R-squared = 0.6706

Durbin-Watson d-statistic (10, 24) = 2.344212

Breusch-Pagan/Cook Weisberg test for heteroskedasticity
Ho: Constant variance

Chi2 (1) = 0.24
Prob >chi2 = 0.6210

Discussion of Results

The results show that the 1977 Clean Air Act amendments are significant in affecting the level of sulfur dioxide. SOX78 has a t-statistic of 2.00 and a coefficient of 0.001 indicating that for every year the 1977 regulation is in place, sulfur dioxide increases by 0.1 percent in ambient air concentrations. Subsequent regulations are insignificant, though the sign on these coefficients indicate that later regulations are related to an improvement in air quality.

Civil referrals to DOJ and the regulatory budget are also insignificant in explaining changes in the level of sulfur dioxide. Increased GDP and improved technology also do not explain any changes in sulfur dioxide concentrations. Although GDP is insignificant, a negative sign on the coefficient for GDP indicates that as GDP increases, the level of sulfur dioxide decreases. This supports previous empirical research on the behavior of sulfur dioxide in the Environmental Kuznets Curve. (Yandle, Bhattarai, and Vijayaraghavan, 2004)

The amount of petroleum consumed, PETROLC has a t-statistic of 2.41 and a coefficient of 0.0001. For every extra BTU of petroleum consumed the amount of sulfur dioxide increases by .01 percent. However, kilowatt hours generated has no effect on levels of sulfur dioxide.

Why might the 1977 regulations lead to an increase in sulfur dioxide levels? Under the 1977 Clean Air Act Amendments, a grandfather clause was added exempting power plants built before 1977 from new emissions standards. Plants that expanded or modernized underwent a "New Source Review" process every five years.

New Source Review required manufacturers to undergo a detailed permitting process and install anti-pollution technology. The requirements were only applicable to existing plants if they made "major modifications", resulting in an increase in emissions. Activities that fell under "routine maintenance" were not considered a modification. Disagreements over what constituted "routine maintenance" versus "major modifications" ensured that many plants continued to operate without being subject to current pollution standards.

At the time of its passage, Congress reasoned that imposing regulations on existing facilities would be too costly. Most of those plants, it was argued, would likely become technologically obsolete and go out of business in a short time. However, New Source Review evolved into a counter-incentive for older plants.[14]

Many companies avoided making improvements or replacing old equipment for fear of being subjected to harsh restrictions and penalties.

In an effort to close the New Source Review loophole, the Clinton administration sued 51 previously exempted power plants forcing them to install pollution control equipment. In 2003, the Bush administration designed a new rule expanding the definition of "routine maintenance" to allow facilities to expand and modernize without paying for emissions cutting devices for up to 20 percent of equipment replacement costs.

The model for sulfur dioxide appears to capture the impact of the 1977 Clean Air Act Amendments. The regulation was inadvertently structured to

[14] Gattuso, Dana Joel "Clearing the Air on Bush's New Plan", The Washington Times, July 8, 2002

have a negative effect on improving air quality, explaining the effect of the SOX78 variable on levels of sulfur dioxide.

An R-squared of 0.67 indicates that the variables explain 67 percent of the variation in levels of sulfur dioxide.

Tests for serial correlation and heteroskedasticity indicate that the model for sulfur dioxide meets the Gauss-Markov criteria for Best Linear Unbiased Estimator.

Conclusion

In some cases federal regulations appear to have a limited effect on air pollution. The introduction of the catalytic converter is associated with a decrease in carbon monoxide levels. The phase-out of leaded gasoline beginning in 1979 and EPA enforcement actions have a positive effect on eliminating lead from the air. However, subsequent regulations in the 1980s and 1990s have no discernable effect on carbon monoxide or lead levels. This may be due to the fact that earlier regulations led to the most dramatic reductions with subsequent regulations proving redundant. Alternatively, if pollution began its decline before federalization, due to shifts in manufacturing and improvements in technology later regulations are not likely to have much effect. Unfortunately, without a longer data series, it is difficult to know this for certain.

The amount of money spent by the EPA on its regulatory budget relative to its staff does not explain any decline in the levels of these pollutants. This may indicate that as bureaucracy grows it may contribute to a lack of agency focus with missions being expanded rather than resources being put towards a few basic goals. Alternatively, resources may be focused on one or two goals, but the methods used to achieve these goals do not necessarily contribute to environmental improvements.

Sulfur dioxide appears to be negatively affected by the presence of the 1977 regulations. This is likely due to the structure of the 1977 Amendments which created a loophole for older plants. This “grandfather clause” exempted older plants from current emissions standards unless they undertook major modifications. This created a disincentive for manufacturers to innovate and introduce efficiencies and thus the regulation may have contributed to an increase of sulfur dioxide in ambient air concentrations.

Other forces such as increased societal wealth and improved technology do not appear to have much explanatory power. However, the amount of petroleum consumed contributes to a slight increase in the level of sulfur dioxide in the atmosphere.

Pre-1970s data is needed to further test the impact of federal regulation on air pollution levels. The results suggest that by piecing together historical data that air pollution began improving before federal regulations were put into effect. But these disjoint pieces in the pre-1970s data do not permit for time series analysis. Further, air pollution is ultimately a local phenomenon. Though regulations are often passed with the welfare of the nation in mind, air quality varies greatly from city to city and region to region. Weather, geography, population density and industry play large roles in determining local air quality conditions. Examining metropolitan historical air quality trends using econometric techniques may provide a much clearer picture of those forces that have contributed to the overall improvement in air quality.

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