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“Have Government Spending and Energy Tax Policies Contributed to make Europe Environmentally Cleaner?”

by

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Contributed to make Europe Environmentally Cleaner?**

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1. INTRODUCTION

The composition and level of government spending has proven to be important in most areas of the economy. Despite this the relationship between government spending and the environment has received little attention in the literature. Energy taxes are quite prominent in most countries in Europe, where they tend to be higher than in most other regions of the world. Despite their significance very few studies have systematically analyzed their effects on pollution¹. This paper examines the effects of government spending and energy taxes on air pollutants using disaggregated data for 21 European countries over the 1995-2006 period. A study by López et al. (2010) developed a theoretical model in which they analyze the relationship between government spending composition and the environment. This is the first study that empirically estimates the impact of fiscal expenditure policies on pollution for a sample of 70 countries but it did not control for energy taxes.

In order to analyze the impact of government spending composition, it is important to use a taxonomy of expenditures that is conceptually meaningful and consistent with the available data. López and Galinato (2007) proposed a taxonomy of government expenditures that distinguishes between expenditures in public goods which alleviate the negative effects of market failures and government expenditures in private goods which may worsen the effects of market failures. Government expenditure in private goods includes subsidies directed to specific

¹ The studies by Fullerton et al. (2009) and Baranzini et al. (2000) use simulation exercises to examine the effects of environmental taxes on emissions.

industries or sectors such as input subsidies, farm programs, grants to corporations, subsidies to the production of fossil fuel, and subsidies to energy consumption.

Government expenditure in public goods include the expenditure in education, health and other social transfers (direct subsidies to households), environmental protection, research and development (R&D), knowledge creation and diffusion as well as conventional public goods such as, institutions and law and order. Unlike government expenditures in private goods, these expenditures may mitigate the effects of market failure and complement rather than substitute for private sector spending. Household subsidies, both direct and indirect via education and health care provision, reduce the effects of liquidity constraints and enable households to increase investment in human capital (Grant, 2007; Attanasio et al., 2008; Japelli, 1990; Zeldes, 1989). Investment on environmental protection, research and development, and creation and diffusion of knowledge, finance activities that otherwise would be under-funded due to the lack of incentives for the private sector to invest in these areas.

The reallocation of government expenditure towards public goods may result in three effects relevant to the environment (López et.al., 2010): 1. higher rates of economic growth which, *ceteris paribus*, may increase pollution; 2. the restructuring of production in favor of human capital-intensive activities that tend to pollute less than physical capital-intensive activities, 3. the reduction of the pollution-output ratio through the increase in efficiency and the creation of cleaner technologies as result of the investments in R&D and in creation and diffusion of knowledge. These effects are identified in the literature as the scale, composition and technique effects, respectively (Antweiler et al., 2001; López et al. 2010). The increase in income may induce a higher demand for more strict regulations and cleaner environment, which is known in the literature as the income effect.

The empirical literature of the determinants of pollution has been dominated by analyses focused on the effects of per capita income and trade policies in search of the so-called environmental Kuznets curve. The literature has examined the determinants of pollution concentrations using cross-country panel data focusing on per capita income as a key explanatory variable, but have not controlled for government spending level and composition, energy taxes, and for other environmental taxes and regulations (Grossman and Krueger, 1995; Harbaugh et al., 2002; Antweiler et al., 2001). This of course makes their estimates to be potentially affected by omitted variable biases unless government spending, energy taxes, and environmental regulations are uniquely determined by per capita income, an assumption that is quite untenable. The fact that some of these studies use country fixed effects does not mitigate this problem to the extent that the above omitted variables are likely to change over time.

In the literature of the environmental Kuznets processes and trade and environment, the problem of omitted variable bias has been acknowledged. Stern (2004) argues that the differences in coefficients between Fixed Effects (FE) and Random Effects (RE) in the estimation of the environmental Kuznets curve can be attributed to the existence of country and time omitted variables that could be correlated with the income coefficient. Several strategies have been used to try dealing with these problems, none of which is satisfactory: some studies have used FE estimators at the monitoring stations level (Harbaugh et al., 2002; Antweiler et al., 2001), while others assume that the unobserved variability is not correlated with the coefficients of interest and use RE estimators (Grossman and Krueger, 1995). Other studies have argued that it is not possible to control for the unobserved heterogeneity caused by the omitted variables at the country level and resort to run cross country regressions using data for a representative year (Frankel and Rose, 2005).

Antweiler et al. (2001) argue that it is possible to assume that unobserved country factors that might affect the determinants of air pollution are fixed over time due to the short number of observations for each country. They argue that there are country-specific omitted variables that are not being controlled for, such as regulations, tariffs and income distribution and propose the use of within country analysis to capture the effects of these variables. Following this argument, Deacon and Norman (2007), analyze different countries separately to control for unobserved cross-country heterogeneity in economic, political and climatic factors, which has the disadvantage of not being able to capture the cross sectional variability that could provide information about the important determinants of pollution at the economic and political level.

Although there have been attempts in the literature to control for the unobserved heterogeneity caused by omitted variables, none of them has controlled for omitted variables that change over time at the country level when using panel data at the monitoring-stations level. One problem has been the great complexity and variability of the myriad of environmental taxes and regulations that dramatically vary across countries and over time, this means that it is very difficult to have the needed data to control for these factors.

The empirical literature on the use of environmental taxes as an instrument to reduce pollution has mainly focused on using simulation exercises to analyze the impact of taxes over the concentration levels of pollution (Fullerton and Heutel, 2007; Bosquet, 2000; Baranzini et al., 2000), rather than using econometric modeling. One of the reasons argued for this choice has been the lack of suitable macro-data (Morley 2010).

Most of the macro empirical analysis focus on the effect of energy or carbon taxes on carbon dioxide emissions, not on local pollutants. Nevertheless, given that the reduction of CO₂

emissions is related to the reduction of fossil fuel consumption, there is an associated reduction on the levels of concentration of local pollutants (Baranzini et al., 2000).

Certain studies have used firm or industry level data to analyze the impact of environmental or energy taxes on the emissions or concentration of air pollutants. Millock and Nauges (2006) is one of the few empirical studies of local pollutants. They perform an econometric analysis of the impact of specific energy taxes in three industrial sectors in France (iron and steel, coke, and chemistry) over the emissions of NO_x and SO₂ and compare it with the effect of subsidies to the same sectors.

Morley (2010) uses panel data from the European Union to study the impact of environmental taxes on the level of total greenhouse gas emissions (CO₂ equivalent) using a macro level data for the 1995-2006 period controlling for per capita GDP and per capita capital. He finds that environmental taxes have a negative, significant and large impact on the emissions of greenhouse gas emissions.

The aim of this study is to empirically estimate the effects of the level and composition of government expenditure and energy taxes on the concentration of major air pollutants using a new approach that greatly mitigates the omitted variable biases that have plagued earlier studies of pollution. We use panel data estimators to analyze the effect of the level and composition of government expenditures and energy taxes over the concentration of Sulfur Dioxide (SO₂), Nitrogen Dioxide (NO₂) and Ozone (O₃) for 21 European countries. These three pollutants were chosen because they are “criteria pollutants”,² their measurements are reliable and consistent over time, have the largest number of observations available and can be regulated.

² These pollutants are defined as “criteria pollutants” because there are air quality standards that define the level of allowed concentrations of these pollutants in ambient air

Apart from considering the effect of fiscal expenditure policies and energy taxes over pollution, factors generally neglected by the literature, we improve on the existing literature on three other important aspects:

1. We use time-varying country effects (TVCE) as a generalization of the conventional fixed country effect (FCE) method, to control for any unobservable variables at the country level that change over time. The use of TVCE method is allowed by the fact that we have a large number of site observations for each country and in each period of time. The TVCE method reduces the risks of spurious correlations between pollution and our variables of interest caused by time-varying as well as fixed omitted variables. In the specific case of our estimation, unobserved or difficult to measure environmental regulations and taxes for example, are likely to be correlated with energy taxes and public expenditures, which if not controlled for would bias the estimated coefficients of such variables. While we control for certain environmental regulations especially those affecting large plants, the environmental regulations as well as the specific environmental taxes in the EU are so extensive and complex that explicitly controlling for them in a comprehensive way is exceedingly difficult. The TVCE method allows to prevent biases due to these and other important omitted variables as long as they are variables that affect all sites within each country and time period (that is, as long as the omitted variables are economy-wide).

2. We compare the impact of government spending composition with the effect of energy taxes. A key question is whether or not a government spending allocation that is more efficient, i.e., that has a higher participation of public goods in total spending, lowers pollution and hence reduces the burden of taxes and regulation as the sole instruments for pollution control.

3. We use a new dataset of air pollution for Europe. The existing empirical estimations have used the GEMS/AIR data which has observations for the period 1971-1996, (Grossman & Krueger, 1995; Antweiler et al., 2001; Harbaugh et al., 2002; Bernauer & Koubi, 2006). The largest number of observations at the monitoring stations level available in the old data sets is about 2,500 for SO₂. Our sample using more recent data has the advantage of including many more monitoring stations for each of 21 European countries, for the 1995-2006 period. The number of observations available for SO₂, for example, is more than 14,000 distributed in 2760 monitoring stations. This large number of observations and large number of monitoring stations per country allow us to implement a method such as the TVCE while still having enough degrees of freedom.

There have been other attempts to control for time-varying unobservable variables. The so-called Added Controls Approach (ACA) sequentially introduces a large number of controls (Altonji et al. 2005). The argument is that if the coefficients of interest are not affected (their significance and sign do not change) when different additional controls are added, then is less likely that these coefficients will be biased by the unobservables. Nevertheless Altonji et al. (2005) cautions about the problems of this methodology arguing that "...is dangerous to infer too much about selection on the unobservables from selection on the observables if the observables are small in number and explanatory power, or if they are unlikely to be representative of the full range of factors that determine an outcome".³ (p. 182).

³ The TVCE approach was used by López et al. (2010) only as robustness check mainly because the TVCE needs to estimate a very large number of coefficients. Since we have a large sample with many sites per country over several years we have enough degrees of freedom to be able to estimate the regressions without worrying about the degrees of freedom lost.

The remainder of this paper is organized as follows: Section 2 presents the econometric model, Section 3 describes the data used in the paper, Section 4 summarizes the results of the empirical analysis and Section 5 concludes the study.

2. ECONOMETRIC MODEL

Benchmark specification

The observations of pollution concentration are obtained from several monitoring stations across the 21 countries in each of the time periods. We assume that the annual average concentration of the pollutant of a particular station i , in country j at time t , Z_{ijt} , is determined by a vector reflecting the stocks of various government-provided goods, G_{jt} , in turn related to the corresponding government expenditure levels, by country-specific energy taxes, M_{jt} , and by certain observed environmental regulations at the EU level, R_t . In addition, we use a series of controls that can be classified as country-specific macroeconomic variables, Y_{jt} , characteristics of monitoring stations, X_{ij} , country climatic characteristics, E_{jt} , unobserved random effects specific to each monitoring station, $\tilde{\psi}_{ij}$, and by (unobserved) country-specific time-varying effects (TVCE), \tilde{v}_{jt} .

The vector of controls Y_{jt} include total tax revenues, the 3 year lagged average of household final consumption expenditure per capita (as a proxy for permanent per capita income) and aggregate investment rate. The vector of characteristics of the monitoring stations, X_{ij} , include elevation, longitude and latitude of the stations, and dummies that describe if the station is located in an area that is rural, suburban, background or in a place with high traffic.

Finally the vector of country climatic characteristics, E_{jt} , include mean temperature in summer and in winter.

Thus we have the following specification:

$$(1) \quad Z_{ijt} = \tilde{\psi}_{ij} + \alpha_1 G_{jt} + \alpha_2 M_{jt} + \alpha_3 R_{jt} + \alpha_4 Y_{jt} + \alpha_5 X_{ij} + \alpha_6 E_{jt} + \tilde{v}_{jt} + \tilde{\varepsilon}_{ijt},$$

Where $\tilde{\varepsilon}_{ijt}$ is a random disturbance.

The time-varying country effects, \tilde{v}_{jt} , which are a generalization of the standard fixed country effects, control for a myriad of possibly unobserved and hence omitted time-varying country variables that may affect the level of pollution concentrations of all the different monitoring stations in each specific country, including environmental regulations and specific taxes as well as macro and microeconomic policies, external shocks, institutional changes and so forth. That is, the specification postulated in Equation (1) controls for both station random effects, $\tilde{\psi}_{ij}$, as well as for non-random country-specific time-varying effects. This formulation is thus much more flexible than most other specifications in the literature.

While we have data on government expenditures flows for various key components we do not have reliable measures of their respective stock levels as would be needed to directly estimate equation (1). We thus express equation (1) alternatively in absolute or log differences. Each of course has different stochastic properties and requires different assumptions. Expressed in absolute changes over time the system is,

$$(2) \quad z_{ijt} = \psi_i + \alpha_1 g_{jt-1} + \alpha_2 m_{jt-1} + \alpha_3 r_t + \alpha_4 y_{jt} + \alpha_5 e_{jt} + v_{jt} + \varepsilon_{ijt},$$

where, $z_{it} \equiv Z_{it} - Z_{it-1}$; $g_{jt-1} \equiv G_{jt} - G_{jt-1}$; $y_{jt} \equiv Y_{jt} - Y_{jt-1}$; $e_{jt} \equiv E_{jt} - E_{jt-1}$; $r_t \equiv R_t - R_{t-1}$;
 $m_{jt-1} \equiv M_{jt} - M_{jt-1}$; $v_{jt} \equiv \tilde{v}_{jt} - \tilde{v}_{jt-1}$; $\psi_i \equiv \tilde{\psi}_i - \tilde{\psi}_{jt-1}$.

The change of the government stock variables from period t-1 to t is equal to the government spending at time t-1 in the respective stock, g_{jt-1} . Thus, an advantage of using differences is that the use of lagged instead of current government expenditure levels is justified. This mitigates possible biases in the estimation of the coefficients due to reverse causality between government spending patterns and pollution concentration. However, even if we use lagged values for the government spending we could still have biases and inconsistencies if the lagged values of these variables are correlated with unobserved or omitted variables that in turn affect current pollution concentration. However, the fact that we control for country-specific time-varying effects (v_{jt}) prevents these biases as long as the omitted variables are economy wide, that is, as long as they impact all monitoring site measures in each country and year.

We consider just two types of government expenditures, expenditures in public goods and government expenditures in private goods. Thus the vector g_{jt-1} is of dimension 2.

3. THE DATA

The air quality data consist of annual observations for three pollutants including sulfur dioxide (SO₂), nitrogen dioxide (NO₂) and ozone (O₃), encompassing 21 countries for the period 1995-2006. Air quality measures are taken from the AirBase dataset which is the air quality information system maintained by the European Environmental Agency through the European Topic Centre on Air and Climate Change. This data base contains information and data from networks and individual stations measuring ambient air pollution within the European Union

(EU) members, EU candidates, as well as Norway and Switzerland. From the 21 countries included 14 have been members of the European Union since at least 1995 and 6 have joined in during the last decade. The list of countries is in Table A3 in the appendix.

We used site level concentration measures for each of the three pollutants. The data include detailed information of monitoring station characteristics and measurement methods. Taking SO₂ as an example, the total number of observations is 14,078 for the 1995-2006 period distributed in 2,759 stations across 21 countries with about 5 annual measurements per site on average.

The government expenditure data is obtained from EUROSTAT database. We use the functional classification of government expenditures at the general government level.⁴ Government expenditure in public goods include expenditures in public order and safety, environment protection, housing and community amenities, health, recreation, culture and religion, education and social protection. We could either use directly each of the two government expenditures or alternatively we can use total government expenditures and the share of public goods in total government expenditures. We use the latter specification mainly because it provides for a natural normalization of government expenditures: share of public goods in total expenditures and share of total government spending in GDP.

The total spending in public goods is thus divided by total government expenditure to obtain the proportion of expenditure in public goods to total government expenditure. Also the

⁴ General Government includes "all institutional units which are other non-market producers whose output is intended for individual and collective consumption, and mainly financed by compulsory payments made by units belonging to other sectors, and/or all institutional units principally engaged in the redistribution of national income and wealth" (European system of accounts, 1995 edition).

total government expenditures are divided by GDP to obtain the share of government spending in the total output value of the economy.

The data for estimating the implicit tax rate on energy as well as the total taxes over GDP are obtained from the “Taxation Trends in the European Union Data for the EU Member States and Norway” (EUROSTAT Statistical Books, 2007). The other macroeconomic variables were obtained from the EUROSTAT database.

The data for monitoring station characteristic were obtained from the Airbase dataset and data for temperature were obtained from the National Climatic Data Center (NCDC) of the U.S. Department of Commerce. We include a regulation variable which is the Large Combustion Plant Regulation dummy. Table A1 in the Appendix presents the data source and descriptions while Table A2 shows the summary statistics of data used in the regressions.

4. RESULTS

4.1 Specification tests

We estimate equation (2) using Panel Data estimation methods. The benchmark model is Random Site Effects combined with Time Varying Country Effects (RSE-TVCE) presented in Table 1. This model takes into account the existence of underlying time-varying unobserved economy-wide variables, such as environmental and non-environmental policies and regulations that may affect pollution levels and which may be correlated with but not necessarily caused by the fiscal variables (government expenditure and taxes).

Also, to test the validity of the standard models we estimated the model using Fixed Site Effects combined with Fixed Country Effects (FSE-FCE) and Random Site Effects combined with Fixed Country Effects (RSE-FCE). Table 2 presents the RSE-FCE estimators and Table 3

presents the FSE-CFE estimators.⁵ We perform the corresponding tests to compare the three different models and to justify the selection of the RSE-TVCE estimators as our benchmark model.

4.1.1 Country specific Time-varying effects.

We test the restriction that country effects are fixed by testing the null hypothesis that $v_{jt} = v_j$ for all j . As can be seen in Table 4 the restricted fixed country effect model is rejected by a wide margin in favor of the TVCE model for each of the three pollutants. Thus, the above tests corroborate the empirical contribution of this paper: that merely controlling for fixed effects is an inadequate procedure.

4.1.2 Biases due to endogenous public expenditures and energy taxes.

The shares of government expenditure on public goods and levels of energy taxes are lagged in the model which should avoid the direct reverse causality between these variables and the levels of pollution; nevertheless, it is possible that such lagged expenditures and taxes could in principle be correlated with important omitted concurrent variables thus introducing biases in the estimates. However, as we argued earlier, the fact that we use time varying effects largely minimizes such risk as these effects control for concurrent omitted variables effects.

4.2 Analysis of the estimates

The estimates of the three models yield in general results that in certain aspects are similar but not in others. Table 5 compares the estimates of the three methods for the effects of the variables of interest, government expenditures and energy taxes. The sign of the effects of the government

⁵The Ordinary Least Squares combined with Time Varying Country Effects (OLS-TVCE) estimators are presented in Appendix C.

spending variables are almost all negative and significant, the only exception being the effect estimated using RSE-TVCE estimator for the share of public expenditures in the ozone equation which turns out to be positive but statistically insignificant. In terms of the value of the coefficients the estimates for NO₂ are in the range of -0.7 to -0.8 in all three estimators, but in the case of SO₂ the estimates provided by the RSE-TVCE method are much more negative than the other two estimators.

The effects of total government expenditures on each of the pollutants are all negative and significant, but their magnitudes are in general lower when the RSE-TVCE estimators are used. This could be a reflection of omitted variable biases affecting the two country fixed effect estimators; important economy-wide variables that are positively correlated with total government expenditures pollution may be in turn negatively correlated with pollution.

In general these estimates allow us to conclude that fiscal spending policies are important determinants of pollution; increasing participation of the government expenditures in the economy and, especially a more public goods orientation of spending are important factors reducing air pollution.

The differences between the RSE-TVCE and both fixed country effect estimators are much greater with respect to the estimated effects of energy taxes. As shown in Tables 2 and 3, both fixed country effects models yield unreasonable estimates for the effects of energy taxes on pollution: They give positive and significant effects for two of the three pollutants, SO₂ and O₃; the effect is negative only in the case of NO₂. These results are of course highly implausible. By contrast, our benchmark model RSE-TVCE estimates in Table 1 are much more plausible. The effects of energy taxes on both SO₂ and NO₂ are negative and significant while the effect on ozone is insignificant.

The signs and significance of the coefficients of the macroeconomic controls are generally plausible and consistent. The impact of changes in income, reflected in the coefficient of the household consumption per capita is positive for all the pollutants in most of the models, the coefficients of SO₂ and Ozone are negative in the RSE-TVCE but not significant. From the literature given that most EU countries have per capita incomes above the income threshold at which pollution starts declining as measured by the standard Kuznets curve models, we would expect the coefficient of the per capita household income to be negative and significant, at least for NO₂ and SO₂. The reason for this divergence with the existing consensus in the literature may be due to the fact that, unlike the literature, we are controlling for energy taxes as well as for government spending patterns and for other economy-wide variables that could be behind the standard estimates of the environmental Kuznets curves. For Ozone the household income effect is positive and significant in FSE-FCE and RSE-FCE and negative and insignificant in RSE-TVCE.

4.2.1 Impact Analysis.

Table 6 shows the effects of the shares of public goods, the ratio of total government expenditure over GDP, and the energy tax over GDP for the three pollutants, measured in terms of change in the % of the standard deviation of the pollutant in response to an increase in the explanatory variable by one standard deviation of the sample. In addition we provide the elasticity effects calculated using the coefficients in the three models, with all effects evaluated at mean values of the variables.

Increasing the share of government expenditures in public goods by 1%, holding total government expenditure constant, may result in a 1.4% reduction of SO₂ concentration and a 0.6% decrease in NO₂ concentrations according to the RSE-TVCE estimates. Comparing within

the sample the former implies that increasing the share of expenditures in public goods by one standard deviation (about 5% of the sample mean) reduces SO₂ concentrations by 8.6% of its standard deviation (or 6.9% of the sample mean) and NO₂ by 5% of its standard deviation (or 2.7% of the sample mean). Thus, it appears that the quantitative impact of changes in the composition of government spending is consistently large for SO₂ and NO₂ in all models.

According to the elasticity estimates in Table 6, a 1% increase in energy taxes reduce the level of SO₂ by 4.2% and 0.4% for NO₂, according with the RSE-TVCE; in the case of ozone the three models give a positive effect of the environmental tax over the level of ozone, but in the case of the RSE-TVCE model the effect is not significant. This could reflect the fact that even when countries can set maximum levels of ozone, it is not possible to control directly as in the case of NO₂ and SO₂. The concentration of ozone is formed from the combination of precursors and climate and weather conditions which might explain the apparent ineffectiveness of energy taxes over the concentration of ozone.

The high values of the elasticity of energy taxes for NO₂ and especially for SO₂ concentrations as provided by the RSE-TVCE suggest a very high degree of effectiveness of energy taxes as a mechanism to reduce such pollutants. These estimates are consistent with a few studies that have measured these effects. Millock & Nauges (2006) estimate elasticities of energy taxes on NO_x and SO₂ that vary from -2.67 to -0.21 depending on the industry analyzed. Morley (2010) using data for EU countries for the same period of our estimations finds elasticity of energy and related taxes on total greenhouse gas emissions (CO₂ equivalent) range between -4.5 and -8.2.

While the elasticities of energy taxes estimated using the RSE-TVCE method are always negative and significant they tend to change dramatically when evaluated at data points other than the mean values. This would suggest that the relationship between energy taxes and pollution is likely to be highly non-linear. Future analyses should allow for some form of non-linearity in order to get more precise estimators.

4.3 Sensitivity Analysis

In addition to the specification tests reported earlier, we perform a series of sensitivity analyses to ascertain the robustness of the estimators obtained with the RSE-TVCE model. We check for extreme data points that may dominate the sign and significance of the key estimates and for individual country dominance.

We conducted three dominance tests. In the first one we re-estimated the model for the three pollutants without the top and bottom 1% of the share of government expenditure in public goods, in order to be able to discard extreme observation dominance of the share of public goods. The second test followed the same procedure by re-estimating the model without the top and bottom 1% of the pollutant measures. The parameters are robust to the changes made in sample. Signs, significance and magnitudes of the parameter estimates from the models are shown in Tables B1 and B2 in Appendix B.

The third test focused on the effect of potential country outliers. We re-estimated our benchmark model (RSE-TVCE) for SO₂, NO₂ and Ozone dropping one country at a time (if the country has less than 5% of the total number of observations) and checked whether they altered the parameter estimates of the share of public goods. As shown in Figures 1A to 3A in Appendix B removing one country at a time does not affect the sign and significance of the estimated

parameters. Thus, these tests and the specification tests reported earlier allow us to conclude that the results are quite robust, not driven by dominant observations.

5. CONCLUSIONS

The most important conclusion of this paper is that the large participation of the public sector in the economy as well as the relatively high priority that most European countries have given to the provision of public goods has contributed in a very significant manner to make them environmentally clean. In addition, we have shown that the relatively high energy tax policy that most European countries have followed over the last decades has also greatly contributed to reduce pollution. These results should be regarded as an added incentive to the EU countries to persist and perhaps increase the emphasis in such policies. Also, they suggest that several non-European countries such as the USA and other large developing countries which currently have much lower energy taxes and fiscal spending policies that are heavily oriented to the provision of private goods instead of public goods, may obtain large environmental dividends by pursuing policies similar to those implemented by some EU countries.

While this paper has not analyzed the issue of climate-changing gases such as carbon dioxide, the results may have some relevance in this respect as well. Most of the air pollutants are emitted jointly so reducing any one of them is associated with changes in the same direction in other pollutant emissions. One could hypothesize that the findings summarized in the above paragraph are valid for carbon emissions as well; increasing the participation of public goods in

government spending and increasing energy taxes are likely to cause lower carbon emissions and thus contribute to mitigating climate change⁶.

To the best of our knowledge this is the first paper that systematically examines the role of fiscal policy and of energy taxes on environmental quality in Europe using a methodology that allows obtaining estimates mostly free of time-varying omitted variable biases. Our results empirically support the theoretical proposition made by López et al. (2010) in which they postulate that “increasing government expenditures in public goods entirely financed by decreasing expenditures in private goods reduces pollution”.

Environmental taxes have a different effect depending on the nature of the pollutant. In the case of SO₂, environmental taxes seem to be more effective than government expenditures, given that SO₂ is produced by the combustion of oil and coal in the generation of energy, the imposition of a tax on this industry has a direct impact on the level of the pollutant. In the case of NO₂ a pollutant caused mainly by the use of cars, government expenditure in public goods seems to be more effective, thus investing in public goods such as public transportation or education has more impact in the reduction of the pollutant than using environmental taxes. Ozone is a new pollutant and it is formed by the combination of other pollutants under special weather and climatic conditions, thus it is a pollutant that cannot be targeted directly, this might explain that the effect of environmental taxes seems positive and the only consistent negative effect seems to be that of the level of government expenditure.

⁶ Of course this presumption would have to be proven directly estimating a model for carbon emissions. However, the existing measures of carbon emissions are only indirect using fuel use and emission coefficients to estimate such emissions. By contrast, the measures of air pollutants used in this study are direct measures of pollutants in the air as measured by a large number of monitoring stations located across the continent. This means that local pollutants are measured with a much greater degree of precision than carbon emissions and therefore the econometric estimates for local air pollutants are much more reliable than those for carbon dioxide.

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Table 1
Random Site Effects with Time Varying Country Effects (RSE-TVCE)
Benchmark Model

	Log Diff SO2	Log Diff NO2	Log Diff Ozone
Share of expenditures in public goods (as % of total government exp) lagged	-1.894*** [0.329]	-0.748*** [0.158]	0.295 [0.231]
Share of total government expenditures over GDP lagged	-0.792* [0.451]	-0.596*** [0.192]	-0.299* [0.173]
Difference of Energy Tax Rate	-2.833*** [0.519]	-0.858*** [0.206]	0.147 [0.157]
Difference of Regulation over large Plants	0.121 [0.175]	0.0456 [0.0946]	7.91E-05 [0.119]
Difference of 3 Year Moving Average of Log of Household final consumption per capita (1995 euros)	11.408*** [1.392]	-0.573 [0.508]	-0.732 [0.632]
Ratio of total tax revenue over GDP (Time Difference)	19.86*** [1.889]	0.146 [1.195]	-3.793*** [1.407]
Investment Rate over GDP lagged	-1.601** [0.690]	-0.947*** [0.365]	-0.63 [0.439]
Observations	14078	15795	12688
No. of Sites	2759	3067	2288
Hausman Test (P-value)			
Overall R-squared	0.152	0.0974	0.171

Robust standard errors in brackets.

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

Estimation includes 125 coefficients for the dummy variables that capture the TVCE, which are not shown in the table. Also not reported in the table are the coefficients for the monitoring station characteristics: elevation, longitude and latitude; for the dummies that define the type of station: rural, suburban or background; as well as for the average country temperature on winter and summer.

Table 2
Random Site Effects with Fixed Country Effects (RSE-FCE)

	Log Diff SO2	Log Diff NO2	Log Diff Ozone
Share of expenditures in public goods (as % of total government exp) lagged	-0.903*** [0.249]	-0.797*** [0.151]	-0.869*** [0.194]
Share of total government exp over GDP lagged	-2.618*** [0.260]	-0.789*** [0.144]	-0.871*** [0.123]
Difference of Energy Tax Rate	0.104*** [0.0339]	-0.0922*** [0.0187]	0.0988*** [0.0208]
Difference of Regulation over large Plants	-0.0456*** [0.0105]	-0.0285*** [0.00727]	-0.0191*** [0.00546]
Difference of 3 Year Moving Average of Log of Household final consumption per capita (1995 euros)	1.706*** [0.441]	0.367 [0.300]	1.577*** [0.273]
Ratio of total tax revenue over GDP (Time Difference)	-0.923** [0.467]	-0.980*** [0.245]	-0.196 [0.223]
Investment Rate over GDP lagged	-2.381*** [0.205]	-0.076 [0.141]	0.144 [0.140]
Observations	14078	15795	12688
No. of Sites	2759	3067	2288
Overall R-squared	0.0514	0.0399	0.0521
Hausman Test (P-value)	0.9924	0.1311	0.0176

Robust standard errors in brackets.

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

The coefficients for monitoring station characteristics: elevation, longitude and latitude; for the dummies that define the type of station: rural, suburban or background; average temperature on winter and summer; as well as the 21 coefficients of the country fixed effects have been estimated but are not reported in the table.

Table 3
Fixed Site Effects with Fixed Country Effects (FSE-FCE)

	Log Diff SO2	Log Diff NO2	Log Diff Ozone
Share of expenditures in public goods (as % of total government exp) lagged	-0.940*** [0.245]	-0.893*** [0.132]	-0.967*** [0.197]
Share of total government exp over GDP lagged	-2.685*** [0.263]	-0.919*** [0.123]	-0.933*** [0.110]
Difference of Energy Tax Rate	0.105*** [0.0393]	-0.0982*** [0.0201]	0.0985*** [0.0193]
Difference of Regulation over large Plants	-0.0497*** [0.0114]	-0.0309*** [0.00768]	-0.0198*** [0.00555]
Difference of 3 Year Moving Average of Log of Household final consumption per capita (1995 euros)	1.816*** [0.460]	0.512 [0.324]	1.620*** [0.250]
Ratio of total tax revenue over GDP (Time Difference)	-0.897* [0.495]	-0.840*** [0.261]	-0.27 [0.205]
Investment Rate over GDP lagged	-2.363*** [0.222]	-0.104 [0.129]	0.157 [0.137]
Observations	14078	15795	12688
Number of fullsiteid	2759	3067	2288
Adjusted R-squared	0.042	0.041	0.065

Robust standard errors in brackets.

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

The coefficients for average country temperature on winter and summer as well as the 21 fixed country effects have been estimated but are not reported in the table.

TABLE 4. SPECIFICATION TEST

Models Compared	SO2		NO2		Ozone	
	LR Test	Preferred Model	LR Test	Preferred Model	LR Test	Preferred Model
Between Random site Effects-Fixed Country effects and Random site Effects with Time Varying Country Effects	1547	with Time Varying Country Effects	982	with Time Varying Country Effects	1742	with Time Varying Country Effects

Critical value: 140.69

TABLE 5: COMPARISON OF THE RESULTS USING THE THREE METHODS

Specification	SO2			NO2			Ozone		
	Coefficient Share of Gov. Exp in Public Goods	Coefficient Energy Tax Rate	Overall R-Squared	Coefficient Share of Gov. Exp in Public Goods	Coefficient Energy Tax Rate	Overall R-Squared	Coefficient Share of Gov. Exp in Public Goods	Coefficient Energy Tax Rate	Overall R-Squared
Random site effects-time varying country effects (RSE-TVCE)	-1.894***	-2.833***	0.152	-0.748***	-0.858***	0.0974	0.295	0.147	0.171
Random site effects-Fixed Country effects (RSE-FCE)	-0.903***	0.104***	0.0514	-0.787***	-0.092***	0.039	-0.869***	0.098***	0.0521
Fixed Site Effects-Fixed Country effects (FSE-FCE)	-0.940***	0.105***	0.042	-0.893***	-0.098***	0.041	-0.967***	0.0985***	0.065

**TABLE 6
SIMULATIONS AND ELASTICITIES**

	SO2			NO2			OZONE		
	RSE-TVCE	RSE-FCE	FSE-FCE	RSE-TVCE	RSE-FCE	FSE-FCE	RSE-TVCE	RSE-FCE	FSE-FCE
Change in the pollutant when the Share of Public Goods increases by one Standard Deviation (% of std dev of pollutant)	-8.6%*	-4.08%*	-4.25%*	-5.0%*	-5.30%*	-5.94%*	6.03%	-14.56%*	-16.20%*
Elasticity of the Share of Public Goods	-1.4*	-0.66*	-0.69*	-0.6*	-0.59*	-0.66*	0.21	-0.64*	-0.71*
Change in the pollutant when the ratio of total government expenditure over GDP increases by one Standard Deviation (% of std dev of pollutant)	-4.7%*	-15.67%*	-16.07%*	-5.4%*	-7.07%*	-8.24%*	-7.16%*	-21.24%*	-22.75%*
Elasticity of the ratio of total gov. exp.	-0.4*	-1.24*	-1.27*	-0.3*	-0.37*	-0.44*	-0.14*	-0.41*	-0.44*
Change in the pollutant when the Energy Tax Rate increases by one Standard Deviation (% of std dev of pollutant)	-157.7%*	5.79%*	5.84%*	-71.7%*	-7.70%*	-8.20%*	3.00%	20.58%*	20.52%*
Elasticity of the Energy Tax Rate	-4.2*	0.15*	0.15*	-0.4*	-0.04*	-0.04*	0.01	0.15*	0.15*

*significant at least at 10%

APPENDIX A

Table A1: Description of Variables

Variable	Description	Years Available	Source
Sulfur Dioxide	SO ₂ concentration, micrograms per cubic meter	1995-2006	AirBase from the European Topic Centre on Air and Climate Change, under contract to the European Environment Agency
Nitrogen Dioxide	NO ₂ concentration, micrograms per cubic meter	1995-2006	AirBase from the European Topic Centre on Air and Climate Change, under contract to the European Environment Agency
Ozone	O ₃ concentration, micrograms per cubic meter	1995-2006	AirBase from the European Topic Centre on Air and Climate Change, under contract to the European Environment Agency
Household final consumption expenditure per capita (3 year moving average)	Household final consumption expenditure is the market value of all goods and services including durable products (such as cars, washing machines, and home computers), purchased by households. It excludes purchases of dwellings but includes imputed rent for owner-occupied dwellings. It also includes payments and fees to governments to obtain permits and licenses. Here, household consumption expenditure includes the expenditures of non-profit institutions serving households, even when reported separately by the country. (1995 Euros)	1989-2006	EUROSTAT
Share of government expenditure on public goods	Government expenditure on public goods over total government expenditure. Public goods are defined as: i) Public order and safety, ii) Environment protection, iii) Housing and community amenities, iv) Health, v) Recreation, culture and Religion, vi) Education, vii) Social protection	1989-2006	EUROSTAT Level of government: general Government
Share of total government expenditure over GDP	Total Government Expenditure (million euros 1995) over GDP (million euros 1995)	1989-2006	EUROSTAT
Share of total Taxes over GDP	Total Revenue Taxes	1989-2006	EUROSTAT
Energy Tax Rate	Implicit Tax Rate on Energy	1995-2006	Taxation trends in the European Union Data for the EU Member States and Norway, EUROSTAT Statistical Books
Investment Rate	Gross Capital Formation in million euros (excluding gross capital formation from the government) over GDP in million euros	1990-2006	EUROSTAT
Regulation on Large Utilities	Large Combustion Plant Regulation dummy, takes the value of 1 from 2001 (year in which it was established), and 0 otherwise	1990-2006	Emission Control Regulations in Europe, from Air pollution in Europe 1990–2004, EEA Report No 2/2007

Table A2. Summary Statistics of the Data Used in Regressions

Variable	Mean	Std. Dev.	Min	Max	Units
SO2	7.20	5.86	.1	85.5	ug/m3 microgram per Cubic Meter
NO2	29.10	15.6	.5	120	ug/m3 microgram per Cubic Meter
O3	68.2	14.7	1.9	137.8	ug/m3 microgram per Cubic Meter
Per Capita Household Consumption (3 year avg)	11,507.8	3,399.3	1,209.6	16,308.1	1995 euros
Ratio of Public Expenditure in Public Goods over Total Government Expenditure	.734	.034	.593	.784	
Ratio of Total Government Expenditure over GDP	.473	.049	.330	.600	
Energy Tax Rate (ITR)	1.48	.45	.22	2.89	Euros per Tonnes of Oil Equivalent
Ratio of Total Tax Revenue over GDP	.253	.034	.189	.495	
Ratio of Total Investment over GDP (rate of investment)	.192	.032	.134	.346	

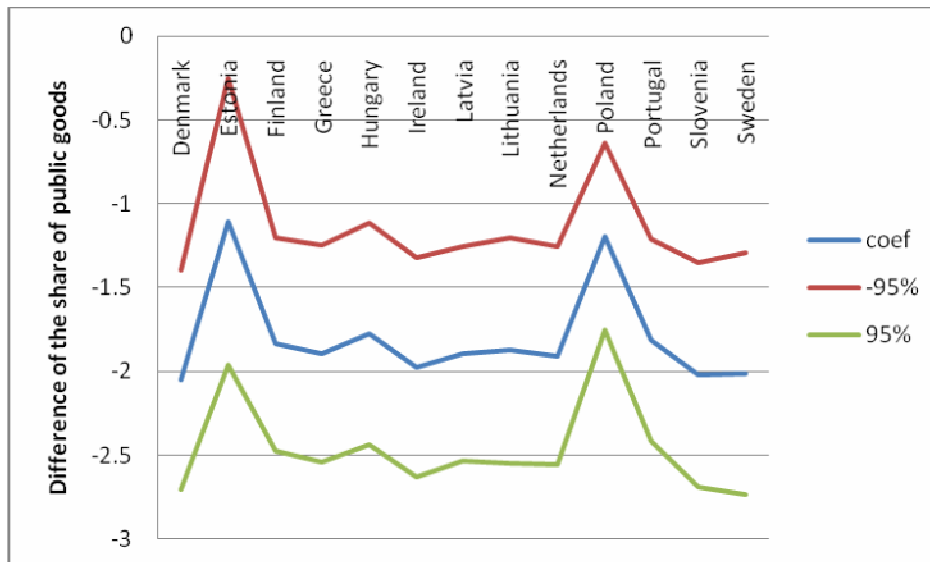
A.3 Country List

Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Netherlands, Poland, Portugal, Slovenia, Spain, Sweden, United Kingdom.

APPENDIX B: Sensitivity Analysis

i. Country dominance Checks*

Figure 1A: RANDOM SITE EFFECTS-TIME VARYING COUNTRY EFFECTS ESTIMATORS: One Country Excluded From Each Estimation of the SO₂ Regression, 95% Confidence Interval



*Excluding countries that have more than 5% of the observations of the sample.

Figure 2A: RANDOM SITE EFFECTS- TIME VARYING COUNTRY EFFECTS
 ESTIMATORS: One Country Excluded From Each Estimation of the NO2 Regression, 95% Confidence Interval

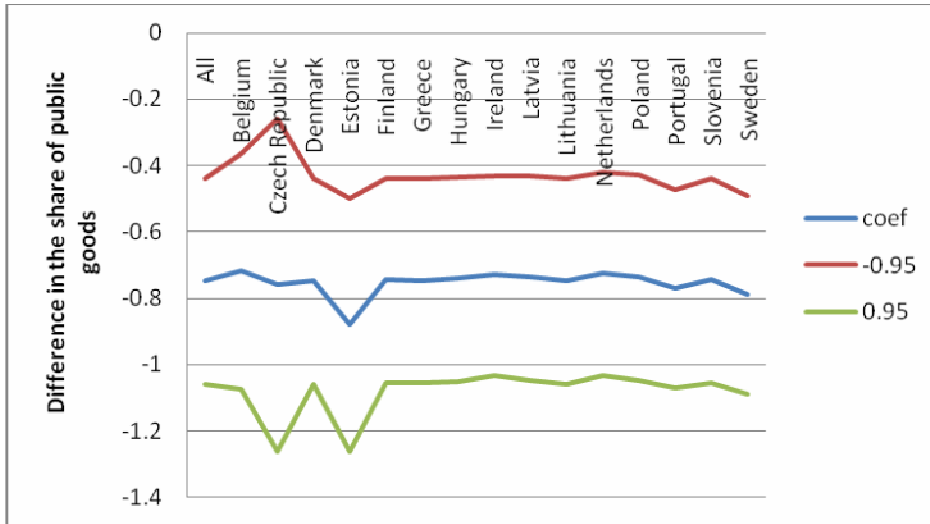
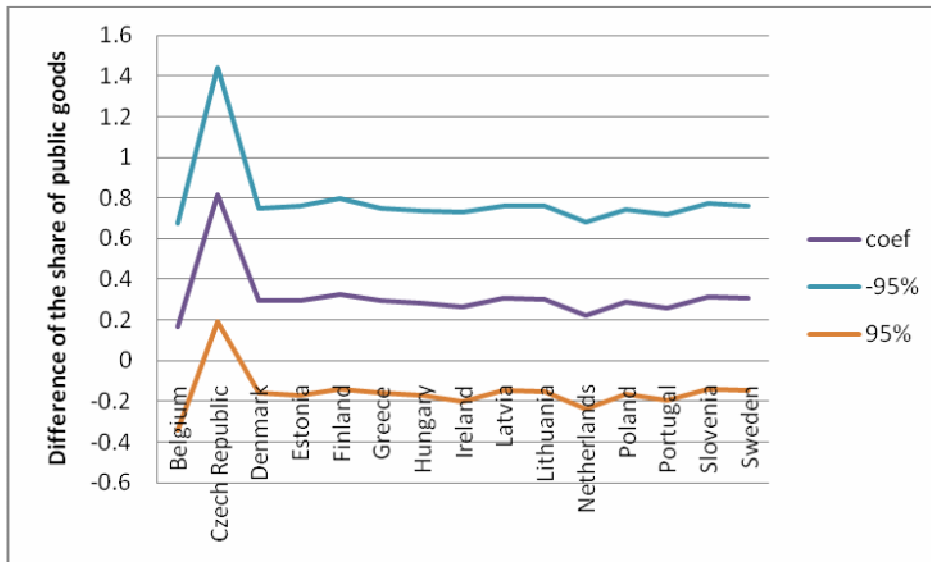


Figure 3A: RANDOM SITE EFFECTS- TIME VARYING COUNTRY EFFECTS
 ESTIMATORS: One Country Excluded From Each Estimation of the O3 Regression, 95% Confidence Interval



ii. Extreme Observations Checks

Table B1
Coefficient of Expenditures in Public Goods (as % of Total Government Expenditure)
Dropping Extreme Observations of the Share of Public Goods

Environmental Quality and Pollution Measure	Bottom 1% of Share of Public Goods Expenditures in each year	Top 1% of Share of Public Goods Expenditures in each year	Top and Bottom 1% of Share of Public Goods Expenditures in each year
SO2	-1.900***	-1.902***	-1.908***
NO2	-0.763***	-0.758***	-0.774***
O3	0.371	0.310	0.370

The models used to estimate these coefficients are Random Site Effects and Time Varying Country Effects.

Table B2
Coefficient of Expenditures in Public Goods (as % of Total Government Expenditure)
Dropping Extreme Observations of the Pollutant

Environmental Quality and Pollution Measure	Bottom 1% of Pollutant in each year	Top 1% of Pollutant in each year	Top and Bottom 1% of Pollutant in each year
SO2	-1.914***	-1.852***	-1.844***
NO2	-0.793***	-0.623***	-0.661***
O3	-0.0347	0.288	-0.0436

The models used to estimate these coefficients are Random Site Effects and Time Varying Country Effects.

APPENDIX C

Ordinary Least Squares combined with Time Varying Country Effects (OLS-TVCE)

	Log Diff SO2	Log Diff NO2	Log Diff Ozone
Share of expenditures in public goods lagged (as % of total government exp) lagged	-0.854*** [0.252]	-0.255** [0.120]	0.301** [0.140]
Share of total government exp over GDP lagged	0.647** [0.309]	0.0783 [0.122]	-0.393*** [0.136]
Difference of Energy Tax Rate	-1.221*** [0.313]	-0.441*** [0.168]	0.0806 [0.135]
Difference of Regulation over large Plants	0.149 [0.171]	-0.0887 [0.0851]	0.0458 [0.106]
Difference of 3 Year Moving Average of Log of Household final consumption per capita (1995 euros)	11.73*** [1.463]	0.0481 [0.502]	-1.073** [0.490]
Ratio of total tax revenue over GDP (Time Difference)	16.97*** [1.903]	-2.151* [1.126]	-3.067*** [1.153]
Investment Rate over GDP lagged	-0.661 [0.645]	-0.311 [0.312]	-0.407 [0.321]
Observations	14078	15795	12688
Adjusted R-squared	0.21	0.0881	0.167

Robust standard errors in brackets. Estimates don't include constant. The controls included are station characteristics: elevation, longitude and latitude; and dummies that define the type of station: rural, suburban or background. Additional controls are average temperature on winter and summer.

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