# Government Spending and Air Pollution in the US

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## Abstract

This study examines the effect of the composition of federal and state government spending on various important air pollutants in the US using a newly assembled data set of government expenditures. The results indicate that a reallocation of spending from private goods (RME) to social and public goods (PME) by state and local governments reduces air pollution concentrations while the composition of federal spending has no effect. A 10 percent increase in the share of social and public goods spending by state and local governments reduces air pollution concentrations by 3 to 5 percent for Sulfur Dioxide, 2 to 3 percent for Particulate Matter 2.5 and 1 to 2 percent for Ozone. The results are robust to various sensitivity checks.


## 1. Introduction

Much attention has been awarded to the arsenal of regulatory policy tools at the disposal of the US policy makers addressing environmental concerns. However, while many efforts have been devoted to study the effects of various economy-wide policies (most prominently trade policies) on the environment, little analysis has been done on the impact of other important economy-wide policies such as fiscal spending policies on environmental outcomes. This is surprising in view of the massive importance of government spending in the US economy. Furthermore, not much consideration has been given to the possible variation of fiscal policy impacts by the level of government. This paper explores the environmental implications when a government embarks on broad fiscal policy changes, altering the composition of government expenditures towards increasing the provision of social and public goods (PME spending) at the cost of private subsidies (RME spending) in order to correct market imperfections. The impact of compositional changes in spending is examined at two levels of government: federal government spending and combined state & local government spending. This link between of fiscal policy and the environment is important particularly because the 2008-2009 financial crisis has put US fiscal policy in the forefront of much debate and scrutiny especially with regards spending priorities.

This paper specifically investigates the impact of US government spending on sulfur dioxide (SO2), particulate matter 2.5 (PM2.5 - particulate matter of diameter size 2.5 microns or smaller) and ozone (O3) concentrations for the time periods 1985-2008, 2000-2008, and 1983-2008 respectively[1]. We study the effects of the size of fiscal expenditures and of a reallocation of spending from RME to PME at the state and local level as well as federal level using for the first time a new panel dataset of government expenditures spanning all states, covering the time period of 1983 to 2008, recently developed by Islam (2011).

We find that shifting the composition of local and state expenditures from RME to PME reduces air pollution concentrations of the three pollutants considered, while the composition of federal spending has no effect. Furthermore, the size of the state and local public sector expenditures has no significant effect on pollution. Total federal spending does have a significant effect on pollution but the sign of the effect is not robust. We find that a 10 percent increase in the share of state and local PME spending reduces air pollution concentrations by the range of 3 to 5 percent for Sulfur Dioxide, 2 to 3 percent for Particulate Matter 2.5 and 1 to 2 percent for Ozone. The results are robust to various sensitivity checks[2].

This study adds to a long literature that has examined the determinants of air pollutants in the US (List and Gallet, 1999; Khanna, 2002). A few studies have examined the impact of the 1990 Clean Air Act Amendments (CAAA) on PM10 concentrations (Aufhammer et al., 2009; Aufhammer et al.,2011), Ozone (Henderson, 1996), SO2 concentrations directly (Carlson et. al, 2000; Greenstone, 2004), as well as indirectly by examining the impact of 1990 CAAA on input substitution from high-sulfur to low-sulfur coal by utility plants (Gerking and Hamilton, 2010). In addition to regulation, community characteristics have also been found to be significant determinants of pollutants (Brooks and Sethi, 1997). In the wider literature there are several studies that have also explored the cross-country determinants of pollutants, specifying various

[1] The focus on SO2, PM2.5, and O3 is justified for several reasons. The data on these pollutants are available for a large period of time, especially for ozone and sulfur dioxide air concentrations. The adverse health effects of each of the three pollutants are well documented. Also since industrial activity is a significant contributor to SO2, PM 2.5 and Ozone air concentrations, the wide range of output elasticities in the literature for energy from a low of 0.01 to a high of 1.035 (Kamerschen and Porter, 2004; Liu, 2004) implies that we expect macro-economic factors to have an impact on the air pollution concentrations. For a full list of output elasticity measures see Table B7 in the online appendix (http://ter.ps/envappendix).

[2] An alternate approach to the current study would be use CGE models as carried out in the literature (Jorgenson and Wilcoxen, 1990). However, CGE models depend upon strong assumptions and lack of data precludes econometric estimation of key supply and demand parameters. Also, CGE models are more effective for global than local pollutants (Bergman, 2005).

mechanisms linking macro-economic factors such as income and trade to environmental outcomes (Shafik and Bandhopadhyay, 1992; Grossman and Krueger, 1995; Barrett and Grady, 2000, Antweiler, Copeland and Taylor, 2001; Frankel and Rose, 2005; Bernauer and Koubi, 2006; Deacon and Norman, 2007;).

This study builds on López, Galinato, and Islam (2011), which explores a similar relationship between government spending composition and pollution across countries. Limitations of López, Galinato, and Islam (2011) include difficulty in accounting for regulation in cross-country studies, highly aggregated spending data, and no distinction between the sources of the government expenditures. In addition, López, Galinato, and Islam (2011) only explore the relationship between government spending and production based pollutants while we also consider consumption based pollutants which has important implications (McAusland, 2008).

The contributions of this study to the literature can be summarized as follows (i) quantifying the relationship between US fiscal spending composition and air pollution using a newly developed highly disaggregated fiscal spending data set, (ii) exploring the difference in the impact of fiscal policy by the level of government, and (iii) using a new estimation method that accounts for time varying omitted variable bias using state specific polynomials of a time trend that exploit the available degrees of freedom. This estimation generalizes similar estimations that have been used in the literature (Cornwell et al., 1990; Jacobsen et al., 1993; Friedberg, 1998; Wolfers, 2006).

The paper is structured as follows. Section 2 provides an overview of SO2, PM 2.5, and O3 pollution sources and regulations implemented in the US. Sections 3, 4, 5, 6, 7 and 8 provide conceptual issues, econometric model, data description, results, robustness, and conclusions respectively.

## 2. Air Pollution Sources and Regulation

Table A6 presents the sources of the SO2 and PM2.5 emissions, and the O3 precursor pollutant emissions - NO and VOC. About 67% of SO2 emissions originate from fuel combustion in electric utilities, while another 23% is from Industrial fuel combustion and processes. The largest contributor towards PM 2.5 emissions is fugitive dust accounting for about 41% of overall emissions. Industrial fuel combustion and processes contribute around 14% of PM 2.5 emissions with forest and agricultural wildfires contributing about 13% and agricultural crops and livestock contributing another 13%. NO and VOC combine to form ground level O3, however the sources of their emissions differ in some respects. Both pollutants have transportation - both on-road and non-road vehicles as a significant source contributing 53% of NO and 44% of VOC emissions. However, although 25% and 16% of NO emissions are from electric utilities and industrial activities respectively, for VOCs, 47% comes from industrial activities with about 0.2% originating from electric utilities.

Air pollution regulation in the US comes in the form of air quality standards and Cap-and-Trade programs for certain pollutants. Initially air pollution regulation in the United States was under state and local government jurisdiction. The Clean Air Act in 1963, followed by the Air Quality Act of 1967 provided funds from the federal government to state and local governments for support and regulation of air pollution. However, the lack of enforcement and several delays in formulating standards by states led to the Clean Air Act Amendments (CAAA) of 1970. This engendered the EPA as well as the National Ambient Air Quality Standards (NAAQS), signaling federal involvement in air pollution control in the US. National air quality standards were published for six pollutants: Sulfur oxides, particulate matter, carbon monoxide, photochemical oxides (ground level ozone), nitrogen oxides, and hydrocarbons (mostly via ozone standards). A whole county violation occurs if all the monitoring sites in a county exceeded the standard air pollution concentrations, while a partial violation was where only some of the air pollution monitors in the county exceeded the standards. A county that violated the standard is assigned a "non-attainment" status. In this case, states were required to submit a state implementation plan (SIP) that indicated how the state planned to meet these standards. If the standards are still not met, the EPA can impose sanctions that may include holding of federal highway funds.

The 1990 Amendments of the Clean Air Act involved more stringent air quality standards and the creation of the Acid Rain Program (Title IV). In order to regulate acid deposition (acid rain) a two stage emission strategy was imposed to reduce sulfur dioxide and nitrous oxides produced from electric utilities. Phase I, implemented in 1995, involved issuing allowances to power plants, which resulted in fines if exceeded. Phase II (began in 2000) imposed tighter caps on phase I plants while emission limits were imposed on cleaner smaller plants. Permits were allowed to be traded and thus the term, Cap and Trade.

## 3. Conceptual Issues

In this section we provide a detailed explanation of the spending dichotomy used in this study. We then sketch out the mechanisms by which the compositional shifts in government spending may affect environmental outcomes.

### 3.1 Spending Categories

The rationale for the government spending categories is based on the presence of credit market failures, positive human capital externalities, and environmental externalities. Productive and wasteful government spending are distinguished by creating two categories – government spending on *market-promoting goods* (PME) and spending on *market restricting goods* (RME). PME spending addresses the market failures and externalities prevalent and thus encompass pure public goods, which are non-rival and non-excludable, and social spending including government expenditures on health, education, affordable housing, social welfare, environment, and research and development expenditures. The private sector under-invests in R & D activities, which generate positive externalities, and also has little incentives to spend in environmental protection, which faces substantial market failures (Hoff and Stiglitz, 2000; Dasgupta, 1996)[3].

PME expenditures tend to complement rather than substitute private investments and also mitigate the effects of market failures, especially credit market failures, which affect a large number of households (Attanasio et. al., 2008; Grant, 2007; Jappelli 1990; Zeldes, 1989). Social subsidies specifically may alleviate liquidity constraints faced by households and therefore increase investment in education and health, which have large positive externalities but tend to be underinvested in (Galor and Zeira, 1993). Conventional public goods, such as legal institutions including law and order are typically underinvested by the private sector, and thus government spending in such activities is merited.

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[3] There is a possibility that public R&D spending may crowd out private R&D spending. However, overall this literature is not conclusive and the results are ambiguous (David et al., 2000).

RME spending usually fall under “development” or “economic affairs” expenditures that involve subsidies directly to firms for activities such as product promotion, commodity market subsidies, grants to corporations, bailouts of failed private financial institutions, and several others. Such expenditures typically tend to promote capital-intensive industries, or substitute private investment as they are typically captured by large corporations, which are typically financially unconstrained (Slivinski, 2007). The costs and ineffectiveness of subsidies that fall under RME spending has been well documented (Coady et. al. 2006)[4]. Furthermore, the availability of RME spending tends to promote directly unproductive, profit-seeking activities (DUP) such as lobbying, by mainly special interest groups. RME spending tends to elicit more rent-seeking activities as firms are fewer than households, and can be grouped by production activity and thus can more easily solve the collective action problem (López and Islam, 2011). Thus RME expenditures are deemed as wasteful spending. The classification presented here is not novel and has been presented in the literature (López, Galinato, and Islam 2011; López and Galinato, 2007). It is also important to note that since this study is exploring the implications of broad fiscal spending policy on the environment, not all specific spending items need to have a direct link to the environment.

### 3.2 Mechanisms

The channels through which the reallocation of spending from RME to PME affects air pollution are conditional on whether pollution is generated from production or consumption activities (McAusland, 2008). López et al. (2011) provide the theoretical background for identifying the channels by which the level and composition of government spending may affect production-generated pollutants. The reallocation of government expenditure from RME to PME goods may trigger: (i) a *scale effect* where the increase in aggregate output results in greater pollution, (ii) *composition effect* where the human capital-intensive nature of PME spending and the physical capital-intensive nature of RME spending implies that a reallocation from RME to PME spending may alter the composition of the economy towards cleaner human capital-intensive sectors resulting in less pollution, and (iii) increased investments in R&D and knowledge diffusion via PME spending may trigger a *technique effect* where cleaner technologies may be developed.

[4] For example the Savings and Loans crisis of the 1980s is estimated to have directly cost US taxpayers $150 billion over the period 1989-1992 (Curry and Shibut, 2000).

An increase in PME spending also affects consumption-based pollutants. It may change the composition of consumption goods, as consumption is shifted towards less polluting goods. For example, increasing PME spending may result in greater investments in public transportation, resulting in consumers altering their preferences away from private forms of transportation that are typically energy intensive, and thus reduce air pollution emissions (Shapiro et al., 2004; Zimmerman, 2005). Increasing the share of PME spending may also increase R&D promoting the consumption of more energy saving goods such as energy saving bulbs and energy saving AC and heating units and others. Increases in human capital may heighten pollution awareness among the general public resulting in a decrease in pollution intensive activities (McConnell, 1997). Using household surveys in Netherlands, Ferrer-i-carbonell et al., (2004), finds that increasing public awareness of pollution changes consumer expenditures towards more sustainable consumption. Such a reallocation of spending may also alter the consumption mix towards less pollution-intensive goods making pollution abatement easier (see Seldon and Song, 1995; Orecchia and Tessitore, 2011).

### 3.3 Federal versus Local Spending

The impact of fiscal spending on environmental outcomes may have diverging effects depending on the level of the government carrying out the policy. There are certain differences in characteristics of federal versus state and local government that may result in differences in the effectiveness of changes in the composition of fiscal spending. This includes differences in bureaucracy or red tape, technical knowledge, flexibility to experiment with policy, accountability to voters, and finally the ability to deal with race-to-the-bottom scenarios.

Given the divergence in size between federal and state government, the former tends to have a larger degree of red tape and bureaucracy than the latter. This in turn leads to a lower degree of flexibility in policy experimentation and also lower responsiveness of the federal government in comparison to the smaller state and local governments.  However federal governments may have the technical expertise to carry out fiscal policy. Oates (2001) argues that in terms of environmental policy, federal government involvement should mainly entail subsidies for abatement technology, research and development, and information dissemination. Furthermore, state governments may face soft budgets in anticipation of federal bailouts.

One concern is the potential for race to the bottom scenarios when state or local government carry out fiscal policy. For instance, state governments may have disincentives to provide social programs given the open nature of their economies due to the fear that they may attract poor individuals and thus limiting their tax revenue base (Oates, 1999). Thus it is also likely that state level governments may engage in spending that is more likely to attract businesses. Competition to attract firms may induce greater RME spending and thus lead to race to the bottom scenarios.

It is important to note that the goal of broad fiscal policy is not necessarily to improve environmental outcomes. Thus conclusions about the efficiency of broad fiscal spending cannot be drawn from any positive or negative effect of fiscal policy on environmental outcomes. The main concern is that specific inefficiencies in particular government spending programs may affect the mechanisms by which broad fiscal policy affects environmental outcomes.

## 4. Econometric Model

We establish the long run relationship between the stocks of government provided goods and air pollution. We posit that pollution concentrations, $Z_{jst}$, at monitoring site $j$, state $s$, averaged over year $t$, are determined by the stocks of private (RME), and social and public goods (PME) provided by the local government ($G_{st}^{ST}$) and federal government ($G_{st}^{FD}$), and a vector of regulations ($\mathrm{R}_{st}$). Given the importance of regulations, we will expand in detail on the elements of the vector of regulations towards the end of the section (subsection 4.2). Additional controls include monitoring site characteristics ($X_{jst}$) and permanent income ($I_{st}$) which consistent with the literature, we proxy using a 3 year moving average of personal income (Antweiler, Copeland, and Taylor, 2001). Finally, the estimation controls for monitoring site effects and unobserved fixed and time varying state effects.

(1)
$$Z_{jst} = \mu_{js} + a_1 G_{st}^{ST} + a_2 G_{st}^{FD} + a_3 I_{st} + a_4 \mathrm{R}_{st} + a_5 X_{jst} + \tilde{\tau}_t + \varphi(t)_{st} + \overline{\varepsilon}_{jst}$$
$$j \in \{1, 2, ......., J\},\ s \in \{1, 2, ......., S\},\ t \in \{1, 2, ......., T\},$$

$\mu_{js}$ is the monitoring site effect that can be either fixed or random. $\varphi(t)_{st}$ is a function of time that controls for fixed and time-varying state-specific effects; $\tilde{\tau}_t$ are the year fixed effects and $\bar{\varepsilon}_{jst}$ is an idiosyncratic error that is assumed to be independent and identically distributed with zero mean and fixed variance.

Since reliable measures of the stock levels of government spending do not exist, an alternative is to use the flows of government spending for which reliable data exist. We thus write Equation (1) below in differences thereby approximating the annual level of government stocks by the corresponding level of government expenditure flows. Therefore:

$$(2) \qquad z_{jst} = \mu_{js} + \gamma_1 g_{st}^{ST} + \gamma_2 g_{st}^{FD} + \gamma_3 y_{st} + \gamma_4 R_{st} + v_{st} + \varepsilon_{jst}$$

where, $z_{jst} \equiv Z_{jst} - Z_{js,t-1}$; $g_{st}^{ST} \equiv G_{st}^{ST} - G_{s,t-1}^{ST}$; $g_{st}^{FD} \equiv G_{st}^{FD} - G_{s,t-1}^{FD}$; $y_{st} \equiv I_{st} - I_{s,t-1}$; $v_{st} \equiv \varphi(t)_{st} - \varphi(t)_{s,t-1}$; $\varepsilon_{jst}$ is an idiosyncratic error that is assumed to be independent and identically distributed with zero mean and fixed variance. Both $z_{jst}$ and $y_{st}$ are in log differences. The elements of vectors $g_{st}^{ST}$ and $g_{st}^{FD}$ include the share of social and public good spending (PME) over total spending, and total spending over GDP for local and federal governments, respectively. The normalizations of PME spending and total spending is convenient as it yields unit free measures of the variables. Since we account for total governments spending, private subsidies (RME) do not need to be explicitly included in the estimation[5].

### 4.1 The Time Varying State Effects (TVS) Method

The $v_{st}$ effect in (2) corresponds to the TVS, which is a state specific polynomial of a time trend that captures the effects of certain state level omitted variables on the pollutants. These omitted variables are often difficult to measure or are not observed. Examples include the actual

[5] Since certain types of PME spending may take a large period of time to have an effect on environmental outcomes, We repeat the estimates in using 3 year averages and find the results are unchanged (see table B6 in the online appendix).

enforcement of regulations, the implementation of policies, as well as state macroeconomic policies, political institutions and so forth. These variables are assumed to follow certain patterns that tend to change over time. This may be non-linear, but not always monotonically, and potentially in a state-specific manner. The evolution of such variables may display some correlation with time.

We are especially concerned about regulation enforcement which is difficult to measure and may be correlated with the share of government spending in PME. An increase in regulation enforcement may coincide with increasing shares of PME spending, especially state and local PME spending since regulation enforcement is typically carried out by state and local governments. It is also feasible that regulation enforcements may evolve overtime following similar patterns as government spending. Omission of regulation enforcement may bias the coefficients of the PME spending variables upwards (more negative). Such omitted control variables may be adequately captured by state-specific polynomial functions of time. We approximate the $\nu_{st}$ effect by a (T-2)$^{th}$ order (state specific) polynomial function of time, where the parameters are allowed to take different values for each state as shown below:

(3) $$\nu_{st} = b_{0s} + b_{1s}(t) + b_{2s}(t)^2 + b_{3s}(t)^3 + ........ + b_{T-2s}(t)^{T-2} + e_{st}$$

Where $b_{0s}, b_{1s}, b_{2s}, b_{3s}, ..... b_{T-2,s}$ are the coefficients of the polynomial function of time (t) that are allowed to be different for each state, and $e_{st}$ is the residual. The coefficients $b_{0s}$ correspond to the fixed state effects and the remaining coefficients capture the state specific time-varying state effects. Substituting (3) into (2) we obtain the estimating equation with a new disturbance term $\tilde{\varepsilon}_{jst} = \varepsilon_{jst} + e_{st}$. The (T-2) polynomial in equation (3) is the highest order approximation with sufficient *degrees* of freedom that allows for the estimation of the effect of the observed state-wide independent variables.

The TVS estimation model is related to estimations present in the literature (Cornwell et al., 1990; Jacobsen et al., 1993; Friedberg, 1998; and Wolfers, 2006). These studies choose up to a quadratic function of time in order to capture individual or state-specific slow moving omitted variables, not really justifying why a quadratic function is adequate for the estimation. The main advantage of the TVS model proposed here over similar estimations in the literature is that the data defines the limit of the time trend polynomial consistent with the degrees of freedom in the data.[6]

To understand the merits of the TVS approach, it helps to contrast it to the alternative approaches used to capture omitted variables. There are essentially 4 options including the TVS approach described: (i) the standard fixed effects model (ii) A full set of state-by-year fixed effects which includes fully interacted state and year dummies, (iii) a state specific time trend, and (iv) polynomials of state specific time trends which we call the TVS approach.

The obvious limitation of specification (i) is that it doesn't account for time varying omitted variables. Approach (ii) involves fully controlling for all the $v_{st}$ effects by using a complete matrix of state-year dummies (also known as state-by-year fixed effects) but of course this would leave no degrees of freedom to estimate the effect of any other state level explanatory variables. The advantage of the TVS approach over this specification is twofold. First the TVS approach needs to estimate a fewer number of parameters than the state-by-year fixed effects. Secondly using the TVS approach with a $(T-2)^{th}$ order approximation may come close to the full state-by-year fixed effects while preserving enough variation in the dependant variable thus allowing for the estimation of state-wide independent variables. Finally approach (iii) uses state specific time trends, which assumes a linear functional form of the omitted variables, while the TVS approach allows for more flexible functional forms.

Furthermore, the TVS is a generalization of the standard fixed state effects model as the fixed state effects correspond to the $b_{0i}$ coefficients in (3). Thus the standard state fixed effects can be regarded as a special case where (3) is restricted by imposing that all coefficients other than the constants be zero. We can test the validity of the state fixed effects model parametrically by

[6] A related estimation method is the interactive effects (Bai, 2009; Kneip, Sickles, and Song, 2012). If the state specific unobserved heterogeneity in the data can indeed be explained by the TVS effects, then the TVS estimation model is more efficient than the interactive effects (Kim and Oka, 2012).

imposing the following restrictions: $b_{1s} = b_{2s} = .... = b_{T-2s} = 0$ for all $s \in \{1, 2, ..., S\}$ while $b_{0s} \neq 0$, for all or some $s$.

### 4.2 Regulation controls

The vector of regulation controls in the estimation model (3) includes the following. We include dummy variables that capture whether a whole county was under non-attainment status, and whether part of the county was under non-attainment status with regards to SO2, PM 2.5 and Ozone, CO, PM10, and NO air quality standards. We are considering violation of standards of all the pollutants since they share common emission sources. This is consistent with the treatment of non-attainment status in estimations in the literature (Aufhammer, 2011). Some studies have found that non-attainment status does have a significantly negative but modest effect on sulfur dioxide concentrations (Greenstone, 2004) while others found that the effect is insignificant with regards to PM10 for the average monitoring site (Aufhammer, 2009; Aufhammer, 2011). The use of fixed year effects captures programs such as the Acid Rain Program or Title IV since this is a federal policy that applies to all states. Site fixed effects tend to capture state specific regulations that do not vary over time.

### 4.3 Other Econometric issues

We now consider additional econometric issues such as reverse causality. If air pollution concentrations are a determinant of PME spending, this would imply that PME spending is correlated with the stochastic error term, $\varepsilon_{jst}$, thus biasing the estimates. However, since the share of PME spending is an aggregate of several spending programs it is unlikely that broad spending policies will be determined by environmental concerns. Therefore, it is less likely that reverse causality is an issue.

Additional econometric concerns such as pollution migration, outlier observations, and structural differences across regions are addressed in the robustness section later on in the paper. We also use the Altonji (2005) methodology, which we call the Added Controls Approach, where we control for several other variables and see whether the coefficients of interest change. Finally we provide the Arellano – Bond “system” GMM estimates.

## 5. Data

Annual site level SO2, PM 2.5 and O3 concentrations are obtained from the US Environment Protection Agency (EPA). The data are an unbalanced panel available from 1985 to 2008 for sulfur dioxide, 2000-2008 for PM 2.5 and 1983-2008 for ozone across 50 States and Washington DC. The number of monitoring stations range from 1456 to 2100 depending on the type of pollutant, with the total number of observations ranging from 8,827 to 23,833. Only data that was collected using a consistent methodology at the monitoring site is used. All the concentrations data used are readings taken from monitoring sites which for SO2 and ozone are the maximum daily reading averaged for the full length of the sample period, and for PM 2.5 are the 98 percentile reading over 24 hours. These measures follow EPA standards, for instance the maximum daily readings are used for SO2 by the EPA as short exposure to SO2 concentrations has harmful health effects. Most empirical studies examining the determinants of pollutants in the US use concentrations data because emissions data is highly interpolated with emissions inventories only taken once every 3 to 5 years (Auffhammer et al., 2011, Auffhammer et al., 2009;  Greenstone, 2004; Henderson, 1996).

Government spending data is obtained from the Spending Allocation Database by State (SADS) constructed by Islam (2011). This database is created by combining three different datasets, all maintained by the US Census Bureau. Each dataset provides spending data by state and differs by the level of government and spending category aggregation. The state and local level data set, known as State Government Finances, is aggregated under broadly defined categories with coverage existing from 1983 to 2008. The allocation of broad categories into PME and RME state and local spending is presented in Table A3.

For federal spending, the Consolidated Federal Funds Report (CFFR) provides disaggregation by specific program, and thus a more precise division of PME and RME spending is possible. Over 1,500 programs are identified by department, and categorized as to whether they fall under two types of PME spending - social goods, non-social public good, or under RME spending (private subsidies). Difficult to categorize spending programs are left under “other” spending categories.[7] The general categorization of each spending category by department is presented in Table A4.[8]

Finally, there is a major potential issue of double counting – some of the CFFR expenditures are directed at states. Since CFFR does not indicate what types of spending are directed at states, a third database - Federal Aid to States (FAS) is used to limit double counting. FAS data contains amounts and details of federal grants to states, under broader categorization than the CFFR. Thus data in the FAS are split into PME and RME spending, and then subtracted from grants from the CFFR to come up with a total of federal spending net of any grants to state and local governments. All federal datasets have time coverage of 1983-2008. Summary statistics of government spending variables and other controls are available in Table A1. Data description, sources and time coverage are presented in Table A2.

## 6. Results

### 6.1 Base Results

Table 1 presents the fixed and random site effects estimates for sulfur dioxide in columns 1 and 2, particulate matter in columns 3 and 4, and ozone in columns 5 and 6 respectively. The Huber/White/Sandwich estimator of variance is used to estimate the standard errors to account for heteroskedasticity. All estimates yield negative coefficients for the share of PME spending at the state and local level of government, with a significance of at least 5%. The coefficients for the share of PME spending at the state level range between -0.37 to -0.46 for SO2, -0.21 to -0.34 for PM 2.5, and -0.07 to -0.1 for O3. The share of PME spending at the state and local level of

[7] Each type of spending is a combination of direct spending and assistance spending. Direct spending includes grants, salaries and wages, procurement contracts, and other direct payments. Direct assistance includes direct loans, guaranteed/insured loans and insurance (see Table A5). Assistance spending may also involve obligations indicated as negative amounts in CFFR. It is difficult to track, by program, when obligations were made, and how to distribute the negative amounts in prior years. Thus, negative figures are retained, and are included in the aggregate estimation of the spending type.

[8] Administrative expenditures appear separately in the CFFR and have to be distributed. In some cases, all the programs in a department can be identified under one category of spending. When a whole department does not fall under one category of spending, the administrative expenditures are divided by the ratio of each type of spending over total department spending. In the case of pre-1993 data, the administrative spending is not allocated by department. Thus the administrative spending is first divided by the department by the proportion of department spending over total spending. This is then further divided into the type of spending, using the proportion of the type of spending over total department spending.

government is negative but largely insignificant. The total federal government spending effect is not robust across pollutants; it has a negative and significant effect for PM 2.5, but loses significance in the SO2 fixed site effects estimations. Furthermore the coefficient of total federal spending switches to a positive sign and remains insignificant for the O3 estimations.[9]

The coefficient for personal income yields a negative coefficient significant at 1% for SO2. In contrast the coefficient for personal income is insignificant for O3 but positive and marginally significant at 10% for PM 2.5 air concentrations. One explanation may be that the personal income variable captures both the scale and income effects. For production generated pollutants, such as SO2, the income effect dominates, while for pollutants with a more significant consumption source, such as O3 and PM 2.5, the scale effect dominates.

Both the partial and whole county non-attainment status variables for SO2 are negative, but only the counties which partially had non-attainment status in the previous year results in a statistically significant reduction in SO2, with a level of significance of 1%. The non-attainment status for lead also has a significant negative effect on SO2 concentrations, which is expected given that since the phasing out of lead from gasoline, industrial processes have been a major contributor towards lead emissions. Both partial and whole PM2.5 non-attainment status in the previous year has a highly significant (1% level) and negative effect on PM 2.5 air concentrations. Also ozone non-attainment status for the whole county has a negative and significant effect on PM 2.5 concentrations. In contrast, ozone non-attainment status has no significant effect on ozone concentrations, however both partial and whole county non-attainment status for the precursor pollutant – NO- has a negative effect on ozone concentrations with significance of at least 5%. Partial non-attainment status of carbon monoxide (CO) also has a significant and negative effect on ozone, which may not be surprising given that transportation is a significant source of both CO and ozone emissions.

[9] Some types of PME spending may take a large period of time to have an effect on environmental outcomes. We repeat the estimates in Table 1 using 3 year averages of the spending variable to capture the long term effects of the share of PME spending. The results in Table 1 are largely retained and are reported in table B6 in the online appendix. This implies that our results may be adequately capturing the affect of increasing the share of PME on the air pollutants.

One interesting result is that non-attainment status for certain pollutants may actually positively contribute to increases in other pollutants. For instance partial and whole county non-attainment status for CO has a marginally significant (mostly 10%) but positive effect on PM2.5 concentrations. Lead concentrations non-attainment status has a positive and significant effect on PM 2.5 concentrations while partial county non-attainment status for PM 2.5 has a positive and significant effect on ozone concentrations. This may imply that in attempt to address non-attainment status for one pollutant, state governments may undertake activities that increase other pollutants. This may mean there is a degree of substitutability in the regulation of pollutants.

### 6.2 Time Varying State Effects (TVS) Results

Table 2 presents the TVS-RSE model where we include both random site level effects and time varying state level effects. Since the lowest number of observations per state is 6 for sulfur dioxide and PM 2.5, we use the 4th polynomial to approximate $v_{st}$ [10]. However, just to check for consistency, we provide estimates including the 5th polynomial. Columns 1 and 2 of table 2 show the 4th and 5th polynomial estimation results respectively for SO2. Similarly, columns 3 and 4 of table 2 show the 4th and 5th polynomial estimation results for PM 2.5, while columns 5 and 6 show the 4th and 5th polynomial estimation results for ozone.

Using the 4th polynomial approximation of $v_{st}$, the coefficient of the share of PME spending at the state and local level retains the negative sign across all pollutants with a 5% level of significance while federal PME spending remains insignificant. The size of the coefficient of the share of PME spending at the state and local level is generally larger than OLS, random, and fixed site effects coefficients reported in table 1. The sign and significance of personal income is similar for all pollutants as in table 1, while total state and local government spending is insignificant. Total federal spending has a positive and significant coefficient for PM 2.5, but is otherwise insignificant for the SO2 and ozone. The non-attainment status variables do not significantly differ from random and fixed estimations in table 1.

[10] The low number of observations for some states is due to the fact that only monitoring sites with a consistent methodology in terms of length of time of the exposure are included in the study

The TVS-RSE residuals as indicated at the bottom of Table 2 are time independent[11]. The log likelihood ratio test favors the TVS-RSE model over using state level fixed effects at the 1% level of significance. We also estimated the TVS-FSE model as indicated in Table B1 in the online appendix (see reference in footnote 1). Although the results are qualitatively similar to the TVS-RSE model, the residuals are generally not time independent.

### 6.3 Magnitude of the Effects

The elasticities of PME spending for state and local governments with respect to SO2, PM 2,5 and ozone concentrations are presented in columns 1,2 and 3 respectively in Table 3. Elasticities using random site effects, fixed site effects, and TVS-RE are presented in rows 1, 2, and 3 respectively. Using the fixed and random site effects estimates in Table 1 and the TVS-RE (4th polynomial) estimates in Table 3, a 10 % increase in the share of PME spending reduces sulfur dioxide concentrations by 4%, 3%, and 5%, PM 2.5 by 3%, 2%, and 3%, and Ozone by 1%, 0.06%, and 2% respectively for state and local governments. The magnitude of all the effects has a significance of at least 5%. The elasticities of 3 to 5% for the share of PME spending with regards to SO2 concentrations are similar to the estimates in Lopez, Galinato and Islam (2011) who find an elasticity of 3% using a panel 38 countries for the time period 1986 to 1999.

A one standard deviation increase in the share of PME spending by state and local governments reduces SO2 concentrations by around 2 to 3%, depending on the type of estimation used. The effect on PM2.5 concentrations is slightly larger with a one standard deviation increase in the share of PME spending resulting in a 3 to 4% decline. The corresponding figures for Ozone concentrations are between 2 to 6%. Results are presented in rows 4,5, and 6 of Table 3.

In almost all cases, the magnitude of the effects is larger for the TVS-RE estimations than the fixed and random site effects. We interpret this result as possible evidence that the TVS-RE estimations may be accounting for time varying omitted variables that weaken the effect of the share of PME spending on the air pollutants as indicated by the smaller coefficient estimates of

[11] The p-values presented at the bottom of table 3 test the time independence of the residual using the estimation

$$\tilde{\varepsilon}_{jst} = \text{constant} + \beta trend$$

PME spending in the fixed and random site effects estimations vis-à-vis the TVS-RE estimations.

## 7. Robustness

We address a few additional concerns regarding our estimations. In additional to the TVS estimation approach that accounts for time varying omitted variables that are difficult to measure, we consider several other variables found in the literature to have a significant effect on environmental outcomes and check whether they affect our results. Furthermore, outliers or particular states may be driving our results. We also consider alternate specifications such as GMM. Furthermore, given the distribution of power plants across the US, there may be structural differences on the impact of PME spending on SO2. Finally, we address the issue of pollution migration through spatial lag and spatial error model panel estimations.

### 7.1 Robustness Check: Added Controls Approach

In addition to the TVS approach, we also address omitted variable bias using the added controls approach. Studies have shown that several factors may directly or indirectly affect environmental quality. Factors such as economic intensity (Antweiler et al., 2001; Grossman and Kruger, 1995; Harbaugh et al., 2002), sector composition (Brooks and Sethi, 1997; Antweiler et al, 2001), socioeconomic characteristics such as racial composition and economic conditions (Brooks and Sethi, 1997; Khanna, 2002) have all been determinants of environmental quality. In addition, pollution abatement costs may influence firms' decisions to pollute and this may influence environmental quality (Levinson , 1996;  Levinson and Taylor, 2008). Since electric utilities contribute significantly to SO2 and O3 emissions, total net generation of electricity may be an important control variable for the base specification in equation (2). Price of natural gas or fuel, fuel taxes, or the level of private capital may influence activities that generate emissions. Several meteorological factors may also affect air quality such as wind speed and direction, temperature, height of monitoring site probe, and elevation above sea level. Finally, pollution readings in a state can be correlated by the no. of monitoring sites in the state. We add a set of variables representing each of the determinants listed above in sequence into the random and fixed site effect estimations in Table 1 to test the robustness of the variables of interest. Some of these controls are interpolated due to sparse data. Pollution abatement costs data is linearly imputed for the years 1987, 1995-1998, 2000-2004, and racial composition data from the census is linearly imputed for the years 1981-1989, 1991-1999. The meteorological data is obtained from a few sites that have the data, and assumed to be representative of the whole state.

Table 4 shows the coefficients of the effect of PME spending for state and local governments as each set of controls are added to the base estimations in Table 1. An increase in the adjusted R-squared relative to the base estimations implies that including the additional sets of controls raises the explanatory power of the model. If the coefficient of PME spending retains the sign and significance, this implies that the coefficient is stable and robust to the additional regressors.

Table 4 shows that the coefficients of PME spending are largely unaffected by the additional sets of control variables. Both the sign and significance of the PME spending coefficient is negative and has a significance of at least 5%. The highly interpolated variables - racial composition proxies and pollution abatement costs – raise the adjusted R squared across pollutants. Caution should be employed in interpreting this as the degree of linear interpolation for these variables is quite intensive. Meteorological conditions also raise the adjusted R squared for SO2 and ozone, while not really altering the goodness of fit for PM 2.5. Considering the potential controls presented in Table 4, we can conclude that the results are robust to omitted variables that are correlated with these sets of variables.

**7.2 Robustness Check: Extreme Observation Dominance**

A small number of outlier observations may be driving the results. In order to address this, we drop the top 1%, the bottom 1%, and both top 1% and bottom 1% observations of the dependent variable (log difference of air concentrations) and the variable of interest (PME spending for the state and local government) and re-estimate the fixed and random state effects estimations in Table 1 and the TVS-RSE estimations in Table 2 using the $4^{th}$ polynomial. The results are presented in Table B3, B4 and B5 in the online appendix for SO2, PM 2.5, and ozone respectively. The signs of the coefficients for PME spending for the state and local levels of government are negative and have at least a 10% level of significance for all the sample alterations for random site effects and fixed site effects. This is also true for TVS-RSE estimates.

Thus extreme or outlier observations do not dominate the results for state and local PME expenditures.

### 7.3 Robustness Check: State Dominance

We also consider the possibility that the results may be driven by a particular state. Thus, we drop each state, one at a go, and re-estimate the fixed and random site effects models in Table 1. Figures 1 through 6 in the online appendix presents the coefficients of PME spending at the state and local level for the fixed and random site level estimation models and the 95% confidence interval for each pollutant. As indicated in the graphs, the sign and significance of PME spending at the state and local level is robust and not dominated by any one particular state in the sample.

### 7.4 Robustness Check: Specification

As a further robustness check, we estimate a dynamic panel model using the Arellano-Bond two-step procedure “System” Generalized Method of Moments (GMM). The GMM estimation accounts for inertia that may exist in the determination of air pollution concentrations and also uses predetermined values as instruments in a systematic way. The estimates are presented in Table B2 in the online appendix. The first column uses collapsed instruments, and the second column presents un-collapsed instruments. The $6^{th}$, $3^{rd}$ and $4^{th}$ lag of endogenous variables are used as instruments for SO2, PM 25, and ozone respectively. The sign and significance of the coefficients of PME spending at the state and local level of government is retained. The lagged dependent variable is insignificant in most cases when using collapsed instruments, but significant when using uncollapsed instruments. The Hansen test indicates that the instruments are exogenous and there is also no second order autocorrelation when using uncollapsed instruments.

### 7.5 Robustness Check: Structural Change for SO2 across Regions

Given that very few coal-fired electric utilities are located in the West and Midwest regions of the US, there is a possibility that the share of PME spending at the state and local level may have no impact on SO2 in these regions. Using the chow test to test for structural change for these regions (see p-values in Table B8 in the online appendix) we find that there is no difference in the effect of the share of PME spending by state and local governments in the Western region from the base estimations. However at the 10% level of significance, we reject that the Midwest region has parameter estimates equal to the base regressions. Re-estimations of the RE and FE models for the Midwest region alone retains the sign and significance of the share of PME spending for state and local governments. We present the p-values of the chow test in table B8 and the classification of regions in table B9 in the online appendix.

### 7.6 Robustness Check: Pollution Migration

Monitoring sites near the border of states may pick up air pollution concentrations originating from neighboring states. Similarly monitoring sites in a state may read low levels of air pollution concentrations as they are blown away to other states. This invites the possibility of spurious correlation. We account for this by estimating spatial lag and error panel models. For these estimations we create a county-level panel dataset, by averaging the pollution concentrations over all the monitoring sites in a county. We only retain counties that have data for the full time period. For the spatial estimations we use a row standardized inverse distance weighting matrix of the 5 nearest counties. The results of the spatial lag and spatial error random effects models are presented separately for each pollutant in Table A7. The maps in figures 7 through 9 in the online appendix show the counties in the sample and the spatial relations between them. The results in Table A7 indicate that the share of PME spending for the state and local level has a negative coefficient and retains significance of about 5% for all pollutants. Both the spatial lag and spatial autocorrelation terms are significant at 1%. This implies that although the spatial aspect of the pollutants is important, the negative effect of the share of PME spending for state and local governments on SO2, O3, and PM2.5 is robust to it.

## 8. Conclusion

This paper examines the effect of government spending at various levels of government on air pollution in the US. We find that the size of the public sector is not important but what matters is the composition of spending at the state and local level of government. A reallocation of government spending from private subsidies to social and public good spending that alleviates market failures and increases public goods, holding total government spending fixed, results in significant reductions in SO2, PM 2.5, and O3 concentrations for state and local governments but not the federal government. After subjecting the results to rigorous tests that limit the effect of omitted variable bias, consider sensitivity towards sample alterations, and account for spatial issues, we find that the effect of state and local PME spending is robust. The results are consistent with the findings of Lopez, Galinato and Islam (2011) who find a negative effect of a reallocation from RME to PME spending on air and water pollutants.

In the light of the present economic circumstances, this study is a timely addition to the debate on US government spending priorities. While the effect of total government spending on pollution appears to be neutral, the reductions of sulfur dioxide air pollution by increasing the share PME spending at the local level may imply that reductions in US state government spending under huge budget deficits should be taken with care. Even though the main goal of fiscal policy is not to alleviate environmental concerns, it is important to consider the effects they may have on the environment, potentially affecting the impact of existing and potentially costly environmental regulations.

**TABLE 1: LOG DIFFERENCE OF AIR POLLUTANTS AND FISCAL SPENDING**

| | SO2 | | PM 2.5 | | Ozone | |
|---|---|---|---|---|---|---|
| | FSE | RSE | FSE | RSE | FSE | RSE |
| Share of PME over Total Spending –State and Local Governments | -0.457*** [0.153] | -0.367*** [0.128] | -0.335*** [0.069] | -0.208*** [0.049] | -0.141*** [0.032] | -0.071** [0.030] |
| Share of PME over Total Spending –Federal Grants, Expenditure, Loans and Insurance | -0.023 [0.078] | -0.001 [0.064] | 0.080* [0.044] | -0.022 [0.025] | -0.024 [0.020] | 0.005 [0.014] |
| Total State and Local Government Spending over GDP | -0.345 [0.296] | -0.363 [0.242] | -0.094 [0.153] | -0.002 [0.082] | -0.103 [0.068] | -0.004 [0.042] |
| Total Federal Government Spending over GDP | -0.223** [0.095] | -0.082 [0.069] | -0.201*** [0.059] | -0.049** [0.023] | 0.006 [0.016] | 0.006 [0.010] |
| Personal Income per Capita by County – log difference (in thousands) | -0.453*** [0.144] | -0.438*** [0.131] | 0.274* [0.156] | 0.207* [0.109] | -0.018 [0.068] | -0.017 [0.061] |
| Non-attainment Status for the whole county in the previous year (SO2 NAAQs) | -0.022 [0.031] | -0.031 [0.030] | | 0.007 [0.051] | 0.015** [0.006] | 0.007 [0.009] |
| Non-attainment Status for part of the county in the previous year (SO2 NAAQs) | -0.024* [0.014] | -0.034** [0.017] | 0.021** [0.010] | 0.006 [0.009] | 0.007*** [0.003] | 0.001 [0.004] |
| Non-attainment Status for the whole county in the previous year (PM 2.5 NAAQs) | -0.026* [0.015] | -0.029* [0.017] | -0.036*** [0.005] | -0.038*** [0.005] | 0.0001 [0.003] | -0.001 [0.004] |
| Non-attainment Status for part of the county in the previous year (PM 2.5 NAAQs) | -0.034 [0.029] | -0.034 [0.031] | 0.025** [0.012] | 0.004 [0.012] | 0.016** [0.007] | 0.017** [0.007] |
| Non-attainment Status for the whole county in the Previous Year (PM10 NAAQs) | -0.027 [0.026] | -0.013 [0.046] | -0.0001 [0.018] | 0.0005 [0.017] | 0.001 [0.005] | 0.001 [0.004] |
| Non-attainment Status for part of the county for the previous year (PM10 NAAQs) | 0.036** [0.016] | 0.026 [0.017] | -0.013 [0.011] | -0.008 [0.010] | 0.004 [0.004] | 0.007 [0.005] |
| Non-attainment Status for the whole county for the Previous Year (O3 NAAQs) | -0.023*** [0.008] | -0.011 [0.009] | 0.026*** [0.005] | 0.006 [0.004] | 0.003 [0.002] | -0.0004 [0.002] |

| | | | | | | |
|---|---|---|---|---|---|---|
| Non-attainment Status for part of the county for the previous year (O3 NAAQs) | -0.048*<br>[0.028] | -0.034<br>[0.031] | 0.036***<br>[0.011] | -0.003<br>[0.010] | 0.002<br>[0.003] | -0.0005<br>[0.004] |
| Non-attainment Status for the whole county for the Previous Year (NO NAAQs) | 0.047<br>[0.046] | 0.057<br>[0.093] | | | -0.044***<br>[0.007] | -0.044**<br>[0.021] |
| Non-attainment Status for part of the county for the previous year (NO NAAQs) | -0.002<br>[0.076] | 0.014<br>[0.087] | | | -0.050***<br>[0.006] | -0.045***<br>[0.008] |
| Non-attainment Status for the whole county for the Previous Year (CO NAAQs) | -0.002<br>[0.014] | 0.001<br>[0.014] | 0.030*<br>[0.016] | 0.022*<br>[0.013] | -0.007<br>[0.005] | -0.001<br>[0.005] |
| Non-attainment Status for part of the county for the previous year (CO NAAQs) | -0.0002<br>[0.011] | 0.004<br>[0.011] | 0.045**<br>[0.018] | 0.021*<br>[0.012] | -0.016***<br>[0.003] | -0.011***<br>[0.003] |
| Non-attainment Status for part of the county for the previous year (lead NAAQs) | -0.090*<br>[0.053] | -0.077**<br>[0.036] | 0.075***<br>[0.021] | 0.049**<br>[0.023] | 0.001<br>[0.006] | 0.002<br>[0.009] |
| Site characteristics and land use dummies | Yes | Yes | Yes | Yes | Yes | Yes |
| Year Effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Adjusted $R^2$ | 0.03 | 0.02 | 0.15 | 0.13 | 0.12 | 0.11 |
| Number of Observations | 15233 | 15233 | 8827 | 8827 | 23833 | 23833 |
| Number of sites | 1668 | 1668 | 1456 | 1456 | 2100 | 2100 |

* significant at 10%; ** significant at 5%; *** significant at 1%, Robust standard errors used

### TABLE 2: LOG DIFFERENCE OF SO2 AND FISCAL SPENDING VARIABLE STATE - RANDOM SITE EFFECTS – TVS-RSE

| | SO2 | | PM 2.5 | | Ozone | |
|---|---|---|---|---|---|---|
| Share of PME over Total Spending –State and Local Governments | -0.581**<br>[0.247] | -0.619**<br>[0.250] | -0.328***<br>[0.093] | -0.244***<br>[0.094] | -0.266***<br>[0.048] | -0.231***<br>[0.050] |
| Share of PME over Total Spending –Federal Grants, Expenditure, Loans and Insurance | -0.061<br>[0.154] | -0.337**<br>[0.156] | 0.267***<br>[0.073] | 0.173<br>[0.106] | -0.034<br>[0.043] | -0.095**<br>[0.045] |
| Total State and Local Government Spending over GDP | -0.687<br>[0.460] | -0.211<br>[0.507] | 0.145<br>[0.238] | 0.437<br>[0.271] | -0.124<br>[0.126] | 0.119<br>[0.151] |
| Total Federal Government Spending over GDP | -0.16<br>[0.240] | 0.111<br>[0.258] | 0.354***<br>[0.124] | 0.279**<br>[0.122] | 0.137***<br>[0.051] | 0.079<br>[0.052] |
| Personal Income per Capita by County – log difference (in thousands) | -0.468***<br>[0.140] | -0.464***<br>[0.142] | 0.228**<br>[0.111] | 0.220**<br>[0.108] | -0.021<br>[0.064] | -0.017<br>[0.065] |
| Non-attainment Status for the whole county in the previous year (SO2 NAAQs) | -0.032<br>[0.028] | -0.035<br>[0.028] | -0.018<br>[0.046] | -0.017<br>[0.045] | 0.006<br>[0.012] | 0.008<br>[0.012] |
| Non-attainment Status for part of the county in the previous year (SO2 NAAQs) | -0.035**<br>[0.017] | -0.038**<br>[0.017] | -0.005<br>[0.008] | -0.005<br>[0.008] | 0.001<br>[0.005] | 0.001<br>[0.005] |
| Non-attainment Status for the whole county in the previous year (PM 2.5 NAAQs) | -0.011<br>[0.019] | -0.01<br>[0.019] | -0.037***<br>[0.006] | -0.039***<br>[0.006] | -0.001<br>[0.004] | -0.001<br>[0.004] |
| Non-attainment Status for part of the county in the previous year (PM 2.5 NAAQs) | -0.037<br>[0.035] | -0.036<br>[0.035] | -0.036**<br>[0.014] | -0.031**<br>[0.014] | 0.003<br>[0.008] | 0.003<br>[0.008] |
| Non-attainment Status for the whole county in the Previous Year (PM10 NAAQs) | -0.017<br>[0.043] | -0.006<br>[0.043] | 0.009<br>[0.014] | 0.009<br>[0.013] | 0.0005<br>[0.005] | 0.001<br>[0.005] |
| Non-attainment Status for part of the county for the previous year (PM10 NAAQs) | 0.02<br>[0.018] | 0.018<br>[0.018] | 0.002<br>[0.009] | -0.0002<br>[0.009] | 0.004<br>[0.005] | 0.005<br>[0.005] |
| Non-attainment Status for the | -0.007 | -0.002 | 0.003 | 0.004 | 0.001 | -0.0002 |

| | | | | | | |
|---|---|---|---|---|---|---|
| whole county for the Previous Year (O3 NAAQs) | [0.010] | [0.011] | [0.004] | [0.004] | [0.002] | [0.002] |
| Non-attainment Status for part of the county for the previous year (O3 NAAQs) | -0.02<br>[0.036] | -0.02<br>[0.036] | -0.002<br>[0.011] | -0.004<br>[0.010] | -0.001<br>[0.005] | -0.002<br>[0.005] |
| Non-attainment Status for the whole county for the Previous Year (NO NAAQs) | 0.04<br>[0.097] | 0.047<br>[0.098] | | | -0.031<br>[0.021] | -0.03<br>[0.021] |
| Non-attainment Status for part of the county for the previous year (NO NAAQs) | -0.019<br>[0.089] | -0.017<br>[0.088] | | | -0.035***<br>[0.008] | -0.035***<br>[0.008] |
| Non-attainment Status for the whole county for the Previous Year (CO NAAQs) | -0.006<br>[0.016] | -0.005<br>[0.016] | -0.009<br>[0.016] | -0.009<br>[0.016] | -0.003<br>[0.006] | -0.003<br>[0.006] |
| Non-attainment Status for part of the county for the previous year (CO NAAQs) | 0.018<br>[0.014] | 0.02<br>[0.014] | 0.002<br>[0.012] | 0.004<br>[0.012] | -0.007*<br>[0.004] | -0.006<br>[0.004] |
| Non-attainment Status for part of the county for the previous year (lead NAAQs) | -0.065*<br>[0.035] | -0.064*<br>[0.035] | 0.029<br>[0.021] | 0.027<br>[0.020] | 0.004<br>[0.009] | 0.0005<br>[0.008] |
| State Dummy x (Time Trend) | Yes | Yes | Yes | Yes | Yes | Yes |
| State Dummy x $(\text{Time Trend})^2$ | Yes | Yes | Yes | Yes | Yes | Yes |
| State Dummy x $(\text{Time Trend})^3$ | Yes | Yes | Yes | Yes | Yes | Yes |
| State Dummy x $(\text{Time Trend})^4$ | Yes | Yes | Yes | Yes | Yes | Yes |
| State Dummy x $(\text{Time Trend})^5$ | No | Yes | No | Yes | No | Yes |
| Site characteristics and land use dummies | Yes | Yes | Yes | Yes | Yes | Yes |
| Year Effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Adjusted $R^2$ | 0.04 | 0.04 | 0.23 | 0.23 | 0.12 | 0.12 |
| Number of Observations | 15233 | 15233 | 8827 | 8827 | 23833 | 23833 |
| Number of sites | 1668 | 1668 | 1456 | 1456 | 2100 | 2100 |
| **Specification Tests** | | | | | | |
| Test for the time independence of the residuals: p-values | 0.9851 | 0.9882 | 0.9656 | 0.9792 | 0.8461 | 0.8540 |
| Correlation coefficient between the residuals and time trend | -0.0002 | -0.0001 | 0.0005 | 0.0003 | 0.0013 | 0.0012 |
| Test for fixed site effect model Ho: $b_{1i} = b_{2i} = b_{3i} = 0$, *for all i* Log Likelihood Ratio Test | 373*** | 452*** | 991*** | 1255*** | 300*** | 498*** |

* significant at 10%; ** significant at 5%; *** significant at 1%, Robust standard errors used

## TABLE 3: MAGNITUDE OF EFFECTS

| | Sulfur Dioxide | Particulate Matter 2.5 | Ozone |
|---|---|---|---|
| **Elasticity of the Share of PME Spending by State and Local Governments** | | | |
| Random Site Effects | -0.30%*** | -0.17%*** | -0.06%*** |
| Fixed Site Effects | -0.37%*** | -0.28%*** | -0.12%** |
| Variable State Random Site Effects (TVS-RE) | -0.48%** | -0.28%*** | -0.22%*** |
| **Change in the Pollutant When the Share of PME Spending by State and Local Governments Increases by 1 Standard Deviation (% of std dev pollutant)** | | | |
| Random Site Effects | -1.88%*** | -2.94%*** | -1.72%*** |
| Fixed Site Effects | -2.35%*** | -4.73%*** | -3.40%** |
| Variable State Random Site Effects (TVS-RE) | -2.98%** | -4.64%*** | -6.44%*** |

* significant at 10%; ** significant at 5%; *** significant at 1%

## TABLE 4: ADDED CONTROLS APPROACH – STATE AND LOCAL SHARE OF PME

| | SO2 | | | | PM 2.5 | | | | Ozone | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FSE | | RSE | | FSE | | RSE | | FSE | | RSE | |
| | Coef. | Adjusted R squared | Coef. | Adjusted R squared | Coef. | Adjusted R squared | Coef. | Adjusted R squared | Coef. | Adjusted R squared | Coef. | Adjusted R squared |
| Base | -0.457*** [0.153] | 0.03 | -0.367*** [0.128] | 0.02 | -0.335*** [0.069] | 0.15 | -0.208*** [0.049] | 0.13 | -0.141*** [0.032] | 0.12 | -0.071** [0.030] | 0.11 |
| <u>Economic Intensity</u> GDP per Land (sq km), GDP growth, Population Density | -0.471*** [0.154] | 0.03 | -0.371*** [0.128] | 0.02 | -0.331*** [0.071] | 0.15 | -0.208*** [0.050] | 0.13 | -0.135*** [0.032] | 0.12 | -0.068** [0.030] | 0.11 |
| <u>Sector Composition</u> Share of Manufacturing over GDP Employment in Manufacturing | -0.457*** [0.156] | 0.03 | -0.359*** [0.129] | 0.02 | -0.276*** [0.071] | 0.16 | -0.228*** [0.049] | 0.13 | -0.137*** [0.032] | 0.12 | -0.069** [0.031] | 0.11 |
| <u>Economic Conditions</u> Unemployment Rate Poverty Rate | -0.456*** [0.154] | 0.03 | -0.357*** [0.128] | 0.02 | -0.338*** [0.069] | 0.16 | -0.181*** [0.051] | 0.13 | -0.145*** [0.032] | 0.12 | -0.067** [0.031] | 0.11 |
| <u>Pollution Abatement Costs & Racial Composition</u> Capital Costs lagged Operating Costs lagged % white, % black | -0.377** [0.179] | 0.04 | -0.414*** [0.147] | 0.04 | -0.357*** [0.080] | 0.17 | -0.257*** [0.060] | 0.15 | -0.233*** [0.034] | 0.16 | -0.088*** [0.028] | 0.16 |
| <u>Wind Speed and Direction</u> Average Wind Speed, Wind Direction | -0.314** [0.155] | 0.03 | -0.258* [0.133] | 0.02 | -0.381*** [0.070] | 0.17 | -0.169*** [0.052] | 0.15 | -0.128*** [0.035] | 0.14 | -0.074** [0.029] | 0.14 |
| <u>Temperature and Geographical Conditions</u> Temperature, Elevation Above Sea Level, Height of Monitoring Site Probe | -0.487*** [0.175] | 0.04 | -0.331** [0.155] | 0.03 | -0.322*** [0.080] | 0.15 | -0.191*** [0.053] | 0.13 | -0.204*** [0.035] | 0.14 | -0.094*** [0.035] | 0.14 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Monitoring Sites<br>No. of Monitoring Sites | -0.436***<br>[0.154] | 0.03 | -0.377***<br>[0.128] | 0.02 | -0.351***<br>[0.069] | 0.16 | -0.208***<br>[0.049] | 0.13 | -0.142***<br>[0.032] | 0.12 | -0.073**<br>[0.030] | 0.11 |
| Fuel Prices (log difference)<br>Natural gas, Diesel | -0.490***<br>[0.153] | 0.03 | -0.395***<br>[0.128] | 0.03 | -0.334***<br>[0.070] | 0.16 | -0.203***<br>[0.049] | 0.13 | -0.138***<br>[0.032] | 0.12 | -0.069**<br>[0.030] | 0.11 |
| Electricity Production<br>Total Net Generation of Electricity | -0.461***<br>[0.178] | 0.03 | -0.436***<br>[0.142] | 0.03 | -0.320***<br>[0.069] | 0.16 | -0.209***<br>[0.050] | 0.13 | -0.221***<br>[0.033] | 0.12 | -0.132***<br>[0.034] | 0.11 |
| Taxes and Private Investment<br>Total tax over GDP<br>Share of Motor and Fuel Taxes over Total Tax<br>Log Difference of Private Capital Stock | -0.493***<br>[0.163] | 0.03 | -0.370***<br>[0.141] | 0.02 | -0.397***<br>[0.092] | 0.14 | -0.226***<br>[0.058] | 0.12 | -0.162***<br>[0.035] | 0.12 | -0.068**<br>[0.032] | 0.11 |

* significant at 10%; ** significant at 5%; *** significant at 1%, Robust standard errors used

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### TABLE A1: SUMMARY STATISTICS

| | Mean | Standard Deviation | Min | Max | Unit |
|---|---|---|---|---|---|
| Sulfur Dioxide | 19.37 | 16.01 | 0.00932 | 222.9 | Parts Per Billion (PPM) |
| Particulate Matter 2.5 | 11.90 | 3.37 | 1 | 36.126 | Micrograms/cubic meter (LC) |
| Ozone | 0.053 | 0.009 | 0.002 | 0.122 | Parts Per Million (PPM) |
| Share of PME over Total Spending – State and Local Governments | 0.820 | 0.042 | 0.582 | 0.933 | Fraction over total state expenditures |
| Share of PME over Total Spending – Direct and Indirect Federal Expenditures | 0.788 | 0.098 | 0.185 | 0.945 | Fraction over total federal grants not via states |
| Total State and Local Government Spending over GDP | 0.176 | 0.030 | 0.084 | 0.300 | Fraction over total Federal Loans and Insurance |
| Total Federal Government Spending over GDP | 0.245 | 0.106 | 0.140 | 0.846 | Fraction Over GDP |
| County Personal Income per Capita | 23,674 | 9.419 | 6,665 | 118,768 | Per capita, USD |
| Latitude | 38.902 | 4.840 | 19.204 | 60.695 | Degrees |
| Longitude | -89.576 | 15.045 | -158.133 | -67.401 | Degrees |
| GDP per Land (sq km) | 8,362,759 | 40,800,000 | 33,536 | 1,580,000,000 | Per Square km (land) |
| GDP growth | 0.057 | 0.040 | -0.310 | 1.290 | Log difference of GDP |
| Population Density | 233 | 485 | 0.951 | 10,391 | Per Square km (land) |
| Share of Manufacturing over GDP | 0.177 | 0.072 | 0.002 | 0.333 | Proportion |
| Employment in Manufacturing | 615,703 | 498,052 | 2,017 | 2,222,373 | Number employed |
| Unemployment Rate | 5.617 | 1.561 | 2.240 | 13.430 | Percentage |
| Poverty Rate | 12.902 | 3.316 | 2.900 | 27.200 | Percentage |
| Pollution Abatement Capital Expenditures | 191.716 | 226.407 | 0.000 | 1699.00 | Millions of dollars |
| Pollution Abatement Operating Costs | 551.047 | 468.784 | 4.900 | 2622.80 | Millions of dollars |

| | | | | | |
|---|---|---|---|---|---|
| Proportion white | 0.833 | 0.092 | 0.258 | 0.986 | Proportion |
| Proportion black | 0.108 | 0.074 | 0.003 | 0.658 | Proportion |
| Average Wind Speed | 5.117 | 1.474 | 0.336 | 24.483 | Knots |
| Average Wind Direction | 191.223 | 14.508 | 47.243 | 225.988 | Degrees |
| Temperature | 55.33 | 10.733 | 25.641 | 133.377 | Fahrenheit |
| Elevation Above Sea Level | 252.788 | 364.268 | 0 | 5040 | Meters |
| Site Prove Height | 5.130 | 4.288 | 1 | 152 | Meters |
| Price of Natural Gas | 5.861 | 2.639 | 1.485 | 36.727 | Dollars per million Btu |
| Price of Diesel | 10.059 | 4.647 | 5.743 | 29.505 | Dollars per million Btu |
| Net Total Electricity Production | 112,214 | 75,342 | 37 | 405,492 | Megawatt Hours in millions |
| Taxes over GDP | 0.086 | 0.014 | 0.035 | 0.127 | Fraction Over GDP |
| Motor Fuel Taxes over Total Tax | 0.046 | 0.019 | 0.004 | 0.130 | Fraction over Total Taxes |
| Capital Stock over GDP | 1.168 | 0.213 | 0.580 | 2.245 | Fraction Over GDP |

**TABLE A2: DATA SOURCE AND TIME PERIODS**

| Variable name | Definition | Years Available | Data Source |
|---|---|---|---|
| Sulfur Dioxide | Sulfur Dioxide concentrations by monitoring site (Daily Hourly Maximum) | 1985-2009 | US Environmental Protection Agency (EPA) |
| Particulate Matter 2.5 | Particulate Matter of 2.5 micrometers in diameter and smaller concentrations by monitoring site (98th percentile reading over 24 hours) | 2000-2009 | US Environmental Protection Agency (EPA) |
| Ozone | Ozone concentrations by monitoring site (Daily Hourly Maximum) | 1980-2009 | US Environmental Protection Agency (EPA) |
| Share of PME over Total Spending –State and Local Governments | US government spending on PME by states. Any federal spending to states are included here | 1983-2008 | US Census Bureau, State Government Finances |
| Share of PME over Total Spending – Direct and Indirect Federal Expenditures | US government spending on PME directly through federal grants and expenditures and federal loans and insurance. This excludes any federal grants to states. | 1983-2008 | US Census Bureau, Consolidated Federal Funds Report (CFFR), Federal Aid to States (FAS) |
| Total State and Local Government Spending over GDP | Total State and Local government spending over GDP | 1983-2008 | US Census Bureau, Consolidated Federal Funds Report (CFFR) |
| Total Federal Government Spending over GDP | Total Federal spending, including loans and insurance over GDP | 1983-2008 | US Census Bureau Consolidated Federal Funds Report (CFFR), Federal Aid to States (FAS) |
| Personal Income per Capita by County | | 1980-2008 | US Census Bureau |
| Non-attainment Status for the whole county for the Previous Year | Dummies take the value of 1 if the whole county was under non-attainment status in the previous year. The non-attain status consists of several dummies each representing a pollutant on which the county may have non-attainment status. These pollutants include: SO2, Ozone, PM 2.5, PM 10, CO, | 1978-2011 | US Environmental Protection Agency (EPA) |

| | | | |
|---|---|---|---|
| | NO, and Lead | | |
| Non-attainment Status for part of county for the Previous Year | Dummies are 1 if part of the county was under non-attainment status in the previous year. The non-attain status consists of several dummies each representing a pollutant on which the county may have non-attainment status. These pollutants include: SO2, Ozone, PM 2.5, PM 10, CO, NO, and Lead | 1978-2011 | US Environmental Protection Agency (EPA) |
| Latitude | | 1980-2009 | US Environmental Protection Agency (EPA) |
| Longitude | | 1980-2009 | US Environmental Protection Agency (EPA) |
| GDP per Land (sq km) | | 1980-2009 | Bureau of Economic Analysis (BEA) |
| GDP growth | | 1980-2009 | Bureau of Economic Analysis (BEA) |
| Population Density | | 1980-2009 | US Census Bureau, State Government Finances |
| Share of Manufacturing over GDP | | 1980-2008 | Bureau of Economic Analysis (BEA) |
| Employment in Manufacturing | | 1980-2008 | Bureau of Economic Analysis (BEA) |
| Unemployment Rate | | 1980-2010 | Bureau of Labor Statistics |
| Poverty Rate | | 1980-2009 | U.S. Bureau of the Census, Current Population Survey, Annual Social and Economic Supplements |
| Pollution Abatement Capital Expenditures | Expenditures by manufacturing establishments collected via surveys. Years 1987, 1995-1998, 2000-2004 are linearly imputed | 1980-1986,1988-1994,1999, 2005) | US Department of Commerce, EPA |
| Pollution Abatement Operating Costs | Expenditures by manufacturing establishments collected via surveys. Years 1987, 1995-1998, 2000-2004 are linearly imputed | 1980-1986,1988-1994,1999, 2005) | US Department of Commerce, EPA |
| Proportion white | 1981-1989, 1991-1999 data linearly imputed | 1980, 1990, 2000-2009 | Population Division, US Census |

| | | | |
|---|---|---|---|
| | | | Bureau |
| Proportion black | 1981-1989, 1991-1999 data linearly imputed | 1980, 1990, 2000-2009 | Population Division, US Census Bureau |
| Average Wind Speed | Wind speed averaged over sites with wind speed readings by state | 1980-2009 | US Environmental Protection Agency (EPA) |
| Average Wind Direction | Wind direction averaged over sites with wind direction readings by state | 1980-2009 | US Environmental Protection Agency (EPA) |
| Temperature | Temperature averaged over sites with temperature readings by state | 1980-2009 | US Environmental Protection Agency (EPA) |
| Elevation Above Sea Level | The elevation (in meters) above the Mean Sea Level (MSL) of the site | 1980-2009 | US Environmental Protection Agency (EPA) |
| Site Prove Height | Height of Monitoring Site Probe | 1980-2009 | US Environmental Protection Agency (EPA) |
| Price of Natural Gas | Natural gas average price, all sectors (including supplemental gaseous fuels). Dollars per million Btu | 1980-2009 | U.S. Bureau of the Census |
| Price of Diesel | Distillate fuel oil price in the transportation sector (diesel). Dollars per million Btu | 1980-2009 | U.S. Bureau of the Census |
| Total Net Generation of Electricity | Total Net generation of electricity by state in billions of megawatt hours | 1990-2010 | US Energy Information Administration (EIA) |
| Taxes over GDP | | 1980-2008 | US Census Bureau, State Government Finances, US Department of Commerce, Bureau of Economic Analysis (BEA) |
| Motor Fuel Taxes over Total Tax | | 1980-2008 | US Census Bureau, State Government Finances |
| Capital Stock over GDP | Capital stock series generated by apportioning national capital stock to individual states using one-digit NAICS income data | 1980-2007 | Yamarik (2011) |
| Taxes over GDP | | 1980-2008 | US Census Bureau, State Government Finances, US Department of Commerce, Bureau of Economic Analysis (BEA) |

### TABLE A3: STATE AND LOCAL SPENDING TYPE CLASSIFICATION

| **Spending Classification** | **Department** |
|---|---|
| Social Goods (PME) | Education<br>Health: (Includes Environmental Protection)<br>Social Security and Welfare:<br>Housing and Community Development: |
| Public Goods – Non social (PME) | Public Order and Safety<br>Transportation and Sanitation<br>Parks, Recreation, and Libraries |
| Private Subsidies (RME) | Economic Affairs<br>Utilities<br>Liquor Stores |
| Other | Un-allocable Government Expenditures<br>Government Administration<br>Insurance Trusts<br>Other (Veteran's bonuses and services, parking facilities) |

### TABLE A4: FEDERAL SPENDING TYPE CLASSIFICATION

| **Spending Classification** | **Department** |
|---|---|
| Social Goods (PME) | Social Security Administration<br>Health and Human Services<br>Education<br>Housing and Urban Development<br>National Science Foundation<br>Office of Personnel Management |
| Public Goods – Non social (PME) | Corps of Engineers<br>Legislative Branch<br>Environmental Protection Agency<br>Justice<br>National Aeronautics and Space Administration<br>Homeland Security |
| Other | Executive Office of the President<br>Defense-Military<br>Veteran Affairs<br>General Services Administration |
| Mixed<br>(Private, Social, Public Goods and other subsidies) | Agriculture<br>Commerce<br>Energy<br>Interior<br>Labor<br>Small Business Administration<br>Transportation<br>Treasury<br>State and Other International Programs<br>Other Independent Agencies |

### TABLE A5: FEDERAL DIRECT SPENDING AND ASSISTANCE CLASSIFICATION

| **Direct Spending** | **Assistance** |
|---|---|
| Grants (Block, Formula, Project, and Cooperative Agreements)<br>Salaries and Wages<br>Procurement Contracts<br>Retirement and Disability Payments for Individuals<br>Other Direct Payments for Individuals<br>Direct Payments Other than for Individuals | Direct Loans<br>Guaranteed/Insured Loans<br>Insurance |

**TABLE A6: SOURCES OF POLLUTANT EMISSIONS – ANNUAL AVERAGES**

| | SO2 | PM2.5 | Ozone Precursors NO | VOC |
|---|---|---|---|---|
| | 1980-2000 | 1990-2000 | 1980-2000 | 1980-2000 |
| **TOTAL - (Thousand short Tons)** | 21,638 | 7,241 | 24938 | 21,392 |
| **SOURCES (% of Total)** | % | % | % | % |
| Electric Utilities: Fuel Combustion | 67 | 2 | 25 | 0.2 |
| Residential and Commercial Activities: Fuel Combustion (excluding Industrial Activities and Electric Utilities) | 3 | 7 | 4 | 4 |
| Industry: Processes and Fuel Combustion (% of Total) | 23 | 14 | 16 | 47 |
| Other Combustion (Agricultural/Forest/Slash Burning Fires) | 0 | 13 | 1 | 5 |
| **Transportation (% of Total)** | | | | |
| On-Road Vehicles | 2 | 4 | 33 | 30 |
| Non-Road Engines and Vehicles | 5 | 6 | 20 | 14 |
| Agriculture & Forestry (Crops and Livestock) | 0 | 13 | 0 | 0 |
| **Fugitive Dust** | | | | |
| Unpaved Roads | 0 | 21 | 0 | 0 |
| Paved Roads | 0 | 9 | 0 | 0 |
| Construction | 0 | 9 | 0 | 0 |
| Other | 0 | 2 | 0 | 0 |
| **Total** | 100 | 100 | 100 | 100 |

Source: Environmental Protection Agency (EPA)

**TABLE A7: SPATIAL LAG AND ERROR MODEL (PANEL – RANDOM EFFECTS)**

| | SO2 | | PM 2.5 | | Ozone | |
|---|---|---|---|---|---|---|
| | Spatial Lag Model | Spatial Error Model | Spatial Lag Model | Spatial Error Model | Spatial Lag Model | Spatial Error Model |
| Share of PME over Total Spending –State and Local Governments | -0.216**<br>[0.103] | -0.228**<br>[0.109] | -0.104**<br>[0.049] | -0.138**<br>[0.058] | -0.065**<br>[0.051] | -0.077**<br>[0.051] |
| Share of PME over Total Spending –Federal Grants, Expenditure, Loans and Insurance | 0.016<br>[0.050] | 0.020<br>[0.051] | -0.029<br>[0.021] | -0.028<br>[0.025] | -0.004<br>[0.014] | 0.004<br>[0.016] |
| Total State and Local Government Spending over GDP | -0.355***<br>[0.137] | -0.368**<br>[0.144] | 0.053<br>[0.050] | 0.034<br>[0.067] | -0.017<br>[0.044] | -0.021<br>[0.054] |
| Total Federal Government Spending over GDP | -0.038<br>[0.042] | -0.037<br>[0.043] | -0.024<br>[0.018] | -0.022<br>[0.020] | 0.006<br>[0.015] | 0.004<br>[0.017] |
| Personal Income per Capita by County – log difference (in thousands) | -0.256<br>[0.169] | -0.262<br>[0.171] | 0.035<br>[0.085] | 0.042<br>[0.087] | -0.122**<br>[0.060] | -0.096<br>[0.064] |
| Non-attainment Status for the whole county in the previous year (SO2 NAAQs) | -0.023<br>[0.027] | -0.023<br>[0.027] | | | 0.0004<br>[0.012] | -0.002<br>[0.012] |
| Non-attainment Status for part of the county in the previous year (SO2 NAAQs) | -0.004<br>[0.015] | -0.004<br>[0.015] | 0.005<br>[0.012] | 0.003<br>[0.012] | -0.001<br>[0.006] | 0.0001<br>[0.006] |
| Non-attainment Status for the whole county in the previous year (PM 2.5 NAAQs) | -0.070***<br>[0.019] | -0.070***<br>[0.020] | -0.041***<br>[0.007] | -0.033***<br>[0.007] | -0.010<br>[0.006] | -0.006<br>[0.007] |
| Non-attainment Status for part of the county in the previous year (PM 2.5 NAAQs) | -0.069<br>[0.049] | -0.068<br>[0.049] | -0.039*<br>[0.022] | -0.040*<br>[0.023] | 0.003<br>[0.020] | 0.001<br>[0.0019] |
| Non-attainment Status for the whole county in the Previous Year (PM10 NAAQs) | 0.007<br>[0.032] | 0.007<br>[0.032] | -0.001<br>[0.012] | -0.002<br>[0.012] | -0.003<br>[0.008] | -0.004<br>[0.008] |
| Non-attainment Status for part of the county for the previous year (PM10 NAAQs) | -0.005<br>[0.019] | -0.006<br>[0.019] | 0.003<br>[0.008] | 0.003<br>[0.008] | 0.003<br>[0.006] | 0.003<br>[0.006] |

| | | | | | | |
|---|---|---|---|---|---|---|
| Non-attainment Status for the whole county for the Previous Year (O3 NAAQs) | -0.006<br>[0.009] | -0.006<br>[0.009] | 0.007*<br>[0.004] | 0.004<br>[0.004] | 0.002<br>[0.002] | 0.0004<br>[0.003] |
| Non-attainment Status for part of the county for the previous year (O3 NAAQs) | 0.017<br>[0.026] | 0.016<br>[0.026] | 0.002<br>[0.009] | 0.002<br>[0.009] | -0.002<br>[0.005] | -0.003<br>[0.005] |
| Non-attainment Status for the whole county for the Previous Year (NO NAAQs) | 0.092<br>[0.086] | 0.092<br>[0.086] | | | -0.031<br>[0.032] | -0.032<br>[0.032] |
| Non-attainment Status for part of the county for the previous year (NO NAAQs) | 0.086<br>[0.052] | 0.087<br>[0.054] | | | -0.039**<br>[0.019] | -0.040**<br>[0.018] |
| Non-attainment Status for the whole county for the Previous Year (CO NAAQs) | 0.0003<br>[0.016] | -0.00003<br>[0.016] | -0.004<br>[0.017] | -0.005<br>[0.017] | -0.002<br>[0.006] | 0.003<br>[0.006] |
| Non-attainment Status for part of the county for the previous year (CO NAAQs) | -0.012<br>[0.013] | -0.012<br>[0.013] | 0.007<br>[0.011] | 0.006<br>[0.011] | -0.002<br>[0.003] | -0.001<br>[0.003] |
| Non-attainment Status for part of the county for the previous year (lead NAAQs) | 0.153***<br>[0.044] | -0.152***<br>[0.044] | 0.032<br>[0.023] | 0.030<br>[0.022] | 0.005<br>[0.015] | 0.001<br>[0.015] |
| Spatial Lag | 0.087***<br>[0.022] | | 0.431***<br>[0.017] | | 0.409***<br>[0.013] | |
| Spatial Autocorrelation | | 0.083***<br>[0.023] | | 0.433***<br>[0.017] | | 0.410***<br>[0.013] |
| Number of Observations | 4008 | 4008 | 3978 | 3978 | 6370 | 6370 |

* significant at 10%; ** significant at 5%; *** significant at 1%, Robust standard errors used