Economic Growth and Environmental Degradation

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Abstract

Economists, ecologists, private industries and government decision-makers have long been interested in the relationships between economic growth and environmental quality. These relationships are often the subject of intense public policy debates such as the current debate surrounding global climate change issues. From an ecological or environmental perspective, the argument is often made that economic growth is bad for the environment. But, what story do the data tell? In order to address the question, a estimable model was used to analyze the effects between gross domestic product (GDP) and environmental indications for air pollution in over 100 metropolitan statistical areas in the United States from 2001-2005. The analysis is then expanded to examine the estimable relationship at the state level. The air pollution indicators include ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, and particulate matter. The results are mixed results. This study finds a statistically significant U-shaped relationship for some of the pollutants; however, the evidence is pretty weak with the exception of ground level ozone. This study does not find evidence to support the traditional EKC inverse U-shaped relationship. These results are compared and contrasted to previous studies providing insight into unresolved theoretical and empirical estimation issues and future research needs.

Key words: Air Pollution, Environmental Economics, Environmental Kuznets Curve

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Introduction

The relationship between the environment and pollution is the subject of intense public debate. Pollution emissions are often used as indicators for environmental quality with the obvious intuition that more emissions imply worse environmental quality. One's intuition may lead to the belief that emissions simply increase linearly as an area's economy grows through time. An examination of the empirical relationship between economic growth and emissions, however, reveals different results.

Grossman and Krueger (1991) proposed that emissions followed an inverse-U shaped path as a country's economy grew over time. The authors defined this relationship as the Environmental Kuznets Curve (EKC) hypothesis named after the Kuznets Curve hypothesis developed by Kuznets in 1955. Since the proposal of the EKC hypothesis several other studies have been conducted to examine the validity of the hypothesis. The findings are mixed—some authors support the hypothesis (Shafik and Bandyopadhyay, 1992; Selden and Song, 1993; Dinda, 2004) while critics are highly suspicious of the hypothesis (Harbough, Levinson, and Wilson, 2002; Stern, 2003).

To date no comprehensive theoretical model has been developed to explain the relationship between environmental quality and economic growth from which an empirical EKC can be explicitly derived. Because of no comprehensive theory exists researchers have only used estimable regression models to examine the relationship. Some of those studies examine the relationship with cross-country effects (Grossman and Krueger, 1991; Shafik and Bandyopadhyay, 1992; Selden and Song, 1993; Lopez and Mitra, 2000; Harbough, Levinson, and Wilson, 2002; Dinda, 2004), while others use within-country effects (Deacon and Norman, 2004). The potential problem with previous studies is that the emissions data from some countries are highly suspect (particularly countries with little environmental regulatory oversight) and could present potential problems of measurement error. Examining the data at a national level may also be suspect because valuable information is potentially lost as the emissions data is aggregated to a national level. Air pollution emissions are measured at thousands of monitoring stations located throughout U.S., so perhaps a more accurate understanding of the relationship between emissions and economic growth could be revealed by examining the local economy surrounding the monitoring station.[i] This study differs from past studies in that it analyzes the more localized relationship between the environment and the economy. Specifically, this study examines the relationship between the gross domestic product (GDP) of a metropolitan statistical area (MSA) with the emissions reported by the monitoring stations within that same MSA. This study also expands upon past research by using a highly accurate data set for emissions offered through the U.S. Environmental Protection Agency's (EPA) Air Quality System (AQS).

This study expands upon past research by introducing meteorological covariates into the estimable regression. The meteorological data is added to the analysis as a recent study conducted by Camalier, Cox, and Dolwick (2007) found that ozone trends in urban areas could be better assessed by controlling for meteorological variables. Thus, the meteorological data was included to better control for exogenous factors that may affect the relationship between economic growth and the environment.

The estimable regression reveals surprising results. Similar to Deacon and Norman (2004), this study finds a statistically significant U-shaped relationship between some of the criterion pollutants and GDP. But the marginal effects of the GDP-squared term are so small that a more plausible explanation is that emissions are decreasing with GDP through time.

Literature Review

Grossman and Krueger (1991) arguably were the first to develop the Environmental Kuznets Curve (EKC) hypothesis to describe how environmental indicators are related to national income. Prior to this work, intuition led policy-makers to believe that pollution levels may simply increase continually as economic growth occurred throughout time. However, Grossman and Krueger (1991) proposed that some environmental indicators, such sulfur dioxide and suspended particulates, improved as incomes and levels of consumption went up. In a follow-up work Grossman and Krueger (1995) analyzed environmental indicators and national GDPs within 42 countries around the world. The authors showed that for some environmental indicators (sulfur dioxides and suspended particulates) economic growth brings an initial phase of environmental deterioration followed by a subsequent phase of improvement after some turning point (Grossman and Krueger, 1995). This finding led the authors to purport that sulfur dioxide and suspended particulate levels follow an inverse U-shaped relationship with GDP through time (Grossman and Krueger, 1995).

Shafik and Bandyopadhyay (1992) conducted a similar cross-country analysis by examining patterns of environmental quality for countries at different income levels.[ii] The authors found that income (national GDP) was the most significant indicator of environmental quality; however, the authors claimed that the relationship between environmental quality and economic growth was far from simple (Shafik and Bandyopadhyay, 1992). The authors argued that some countries were able to “grow out of” environmental pollution problems with economic growth, but they posited that the process was not necessarily automatic and that policies and investments were necessary to reduce degradation (Shafik and Bandyopadhyay, 1992).

Selden and Song (1993) identified four air pollutants that followed the inverted-U relationship between pollution and economic growth.[iii] Specifically, the authors examined per capita emissions and per capita GDP in thirty countries. The authors found that carbon dioxide emissions did not follow the inverted-U relationship, but rather appeared to rise monotonically with income (Selden and Song, 1993).

Lopez and Mitra (2000) examine the EKC but take into account the implications of corruption and rent-seeking behavior by the government. The authors find that the existence of corruption is not likely to preclude the inverted-U shape between environmental pollution and economic growth; however, they posit that at, "any level of per capita income the pollution levels corresponding to corrupt behavior are always above the socially optimal level" (Lopez and Mitra, 2000).

Harbough, Levinson, and Wilson (2002) tested the robustness of the EKC hypothesis (i.e., hypothesized relationship between national income and pollution). The authors found that the relationship is highly sensitive to different functional forms within the model, changes in data or years, and changes to covariates in the model (Harbough, Levinson, and Wilson, 2002). The authors, therefore, concluded that there is little empirical evidence for the EKC hypothesis. The authors noted at the end of their analysis that the pollution levels monitored at a particular station is almost certainly related to the economic activity and population density surrounding the station (Harbough, Levinson, and Wilson, 2002).

Deacon and Norman (2004) examined with-in country relationships between air pollution and national income as opposed to cross-country relationships as had been examined in prior works. The authors found that sulfur dioxide fitted well within the EKC hypothesis, but found that particulate matter and smoke followed a U-shape instead of an inverted-U as proposed by the EKC hypothesis (Deacon and Norman, 2004). Based upon their observations, the authors offered an alternative hypothesis—that decreases in air pollution are instead a function of public support for environmental protection beginning in the 1970s (Deacon and Norman, 2004).

Stern (2003) critiques the EKC hypothesis by decomposing the pollution emissions and examining the statistical considerations of the hypothesis. He argues that urban ambient concentrations of some pollutants may follow the inverted-U shaped relationship with income; however, he claims that EKC is not likely a complete model of pollution emissions or concentrations (Stern, 2003).

Dinda (2004) offers a survey of the EKC hypothesis. According to Dinda (2004), a meta-analysis of past studies reveals that the EKC relationship holds with pollution in the shorter term and local impacts, as opposed to long-term impacts in a larger regional area. The author claims that only sulfur dioxide, suspended particulate matter, nitrogen oxide, and carbon monoxide follow the EKC relationship (Dinda, 2004). In contrast, global environmental indications such as carbon dioxide, do not follow the EKC relationship but appear to increase monotonically with income (Dinda, 2004).

Methodology

Air Pollution Emissions-GDP Relationship

The focus of this analysis is on the relationship between air pollution emissions, *m*, and real GDP, *y*; controlling for socioeconomic covariates, in a vector *x*, and meteorological covariates, in a vector *z*,

$$\log(m_{it}) = \beta_0 + \beta_1 y_{it} + \beta_2 y_{it}^2 + \beta_x x_{it} + \beta_z z_{it} + c_i + \varepsilon_{it}, \qquad (1)$$

where i is a city, state, or regional index, t is a time index, c is unobserved heterogeneity, and ε is a disturbance term with mean zero and finite variance.

Model (1) provides us to test several forms of the environmental-economic development relationships:[iv]

(i) $\beta_1 = \beta_2 = 0.$ No relationship between y and m.
(ii) $\beta_1 > 0$ and $\beta_2 = 0.$ A monotonically increasing or linear relationship between y and m.
(iii) $\beta_1 < 0$ and $\beta_2 = 0.$ A monotonically decreasing relationship between y and m.
(iv) $\beta_1 > 0$ and $\beta_2 < 0.$ An inverted-U-shaped relationship, i.e., EKC.
(v) $\beta_1 < 0$ and $\beta_2 > 0.$ A U-shaped relationship.

Several different functional forms of variables within model (1) were tested. The log-level format fit the data best so it was chosen as the final model. The socioeconomic covariates—population estimates and aggregate commute times—are both expected to enter (1) with a positive sign; i.e., population size and commute times are expected to increase emission levels on average. The meteorological covariates will have somewhat ambiguous affects in (1) in that meteorological factors affect each of the criterion pollutants in a unique way. For example, Camalier, Cox, and Dolwick (2007) argue that increased temperatures usually increase ground level ozone, but high winds speeds may decrease ozone concentrations within a particular area.

A time-demeaned, fixed effects panel regression was used to estimate equation (1). A fixed effects model was chosen to allow for arbitrary correlation between y_{it} and c_i, the unobserved heterogeneity, within the model. By using the fixed effects transformation, the unobserved heterogeneity (or unobserved effects) is eliminated when the data is time-demeaned. Such a transformation helps the model control for unobserved factors (such as technology) that may decrease pollution emissions levels absent any changes in GDP. To control for heteroskedasticity in the model, heteroskedastic-robust standard errors were estimated

(Wooldridge, 2002). According to Wooldridge (2002), the heteroskedastic-robust standard errors are robust to heteroskedasticity, therefore, they are asymptotically valid. Thus normal hypothesis testing procedures can ensue. To ensure that these standard errors are asymptotically valid a second fixed effects regression was conducted using a panel bootstrapped procedure with 399 replications.[v] According to Cameron and Trivedi (2005), bootstrapping procedures can provide asymptotic refinements that can lead to better approximation in-finite samples.

A first-differenced (FD) estimator could also be used to estimate model (1) as its procedure involves the fixed effects transformation to eliminate the unobserved heterogeneity. Wooldridge (2002) argues that a fixed effects (FE) estimator is more efficient than a first-differenced (FD) estimator if the residuals are serially uncorrelated. He adds that the FD estimator is more efficient if the residuals follow a random walk. However, he claims that the true efficient estimator often lies somewhere in between the two the regression types (Wooldridge, 2002). Therefore, a test for serial correlation among the residuals for all regressions was conducted for each of the pollutants. Because the truth may like somewhere in between the two procedures, both the FE and FD regressions are conducted along with a FE regression with bootstrap estimated errors for all the pollutants at both the state and metropolitan level.

Data

The GDP data (both metropolitan statistical area and state) for this study were obtained from the Bureau of Economic Analysis (BEA) within the U.S. Department of Commerce (2008). All values are represented in real GDP (in 2000 U.S. billion dollars). The BEA only has metropolitan GDP data available for the years 2001-2005, so that time period was used as the basis for the state and regional GDP data range.

The air pollution emissions data were obtained from the EPA's AQS data mart (U.S. EPA, 2008). The criterion pollutants include carbon monoxide, ground level ozone, lead, nitrogen dioxide, particulate matter, and sulfur dioxide. The lead measures were not abundant enough among the data set and therefore were dropped later from the analysis. Particulate matter is broken down in two categories: one, less than 2.5 micrometers in diameter (smoke or haze) and two, greater than 2.5 but less than 10 micrometers in diameter (the EPA defines this as "inhalable coarse particles" (U.S. EPA, 2008). The concentrations of each pollutant were averaged across the reported emissions within a particular area for the year. By averaging concentrations, temporal variability is lost; however, the loss is acceptable because the goal of this research is to uncover general relationships underlying emissions and GDP.

The BEA's measure of metropolitan GDP included 364 MSAs. Because of time constraints the data was parsed to only examine the top four most populace MSAs within each state—that reduced the data set to 173 MSAs.[vi] Of the four most populace MSAs, a particular metropolitan area was dropped from the analysis if it did not possess at least three of the six criterion pollutants—this reduced the observations to the final number of 127 MSAs.

The socioeconomic covariates include population estimates and aggregate commute time for workers over 16 years of age. The population estimates were obtained from the U.S. Census Bureau's annual population estimates 2000-2008 (U.S. Census, 2008). The aggregate commute time estimates were obtained from the U.S. Census Bureau's American Community Survey (U.S. Census, 2008). Aggregate commute time is the sum of time each worker (who does not work at home and is over the age of 16) within an MSA or (state) spends round trip commuting to work and then back home—it is measured in minutes. Aggregate commute time is used as a proxy to estimate traffic congestion within a metropolitan area. Traffic congestion often leads to higher levels of emissions including carbon monoxide.

The meteorological covariates include average direct solar radiation, precipitation, average temperature, opacity of cloud cover, relative humidity, and average wind speed. The meteorological data were obtained from the National Oceanic and Atmospheric Administration's (NOAA) National Solar Radiation Data Base (NOAA, 2008). The meteorological covariates are used as means to control for exogenous variables that may affect the relationship between emissions and GDP.

[Place Table 1 Approximately Here]

Estimation Results

Carbon Monoxide

Tables 2 and 3 represent the estimation results for carbon monoxide at the MSA and state level. A test for serial correlation among the estimated residuals indicated that residuals were serially uncorrelated at the MSA level, but correlated at the state level. Therefore, the FE estimator should be sufficient at the MSA level, but the FD estimator should be sufficient at the state level. As can be gleaned in the results, both current GDP and current GDP-squared is statistically significant at the 5% level with the FE estimates; however, the FE estimates with the bootstrap estimated standard errors (SEs) are not significant. With the small sample size, the FE bootstrap estimates may have better asymptotic refinements than the FE robust estimates. Thus, there appears to be some evidence that economic growth has an effect on CO emissions in urban areas, but the results are skeptical. These findings seem to imply a U-shaped relationship between CO and GDP. According to EPA (2008), carbon monoxide is primarily an urban problem—56% of CO emissions are created by car exhaust. Therefore, significant results are expected at the MSA level.

[Place Table 2 Approximately Here]

[Place Table 3 Approximately Here]

The results for the state level estimates are listed in Table 3. As revealed above there was serial correlation at the state level; however, Wooldridge (2002) indicated that the true most efficient estimator may lie somewhere between FE and FD in the presence of serial correlation. None of the FD estimators are significant, but all the FE estimators are significant including the one with bootstrap estimated SEs. Due to the serial correlation, however, these estimates are viewed with a bit of skepticism. Given the lack of significance of the GDP-squared term in the FE bootstrap model it appears that CO emissions are decreasing monotonically with economic growth at the state level. The EPA (2008) indicates a decreasing trend in national average CO concentrations since 1980.

[Place Table 4 Approximately Here]

[Place Table 5 Approximately Here]

Nitrogen Dioxide

The results for the nitrogen dioxide estimates are listed in Tables 4 and 5. The test for serial correlation among the residuals indicated that NO_2 had serial correlation at both the MSA and state level. Both current GDP and current GDP-squared are marginally significant (10% level) with the FD estimator which is arguably the most efficient estimate under serial correlation. Because the signs for GDP and GDP-squared are negative and positive respectively, these results offer weak evidence for a U-shaped relationship between NO_2 and GDP.

The state estimates listed in Table 5 indicate that current GDP and current GDP-squared are marginally significant with the FE estimates, however in the presence of serial correlation these estimates are highly suspect. Current GDP in the FD model (which is arguably more efficient) is marginally significant at the 10% level, whereas current GDP-squared in the same model is insignificant. Thus, it appears that NO_2 emissions are decreasing monotonically with GDP at the state level. Like the CO emissions, the EPA (2008) indicates that NO_2 emissions have been trending downward since 1980.

[Place Table 6 Approximately Here]

[Place Table 7 Approximately Here]

Ground level ozone

The results for the ozone estimates are listed in Tables 6 and 7. The test for serial correlation found that the residuals were not correlated at the MSA level, but were correlated at the state level. Based upon this result, the FE estimator is arguably more efficient at the MSA level, but the FD estimator is more efficient at the state level. At the MSA level the GDP estimates are statistically significant across all the regressions except for the FE with the bootstrap SEs; these estimates are highly statistically significant (1% level) in both FD models. The GDP-squared estimates are significant across the same regressions and again are highly significant (1% level) in the current FD model and significant in the lagged FD model (5%). Given the robustness across the models it appears that GDP has an effect on ground level ozone, although this is viewed with a bit of skepticism given the lack of the significance of the FE bootstrap estimates. The regressions seem to indicate that a U-shaped relationship exists between O_3 emissions and GDP.

According to the EPA (2008), ground level ozone is primarily of an urban problem, but wind can carry O_3 concentrations to rural areas, so it is possible but not likely that state-level results will be significant. As Table 7 indicates none of the estimators are significant at the state level, which is consistent with expectations.

[Place Table 8 Approximately Here]

[Place Table 9 Approximately Here]

Particulate Matter (less than 10 micrometers in diameter)

As can be gleaned in the MSA results in Tables 8 and 9, GDP is insignificant across all regression models at both the MSA and state level. Thus, GDP seems to have no affect on PM_{10} emissions. The EPA (2008) indicates that PM_{10} concentrations have been decreasing nationally since 1980.

[Place Table 10 Approximately Here]

[Place Table 11 Approximately Here]

Particulate Matter (less than 2.5 micrometers in diameter)

A test for serial correlation amongst the residuals in the $PM_{2.5}$ estimates indicated serial correlation; thus, FD estimates should be more efficient. The estimates within the FD model for lagged GDP and lagged GDP-squared are both statistically significant at the .05 level as can be seen in Table 10, although because the FE bootstrap model is not significant these findings are suspect. Again, the sign of GDP is negative and GDP-squared is positive indicating a U-shaped relationship between GDP and $PM_{2.5}$.

The results for the state level estimates are listed in Table 11. As with the PM_{10} estimates, none of the estimates for $PM_{2.5}$ are significant at the state level. The EPA (2008) only began to monitor $PM_{2.5}$ in 1999, yet the EPA still finds a decreasing trend in that short time.

[Place Table 12 Approximately Here]

[Place Table 13 Approximately Here]

Sulfur Dioxide

The results for the sulfur dioxide estimates are listed in Tables 12 and 13. The test for serial correlation indicated that no serial correlation at the MSA level, but correlation at the state level. As can be gleaned in Table 10, only the FE regressions yielded statistically significant results, except for the FE regression with the bootstrap SEs. The results of the FE bootstrap regression throw some doubt on the asymptotic validity of the FE results. Nevertheless, the signs of both GDP and GDP-squared in both regressions indicate again a U-shaped relationship. The lagged GDP estimates seem to have a larger affect on average on SO_2 emission than current GDP.

The state level results for the sulfur dioxide estimates are listed in Table 13. Only the FD model finds a marginally significant relationship at the state level—which given the serial correlation should be the more efficient model. GDP is only marginally significant at the 10% level and GDP-squared is statistically significant at the 5% level with negative and positive signs respective. Again, these findings seem to indicate U-shaped relationship. The EPA (2008) argues that SO2 emissions have decreased substantially since 1980.

Conclusion

This study examined the EKC hypothesis using more localized data analysis than previous studies. Using the local emissions and GDP data, this study finds no support for the inverse-U shaped relationship as proposed by some earlier studies. Instead this study find weak evidence at the MSA level for a U-shaped relationships with carbon monoxide, nitrogen dioxide, particulate matter (less than 2.5 micrometers in diameter), and sulfur dioxide. Weak evidence for a U-shaped relationship with sulfur dioxide is also found at the state level. Stronger evidence was found for a U-shaped relationship with ground level ozone at the MSA level. Carbon monoxide and nitrogen dioxide were found to be monotonically decreasing with GDP at the state level.

Given the preponderance of U-shaped relationship found it would appear that Deacon and Norman's (2004) alternative hypothesis fit the data empirically. Deacon and Norman (2004) posit that public support for environmental protection and regulation has sparked efforts to improve environmental quality. This study on the whole found some weak evidence for a U-shaped relationship, but the marginal effects of the GDP-squared variable were very small across all the pollutants. Therefore, a more plausible explanation seems to be that the emissions decreased with GDP. This explanation seems to fit Deacon and Norman's (2004) proposed hypothesis. Therefore, this study seems to find little evidence to support the EKC hypothesis.

Future Research

This study could have benefited by having a longer data set than 2001-2005; however, the BEA only started estimating GDPs for MSAs starting in 2001.

This study could also benefit from more accurate measures of pollution emissions. Emissions are measured often by several different monitoring stations within a particular area. There is a high likelihood of spatial correlation within the emissions data. More accurate measures may come from spatial statistics models.

[i] The U.S. Environmental Protection Agency's Air Quality System utilizes 5,000 active monitoring stations within the U.S. (U.S. EPA, 2008).

[ii] Shafik and Bandyopadhyay's study included 149 countries for the period 1960-1990

[iii] The identified air pollutants were suspended particulate matter, sulfur dioxide, nitrogen oxide, and carbon dioxide

[iv] These relationships are provided by Dinda (2004). Some previous studies, such as Dinda (2004), include a cubic functional form of GDP in the right hand side of equation (1). The cubic form was insignificant across all the regressions of the criterion pollutants at both metropolitan and state level, so it was not included in this analysis.

[v] The number of replications was chosen based upon the findings of Davidson and MacKinnon (2000), who recommend 399 replications for tests at significance level of 0.05.

[vi] It should be noted that parsing the data presents no serious problem to the analysis since the purpose of this study is not infer a causal relationship to some population.

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Appendix

Table 1. Definition of Variables Used in Panel Data Analysis

Variable name	Variable Label
ln(CO)	Natural log of carbon monoxide
ln(NO_2)	Natural log of nitrogen dioxide
ln(O_3)	Natural log of ground level ozone
ln($PM_{2.5}$)	Natural log of particulate matter <2.5 micrometers
ln(PM_{10})	Natural log of particulate matter >2.5, <10 micrometers
ln(SO_2)	Natural log of sulfur dioxide
GDP	Gross domestic product, (2000, U.S. $Billion)
GDP^2	Gross domestic product—squared
Pop	Estimated population
Comm	Aggregate commute time to work in minutes
Avdir	Average Direct Solar Radiation
Tot	Total overhead sky opacity
Opq	Opacity (cloud cover)
H_2O	Average annual precipitation
Avtemp	Average annual temperature
Rh	Relative humidity
Avws	Average wind speed

Table 2. Carbon Monoxide MSA Estimates

	FE	FE Boot[a]	FE Lag GDP[b]	FD	FD Lag GDP[c]
VARIABLES	ln(CO)	ln(CO)	ln(CO)	ln(CO)	ln(CO)
gdp	-0.0115**	-0.0115	-0.0205	-0.0111	-0.0195
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
gdpsq	0.0000**	0.0000	0.0000**	0.0000	0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
pop	0.0000*	0.0000	0.0000	0.0000	0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
comm	-0.0000	-0.0000	0.0000	0.0000	-0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
avdir	0.0001	0.0001	0.0002**	0.0002**	0.0004***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
tot	0.0378	0.0378	0.0718	0.1007	0.0619
	(0.16)	(0.18)	(0.21)	(0.21)	(0.27)
opq	-0.0362	-0.0362	-0.0315	-0.0645	-0.0063
	(0.16)	(0.18)	(0.22)	(0.22)	(0.30)
htwoo	0.1296	0.1296	0.4049*	0.3701*	0.3385
	(0.08)	(0.09)	(0.22)	(0.20)	(0.27)
avtemp	-0.0137	-0.0137	-0.0278	-0.0269	-0.0135
	(0.02)	(0.02)	(0.03)	(0.03)	(0.05)
rh	0.0031	0.0031	0.0029	0.0056	0.0184
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
avws	-0.0294	-0.0294	-0.0485	-0.0445	-0.0800
	(0.08)	(0.08)	(0.08)	(0.10)	(0.14)
Constant	7.8558***	7.8558***	7.0745***	5.5734***	3.9496**
	(1.05)	(1.16)	(1.47)	(1.25)	(1.66)
Observations	327	327	268	227	169
Number of city	100	100	99	59	57
R-squared	0.03	0.03	0.09	.	.

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

a. This is the fixed effects model with the bootstrap estimated standard errors.
b. This is the fixed effects model with lag terms for GDP and GDP-squared.
c. This is the first-differenced model with lag terms for GDP and GDP-squared.

Table 3. Carbon Monoxide State Estimates

	FE	FE Boot[a]	FE Lag GDP[b]	FD	FD Lag GDP[c]
VARIABLES	ln(CO)	ln(CO)	ln(CO)	ln(CO)	ln(CO)
gdp	-0.0131***	-0.0131**	-0.0134**	-0.0082	-0.0092
	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)
gdpsq	0.0000***	0.0000	0.0000**	0.0000	0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
pop	0.0000	0.0000	0.0000	0.0000	0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
comm	0.0000*	0.0000	0.0000	-0.0000	-0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
avdir	-0.0000	-0.0000	0.0001	0.0001	0.0002*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
tot	-0.1964	-0.1964	-0.3463	-0.2834	-0.5015*
	(0.47)	(0.46)	(0.47)	(0.22)	(0.27)
opq	0.1301	0.1301	0.1929	0.2714	0.5477*
	(0.49)	(0.48)	(0.47)	(0.23)	(0.29)
htwoo	0.0690	0.0690	0.5005*	0.2690	0.1862
	(0.23)	(0.24)	(0.28)	(0.16)	(0.27)
avtemp	-0.0097	-0.0097	-0.0142	0.0191	0.0477
	(0.05)	(0.04)	(0.04)	(0.03)	(0.04)
rh	0.0034	0.0034	0.0140	0.0041	0.0106
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
avws	-0.0877	-0.0877	-0.1123	-0.0736	-0.0080
	(0.15)	(0.16)	(0.23)	(0.09)	(0.13)
Constant	11.3015***	11.3015***	9.7092***	7.7287***	8.1002***
	(1.81)	(2.27)	(1.97)	(0.89)	(1.38)
Observations	244	244	195	195	146
Number of state	49	49	49	49	49
R-squared	0.08	0.08	0.12	.	.

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

a. This is the fixed effects model with the bootstrap estimated standard errors.
b. This is the fixed effects model with lag terms for GDP and GDP-squared.
c. This is the first-differenced model with lag terms for GDP and GDP-squared.

Table 4. Nitrogen Dioxide MSA Estimates

	FE	FE Boot[a]	FE Lag GDP[b]	FD	FD Lag GDP[c]
VARIABLES	$\ln(NO_2)$	$\ln(NO_2)$	$\ln(NO_2)$	$\ln(NO_2)$	$\ln(NO_2)$
gdp	-0.0064	-0.0064	-0.0123*	-0.0105*	-0.0171*
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
gdpsq	0.0000	0.0000	0.0000**	0.0000*	0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
pop	0.0000	0.0000	0.0000	0.0000**	0.0000*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
comm	0.0000	0.0000	0.0000	-0.0000	-0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
avdir	0.0002*	0.0002*	0.0002**	0.0001	0.0002*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
tot	-0.1872*	-0.1872*	-0.2384	-0.1855	-0.0906
	(0.10)	(0.11)	(0.15)	(0.19)	(0.23)
opq	0.2410**	0.2410**	0.2619	0.1699	0.0161
	(0.11)	(0.12)	(0.17)	(0.20)	(0.26)
htwoo	0.0527	0.0527	0.0662	0.0660	0.0614
	(0.09)	(0.10)	(0.20)	(0.14)	(0.19)
avtemp	0.0027	0.0027	0.0187	0.0064	0.0034
	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)
rh	0.0084	0.0084	0.0183**	0.0155**	0.0176**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
avws	-0.0126	-0.0126	-0.0100	0.0417	0.1543
	(0.08)	(0.08)	(0.09)	(0.08)	(0.11)
Constant	7.3373***	7.3373***	6.1198***	6.2268***	5.8738***
	(0.93)	(1.02)	(1.17)	(1.04)	(1.43)
Observations	211	211	173	143	109
Number of city	68	68	64	37	37
R-squared	0.06	0.06	0.16	.	.

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

a. This is the fixed effects model with the bootstrap estimated standard errors.
b. This is the fixed effects model with lag terms for GDP and GDP-squared.
c. This is the first-differenced model with lag terms for GDP and GDP-squared.

Table 5. Nitrogen Dioxide State Estimates

	FE	FE Boot[a]	FE Lag GDP[b]	FD	FD Lag GDP[c]
VARIABLES	$\ln(NO_2)$	$\ln(NO_2)$	$\ln(NO_2)$	$\ln(NO_2)$	$\ln(NO_2)$
gdp	-0.0148*	-0.0148	-0.0276*	-0.0191	-0.0251
	(0.01)	(0.01)	(0.02)	(0.01)	(0.02)
gdpsq	0.0000*	0.0000	0.0000	0.0000	0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
pop	0.0000	0.0000	0.0000	0.0000	0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
comm	0.0000	0.0000	0.0000	0.0000	0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
avdir	0.0004	0.0004	0.0005*	0.0005	0.0002
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
tot	-0.6114	-0.6114	-0.6761	-0.3564	-0.4842
	(0.67)	(0.63)	(0.51)	(0.66)	(0.60)
opq	0.9547	0.9547	1.0630*	0.7716	0.8296
	(0.70)	(0.68)	(0.62)	(0.68)	(0.63)
htwoo	-0.4124	-0.4124	-0.2397	-0.0516	-0.5399
	(0.48)	(0.49)	(0.36)	(0.59)	(0.63)
avtemp	0.0652	0.0652	0.0634	0.0262	0.1350
	(0.07)	(0.07)	(0.08)	(0.09)	(0.10)
rh	0.0033	0.0033	0.0031	0.0029	-0.0029
	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)
avws	-0.1528	-0.1528	-0.4583	-0.2736	-0.1322
	(0.21)	(0.23)	(0.28)	(0.27)	(0.29)
Constant	7.4534***	7.4534***	9.2544***	6.6577**	9.7731***
	(2.49)	(2.74)	(2.30)	(3.17)	(3.39)
Observations	243	243	195	194	146
Number of state	49	49	49	49	49
R-squared	0.05	0.05	0.08	.	.

*** p<0.01, ** p<0.05, * p<0.1
Robust standard errors in parentheses

a. This is the fixed effects model with the bootstrap estimated standard errors.
b. This is the fixed effects model with lag terms for GDP and GDP-squared.
c. This is the first-differenced model with lag terms for GDP and GDP-squared.

Table 6. Ozone MSA Estimates

	FE	FE Boot[a]	FE Lag GDP[b]	FD	FD Lag GDP[c]
VARIABLES	$\ln(O_3)$	$\ln(O_3)$	$\ln(O_3)$	$\ln(O_3)$	$\ln(O_3)$
gdp	-0.0126**	-0.0126	-0.0192**	-0.0176***	-0.0285***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
gdpsq	0.0000**	0.0000	0.0000***	0.0000***	0.0000**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
pop	0.0000**	0.0000	0.0000	0.0000**	0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
comm	0.0000	0.0000	0.0000	-0.0000	-0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
avdir	0.0001	0.0001	0.0001	0.0000	0.0001
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
tot	-0.0230	-0.0230	-0.0537	0.0061	-0.1161
	(0.10)	(0.11)	(0.16)	(0.14)	(0.17)
opq	0.0591	0.0591	0.0539	-0.0190	0.1703
	(0.11)	(0.11)	(0.17)	(0.15)	(0.19)
htwoo	-0.0479	-0.0479	-0.0586	0.0061	0.0863
	(0.08)	(0.08)	(0.19)	(0.13)	(0.17)
avtemp	0.0058	0.0058	0.0100	-0.0069	-0.0272
	(0.02)	(0.02)	(0.03)	(0.02)	(0.03)
rh	-0.0019	-0.0019	0.0025	0.0019	-0.0008
	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)
avws	-0.0395	-0.0395	-0.0460	-0.0149	-0.1040
	(0.04)	(0.04)	(0.04)	(0.07)	(0.09)
Constant	8.5267***	8.5267***	8.3788***	8.1884***	8.4862***
	(0.48)	(0.56)	(0.68)	(0.82)	(1.00)
Observations	311	311	258	217	164
Number of city	94	94	94	56	56
R-squared	0.05	0.05	0.07	.	.

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

a. This is the fixed effects model with the bootstrap estimated standard errors.
b. This is the fixed effects model with lag terms for GDP and GDP-squared.
c. This is the first-differenced model with lag terms for GDP and GDP-squared.

Table 7. Ground Level Ozone State Estimates

	FE	FE Boot[a]	FE Lag GDP[b]	FD	FD Lag GDP[c]
VARIABLES	$\ln(O_3)$	$\ln(O_3)$	$\ln(O_3)$	$\ln(O_3)$	$\ln(O_3)$
gdp	-0.0002	-0.0002	0.0030	-0.0024	-0.0053
	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)
gdpsq	-0.0000	-0.0000	-0.0000	0.0000	0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
pop	0.0000	0.0000	0.0000	0.0000	-0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
comm	-0.0000	-0.0000	-0.0000	-0.0000	0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
avdir	0.0001	0.0001	0.0002	0.0001	0.0001
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
tot	-0.4678	-0.4678	-0.3111	-0.0563	0.1003
	(0.31)	(0.31)	(0.36)	(0.22)	(0.28)
opq	0.4742	0.4742	0.2383	-0.0066	-0.1720
	(0.34)	(0.34)	(0.39)	(0.23)	(0.29)
htwoo	0.1201	0.1201	0.6898*	0.3989**	0.6311**
	(0.17)	(0.17)	(0.40)	(0.18)	(0.29)
avtemp	-0.0019	-0.0019	-0.0062	-0.0276	-0.0760*
	(0.05)	(0.04)	(0.06)	(0.03)	(0.04)
rh	0.0024	0.0024	0.0141	0.0036	-0.0069
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
avws	0.0583	0.0583	0.0128	0.0384	0.2453*
	(0.12)	(0.12)	(0.16)	(0.09)	(0.13)
Constant	10.0255***	10.0255***	7.9280***	9.9807***	12.7616***
	(1.59)	(1.53)	(1.60)	(0.94)	(1.46)
Observations	254	254	203	203	152
Number of state	51	51	51	51	51
R-squared	0.04	0.04	0.07	.	.

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

a. This is the fixed effects model with the bootstrap estimated standard errors.
b. This is the fixed effects model with lag terms for GDP and GDP-squared.
c. This is the first-differenced model with lag terms for GDP and GDP-squared.

Table 8. Particulate Matter (Less than 10 micrometers) MSA Estimates

	FE	FE Boot[a]	FE Lag GDP[b]	FD	FD Lag GDP[c]
VARIABLES	$\ln(PM_{10})$	$\ln(PM_{10})$	$\ln(PM_{10})$	$\ln(PM_{10})$	$\ln(PM_{10})$
gdp	0.0176	0.0176	0.0051	0.0042	-0.0172
	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)
gdpsq	-0.0000	-0.0000	-0.0000	-0.0000	0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
pop	-0.0000	-0.0000	0.0000	0.0000	0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
comm.	0.0000	0.0000	0.0000	0.0000	0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
avdir	0.0001	0.0001	0.0003	0.0003	0.0004*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
tot	0.8267	0.8267*	1.1366	0.8682*	0.2482
	(0.51)	(0.50)	(0.71)	(0.47)	(0.36)
opq	-0.8041*	-0.8041*	-1.1240	-0.7691	0.0153
	(0.48)	(0.48)	(0.71)	(0.50)	(0.40)
htwoo	0.6076	0.6076	0.6314	0.7607*	0.4815
	(0.40)	(0.40)	(0.51)	(0.39)	(0.33)
avtemp	-0.0366	-0.0366	-0.0513	-0.0421	-0.1051
	(0.05)	(0.05)	(0.06)	(0.08)	(0.07)
rh	0.0191*	0.0191	0.0263*	0.0195	-0.0095
	(0.01)	(0.01)	(0.02)	(0.02)	(0.01)
avws	-0.2164	-0.2164	0.0230	0.0708	0.0691
	(0.23)	(0.23)	(0.24)	(0.23)	(0.18)
Constant	2.6534	2.6534	-0.1487	-0.6494	2.5561
	(2.41)	(2.63)	(2.36)	(2.53)	(1.84)
Observations	334	334	274	222	164
Number of city	112	112	110	59	58
R-squared	0.07	0.07	0.07	.	.

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

a. This is the fixed effects model with the bootstrap estimated standard errors.
b. This is the fixed effects model with lag terms for GDP and GDP-squared.
c. This is the first-differenced model with lag terms for GDP and GDP-squared.

Table 9. Particulate Matter (less than 10 micrometers) State Estimates

	FE	FE Boot[a]	FE Lag GDP[b]	FD	FD Lag GDP[c]
VARIABLES	ln(PM_{10})	ln(PM_{10})	ln(PM_{10})	ln(PM_{10})	ln(PM_{10})
gdp	-0.0064	-0.0064	0.0106	-0.0037	-0.0011
	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)
gdpsq	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
pop	0.0000***	0.0000**	0.0000	0.0000	0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
comm	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
avdir	0.0001	0.0001	0.0008	0.0006	0.0006
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
tot	0.1706	0.1706	0.5973	1.0811	1.6795
	(1.19)	(1.31)	(0.93)	(0.92)	(1.10)
opq	0.6314	0.6314	0.0918	-0.9094	-1.5535
	(1.40)	(1.52)	(1.08)	(0.95)	(1.16)
htwoo	-1.4537**	-1.4537**	0.2431	-0.4181	0.1183
	(0.69)	(0.67)	(0.67)	(0.72)	(1.14)
avtemp	0.1957	0.1957	0.1560	0.0569	0.0917
	(0.13)	(0.13)	(0.16)	(0.13)	(0.17)
rh	-0.0093	-0.0093	0.0574*	0.0833**	0.0810*
	(0.04)	(0.04)	(0.03)	(0.03)	(0.04)
avws	-0.3389	-0.3389	-0.4371	-0.3177	-0.1009
	(0.47)	(0.52)	(0.48)	(0.39)	(0.52)
Constant	0.3287	0.3287	-6.4805	-2.6526	-10.1764*
	(3.91)	(5.15)	(4.91)	(3.84)	(5.79)
Observations	255	255	204	204	153
Number of state	51	51	51	51	51
R-squared	0.09	0.09	0.10	.	.

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

a. This is the fixed effects model with the bootstrap estimated standard errors.
b. This is the fixed effects model with lag terms for GDP and GDP-squared.
c. This is the first-differenced model with lag terms for GDP and GDP-squared.

Table 10. Particulate Matter (Less than 2.5 micrometers) MSA Estimates

	FE	FE Boot[a]	FE Lag GDP[b]	FD	FD Lag GDP[c]
VARIABLES	$\ln(PM_{2.5})$	$\ln(PM_{2.5})$	$\ln(PM_{2.5})$	$\ln(PM_{2.5})$	$\ln(PM_{2.5})$
gdp	-0.0135*	-0.0135	-0.0316**	-0.0067	-0.0410**
	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)
gdpsq	0.0000**	0.0000	0.0000**	0.0000	0.0000**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
pop	0.0000	0.0000	0.0000	-0.0000	0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
comm	-0.0000	-0.0000	0.0000	0.0000	0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
avdir	0.0001	0.0001	0.0002	0.0002	0.0001
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
tot	-0.0492	-0.0492	0.0701	0.0161	0.3181
	(0.38)	(0.38)	(0.29)	(0.30)	(0.33)
opq	0.0021	0.0021	-0.0942	-0.0252	-0.3186
	(0.36)	(0.37)	(0.29)	(0.31)	(0.37)
htwoo	0.1083	0.1083	0.3170	0.3574	0.2365
	(0.15)	(0.16)	(0.25)	(0.23)	(0.33)
avtemp	-0.0101	-0.0101	-0.0136	-0.0199	0.0233
	(0.06)	(0.06)	(0.05)	(0.05)	(0.06)
rh	0.0004	0.0004	0.0021	0.0039	0.0168
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
avws	0.0507	0.0507	0.0659	0.0190	-0.2535
	(0.15)	(0.17)	(0.16)	(0.14)	(0.17)
Constant	5.2592***	5.2592***	3.9048**	4.0353***	3.3463*
	(1.59)	(1.67)	(1.51)	(1.33)	(1.75)
Observations	380	380	315	260	195
Number of city	120	120	120	67	67
R-squared	0.02	0.02	0.05	.	.

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

a. This is the fixed effects model with the bootstrap estimated standard errors.
b. This is the fixed effects model with lag terms for GDP and GDP-squared.
c. This is the first-differenced model with lag terms for GDP and GDP-squared.

Table 11. Particulate Matter (less than 2.5 micrometers) State Estimates

	FE	FE Boot[a]	FE Lag GDP[b]	FD	FD Lag GDP[c]
VARIABLES	ln($PM_{2.5}$)	ln($PM_{2.5}$)	ln($PM_{2.5}$)	ln($PM_{2.5}$)	ln($PM_{2.5}$)
gdp	-0.0067	-0.0067	-0.0088	-0.0042	-0.0046
	(0.00)	(0.01)	(0.01)	(0.00)	(0.01)
gdpsq	0.0000	0.0000	0.0000	0.0000	0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
pop	-0.0000	-0.0000	-0.0000	0.0000	0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
comm	0.0000**	0.0000**	0.0000	-0.0000	0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
avdir	-0.0000	-0.0000	0.0001	0.0001	0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
tot	0.1918	0.1918	-0.0822	0.1429	0.0473
	(0.25)	(0.25)	(0.21)	(0.18)	(0.18)
opq	-0.3062	-0.3062	-0.0636	-0.1854	-0.0435
	(0.26)	(0.26)	(0.21)	(0.18)	(0.19)
htwoo	0.0562	0.0562	0.2392	0.2488*	0.0626
	(0.15)	(0.15)	(0.18)	(0.14)	(0.19)
avtemp	-0.0602	-0.0602	-0.0500	-0.0158	0.0313
	(0.05)	(0.05)	(0.04)	(0.02)	(0.03)
rh	0.0029	0.0029	-0.0016	-0.0005	-0.0003
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
avws	0.3118**	0.3118**	0.3735**	0.2723***	0.0941
	(0.12)	(0.13)	(0.15)	(0.08)	(0.09)
Constant	8.7240***	8.7240***	8.3311***	5.4562***	5.8009***
	(1.49)	(1.66)	(1.42)	(0.72)	(0.95)
Observations	255	255	204	204	153
Number of state	51	51	51	51	51
R-squared	0.18	0.18	0.22	.	.

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

a. This is the fixed effects model with the bootstrap estimated standard errors.
b. This is the fixed effects model with lag terms for GDP and GDP-squared.
c. This is the first-differenced model with lag terms for GDP and GDP-squared.

Table 12. Sulfur Dioxide MSA Estimates

	FE	FE Boot[a]	FE Lag GDP[b]	FD	FD Lag GDP[c]
VARIABLES	ln(SO_2)	ln(SO_2)	ln(SO_2)	ln(SO_2)	ln(SO_2)
gdp	-0.0151**	-0.0151	-0.0347***	-0.0191	-0.0274
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)
gdpsq	0.0000**	0.0000	0.0000***	0.0000	0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
pop	0.0000*	0.0000	0.0000*	0.0000	0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
comm	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
avdir	0.0001	0.0001	0.0002	0.0001	0.0005**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
tot	-0.2346	-0.2346	-0.0729	0.0111	0.0418
	(0.38)	(0.35)	(0.48)	(0.45)	(0.49)
opq	0.1463	0.1463	-0.0902	-0.2100	-0.1546
	(0.41)	(0.39)	(0.51)	(0.47)	(0.53)
htwoo	0.0988	0.0988	0.2288	0.1739	0.3768
	(0.15)	(0.17)	(0.27)	(0.33)	(0.37)
avtemp	0.0313	0.0313	0.0284	0.0367	-0.0372
	(0.05)	(0.05)	(0.06)	(0.07)	(0.08)
rh	0.0092	0.0092	0.0156	0.0214	0.0327*
	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)
avws	0.0524	0.0524	-0.0552	-0.0949	-0.2758
	(0.12)	(0.13)	(0.13)	(0.20)	(0.22)
Constant	7.3748***	7.3748***	6.6469**	6.1005**	6.0850**
	(1.63)	(1.78)	(2.56)	(2.44)	(2.82)
Observations	238	238	196	160	120
Number of city	78	78	76	42	41
R-squared	0.06	0.06	0.12	.	.

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

a. This is the fixed effects model with the bootstrap estimated standard errors.
b. This is the fixed effects model with lag terms for GDP and GDP-squared.
c. This is the first-differenced model with lag terms for GDP and GDP-squared.

Table 13. Sulfur Dioxide State Estimates

	FE	FE Boot[a]	FE Lag GDP[b]	FD	FD Lag GDP[c]
VARIABLES	ln(CO)	ln(CO)	ln(CO)	ln(CO)	ln(CO)
gdp	-0.0063	-0.0063	-0.0032	-0.0158*	-0.0004
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
gdpsq	0.0000	0.0000	0.0000	0.0000**	0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
pop	0.0000	0.0000	-0.0000	0.0000	-0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
comm	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
avdir	0.0003	0.0003	0.0003	0.0002	-0.0000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
tot	0.9261*	0.9261*	1.0492	0.2086	-0.1496
	(0.51)	(0.56)	(0.74)	(0.42)	(0.38)
opq	-0.7353	-0.7353	-0.8641	0.0919	0.2971
	(0.47)	(0.51)	(0.74)	(0.43)	(0.40)
htwoo	-0.1127	-0.1127	-0.4492	-0.2850	-0.2823
	(0.38)	(0.38)	(0.51)	(0.34)	(0.39)
avtemp	-0.0362	-0.0362	-0.0322	0.0164	0.0986
	(0.07)	(0.07)	(0.06)	(0.06)	(0.06)
rh	-0.0046	-0.0046	-0.0043	-0.0155	-0.0004
	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)
avws	0.2722*	0.2722*	0.1383	0.1030	0.0885
	(0.14)	(0.16)	(0.18)	(0.17)	(0.18)
Constant	9.1855***	9.1855***	11.7208***	12.1544***	13.2838***
	(2.44)	(2.87)	(2.36)	(1.84)	(2.01)
Observations	246	246	198	196	148
Number of state	50	50	50	50	50
R-squared	0.05	0.05	0.05	.	.

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

a. This is the fixed effects model with the bootstrap estimated standard errors.
b. This is the fixed effects model with lag terms for GDP and GDP-squared.
c. This is the first-differenced model with lag terms for GDP and GDP-squared.