DISCUSSION PAPER SERIES

No. 8551

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INTERNATIONAL MACROECONOMICS

Centre for Economic Policy Research

www.cepr.org

ISSN 0265-8003

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Discussion Paper No. 8551
August 2011

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This Discussion Paper is issued under the auspices of the Centre's research programme in **INTERNATIONAL MACROECONOMICS**. This paper is produced as part of the project Growth and Sustainability Policies for Europe (GRASP), a Collaborative Project funded by the European Commission's Seventh Research Framework Programme, Contract number 244725. Any opinions expressed here are those of the author(s) and not those of the Centre for Economic Policy Research. Research disseminated by CEPR may include views on policy, but the Centre itself takes no institutional policy positions.

CEPR Discussion Paper No. 8551

August 2011

ABSTRACT

Why Europe has become environmentally cleaner: Decomposing the roles of fiscal, trade and environmental policies*

This paper systematically examines the role of fiscal policy, trade and energy taxes on environmental quality in Europe using disaggregated data for 12 European countries over the 1995-2008 period. It uses a methodology that obtains estimates mostly free of time-varying omitted variable biases. Controlling for the scale effect, our estimations show that fiscal policies and energy taxes are effective in reducing the concentration of certain pollutants through different mechanisms. We also find that trade has a direct effect on production pollutants, which is most likely due to an output composition effect, but not on consumption pollutants. Increasing the share of fiscal spending and shifting the emphasis of fiscal spending towards public goods and against non-social subsidies has a surprising and unintended beneficial effect on the concentrations of ozone, perhaps the most difficult to control pollutant. Finally, energy taxes appear to have an important effect in reducing nitrogen dioxide pollution but it has no effect on ozone and sulfur dioxide.

JEL Classification: H40, H50, O13 and O44
Keywords: government spending, pollutions, public goods and taxes

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* The authors thank Antonio Estache and Asif Islam for useful comments.

Submitted 15 August 2011

1. Introduction

This paper provides a decomposition analysis that quantifies what portion of the observed pollution reductions in the twelve richest European countries can be attributed to fiscal policies, trade, and energy taxes and regulations. We show that fiscal policies and increasing trade openness explain the largest portion of the observed reductions of production-originated pollutants (e.g., sulfur dioxide) while energy taxes explain most of the observed decreases of pollutants originated in consumption activities (e.g., nitrogen dioxide). This is the first econometric study that compares the effects of fiscal expenditure policies, energy taxes and trade openness on environmental quality in Europe.

In doing this analysis we show for the first time that a policy factor that so far has been largely neglected plays a key role in affecting pollution: fiscal spending policy. Fiscal spending has proven to be important in most areas of the economy.[1] However the relationship between fiscal policies and environmental quality has received scant attention in the literature. Fiscal factors are likely to be especially important in Europe where the participation of government spending in the economy tends to be higher than in most other regions of the world (Dewan and Ettlinger, 2009).

This paper also examines how increases in trade intensity affect pollution in wealthy countries. Earlier studies (Grossman and Krueger, 1992; Antweiler *et al.*, 2001, Frankel and Rose. 2005, among others) have already examined the effect of trade on pollution using samples that include a large proportion of middle income and poor countries. These studies have found that trade contributes to reduce pollution. This result may be driven by environmental

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[1] Studies have focused for example on the effects of public expenditure level and composition on poverty reduction, income distribution and inequality (Kaplow, 2006), unemployment (Fougerè *et al.*, 2000), education (Hanushek, 2003), and many other areas.

improvements in poor and middle income countries due to the fact that trade may facilitate their importation of cleaner technologies already existing in rich countries (Antweiler *et al.*, 2001). However, trade may not increase environmental efficiency in rich countries; it may merely induce them to shift production towards cleaner outputs thus displacing their dirty industries to poor countries. We also analyze the effect of energy taxes and certain environmental regulations which may increase the incentives in rich countries to produce new more environmentally efficient technology (Knigge and Görlach, 2005).

The empirical literature on trade and environment has examined how trade affects pollution, using cross country panel data, controlling for per capita income, but have not controlled for government spending level and composition and energy taxes. The studies that look at the effect of trade on environment may be affected by omitted variable bias as recognized by Antweiler *et al.*, 2001. These studies use two way fixed effect (TWFE) to deal with the bias; however this procedure is not efficient to control for country specific time varying omitted variable bias.

The empirical literature on the effects of energy and environmental taxes has mainly used simulation exercises, rather than econometric modeling (Baranzini *et al.*, 2000; Fullerton and Heutel, 2007, Fullerton et al., 2009). One of the reasons argued for this methodology has been the lack of suitable data that may capture the enormous variability of institutional and policy variables that may affect pollution (Morley 2010). Another strand of the literature has used firm or industry level data (Millock and Nauges, 2006; Morley, 2010). These studies find that energy and environmental taxes have a negative and significant impact on air pollutants. However, these studies are also likely to be affected by issues concerning time varying omitted variables discussed earlier.

The aim of the study is to estimate empirically the effects of the level and composition of government expenditures, trade, and energy taxes on three major air pollutants, sulfur dioxide (SO2), nitrogen dioxide (NO2) and ozone (O3). [2] SO2 is produced by industrial processes and electricity generation and it is considered a "production pollutant". NO2 is produced mostly by road vehicles and can be considered a "consumption pollutant." O3 also falls under "consumption pollutants" as it is the product of the combination of Nitrogen Oxides (NOx) and volatile organic compounds.

We improve the analysis of the determinants of pollution on two other important aspects:

1. We introduce a method that generalizes the conventional Fixed Country Effects (FCE) approach; a method that we call time-varying country-specific effects (TVCE).

The TVCE method reduces the risks of spurious correlation between pollution and the variables of interest caused by time-varying as well as fixed unobserved or difficult-to-measure variables which may be correlated with the variables of interest. While we directly control for certain environmental regulations, especially those affecting large plants and NOx, there are many other economic and institutional variables that may affect pollution which are difficult to measure and hence exceedingly difficult to directly control for. The TVCE is a parsimonious and eclectic approach that allows for indirectly controlling for omitted variables without a direct measurement of them.[3]

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[2] We select these pollutants because their measurements are reliable and consistent over time, they have the largest number of observations available, they can be regulated, and accepted quality standards exist for them (EPA, 2010).

[3] An alternative method to control for time-varying unobservable variables is the so-called Added Controls Approach which sequentially introduces a large number of controls (Altonji *et al.*, 2005). Nevertheless Altonji *et al.* (2005) do caution about this methodology: "….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". (p. 182).

2. We use a new dataset of air pollution for Europe. The existing empirical estimations have used the GEMS/AIR data which have observations for the period 1971-1996, (Grossman and Krueger, 1995; Antweiler *et al.*, 2001; Harbaugh *et al.,* 2002; Bernauer and Koubi, 2006). Our sample, using more recent data, has the advantage of including more monitoring stations in each of the countries analyzed, for the 1995-2008 period. The number of observations available for SO2, for example, is five times larger than in the old data set, with about 16,000 observations distributed in 2,666 monitoring stations. This large number of observations allows us to implement the TVCE method, which as we shall see requires us to estimate a large number of auxiliary coefficients. An additional advantage of the sample under study is the relative homogeneity of the countries in relation to trade policies, which allow us to understand the effects of trade on production and consumption pollutants in developed countries, avoiding the possible mixed effect found in more heterogeneous samples that include countries with different levels of income.

The remainder of this paper is organized as follows: Section 2 discusses conceptual issues, Section 3 presents the econometric model, Section 4 describes the data, Section 4 summarizes the results and Section 5 concludes.

2. Conceptual Issues

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 on what they term “public goods,” defined as those that alleviate the negative effects of market failures, and expenditures on “private goods,” which do little to

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mitigate market imperfections.[4] Accordingly, government expenditures on public goods include expenditures on education, health, social transfers, environmental protection, research and development (R&D), knowledge creation and diffusion, as well as conventional public goods such as, institutions and law and order. By contrast, government expenditures on private goods are subsidies to special interest groups including credit and input subsidies, farm commodity programs, subsidies to the production and consumption of fossil fuels, periodic bail outs of corporations deemed too large to fail, and others.

Unlike government expenditures on private goods, expenditures on public goods may complement rather than substitute private sector spending. Household subsidies, both direct and indirect via education and health care provision, mitigate the negative effects of liquidity constraints on investments in human capital (e.g. Galor and Zeira, 1993) which according to recent studies affect a significant portion of households even in wealthy countries (Zeldes, 1989; Japelli, 1990; Grant, 2007; Attanasio *et al.*, 2008).[5] Investment in environmental protection, research and development, and creation and diffusion of knowledge, finance activities that otherwise would be under-funded due to generally insufficient market incentives for the private sector to invest in these areas (Dasgupta, 1996; Hoff and Stiglitz, 2000).

A reallocation of government expenditure from private to public goods may result in two main effects on the environment (López *et al.*, 2011): (1) The expansion of aggregate output which may increase pollution (scale effect); (2) the restructuring of production in favor of human

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[4] Fiorito and Kollintzas (2004) provide a different but related taxonomy based on the relationship between the types of goods provided by the government and private consumption. *Public goods* are defined as those that cannot be provided by the private sector such as defense, public order and justice. *Merit goods* include health, education and others that are in part provided by the private sector but where the public sector may have an important complementary role.

[5] In addition, studies have shown that human capital investments often have spillovers that increase their social value beyond their private returns (Blundell *et al.*, 1999; Fleisher *et al.*, 2010).

capital–intensive activities that tend to pollute less than physical capital-intensive activities (output composition effect). In addition, fiscal spending reallocation towards public goods may also induce more investments in R&D and in diffusion of knowledge, which in turn could lead to cleaner technologies thus triggering the technique effect.

The impact of trade expansion on the environment has also been associated with scale, technique and composition effects (Grossman and Krueger, 1992; Antweiler *et al.*, 2001; Frankel and Rose, 2005). The effects of trade vary depending on the nature of the pollutant and on the level of income of the economy. Increases in the volumes of trade may cause an expansion of the economic activity (scale effect) thus, ceteris paribus, raising production-generated pollution. Trade may also induce a technique effect on pollution but this effect has been mainly considered to be due to the fact that trade increases income, which in turn may raise the desire of stricter environmental regulations. Hence, if we control for real income, taxes and regulations, as we do here, the remaining effect of trade should capture mostly the output composition effect. Trade could also affect pollution by facilitating transfers of technology. The increased technology transfer effect is most important for poor countries that tend to be the ones that receive technologies from the more advanced countries. However, given that our sample includes only rich countries which are the ones that generate environmentally clean technologies, this effect should not impact their own environments so much.

Environmental regulations and environmental taxes may have an effect on the environment mostly through the technique effect, in which the level of emissions per unit of goods produced or consumed is reduced (Knigge and Görlach, 2005). Environmental and energy taxes directly increased the costs of “dirty” inputs or of dirty consumption goods such as fuels or gasoline, thus inducing their savings and substitution. While these policies may also induce some output composition effect by increasing the relative price of the outputs that use dirty inputs more intensively, this effect is likely to be weak. As Karp (2011) argues, one possible explanation for the weakness of the composition effect of environmental policies is that the costs of complying with environmental regulations account for only a small share of total production costs, creating little incentives to relocate production of dirty goods. Thus, unlike economy-wide policies energy taxes and regulations are likely to have first order effects on techniques and structure of consumption goods and only a second order effect on production composition.

Controlling for the scale effect, and given the sample of developed countries and the type of pollutants considered in our analysis, it is expected that energy taxes and environmental regulations mostly amplify the technique effect; trade mostly influences the composition effect in the case of production pollutants and have little effect on pollution produced by consumption activities. Fiscal policies may affect pollution via both the technique and output composition effects.

3. Econometric Model

We assume that the annual average pollutant concentration at monitoring station *i*, in country *j* at time *t*, Z_{ijt} , is determined by a vector reflecting the stocks of public and private goods provided by the government, $\mathbf{G_{jt}}$, trade intensity TI_{jt}, country-specific energy taxes, M_{jt}, and certain environmental regulations at the country level, R_{jt}. In addition, we control for the three year average of household final consumption expenditure per capita (as a proxy for permanent per capita income), Y_{jt}. We also control for temperature using heating degree days, E_{jt}. Finally, the model controls for unobserved monitoring station and fixed and time-varying unobserved country effects.

While we have data on government expenditure flows for various key components we do not have reliable measures of their respective stock levels. Similarly, we have data on private investment but not on private capital stocks. We thus write Equation (1) below in differences so that the annual differences of the government stocks can be approximated by the lagged level of the corresponding government expenditures and the differences of the private capital stocks by the lagged level of private investment. We then have,

$$z_{ijt} = \psi_{ij} + \alpha_1 \mathbf{g_{j,t-1}} + \alpha_2 ti_{j,t} + \alpha_2 m_{j,t} + \alpha_3 r_{jt} + \alpha_4 y_{j,t} + \alpha_5 E_{jt} + v_{jt} + \tilde{\varepsilon}_{ijt} \qquad (1)$$

$$i \in \{1, 2, ..., I\},\ j \in \{1, 2, ..., J\},\ t \in \{1, 2, ..., T\},$$

where, $z_{ijt} \equiv Z_{ijt} - Z_{ij,t-1}$; $\mathbf{g_{j,t-1}} \equiv \mathbf{G_{jt}}\text{-}\mathbf{G_{j,t-1}}$; $ti_{jt} \equiv TI_{jt} - TI_{j,t-1}$; $m_{jt} \equiv M_{jt} - M_{j,t-1}$; $r_{jt} \equiv R_{jt} - R_{j,t-1}$; $y_{j,t\text{-}1} \equiv Y_{jt}\text{ - }Y_{jt\text{-}1}$; ψ_{ij} is an unobserved monitoring station effect; v_{jt} is an unobserved function that includes fixed and time-varying, country-specific effect; and $\tilde{\varepsilon}_{ijt}$ is an idiosyncratic error that is assumed to be independent and identically distributed with zero mean and fixed variance.[6]

The v_{jt} effect corresponds to the TVCE. We approximate the v_{jt} effect by a (T-2)th order (country specific) polynomial function of time,

$$v_{jt} = b_{0j} + b_{1j}\tau \ + b_{2j}\tau^2 + b_{3j}\tau^3 + ... + b_{T-2,j}\tau^{T-2} + \mu_{jt} \qquad (2)$$

where τ is a time trend variable $(\tau = 1, ..., T)$, $b_{0j}, b_{1j}, b_{2j}, ..., b_{T-2,j}$ are country-specific coefficients and μ_{jt} is the residual. Using (2) in (1) we obtain the estimating equation where the new disturbance term is $\varepsilon_{ijt} \equiv \tilde{\varepsilon}_{ijt} + \mu_{jt}$. The (T-2)th order (country specific) polynomial function of time in Equation (2) is the maximum order of approximation that allows for sufficient degrees of freedom to estimate the effects of observed country variables on pollution.

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[6] The fixed station characteristics $\mathbf{X_{ij}}$ vanish as a consequence of first differencing. e

To fully control for the effects of the omitted variables it would be necessary to use the complete matrix of country-year dummies. It can be shown that estimating a $(T-1)^{th}$ order polynomial function of time for each country is equivalent to using the complete matrix of country-year dummies. A problem with doing this is that it would not be possible to estimate the effect of any observed countrywide variables because in this case the matrix of explanatory variables would be singular. However, if we assume that the unobserved effects are not completely anarchic and instead follow certain time patterns (which could be non-linear and non-monotonic function of time), the $(T-2)^{th}$ order approximation may be sufficient to capture these patterns while still permitting for the estimation of the effects of the observed country variables.[7]

While it is not certain that our assumption that the unobserved time patterns can be fully captured by the (T-2)th polynomial approximation, we can test whether the μ_{jt} residuals (and therefore the $\varepsilon_{ijt} \equiv \tilde{\varepsilon}_{ijt} + \mu_{jt}$ error term) are time independent. If the hypothesis that the residuals are time independent is not rejected, then the (T-2)th order polynomial approximation may be sufficient to uncover the full time pattern of the effects of the omitted variables on the endogenous variable, and thus the TVCE approach would be effective in mitigating time-varying country-idiosyncratic omitted variable biases. By contrast, rejection of this hypothesis would suggest that the effects of omitted variables are not fully controlled for.

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[7] The TVCE approach indeed follows the tradition of classical regression analysis of using prior information (or assumptions) as a means to economizing the number of parameters. For example, in pure cross-country regressions the full use of country effects would not allow estimating the effects of the (observed) variables of interest, and thus a common approach is to use regional effects instead of country effects. The prior information or assumption is that the countries within the region may have common unobserved effects.

The TVCE method is indeed a generalization of the standard fixed-country effect (FCE) model. The FCE can be defined as applying to levels in which case first differencing, as in equation (1), would wipe them out. More generally, we may apply the FCE to a regression in differences instead of merely to levels.[8] Applying FCE to first differences can be interpreted as a first order approximation of the unobserved country effects.[9] In the case where the total number of time observations per country is greater than 3, the (T-2)th order approximation of the TVCE method is more general allowing for the FCE-in-differences estimators to be nested within the TVCE estimators. That is, the FCE-in-differences model can be tested as an especial case of the TVCE estimators by parametrically testing the restrictions, $b_{1j} = b_{2j} = ... = b_{T-2,j} = 0$ for all $j \in \{1, 2, ..., J\}$, while $b_{oj} \neq 0$, for at least some j.

4. Data

The air pollution data consist of annual averages of observations for SO2, NO2 and O3, measured at a large number of monitoring stations in 12 countries for the period 1995-2008. Air quality measures are taken from the AirBase dataset maintained by the European Environmental Agency. These data include measures of ambient air pollution by monitoring station located within the European Union members and country candidates. All 12 countries have been members of the EU since at least 1995. The list of countries is provided in Table A.1.

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[8] The inclusion of the FCE in regressions in differences has been often used in the literature examining the determinants of economic growth (defined as log difference of per capita GDP), in which FCE are used to control for unobserved time-invariant country specific characteristics (see for example, Fölster and Henrekson, 2001 and Afonso and Furceri, 2010).

[9] If the country effect in the level equation is $b_{00j} + b_{0j}\tau$ then by first differencing the regression, the level FE (b_{00j}) vanishes and the FCE applying to differences becomes b_{0j}.

Government expenditure, household final consumption and trade data are obtained from the EUROSTAT database. We use the functional classification of government expenditures at the general government level. The government expenditures on public goods include expenditures on public order and safety, environment protection, housing and community amenities, health, recreation, culture and religion, education and social protection. Trade intensity is defined as the sum of exports and imports of goods and services as proportion of GDP.

The implicit tax rate on energy and total tax revenue data are obtained from EUROSTAT Statistical Books (2010). The heating degree days data is obtained from the EUROSTAT database. Table A.2 presents the description and source of data, while Table A.3 provides summary statistics of the variables used in the regressions.

5. Estimation and Results

In estimating (1) and (2) we normalize the total government expenditures by GDP and the government expenditures on public goods by total government expenditures. We also normalize trade intensity (exports plus imports) by GDP. These normalizations are convenient because they yield unit free measures of the variables, which diminish the problems of comparing currency values and inflation across time and countries.

We use a sixth order polynomial approximation for the time- varying country effects (equation 2). The reason for limiting the approximation to the sixth order is that in our unbalanced panel data we have countries for which there are only eight years of observations. This effectively implies that we can estimate a maximum of seven coefficients per country to capture the ν_{jt} effect (the b_{0j} and the six b_{tj} coefficients for each country) in order to preserve enough degrees of freedom to allow for the estimation of the variables of interest.

The monitoring station effect ψ_{ij} may be uncorrelated with the observed explanatory variables in which case we can use a random station effect model. Alternatively, we may allow for arbitrary correlation between the unobserved monitoring station effect and the observed explanatory variables in which case we would need to use fixed monitoring station effects. We use both random station effects and fixed station effects in combination with time-varying country-specific effects (RSE-TVCE and FSE-TVCE, respectively). We present the results obtained using RSE-TVCE in Table 1 while Table 2 shows the FSE-TVCE estimators.[10] Since, as can be seen in Tables 1 and 2 both estimators yield qualitatively identical results, we use for the subsequent analysis the RSE-TVCE estimators which are likely to be more efficient.

5.1 Specification Tests

5.1.1 Testing for time independence of the residuals.

The first specification test in Table 1 shows the p-values testing the significance of the coefficients associated with the time trend variable in the regression of the residuals ($\varepsilon_{ijt} = constant + \beta\tau$). In addition, the second specification test in Table 1 also shows the simple correlation coefficients between the residuals and the time trend. The coefficients of the trend values as well as the correlation coefficients are insignificant at the 1% level of significance for the three pollutants. These tests suggest that our assumption that the μ_{jt} error component is time-independent is valid for SO2, NO2 and O3 and hence that the TVCE approach adequately controls for time-varying, country-specific omitted variables.

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[10] The standard errors in all the estimates are robust to heteroskedasticity and autocorrelation.

5.1.2 Testing the Fixed Country Effect model.

We test the null hypothesis that $b_{1j} = b_{2j} = b_{3j} = b_{4j} = b_{5j} = b_{6j} = 0$ for all j which, as discussed earlier, is a test for the validity of the Fixed Country Effects model. The restricted model is rejected at 1% level of significance in favor of the TVCE model for each of the three pollutants, meaning that the often used fixed country effect specification is statistically rejected.

The coefficients $b_{1j}, b_{2j}, b_{3j}, b_{4j}, b_{5j}, b_{6j}$ are jointly significant at 1% level of significance and the majority of them are significant at 1%. This, in conjunction with the relatively large impact that the inclusion of these effects have on the estimates of the coefficients of the key variables, reflect the importance of the RSE-TVCE approach.[11]

5.1.3 Reverse causality.

Consistent with the econometric model presented in Section 3, the normalized government expenditures are lagged in the model. This may avoid the direct reverse causality between these variables and the concentration level of the pollutants, often a source of biases of the estimated coefficients. In principle it would be possible that such lagged expenditures are correlated with other concurrent omitted variables which would still cause biases in the estimated coefficient. However, as we argued earlier, the country-specific time-varying effects largely minimize such a risk as these effects control for omitted variables.

It may be argued that reverse causality may be an issue for energy taxes as the tax variable is not lagged. Higher levels of pollution may be a factor that induces governments to raise energy taxes in which case the reverse causality bias on the coefficient of the energy tax

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[11] Table C.1 in Appendix C presents a summary of the analysis of the predicted values of the TVCE function. In most of the countries the effect of the omitted variables has been negative for SO2, and has changed sign over time for NO2 and O3. The majority of the predicted values of the TVCE function are non monotonic and have at least 2 turning points.

variable would be upwards. However, it is unlikely that the level of energy taxes are influenced much by variations in local pollution as energy tax policies are mostly motivated in renewable energy and climate change policies rather than on local pollution-related objectives (Newberry, 2005; Biermann and Brohm, 2005; Decker and Wohar, 2007). But even if reverse causality were indeed an issue, the finding of a negative effect of the energy tax on pollution, as we do find when using the RSE-TVCE estimates, would merely make such estimates a lower bound measure of the true effect and would not alter the sign of the estimates. That is, if we corrected for reverse causality biases the estimates of the effect of the energy tax would be even more negative than what we obtain.

5.2 Analysis of the Estimates

5.2.1 Impact Analysis

The estimates indicate negative and significant effects of the government spending level and composition on SO2 and O3, and negative but not statistically significant effects on NO2, as shown by the share of expenditures in public goods over total government expenditure coefficient and the share of total government expenditure over GDP coefficient (Table 1). Trade shows a negative and significant effect on SO2 concentrations but not on the other pollutants, and energy taxes exert a negative and significant effect on NO2 but not on the other pollutants.

In Table 3 we show the elasticities for the main determinants of each pollutant. The importance of each one these effects is also expressed by the relative changes within the sample (impact of changes in the explanatory variables in one standard deviation as proportion of the sample standard deviations of the pollutant).

Increasing the share of government expenditures on public goods by 1%, holding total government expenditure constant, may result in a 3.9% reduction of SO2 concentrations and a 1.25% decrease in the case of O3. Increasing the share of expenditures on public goods by one standard deviation reduces SO2 concentrations by 22.7% and those of O3 by 19.4% of their respective standard deviations.

The concentrations of SO2 and O3 may be reduced by 2.6% and 0.82% respectively if total government expenditure increases by 1%. The increase of one standard deviation of the share of total expenditure with respect to GDP may result in a standard deviation reduction of 35.1% for SO2 and 31.7% in the case of O3.

We find that the elasticity of energy taxes is -0.31 for NO2. If the energy tax rates increase by one standard deviation, the concentration of NO2 may be reduced by 12% of its standard deviation.[12] The estimated effects of energy taxes are not significant for SO2 which is a production pollutant caused mainly by industrial processes and electricity generation; neither did we find statistically significant effects of energy taxes on O3, a consumption pollutant that is formed by certain precursor gases in combination with weather conditions.[13] Our results suggest that energy taxes only have effect on pollution levels caused mainly by road and off-road fuel consumption.

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[12] These findings are consistent with the elasticity estimates in a few studies that have measured these effects. Millock and Nauges (2006) estimate elasticities of energy taxes on NO2 and SO2 that vary from -2.7 to -0.2 depending on the industry analyzed

[13] One of the reasons energy taxes do not have a significant effect on O3concentrations might be the nature of this pollutant since it is not emitted directly by any source and it is rather formed by the combination of certain precursor gases especially under hot and sunny weather conditions (EEA, 2009). Another possible reason might be the positive effect of energy taxes over the participation of diesel vehicles on the automobile fleet (data that is not available for all countries and time periods); diesel vehicles tend to emit three times more ozone-precursor gases than gasoline vehicles. Vestreng *et al.,* 2008 has shown that this is true in the countries where systematic data on the participation of diesel vehicles are available.

Trade has a negative and significant effect on SO2 and no significant effect on NO2 nor on O3 concentrations. The estimates imply that increasing trade intensity by 1% may result in a 1.1% reduction of SO2. If trade intensity is increased by one standard deviation, SO2 concentrations are reduced by 49% of its standard deviation. Hence, as predicted by our conceptual analysis, trade affects "production" pollutants most likely through the composition effect but does not affect "consumption" pollutants .

The coefficients of the per capita level of household consumption are positive in our estimates and mostly significant while most existing empirical studies for high income countries obtain a negative effect on local pollutants. This divergence may stem from our effort to mitigate the omitted variable biases by controlling for energy taxes, environmental regulation and other unobserved economy-wide variables that may be positively correlated with per capita income or consumption and that have a negative impact on pollution. The standard estimates of previous studies are likely to attribute the effects of these variables to per capita income and thus conclude that increasing per capita income may reduce pollution. By contrast our estimates isolate the pure effect of income or consumption on pollution.

5.2.2 Decomposition Analysis.

Table 4 shows the average annual changes in all pollutants for the analyzed period and the decomposition of fiscal, trade and environmental policy effects on each one of them. Production pollutants, SO2 in particular, has decreased very rapidly over the period at an annual rate of 8.5% but consumption pollution has not improved nearly as much. NO2 concentrations have fallen by only 1.4% per annum and ozone concentrations have increased in almost all countries showing an average annual rate of increase of 0.9%.

As mentioned in the conceptual section, we would expect fiscal policies to mostly affect air pollution concentration by increasing the composition and technique effects. We also argue that trade exerts its effect mostly through the composition effect on production pollutants while its technique effect is likely negligible for consumption pollutants. We also expected that environmental policies and energy taxes would affect consumption pollution mainly via the technique effect. As can be seen in Table 4, these predictions are fully corroborated by the empirical results.

SO2 reductions are mostly explained by trade and fiscal policies, which together explain practically all the observed reductions, meaning that without those policies SO2 levels would have increased over the analyzed period. The large contribution of trade may be the result of the shifting of production towards cleaner possibly human capital-intensive industries. Environmental regulation, specifically the "Large Combustion Plant Directive", also contributes to the reduction in SO2 concentrations possibly through a technique effect.

In the case of NO2 energy taxes explain a major part of the modest observed reductions, about 52% reduction which is most likely associated with technique effects. This suggests that energy taxes are an effective instrument to reduce this type of consumption pollutant, and reflects the European countries' demand (on average) for less NO2 emissions per unit of goods consumed.

Fiscal policies associated with an increase participation of government spending in GDP and progressive shifts towards the provision of public goods have a strong (unintended) effect towards reducing ozone. In fact, the combined effect of the observed fiscal spending policies in Europe has been to induce a reduction of ozone concentrations by more than 1% per annum. That is, if Europe had not increased the share of government spending in GDP and if it had not change the spending composition towards public goods, ozone would have increased twice as fast as what in fact occurred. The European fiscal spending policies may explain why in these countries O3 concentrations have not increased nearly as much as in other regions of the world. Additionally, fiscal policies are the only policies considered that have any effect on ozone pollution, which is probably the most difficult to control among the measured pollutants.

5.3 Sensitivity Analysis

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

We conducted two types of dominance tests. In order to account for extreme data points we first re-estimate the model by excluding observations in the top and bottom 1% of the share of government expenditures on public goods. The same procedure is followed by re-estimating the model without observations in the top and bottom 1% of the energy tax rate, pollutant concentration and trade intensity. The parameters are robust to the sample changes, except for the case of trade when dropping the bottom 1% of SO2. This result indicates that the effect of trade is weak even on production pollutants, once we control for energy taxes, environmental regulations, fiscal expenditure as well as other unobserved factors. Signs, significance and magnitudes of the parameter estimates from these models are shown in Tables B.1 to B.6 in Appendix B.

The second type of tests focuses on the effect of potential country dominance. We re-estimate our benchmark models, dropping one country at a time, to check whether they alter the parameter estimates of the share of public goods (for the SO2 and O3 regressions), of the energy taxes (for the NO2 regressions) and of trade (for SO2). As shown in Figures B.1 to B.4 in

Appendix B, removing one country at a time does not affect the sign and significance of the estimated parameters, with the exception of share of public goods over government expenditure in the O3 regression, which seems to be dependent on Italy.[14]

6. Conclusion

This study finds that fiscal, trade and energy tax policies implemented by the twelve most developed European countries have had different impacts on the analyzed pollutants. Large and increasing public sector participation and increasing prioritization of public goods over private goods in most European countries have had a hitherto ignored effect by contributing to a cleaner environment. In addition, we find that the high energy tax policy adopted by the majority of the European countries over the last few decades have substantially contributed to reduce the levels of one important consumption pollutant, NO2, but not of ozone. The direct effect of trade intensification has only affected SO2 concentrations but not any of the consumption pollutants.

Controlling for the scale effect, our estimations show that fiscal policies, trade, and energy taxes are effective in reducing the concentration of different pollutants through different mechanisms. Trade contributes by increasing the composition effect on “production” pollutants, reallocating production towards cleaner industries given Europe’s comparative advantage in producing human capital intensive goods. As for “consumption” pollutants, the direct effect of trade is negligible and fiscal policies also contribute to reducing one important consumption pollutant, O3.

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[14] It is worth noticing that Italy includes a large number of observations, more than 1,500 observations or about 8% of the total. Thus, this does not necessarily indicate a lack of robustness of the estimators; it is indeed remarkable that the coefficients are robust to the exclusion of all other countries even if dropping individual countries often entails removing 7% or more of the total observations.

Energy taxes have had an impact on consumption pollutants that can be directly related to energy consumption such as NO2 but have been ineffective on reducing the levels of O3 which is a pollutant that is much more difficult to control.

These results should be regarded as an added incentive for EU countries to at least persist if not increase the emphasis on fiscal policies and energy taxes that trigger the development on new technologies. The study may also present an argument for other countries which have not yet adopted these policies to implement them. The results have implications for several non-European countries including the USA and large developing countries which currently have much lower energy taxes and fiscal spending policies that are heavily oriented to provide private goods instead of public goods. Pursuing fiscal policies as adopted by some European countries may potentially have a large and unintended environmental pay-off.

To the best of our knowledge this is the first paper that systematically examines the role of fiscal spending policy, trade and energy taxes on Europe's environmental quality, using a methodology that allows obtaining estimates mostly free from time-varying omitted variable biases.

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Table 1
Random Monitoring Stations Effects with Time Varying Country Effects (RSE-TVCE)

	Ln Diff SO2	Ln Diff NO2	Ln Diff O3
Share of expenditures in public goods over total government expenditures (lagged)	-5.33** [1.27]	-0.19 [0.49]	-1.69** [0.52]
Share of total government expenditures over GDP (lagged)	-5.52** [1.78]	-0.37 [0.71]	-1.73* [0.77]
Time difference of Energy Tax Rate	-0.11 [0.06]	-0.18** [0.03]	0.057 [0.04]
Time difference of Regulation over large Plants	-0.49** [0.07]		
Time difference of Regulation over NOx		-0.34 [0.51]	1.54 [0.83]
Time difference of Log of Trade (X+M)/GDP	-1.13** [0.40]	-0.41 [0.25]	-0.21 [0.43]
Time difference of 3 Year Moving Average of Ln of Household final consumption per capita	0.053** [0.02]	0.004 [0.01]	0.026* [0.01]
Observations	16,222	19,374	15,282
No. of Monitoring Stations	2,666	3,176	2,274
Overall R-Squared	0.11	0.06	0.10
Specification tests:			
1. Test for the time independence of the residuals: p-values[1]	0.99	0.99	0.99
2. Correlation coefficient between the residuals and τ	-0.00001	0.00001	0.00001
3. Testing the fixed country effects-random site effects model: Log Likelihood Ratio Test Ho: $b_{1j} = b_{2j} = ... = b_{T-2,j} = 0$	426**	322**	316**

Robust standard errors in brackets.
* significant at 5%; ** significant at 1%
Not reported in the table are 77 coefficients for each equation for the variables that capture the TVCE, 12 coefficients for year effects and one coefficient for heating degree days.

[1] Regressions estimated for testing time independence of the residuals: $\varepsilon_{ijt} = constant + \beta\tau$. The values of $\hat{\beta}$ (standard error) for SO2, NO2 and O3 are -2.38e-12 (.0007246), 2.72e-06 (0. 00038), and 2.89e-11 (0. 0003573), respectively.

Table 2

Fixed Monitoring Stations Effects with Time Varying Country Effects (FSE-TVCE) Regressions

	Ln Diff SO2	Ln Diff NO2	Ln Diff O3
Share of expenditures in public goods over total government exp (lagged)	-5.92** [1.34]	-0.27 [0.54]	-1.68** [0.58]
Share of total government expenditure over GDP (lagged)	-6.17** [1.91]	-0.12 [0.79]	-1.61 [0.86]
Time difference of Energy Tax Rate	-0.14* [0.07]	-0.20** [0.034]	0.05 [0.04]
Time difference of Regulation over large Plants	-0.47** [0.08]		
Time difference of Regulation over NOx		-0.55 [0.66]	1.70 [1.06]
Time difference of Log of Trade (X+M)/GDP	-1.09* [0.48]	-0.37 [0.27]	-0.23 [0.48]
Time difference of 3 Year Moving Average of Ln of Household final consumption per capita	0.06* [0.02]	0.04** [0.01]	0.05** [0.01]
Observations	16,222	19,374	15,282
Overall R-Squared	0.12	0.07	0.13
No. of Monitoring Stations	2,666	3,176	2,274
Specification tests:			
1. Test for the time independence of the residuals: p-values[1]	0.99	0.99	0.99
2. Correlation coefficient between the residuals and τ	-0.00001	0.00001	0.00001
3. Testing the fixed country effects-random site effects model: Log Likelihood Ratio Test Ho: $b_{1j} = b_{2j} = ... = b_{T-2,j} = 0$	463**	361**	403**

Robust standard errors in brackets.

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

Not reported in the table are 66 coefficients for each equation for the variables that capture the TVCE, 12 coefficients for year effects and one coefficient for heating degree days.

Table 3
Elasticities and Sample Quantitative Effects

	SO2	NO2	O3
Elasticity of the Share of Public Goods	-3.91**	n. s.	-1.25**
Change in the pollutant when the Share of Public Goods increases by one Standard Deviation (% of std dev of pollutant)	-22.70%**	n. s.	-19.45%**
Elasticity of the ratio of total government expenditure over GDP	-2.63**	n. s.	-0.82*
Change in the pollutant when the ratio of total government expenditure over GDP increases by one Standard Deviation (% of std dev of pollutant)	-35.10%**	n. s.	-31.37%*
Elasticity of the Energy Tax Rate	n. s.	-0.31**	n. s.
Change in the pollutant when the Energy Tax Rate increases by one Standard Deviation (% of std dev of pollutant)	n. s.	-12.32%**	n. s.
Elasticity of Trade	-1.13**	n. s.	n. s.
Change in the pollutant when Trade increases by one Standard Deviation (% of std dev of pollutant)	-49.23%**	n. s.	n. s.

* significant at 5%; ** significant at 1%
n. s.: non significant

Table 4
Decomposition analysis of the effect of the various factors

	Annual average rate of growth of the pollutant (%)	Annual average contribution (in percentage points)				
		Fiscal Policy		Environmental Policy		Trade Policy
		Government provided social capital	Government provided non-social capital	Regulation	Energy taxes	
SO2	-8.51	-5.56*	-2.27*	-3.79*	n. s.	-2.76*
NO2	-1.37	n. s.	n. s.	n. s.	-0.58*	n.s.
O3	0.91	-0.39*	-0.71*	n. s.	n. s.	n.s.

Note: The rates of growth used to create this table were calculated as the annual average growth. In the case of the pollutant the annual rate of growth of each monitoring station was calculated, and then a country average was taken for each country and finally the average over all of the years available in the sample. For the rest of the variables at the country level, first the rate of growth with respect to the previous year was calculated then the average of the whole period.
*Significant to at least 5%

Appendix A

Table A.1
Country List

Austria	Denmark	France	Netherlands
Belgium	Spain	United Kingdom	Portugal
Germany	Finland	Italy	Sweden

Table A.2
Description of Variables

Variable	Description	Years Available	Source
Sulfur Dioxide	Year average of daily mean SO2 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	Year average of daily mean NO2 concentration, micrograms per cubic meter	1995-2008	
Ozone	Year average of daily mean O3 concentration, micrograms per cubic meter	1995-2008	
Household final consumption expenditure per capita (3 year moving average)	Market value of all goods and services including durable products purchased by households.	1989-2008	EUROSTAT
Share of government expenditure on public goods	Government expenditure on public goods over total government expenditure. Including: Public order and safety, Environment protection, Housing and community amenities, Health, Recreation, culture and Religion, Education, Social protection	1989-2008	
Share of total government expenditure over GDP	Total Government Expenditure over GDP	1989-2008	
Trade Intensity	Imports of goods and services plus exports of goods and services over GDP	1994-2008	
Energy Tax Rate	Implicit Tax Rate on Energy	1995-2008	EUROSTAT Statistical Books (2009)
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	1990-2008	EEA Report No 2/2007
Regulation on NOx	Reciprocal of the target values of NOx under the Directive for NOx.	1990-2008	EEA Report No 2/2007
Heating Degree Days	Measurement that reflects the demand for energy needed to heat a home or business	1995-2008	EUROSTAT

Table A.3
Summary Statistics

Variable	Mean	Std. Dev.	Min	Max	Units
SO2	6.73	5.47	0.003	85.47	ug/m3 microgram per Cubic Meter
NO2	29.26	15.72	0.31	120.13	
O3	48.31	13.91	0.96	117.17	
Household final consumption expenditure per capita (3 year moving average)	2.08	1.14	-0.45	5.30	1995 Euros
Share of government expenditure on public goods	0.74	0.03	0.65	0.80	
Share of total government expenditure over GDP	0.47	0.05	0.38	0.63	
Energy Tax Rate	1.66	0.37	0.91	3.16	Euros per Ton of Oil Equivalent
Trade Intensity	0.74	0.26	0.47	1.73	
Heating Degree Days	0.95	0.06	0.80	1.19	

Appendix B

B.1 Extreme Observations Checks

Dropping the top and bottom 1% of the observations on each year.

Table B.1
Coefficient of Share of Expenditures in Public Goods in the RSE-TVCE Regressions

Regression	Bottom 1% of Share of Public Goods Expenditures	Top 1% of Share of Public Goods Expenditures	Top and Bottom 1% of Share of Public Goods Expenditures
SO2	-5.35**	-5.33**	-4.33**
O3	-1.40**	-1.65**	-3.13**

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

Table B.2
Coefficient of Share of Expenditures in Public Goods in the RSE-TVCE Regressions

Regression	Bottom 1% of Pollutant	Top 1% of Pollutant	Top and Bottom 1% of Pollutant
SO2	-6.34**	-4.22**	-5.04**
O3	-1.66**	-1.13*	-1.19**

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

Table B.3
Coefficient of Energy Tax in the RSE-TVCE Regressions

Regressions	Bottom 1% of Energy Tax Rate	Top 1% of Energy Tax Rate	Top and Bottom 1% of Energy Tax Rate
NO2	-0.19**	-0.19**	-0.32**

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

Table B.4
Coefficient of Energy Tax in the RSE-TVCE Regressions

Regressions	Bottom 1% of Pollutant	Top 1% of Pollutant	Top and Bottom 1% of Pollutant
NO2	-0.19**	-0.19**	-0.20**

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

Table B.5
Coefficient of Trade Intensity in the RSE-TVCE Regressions

Regressions	Bottom 1% of Trade Intensity	Top 1% of Trade Intensity	Top and Bottom 1% of Trade Intensity
SO2	-1.19**	-0.93*	-1.04*

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

Table B.6
Coefficient of Trade Intensity in the RSE-TVCE Regressions

Regressions	Bottom 1% of Pollutant	Top 1% of Pollutant	Top and Bottom 1% of Pollutant
SO2	-0.21	-1.27**	-0.46

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

B.2 Country dominance Checks

Dropping one country in each estimation

Figure B.1
Coefficient of the Share of public Goods in the RSE-TVCE Regression for SO2

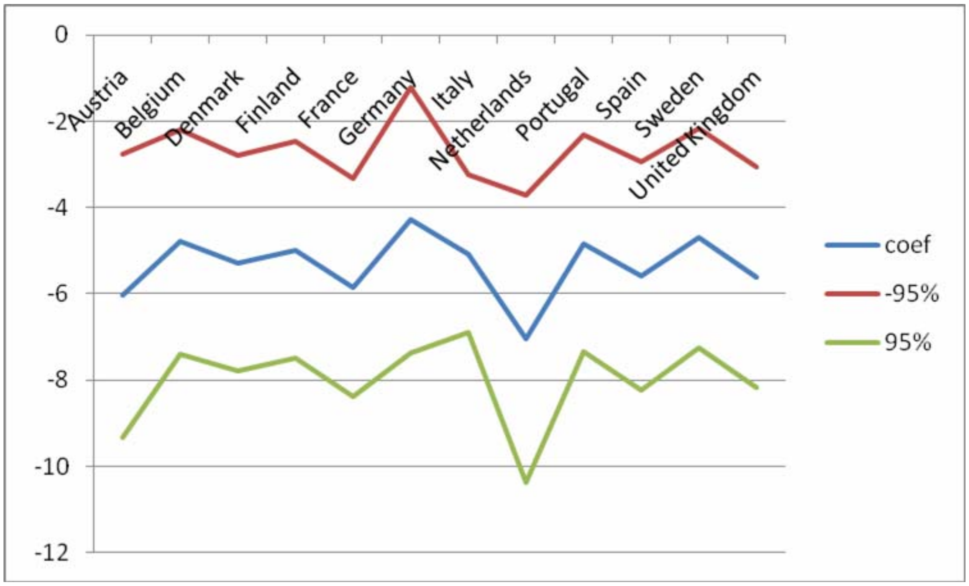


Figure B.2
Coefficient of the Share of public Goods in the RSE-TVCE Regression for O3

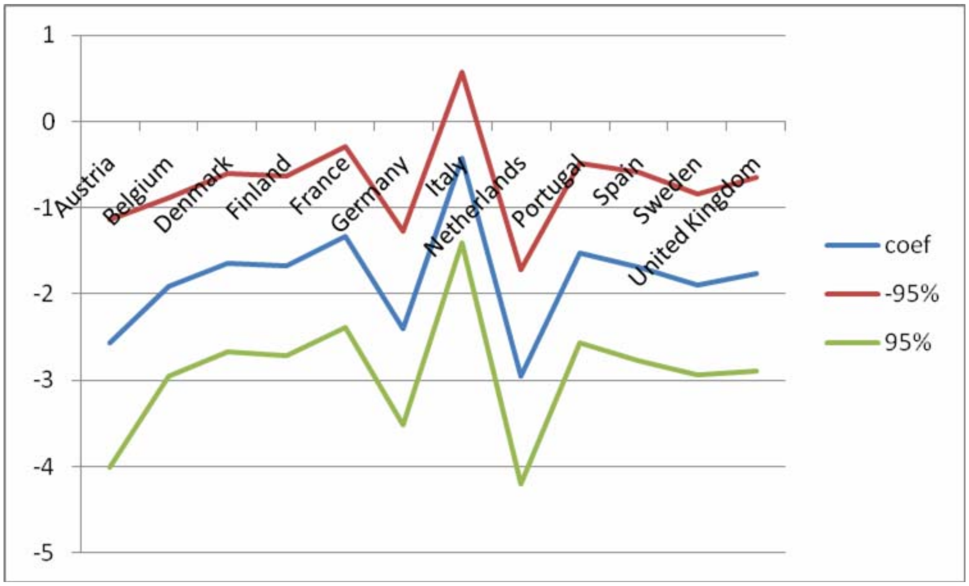


Figure B.3
Coefficient of the Energy Taxes in the RSE-TVCE Regression for NO2

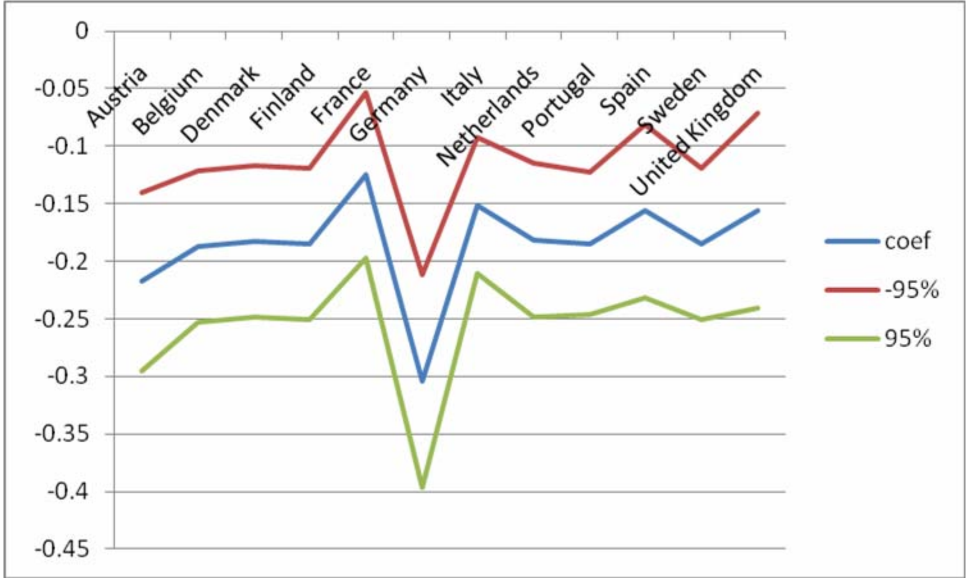
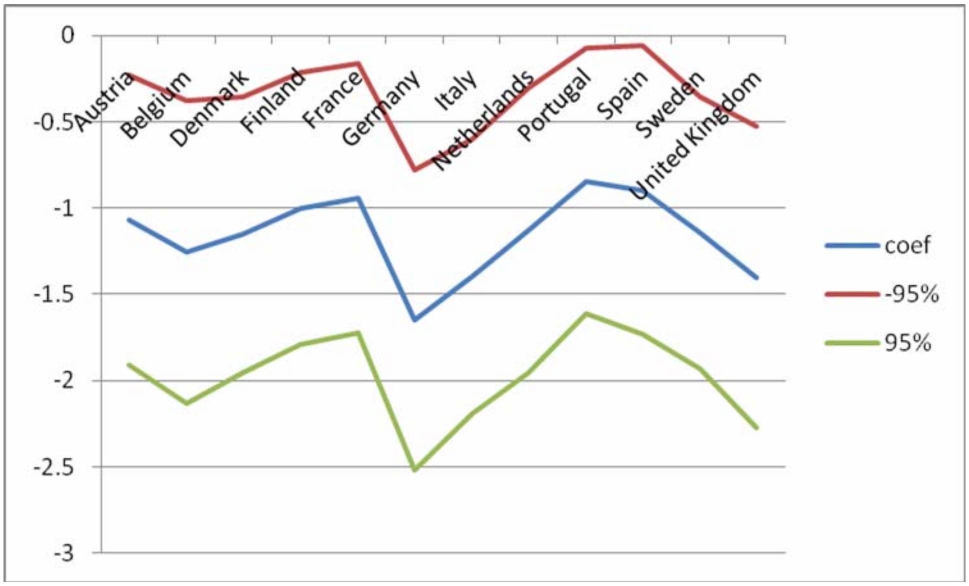


Figure B.4
Coefficient of the Trade Intensity in the RSE-TVCE Regression for SO2



Appendix C

Table C.1
Analysis of the Predicted Values of the Time-Varying Country Effects (ν_{jt})

	SO2	NO2	O3
Number of countries with $b_{1j}=b_{2j}=b_{3j}=0$	4	5	5
Signs of the Predicted ν_{jt} Values			
Number of countries with positive predicted values for all years	0	0	0
Number of countries with negative predicted values for all years	6	0	4
Number of countries with predicted values that change sign over time	5	11	7
Monotonicity of the Predicted ν_{jt} Values			
Number of countries with monotonic predicted values over time	0	0	0
Number of countries with one turning point in the predicted values	3	0	0
Number of countries with two turning points in the predicted values	8	11	11