Ecological Economics 91 (2013) 48–56

Contents lists available at SciVerse ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Analysis

The Effect of Government Expenditure on the Environment: An Empirical Investigation

George E. Halkos *, Epameinondas A. Paizanos

Laboratory of Operations Research, Department of Economics, University of Thessaly, Korai 43, 38333 Volos, Greece

ARTICLE INFO

Article history:
Received 17 July 2012
Received in revised form 23 March 2013
Accepted 7 April 2013
Available online xxxx

JEL classification:
E60
Q53
Q54
Q56

Keywords:
Government expenditure
Environment
Direct effects
Indirect effects

ABSTRACT

This paper examines the impact of government spending on the environment using a panel of 77 countries for the time period 1980–2000. We estimate both the direct and indirect effects of government spending on pollution. The indirect effect in particular operates through the impact of government spending on income and the subsequent effect of the income level on pollution. To take into account the dynamic nature and the potential endogeneity in the relationships examined, appropriate econometric methods are used. For SO_2, government spending is estimated to have a negative direct impact on per capita emissions, while the direct effect is insignificant on CO_2 pollution. The indirect effect on SO_2 is negative for low income levels and becomes positive as income increases, while it remains negative for CO_2 for the most part of the sample range. The resultant total effects follow the patterns of the indirect effects, which dominate their respective direct ones for each pollutant. Policy implications from the results vary depending on the income level of the considered countries.

1. Introduction

Government expenditure has recently expanded in many countries to alleviate the adverse effects of the 2008–2009 economic crises. A large fraction of GDP is spent by governments affecting a variety of economic variables and prosperity in particular. Recent studies suggest that government expenditure is an important determinant of environmental quality (Bernauer and Koubi, 2006; Frederik and Lundström, 2001; Lopez et al., 2011). The mechanisms through which prosperity, government expenditure and environment interact with each other are investigated in theoretical papers by Heyes (2000), Lawn (2003) and Sim (2006). However, despite the important influence that public spending may have on the environment, this relationship has not been studied extensively in the literature.

The effect of government spending on the environment may be distinguished between direct and indirect effects. On the one hand, higher government expenditure is more likely to include redistributive transfers, which result to increased income equality and thus to higher demand for environmental quality. Moreover, if the environment is a luxury public good, it is likely that it will only be demanded when the demand for other public goods has been satisfied, i.e. at large levels of government size (Frederik and Lundström, 2001). In a related study, Lopez et al. (2011) identify four mechanisms by which the level and composition of fiscal spending may affect pollution levels,[1] namely the scale (increased environmental pressures due to more economic growth), composition (increased human capital intensive activities instead of physical capital intensive industries that harm the environment more), technique (due to higher labor efficiency) and income (where increased income raises the demand for improved environmental quality) effects.

On the other hand, government size has been found to reduce prosperity (Bajo-Rubio, 2000; Bergh and Karlsson, 2010; Folster and Henrekson, 2001; Ghali, 1998) which may in turn lead to lower pollution at some levels and to higher pollution at others, depending on the shape of the Environmental Kuznets Curve (EKC), as shown by Grossman and Krueger (1995). Therefore, the total effect of government expenditure on the environment cannot be determined a priori.

Given this background and following a similar empirical strategy to that used by Welsch (2004) and Cole (2007),[2] our purpose is to investigate first how government expenditure affects pollution at given

* Corresponding author at: Department of Economics, University of Thessaly, Korai 43, Volos 38333, Greece. Tel.: +30 24210 74920; fax: +30 24210 74772.
E-mail address: halkos@uth.gr (G.E. Halkos).*URL:* http://www.halkos.gr/ (G.E. Halkos).

[1] In particular, they examine the effect of the share of public goods in total government expenditure on pollution.

[2] In particular, they examined the effect of corruption on pollution, also distinguishing between direct and indirect effects.

0921-8009/$ – see front matter
http://dx.doi.org/10.1016/j.ecolecon.2013.04.002

income levels and other control variables, in particular to estimate a direct effect that mainly captures the composition effect and part of the technique effect, as defined in Lopez et al. (2011) and described in the Methodology section of this study; and then to examine the effect of government expenditure on the environment through the government expenditure impact on income (indirect effect) and to add the indirect effect to the direct effect to obtain the total effect.

The majority of the studies examining the government size–growth relationship find a negative impact of the former on the latter. Increasing public expenditure may deteriorate economic growth by crowding-out the private sector, due to government inefficiencies, distortions of the tax and incentives systems and interventions to free markets (Afonso and Furceri, 2008; Bajo-Rubio, 2000; Barro, 1991). In addition, the share of government expenditure dedicated to productivity increase in the private sector is typically smaller in countries with big governments (Folster and Henrekson, 2001). Furthermore, related papers by Bergh and Karlsson (2010) and Afonso and Jalles (2011) find that government size correlates negatively with growth. At the same time, government expenditure may also have a positive effect on economic performance, due to positive externalities, by harmonizing conflicts between private and social interests, providing a socially optimal direction for growth as well as offsetting market failures (Ghali, 1998).

The estimated sign of the direct effect of government size on pollution is ambiguous in the empirical literature. Frederik and Lundström (2001) investigate the effect of political and economic freedom on the level of CO_2 emissions and find that the effect of government size on levels of pollution differs according to the initial government size. They suggest that increased economic freedom, in terms of lower government size, decreases CO_2 emissions when the size of government is small but increases emissions when the size is large.

According to Bernauer and Koubi (2006) an increase in the government spending share of GDP is associated with more air pollution and this relationship is not affected by the quality of the government. However, they do not consider quadratic or cubic terms of income in their analysis and they ascribe their finding to the ambiguous hypothesis that higher income leads to both bigger government and better air quality.

Recently, Lopez et al. (2011) provide a theoretical basis for determining the effect of government expenditure on pollution. Specifically, they stress the importance and estimate empirically the effect of fiscal spending composition on the environment. They argue that a reallocation of government spending composition towards social and public goods reduces pollution. Moreover, they find that increasing total government size, without changing its orientation, has a non-positive impact on environmental quality. However, in a related study, Lopez and Palacios (2010) examine the role of government expenditure and environmental taxes on environmental quality in Europe and report total government expenditure as a negative and significant determinant of air pollution, even after controlling for the composition of public expenditure.

To the best of our knowledge the present paper is the first that distinguishes between the direct and indirect effects of fiscal spending on the environment. For that reason, a two-equation model was jointly estimated, employing a sample of 77 countries covering the period 1980–2000 for two air pollutants (sulfur dioxide, SO_2 and carbon dioxide, CO_2). In estimating the proposed model we take into account the dynamic nature of the relationships examined, by employing appropriate econometric methods for the estimation of dynamic panels for the first time in this area of research. Furthermore, appropriate GMM estimation methods are used to mitigate potential reverse causality biases of the explanatory variables.

The remainder of the paper is organized as follows: Section 2 presents the data used in the analysis and Section 3 discusses the proposed econometric models. The empirical results are reported in Section 4 while the final section concludes the paper.

2. Data

Our sample consists of 77 countries[3] with a full set of SO_2, CO_2, share of government expenditure, GDP/c and other explanatory variables information for the period 1980–2000. The analysis takes place up to the year 2000 because of limited availability of data on SO_2 after this period. Consequently, for reasons of comparability we also perform the analysis of CO_2 for the same time period. The database consists of 1617 observations per variable.[4]

To avoid dependence of results on geographic location characteristics and atmospheric conditions, emissions of the two pollutants were used rather than their concentrations. An important distinction between the two pollutants that has to do with their atmospheric life characteristics is their geographical range of effect (Cole, 2007). Considering that two-thirds of SO_2 moves away from the atmosphere within 10 days after its emission, its impact is mainly local or regional and thus, historically, sulfur dioxide has been subject to regulation. In contrast, CO_2 has not been regulated by governments, since its atmospheric life varies from 50 to 200 years and hence its impact is global.

The sources of pollution vary by pollutant. The main sources of SO_2 emissions are electricity generation and industrial processes. On the other hand, apart from energy transformation and industry, an important source of CO_2 emissions is transport. Apparently SO_2 pollution is characterized as production-generated, while CO_2 emissions are a mix between production and consumption-generated pollution. This distinction is important since the mechanism by which government expenditure size affects consumption pollution is likely to differ compared to production pollution. SO_2 emissions can be decreased by reducing consumption of fossil fuels (especially high-sulfur content coal), by using smoke-scrubbing equipment in power plants and by increasing energy efficiency. However, in consumption related pollutants the use and influence of environmental policies are more difficult, since the main tool to reduce these is the implementation of environmental taxes, which are often avoided as they are not politically popular.

3. Methodology

The proposed model consists of two equations jointly estimated, one being a conventional cubic formulation of the EKC augmented by the share of government expenditure over income and the second expressing income as a function of government expenditure and other factors. Specifically,

$$\ln(P/c)_{it} = \mu_i + \zeta_t + \beta_1 \ln Govshare_{it} + \beta_2 \ln(GDP/c)_{it} + \beta_3(\ln(GDP/c))^2_{it} + \\ +\beta_4(\ln(GDP/c))^3_{it} + \beta_5 X_{it} + \varepsilon_{it} \tag{1}$$

$$\ln(GDP/c)_{it} = \gamma_i + \delta_t + \alpha_1 \ln Govshare_{it} + a_2 \ln Z_{it} + u_{it} \tag{2}$$

where subscripts i and t represent country and time respectively and all variables are expressed in natural logarithms, unless otherwise stated.

The income variable and its powers in (1) control for scale effects. To control for income effect we use the household final consumption expenditure, while total private investment is used as a proxy for capital stock. Institutional factors reflecting pollution regulation are taken into account by using a measure of democracy level, however

[3] Albania, Algeria, Argentina, Australia, Austria, Belgium, Bolivia, Brazil, Bulgaria, Canada, Cape Verde, Chile, China, Colombia, Cuba, Denmark, Djibouti, Dominican Rep, Equador, Egypt, El Salvador, Finland, France, Germany, Ghana, Greece, Guatemala, Honduras, Hong Kong, Hungary, India, Indonesia, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kenya, Lebanon, Liberia, Mauritius, Mexico, Morocco, Mozambique, Nepal, Netherlands, New Zealand, Nicaragua, Nigeria, Norway, Panama, Paraguay, Peru, Philippines, Poland, Portugal, Romania, Sierra Leone, South Africa, South Korea, Spain, Sri Lanka, Sudan, Sweden, Switzerland, Syria, Thailand, Togo, Trinidad, Tunisia, Turkey, Uganda, United Kingdom, United States, Uruguay, Venezuela.

[4] Table A1 of the Appendix A provides data sources and descriptions for all variables.

Table 1
Estimates of the impact of government share on per capita income.

Model	OLS	FE	DFE	GMM A-B
	(1)	(2)	(3)	(4)
Log government share	−0.198*** (0.042)	−0.210*** (0.069)	−0.872*** (0.328)	−1.809***
Log investment	0.688*** (0.039)	0.142*** (0.038)	0.430* (0.227)	0.876**
Log school	0.830*** (0.109)	0.130 (0.099)	0.290 (0.475)	0.108
Population growth	−0.239*** (0.036)	−0.014** (0.006)	−0.255*** (0.077)	−0.222***
Trade-openness	0.002*** (0.000)	0.003*** (0.001)	0.006* (0.0035)	0.022***
Constant	3.383*** (0.557)	7.855*** (0.489)		
R^2	0.493	0.201		
F test	0.000	0.000		
Wald test				0.000
Hausman FE v. RE		0.000		
Cragg–Donald F-stat				
Hausman PMG v. DFE			1.000	
Hansen test				0.202
Hansen IV subset				0.743
A–B test of AR(1)				0.000
A–B test of AR(2)				0.092
Nobs/Countries/IVs	1596	1596/76	1520/76	1406/74/61

Note: Robust standard errors are in parentheses. All tests' values reported are probabilities.
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.

this proxy is imperfect and we expect that the government variable also captures some of the unobserved environmental regulation. We also use the share of trade over GDP to examine whether involvement in international trade affects pollutants and population density, which captures part of the scale effect. Finally, μ_i is a country effect which can be fixed or random, ζ_t is a time effect common to all countries and ε_{it} is a disturbance term with the usual desirable properties. Thus, following the terminology used to classify the pollution effects in the trade literature, the coefficient on the government expenditure variable mainly captures the composition effect and part of the technique effect.

Eq. (2) is an augmented Solow model widely used in the growth literature (Barro, 1998; Mankiw et al., 1992). In particular, it is a production function based formulation and expresses income as a function of the share of government expenditure in GDP and other explanatory factors like investment and education as proxies for capital and human stock, population growth, inflation rate to consider the impact of the macroeconomic environment and a measure of openness to international trade. Finally, γ_i and δ_t represent country and time effects respectively while u_{it} is an error term.

3.1. Econometric Issues and Estimation

In estimating Eqs. (1) and (2) we must take into account the unobserved heterogeneity across countries. The standard approach is to use fixed (hereafter FE) and random effects (hereafter RE) model formulations with the choice depending on the assumption adopted about the correlation between the cross-section specific error-component and the explanatory variables. When such correlation is present, then RE estimators are not consistent and efficient and the use of FE is more appropriate. For instance, in the pollutants' equations these country-specific characteristics may include differences in climate, geography and fossil fuels endowments, all of them potentially correlated with emissions (Leitao, 2010). Additionally, it is very likely that country unobserved characteristics are correlated with income and the other explanatory variables, implying that FE estimation is preferred. This assumption is supported by the use of Hausman test, in which the RE model was rejected in favor of the FE model, for both Eqs. (1) and (2).

Since the balanced panel data used in this paper consists of large N and T dimensions, non-stationarity is important. We are particularly

Table 2
Panel data unit root tests.

Variable	No trend c-s means	No trend minus c-s means	With trend c-s means	With trend minus c-s means
	(1)	(2)	(3)	(4)
LogSO_2/c	0.063	0.763	0.367	0.526
Δ(Log SO_2/c)	0.000	0.000	0.000	0.000
LogCO_2/c	0.383	0.093	0.000	0.000
Δ(LogCO_2/c)	0.000	0.000	0.000	0.000
LogGovernment share	0.821	0.511	0.464	0.527
Δ(LogGovernment share)	0.000	0.000	0.000	0.000
LogGDP/c	1.000	0.980	1.000	1.000
Δ(LogGDP/c)	0.000	0.000	0.000	0.000
LogTrade-openness	0.924	0.022	0.345	0.137
Δ(Log Trade-openness)	0.000	0.000	0.000	0.000
LogInvestment	0.986	0.063	0.466	0.797
Δ(Log Investment)	0.000	0.000	0.000	0.000
Loghousehold consumption	1.000	0.760	0.801	0.655
Δ(Log household consumption)	0.000	0.000	0.000	0.000
Democracy level	0.156	0.999	0.109	0.990
Δ(Democracy level)	0.000	0.000	0.000	0.000
Population density	0.347	1.000	1.000	1.000
Δ(Population density)	0.000	0.000	0.000	0.605

Note: Fisher-type Phillips–Perron unit root tests performed on each panel including one Newey–West lag. All values reported are probabilities. C-s stands for cross-sectional means.

Table 3
Pedroni residual cointegration test for the pollution equations.

	SO_2/c		CO_2/c	
	Statistic	Probability	Statistic	Probability
Panel v-statistic	−5.110	1.000	4.228	0.000
Panel rho-statistic	8.904	1.000	9.360	1.000
Panel PP-statistic	−48.42	0.000	−17.72	0.000
Panel ADF-statistic	−9.604	0.000	−8.128	0.000
Group rho-statistic	12.82	1.000	13.31	1.000
Group PP-statistic	−54.63	0.000	−18.52	0.000
Group ADG-statistic	−8.973	0.000	−7.237	0.000
Kao-test (Engle-based)	−42.26	0.000	−39.25	0.000

concerned about the dynamic misspecification of the pollutants' equations as pointed-out by Halkos (2003). If we rely on a static model, then all adjustments to any shock occur within the same time period in which they occur, but this could be justified only in equilibrium or if the adjustment mechanism is rapid. According to Perman and Stern (1999) this is extremely unlikely and instead, it is expected that the return to long-run equilibrium emission levels is a rather slow process.

To estimate a non-stationary dynamic panel we employ the dynamic fixed effects (DFE) estimator developed by Pesaran and Smith (1995) and Pesaran et al. (1997, 2004). In DFE estimation we assume that intercepts differ across countries but that the long-run coefficients are equal across countries. However, if equality of the slope coefficients does not hold in practice, this technique yields inconsistent estimators. This assumption is tested using a Hausman test.

For Eq. (1), adopting the formalization by Blackburne and Frank (2007), we set-up an initial general autoregressive-distributed lag model AD ($p,q_1,\ldots,q_k$) of the form:

$$\ln(P/c)_{it} = \mu_i + \sum_{j=1}^{p} \lambda_{ij} \ln(P/c)_{i,t-j} + \sum_{j=0}^{q} \beta_{ij}^{'} K_{i,t-j} + \varepsilon_{it} \tag{3}$$

where number of countries $i = 1,2,\ldots,N$; number of periods $t = 1,2\ldots,T$, for sufficiently large T; K_{it} a $k \times 1$ vector of explanatory variables including government expenditure and income variables; and μ_i a country-specific effect.

If the variables in Eq. (3) are integrated of order one (that is I(1)) and cointegrated, then the error term is an I(0) process for all i. A principle feature of cointegrated variables is their responsiveness to any deviation from the long-run equilibrium. Hence, it is possible to specify an error correction model in which deviations from the long-run equilibrium affect the short-run dynamics of the variables. The error correction equation is formed as:

$$\begin{aligned}\Delta \ln(P/c)_{it} = \phi_i \left[\ln(P/c)_{i,t-1} - \zeta_i^{'} K_{it} \right) \\ + \sum_{j=1}^{p-1} \lambda^{*}{}_{ij} \Delta \ln(P/c)_{i,t-1} + \sum_{j=0}^{q-1} \beta_{ij}^{'*} \Delta K_{i,t-j} + \mu_i + \varepsilon_{it}\end{aligned} \tag{4}$$

where $\phi_i = -(1 - \sum_{j=1}^{p} \lambda_{ij})$, $\zeta_i = \sum_{j=0}^{q} \beta_{ij}/(1 - \sum_k \lambda_{ik})$, $\lambda_{ij}^* = -\sum_{m=j+1}^{p} \lambda_{im} j = 1,2,\ldots,p-1$ and $\beta_{ij}^* = -\sum_{m=j+1}^{q} \beta_{im} j = 1,2,\ldots,q-1$.

Nonlinearity in the parameters requires that the models are estimated using maximum likelihood.

Another econometric concern for Eqs. (1) and (2) is the bias occurring from the potential endogeneity between government spending with pollution and income respectively. Government spending often increases with pollution because governments implement ecological taxes. Moreover, the exact relationship between government spending and income is an active research area but there is empirical and anecdotal evidence (e.g. Lane, 2003) that governments often alter the amount and composition of fiscal spending to deal with the effects of business cycles.

To address this reverse causality problem we use the Arellano and Bond (1998) Generalized Method of Moments (GMM). GMM accounts for the inertia that is likely to exist in the determination of the dependent variables and mitigates potential reverse causality biases of the explanatory variables by using predetermined and exogenous variables as instruments in a systematic way. For both equations we assume that lagged dependent variables, as well as government expenditure and income are endogenous and treat all other explanatory variables as strictly exogenous.

Moreover, we use an additional exogenous instrumental variable for Eq. (1), namely the lagged weighted average of government expenditure in other countries, weighting by the inverse of the distance between the two countries. Since we use emissions rather than concentrations of pollutants, the lagged weighted average government spending in other countries is not expected to affect directly emission levels in a given country, but only through its effect on that county's government expenditure and income.

In Eq. (2) we also employ the democracy level as an exogenous instrument.[5] There are many empirical studies suggesting a relationship between public expenditure and level of democracy in a country. Boix (2003) suggests that a large share of the public sector depends on the level of democracy, while according to Aidt et al. (2006) cutting down socio-economic restrictions to the voting system leads to larger public share of GDP, mainly through increasing spending on infrastructure and internal security. Martin and Plumber (2003) find a U-shaped relationship between level of political participation and spending behavior of opportunistic governments. Additionally, there is a lack of sufficient empirical evidence about the existence of a significant relationship between income level and democracy (Acemoglu et al., 2008; Barro, 1996).

For both equations we test the validity of instruments with the Hansen test,[6] which failed to reject the null that the instrumental variables are uncorrelated with the residuals. We also report the Difference Hansen test for the exogenous IV subset which does not reject the null that the subset is valid.

3.2. Capturing the Effects of Government Expenditure on Pollution

Given the direct and indirect effects, the total effect of government spending on pollution can be expressed as:

$$\frac{d(P/c)}{dGovshare} = \frac{\partial(P/c)}{\partial Govshare} + \frac{\partial(P/c)}{\partial(GDP/c)} \frac{\partial(GDP/c)}{\partial Govshare} \tag{5}$$

where the first expression is the direct effect and the latter is the indirect effect via government expenditure impact on prosperity. It should be noted that while the direct effect remains constant throughout the whole income range, the indirect and hence the total effect depend on the level of per capita income, because of the inclusion of quadratic and cubic income terms in (1).

4. Results

Table 1 presents the coefficient estimates of per capita income, by applying different estimation methods.[7] To account for autocorrelation and heteroskedasticity, all standard errors reported are robust and in particular for FE estimation we report the Huber–White-Sandwich estimates of the variance–covariance matrix. The estimated effect of the

[5] Exclusion of the additional instrumental variables, in both equations, did not alter the results in any significant way.

[6] We report the Hansen test instead of the Sargan statistic since the latter is not robust and shows tendency to over-reject when heteroskedasticity and/or autocorrelation are present in the model (Arellano and Bond, 1991).

[7] The variation of the number of observations across different methods is due to appropriate use of lagged variables and availability of data for all variables used.

Table 4a
Estimates of pollution emissions/c.

	SO_2/c		CO_2/c	
	FE	DFE	FE	DFE
	(1)	(2)	(3)	(4)
Log(government share)	−0.292** (0.134)	−0.910*** (0.305)	−0.096 (0.101)	−0.256* (0.143)
LogGDPc	−50.49*** (12.56)	−36.51** (17.74)	−18.23*** (5.370)	−13.17** (6.502)
$(LogGDPc)^2$	6.642*** (1.541)	5.136** (2.160)	2.402*** (0.638)	1.792** (0.777)
$(LogGDPc)^3$	−0.283*** (0.063)	−0.231*** (0.088)	−0.099*** (0.025)	−0.075** (0.031)
Log(trade-openess)	−0.157*** (0.057)	−0.075 (0.143)	−0.104 (0.065)	−0.071 (0.058)
Log(investment)	−0.064 (0.060)	0.175 (0.127)	0.100** (0.048)	0.139** (0.056)
Log(household consumption)	−0.468 (0.340)	−1.313 (0.823)	−0.377 (0.264)	−0.479 (0.348)
Democracy level	−0.007 (0.005)	0.001 (0.010)	0.001 (0.004)	0.005 (0.005)
Population density	1.245 (2.069)	8.567** (3.521)	6.285*** (1.265)	7.283*** (1.453)
Constant	123.60*** (33.59)		44.22*** (14.41)	
Error correction term		−0.154*** (0.033)		−0.272*** (0.035)
Turning points	672/9321	369/7406	437/24,101	314/26,370
R^2	0.317		0.495	
F test	0.000		0.000	
Hausman FE v. RE	0.001		0.000	
Hausman MG v. PMG		1.000		0.851
Hausman PMG v. DFE		0.998		1.000
Nobs/countries	1480/74	1406/74	1480/74	1406/74

Note: Robust standard errors in parentheses. All tests' values reported are probabilities.
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.

Table 4b
Estimates of pollution emissions/c using GMM.

	SO_2/c		CO_2/c	
	First-differences	Orthogonal-deviations	First-differences	Orthogonal-deviations
Log government share	−0.903**	−1.107***	0.193	0.005
LogGDPc	−114.27**	−127.83**	−50.13***	−44.97**
$(LogGDPc)^2$	14.86***	16.38**	6.266***	5.646**
$(LogGDPc)^3$	−0.627***	−0.686**	−0.253***	−0.229**
Log(trade-openess)	−0.074	−0.111	−0.082	−0.099
Log(investment)	0.067	0.111	0.087**	0.156***
Log(household consumption)	−0.760***	−0.556	−0.026	−0.301
Democracy level	−0.004	−0.005	0.001	0.002
Population density	4.545	0.693	4.935*	5.518***
Turning points	742/9799	944/8691	898/16,481	880/15,678
Wald test	0.000	0.000	0.000	0.000
Hansen test	0.270	0.181	0.174	0.207
Hansen IV subset	0.173	0.042	0.086	0.080
A–B test of AR(1)	0.001	0.000	0.009	0.005
A–B test of AR(2)	0.331	0.325	0.357	0.328
Nobs/countries/IVs	1425/75/60	1425/75/60	1425/75/60	1425/75/60

Note: Robust standard errors in parentheses. All tests' values reported are probabilities.
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.

government expenditure share on GDP is negative and statistically significant, at the 1% level, regardless of the method used.

The FE estimates are presented in the second column. The estimated coefficient of government expenditure is equal to −0.210, while the DFE estimate of government size effect on income is −0.872 suggesting that consideration of dynamics increases the estimated impact of government share on per capita income, even without accounting for endogeneity.

In the fourth column, applying the Arellano–Bond two-step[8] GMM estimator, dynamics are still taken into account but government share is now treated as endogenous. We use first-differences and orthogonal-deviations GMM to control for fixed country effects. The significance of the lagged dependent variable (p-value = 0.000) suggests that dynamic specifications should be preferred. It should be noted that the assumption of uncorrelated u_{it} is important here, so tests for first- and second-order serial correlation related to the residuals from the estimated equation are reported in the fourth column. These tests are asymptotically-distributed as normal variables under the null hypothesis of no-serial correlation. The test for AR(1) is rejected as expected, while there is no evidence that the assumption of serially uncorrelated errors is inappropriate at least for 1% and 5% significance levels.

We report long-run estimates, calculated by dividing each estimated short-run coefficient by one minus the coefficient of the lagged dependent variable. To obtain robust standard errors, the Windmeijer's finite-sample correction for the two-step covariance matrix is used. The estimated impact of government expenditure on GDP is even greater in that case, suggesting that an increase of 1% in the share of government spending of GDP, ceteris paribus, reduces per capita income by 1.809%.

[8] Since there is evidence of heteroskedasticity we apply the more appropriate two-step Arellano–Bond procedure.

Table 5
Impact of government spending on pollutants (elasticities).

	SO_2/c			CO_2/c		
Effects	FE	DFE	GMM (F–D)	FE	DFE	GMM (F–D)
Direct	−0.292** (0.134)	−0.910*** (0.305)	−0.903** (0.390)	−0.096 (0.101)	−0.256* (0.143)	0.193 (0.186)
Indirect	−2.063** (1.027)	−1.462 (1.356)	−4.628** (2.048)	−2.094** (0.984)	−1.899* (1.012)	−2.843** (1.211)
Total	−2.355	−2.372	−5.532	−2.094	−2.155	−2.843
Change of sign point	10,003	9,268	10,809	24,210	30,201	16,438

Note: Indirect and total effects are calculated at sample median level of per capita income ($4669). Robust standard errors in parentheses. Standard errors of the indirect effect are estimated using the Delta method for estimating the variance of a non-linear function.
* Significant at 10%.
** Significant at 5%.
** Significant at 1%.

The signs and significance of the coefficients associated with the other control variables are all plausible and consistent with the literature, apart from the human capital proxy which although has the expected sign, is significant only in the OLS estimates. The impact of capital stock, represented by the share of investment in GDP, is positive and significant across all estimation methods. Population growth has a consistent negative and significant effect, while the trade-openness coefficient is also significant with an expected positive sign.

We use the Arellano–Bond estimates as benchmarks, therefore subsequent analysis and the estimation of the EKC equation are based on fitted values of real per capita income from the GMM estimation.

Before turning to the estimation of per capita pollution we should examine the time series properties of the main variables used. Testing for unit roots in panel data requires both the asymptotic behavior of the time-series dimension T, and the cross-section dimension N, to be taken into consideration. Since the panel data set we examine consists of both $N \to \infty$ and $T \to \infty$ dimensions, the tests of stationarity performed are based on the Fisher-type Phillips–Peron unit root test. The test allows heterogeneity of the autoregressive parameter and although in its general form does not control for cross-sectional dependence, is more powerful than Levin et al. (2002) in that case.[9] Table 2 presents the results of the Phillips–Perron unit root tests on the variables of interest. There is evidence against stationarity in levels, since in all cases our variables are I(1).

Additionally, application of the DFE method requires that the variables in the model are cointegrated meaning that there is a long-run relationship among them. Table 3 presents the Pedroni and the Kao (Engle based) cointegration tests for the two pollutants equations. We reject the null hypothesis of no-cointegration at the conventional statistical significance level of 0.05 in four of the seven cases for the SO_2 equation and in five cases for CO_2. However, in terms of raw power of the statistics for relatively small values of T the rho and panel-v statistics are the most conservative and show a tendency to over-reject (Pedroni, 2004), suggesting that evidence of cointegration is even stronger than that depicted in Table 3.

Table 4a provides estimates of per capita pollution emissions utilizing the results of GMM estimates of Eq. (2). In our model, as mentioned, according to the Hausman test FE is preferred to RE. Hence, for each pollutant we report FE and DFE estimates. Based on FE estimates (columns 1 and 3) the government share of GDP has a negative and significant direct effect on SO_2/c and an insignificant negative relationship with CO_2/c.

Dynamics are taken into account in the estimates reported in columns 2 and 4 of Table 4a. Comparing the MG and PMG estimators, with the use of a Hausman test, we see that the PMG estimator, the efficient estimator under the null hypothesis, is preferred and thus, assuming long-run coefficients to be equal across panels, it is more appropriate in our panel. Additionally, another application of the Hausman test suggests that the simultaneous equation bias between the error term and the lagged dependent variable is minimal in our panel and we may conclude that the DFE model is the most appropriate. DFE estimates suggest that the government share of income possesses a negative relationship with SO_2/c and CO_2/c, which is significant at 1% and 10% significance levels respectively.

Finally, Table 4b reports GMM First-Difference and Orthogonal-Deviations estimates of the EKC equation. The estimated effect of government expenditure on the environment is similar in magnitude to the DFE estimates for both pollutants but is statistically significant only in the case of SO_2. Since GMM estimates take into account dynamics and mitigate reverse causality biases, in what follows first-differences GMM results will be used as benchmark.

Both pollutants have a significant cubic relationship with per capita income in all estimates. Interestingly, taking into account endogeneity in the A-B GMM estimates produces turning points for CO_2 well within the sample. The household income effect is negative, although insignificant in all cases except for SO_2 in first-differences GMM. The share of investment is found to increase pollution, but the effect is significant only for CO_2. On the other hand, the coefficient of trade-openness is always negative, but mostly insignificant. Finally, the effect of population density is robustly positive, while the democracy index is insignificant in all specifications.

Table 5 presents the direct, indirect and total effects of government expenditure on pollution based on the estimates in Tables 4a–4b. Since the indirect and thus the total effects depend on the level of income, the effects in Table 5 are calculated at the sample median level of income.

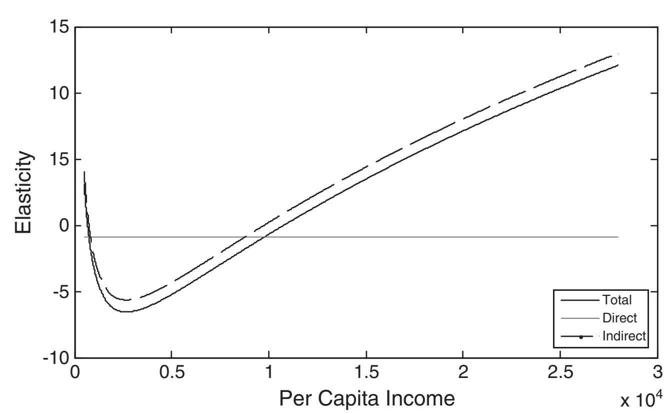

Fig. 1. The effect of government share on $SO_{2/c}$.

[9] We also compute the mean of the series across panels and subtract this mean from the series (columns 2 and 4 in Table 2) to mitigate the impact of cross-sectional dependence.

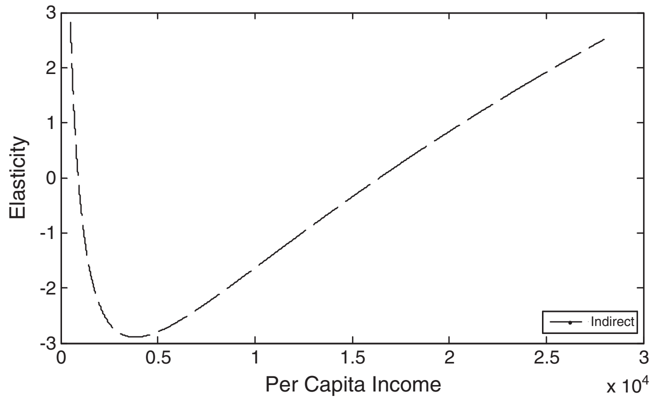

Fig. 2. The effect of government share on $CO_{2/c}$.

A negative direct effect of government share of income on pollution is estimated by all models, as indicated in Tables 4a and 4b. Concentrating on GMM results, an increase of government expenditure by 1%, ceteris paribus, may result in a 0.903% reduction of SO_2/c. However, the direct effect on CO_2 is insignificant. The indirect effects are statistically significant and negative at the median income level, leading to a negative total effect for both pollutants. The negative sign of the indirect effect occurs from the positive relationship between income and pollution at the median income level. Explicitly, at the sample median level of income an increase in the government share of GDP leads to a reduction in income and, as a result, to a reduction in emissions. Additionally, the estimated indirect effects are notably larger than the direct effects.

Figs. 1 and 2 present the direct, indirect and total effects of government share of income on emission levels against per capita income. For CO_2 the direct effect is insignificant and we do not take it into account. The indirect effect increases with per capita income, since $\frac{\partial(GDP/c)}{\partial(Govshare)} = -1.809$ and $\frac{\partial(P/c)}{\partial(GDP/c)}$ falls from 1.27 to −7.17 for SO_2/c and from 0.22 to −1.39 for CO_2/c throughout the sample income range. These patterns largely depend on the relationship between pollution and income levels described by the EKC.

The total effect of government share on SO_2/c is negative for low levels of per capita income and then turns to positive, while the total effect on CO_2/c is also negative but becomes positive only for very high income levels.[10] Table 5 also reports the estimated income level at which total effect changes from negative to positive. Particularly, GMM estimates indicate that this level is $10,809 for SO_2/c and $16,438 for CO_2/c, i.e. total effect of government share of income on CO_2/c is negative through most of the sample income range. From the figures it becomes clear that the pattern of total effect is determined by the shape of the indirect effect.

The results of Table 5 suggest that the direct effect of government spending on pollution is insignificant and considerably smaller for CO_2, in absolute values. This finding comes as no surprise if we take into consideration both pollutants' impact on human health and the technological capabilities of reducing their levels in the atmosphere. In particular, SO_2 emissions externalities are local and immediate while CO_2 emissions externalities are global and occur mostly in the future. Local environmental degradation, as in the case of SO_2, increases demand for technological improvements to diminish that impact.

The difference in magnitude and significance between the estimated direct effects of government expenditure on SO_2 and CO_2 could also be explained by how the different types of pollutants respond to certain policies. In particular, as already mentioned, the regulation of production generated pollutants, like SO_2, is expected to be more straightforward and this is reflected in the estimated effects.

Table 6
Robustness checks for omitted variables bias.

Relative correlation restriction (Λ)	Bounds on Government share effect by pollutant $[\theta_L(\Lambda), \theta_H(\Lambda)]$	
	SO_2/c	CO_2/c
{0.00}	−0.360*	−0.150
	(−0.650, −0.070)	(−0.365, 0.065)
[0.00, 1.00]	[−0.476, −0.360]	[−0.150, 0.212]
	(−1.066, −0.092)	(−0.331, 0.561)
[0.00, 2.00]	[−0.763, −0.360]	[−0.150, 1.023]
	(−2.527, −0.095)	(−0.334, 2.822)
[0.00, 2.50]	(−∞,0)	(−∞,∞)
	(−∞,0)	(−∞,∞)
[0.00, 13.00]	(−∞,0)	(−∞,∞)
	(−∞,0)	(−∞,∞)
[0.00, 15.00]	(−∞,∞)	(−∞,∞)
	(−∞,∞)	(−∞,∞)
λ*	2.25	2.25
λ(0)	13.20	0.47

Note: Bounds on effect of government share of GDP on pollution emissions/c, given relative correlation restrictions. Intervals in square brackets are the bounds themselves, while intervals in round brackets are Imbens–Manski 95% cluster-robust asymptotic confidence intervals.
* Significant at 5%.

4.1. Sensitivity Analysis

If government expenditure composition is omitted then this could bias the impact of government expenditure on pollution. We perform a sensitivity analysis for the EKC equation including a government expenditure composition variable, constructed as described in Lopez et al. (2011). For SO_2 the estimated coefficient of this variable was insignificant, while the magnitude and significance of the government expenditure remained unchanged. Interestingly, we found that composition of government spending matters in the case of CO_2, where its sign was negative and significant at the 5% level, while the sign of the government expenditure remained unchanged compared to the main results.[11]

Additionally, we test the existence of potential biases from omitted time-variant variables. Apart from the composition of government expenditure we particularly care about the environmental regulations effect. Table 6 reports the results from estimating the effect of government expenditure under a series of relative correlation restrictions, using the method proposed by Krauth (2011). To account for country fixed-effects, each variable is expressed in terms of deviation from the corresponding country-level average. The results suggest that the estimated effect for SO_2/c is robust, while the same does not hold for CO_2/c, as expected. We find that for the effect on SO_2/c to cease being strictly negative the correlation between government expenditure and unobservables would need to be 13.20 times larger than the correlation with the observables, which seems highly unlikely. However, for CO_2/c a relative correlation of only 47% or greater,

[10] Notably, for both pollutants, in very low levels of income (below the 5% percentile) the total effect is positive.

[11] The sample was smaller in this analysis due to limited availability (or even absence) of data for government spending composition for some countries, and this may affect the results, for example by introducing selection bias. We have also performed a sensitivity test including government spending composition in the income equation as suggested by López and Galinato (2007). Its coefficient was insignificant at all significance levels, while that of government expenditure was not altered in magnitude and significance.

Table 7
Robustness checks of the estimates on the total effect of government share on the pollutants.

	SO_2/c		CO_2/c	
	DFE	GMM(F–D)	DFE	GMM(F–D)
Bottom 1% of government share dropped	−2.743 (8959)	−5.645 (10,701)	−2.307 (24,682)	−3.481 (16,230)
Top 1% of government share dropped	−2.250 (8090)	−6.643 (10,913)	−2.288 (24,670)	−3.182 (14,544)
Bottom and top 1% of government share dropped	−2.480 (7780)	−6.926 (10,570)	−3.057 (29,351)	−4.414 (16,188)
Bottom 1% of pollutant dropped	−2.344 (9433)	−5.413 (10,469)	−2.202 (32,001)	−2.423 (16,570)
Top 1% of pollutant dropped	−2.282 (9491)	−4.517 (10,400)	−2.293 (32,432)	−2.821 (15,360)
Bottom and top 1% of pollutant dropped	−2.171 (9520)	−4.445 (11,093)	−1.942 (24,826)	−2.520 (16,026)

Note: Indirect effects are calculated at the sample median level of per capita income ($4669). Effects presented are based on DFE and GMM(F–D) estimations of the EKC equation. Change of sign points in parentheses.

implies that the point estimate of the effect includes zero and thus is not strictly negative.

We decided not to include interactive terms like government expenditure-income in the EKC equation, since our primary aim is to examine whether government expenditure intermediates between income and pollution. If such a mechanism exists, it should show up in our model; and if our model can show this while making only the smallest deviation from the previous literature, so much the better.[12] However, a robustness check of the significance of the variables (government spending × GDP/c) and its square was performed. The interactive terms were found to be insignificant when all powers of income were included in the equation, but were significant when just the level of GDP/c was used, thus confirming the existence of an indirect effect.

We estimated also the income equation with inclusion of government spending squared, to test whether there are decreasing returns to the government spending and income relationship, which could potentially affect the estimates of indirect and total effects. However, there was no evidence of a quadratic relationship between income and government expenditure.

Finally, we present dominance tests for extreme observations. Concentrating on DFE and GMM estimates, we present the total effect of government share on both pollutants, as well as the turning points of these effects, when extreme observations are dropped from the analysis. The model was estimated without the top and bottom 1% of government share expenditure data and then a similar approach was followed with the pollutant measures. Comparing the results of Tables 7 and 5, it can be seen that the total effects' magnitude and the estimate of the point at which the effect turns positive, are robust across the different datasets, indicating that the results are not determined by a small number of observations.

5. Conclusions

This paper, using a sample of 77 countries for the period 1980–2000 and a two equation model jointly estimated, examines the impact of government size on pollution taking into account the dynamic nature of this relationship. Our results confirm the theoretical and empirical developments on the existence of a correlation between income and pollution as well as between government size and economic performance. The reported results are not affected by biases, which may occur by omitted variables and existence of extreme observations.

The estimated direct effect of government expenditure is negative and significant for SO_2, but insignificant for CO_2. Estimation of a non-positive direct effect of government size on SO_2 is in line with recent findings by Lopez et al. (2011) and Lopez and Palacios (2010). On the other hand, the indirect effect which is considered for the first time here varies depending on income levels. The total effect is largely determined by the more dominant indirect effect. In particular, for SO_2, the total impact is negative, although decreasing in absolute value, for low levels of income and then becomes positive for more developed countries. In contrast, for CO_2 the total effect is also negative but it turns positive only for very high income levels.

We attribute these results to the different characteristics of the pollutants that may determine the effect of government expenditure on them, such as duration of their atmospheric lives, geographical and time scale of their effects on human health and on whether they are mainly production or consumption generated.

Policy implications, occurring from the analysis, differ according to the level of income in a country. Results suggest that reducing government size enhances economic performance. However, cutting government expenditure should be undertaken with particular care in some levels of GDP. For SO_2 and CO_2 pollution, results suggest that reducing government size in countries with an income level less than $10,809 and $16,438 respectively, leads to deterioration of environmental quality. Therefore, cutting government expenditure in these countries should be accompanied by appropriate environmental regulation along with the establishment of international environmental treaties.

On the other hand, in countries with higher income levels, cutting government expenditures leads to improvements in both income and environmental quality. These implications bear some resemblance to the EKC. In particular, countries with income level at the decreasing area of the EKC are more likely to have already established the environmental legislation and to have undertaken public expenditures for the improvement of environmental quality, thus they are susceptible to diminishing returns from a further increase in government size. In that context and combining our findings with the results from Lopez et al. (2011), cutting out public spending items that increase market failure will be the most beneficial, especially for CO_2 pollution.

Acknowledgments

This research has been co-financed by the European Union (European Social Fund—ESF) and Greek national funds through the Operational Program “Education and Lifelong Learning” of the National Strategic Reference Framework (NSRF)—Research Funding Program: Heracleitus II. Investing in knowledge society through the European Social Fund. We confirm that the above mentioned funding sources did not have any involvement in study design, collection and interpretation of data, the writing of the paper and the decision to submit the article for publication. We would like also to thank three anonymous referees for their helpful and constructive comments. Any remaining errors are solely the authors' responsibility.

[12] For similar approaches see Barrett and Graddy (2000) and Welsch (2004).

Appendix A. Data Description and Sources

Variable	Description	Source
SO_2/c	Sulfur dioxide emissions per capita, 1000 t of sulfur	Stern (2005)
CO_2/c	Carbon dioxide emissions per capita, tons of carbon	Boden et al. (2009)
Government share	Government share of real GDP/c	Penn World Table (2009)
GDPc	GDP per capita (Constant US $1990)	Maddison (2010)
Investment	Investment share of real GDP/c	Penn World Table (2009)
Household consumption	Household consumption as a share of Real GDP/c	Penn World Table (2009)
Trade-openness	Share of imports and exports in GDP	Penn World Table (2009)
Population growth	Annual population growth rate	Maddison (2010)
School	Primary school enrollment (% gross)	World Bank (2011)
World government share	Weighted average of government share of real GDP/c in other countries	Authors' calculations
Democracy	Degree of democracy, scaled −10 to 10	Polity IV Project (2010)

References

Acemoglu, D., Johnson, S., Robinson, J.A., Yared, P., 2008. Income and democracy. American Economic Review 98 (3), 808–842.

Afonso, A., Furceri, D., 2008. Government size composition, volatility and economic growth. European Central Bank Working Paper Series no. 849 (January).

Afonso, A., Jalles, J.T., 2011. Economic performance and government size. European Central Bank Working Paper Series no. 1399 (November).

Aidt, T.S., Dutta, J., Loukoianova, E., 2006. Democracy comes to Europe: franchise extension and fiscal outcomes 1830–1938. European Economic Review 50 (2), 249–283.

Arellano, M., Bond, S., 1991. Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. Review of Economic Studies 58, 277–297.

Arellano, M., Bond, S., 1998. Dynamic Panel Data Estimation Using DPD98 for GAUSS, Mimeo. Institute for Fiscal Studies, London.

Bajo-Rubio, O., 2000. A further generalization of the Solow growth model: the role of the public sector. Economic Letters 68, 79–84.

Barrett, S., Graddy, K., 2000. Freedom, Growth, and the Environment. , 5. Environment and Development Economics, Cambridge University Press, pp. 433–456 (October).

Barro, R.J., 1991. Economic growth in a cross section of countries. Quarterly Journal of Economics 106 (2), 407–443.

Barro, R.J., 1996. Democracy and growth. Journal of Economic Growth 1 (1), 1–27.

Barro, R.J., 1998. Determinants of Economic Growth: A Cross-Country Empirical Study, 1st ed. , vol. 1. MIT Press Books, The MIT Press (no. 0262522543).

Bergh, A., Karlsson, M., 2010. Government size and growth: accounting for economic freedom and globalization. Public Choice 142 (1), 195–213.

Bernauer, T., Koubi, V., 2006. States as Providers of Public Goods: How Does Government Size Affect Environmental Quality? Available at SSRN http://ssrn.com/abstract=900487.

Blackburne III, E.F., Frank, M.W., 2007. Estimation of nonstationary heterogeneous panels. The Stata Journal 7 (2), 197–208.

Boden, T.A., Marland, G., Andres, R.J., 2009. Global, Regional, and National Fossil-Fuel CO_2 Emissions. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A. http://dx.doi.org/10.3334/CDIAC/00001.

Boix, C., 2003. Democracy and Redistribution. Cambridge University Press, New York.

Cole, M.A., 2007. Corruption, income and the environment: an empirical analysis. Ecological Economics 62, 637–647.

Folster, S., Henrekson, M., 2001. Growth effects of government expenditure and taxation in rich countries. European Economic Review 45, 1501–1520.

Frederik, C., Lundström, S., 2001. Political and economic freedom and the environment: the case of CO2 emissions. Working Paper in Economics no. 29. University of Gothenburg, Gothenburg.

Ghali, K.H., 1998. Government size and economic growth: evidence from a multivariate cointegration analysis. Applied Economics 31, 975–987.

Grossman, G., Krueger, A., 1995. Economic growth and the environment. Quarterly Journal of Economics 110, 353–377.

Halkos, G., 2003. Environmental Kuznets Curve for sulfur: evidence using GMM estimation and random coefficient panel data models. Environment and Development Economics 8, 581–601.

Heston, Alan, Summers, Robert, Aten, Bettina, 1996. Democracy and growth. Journal of Economic Growth 1 (1), 1–27.

Heyes, A., 2000. A proposal for the greening of textbook macro: 'IS-LM-EE'. Ecological Economics 32, 1–7.

Krauth, B., 2011. Bounding a Linear Causal Effect Using Relative Correlation Restrictions, Discussion Papers dp11-02. Department of Economics, Simon Fraser University.

Lane, P.R., 2003. The cyclical behavior of fiscal policy: evidence from the OECD. Journal of Public Economics 87, 2661–2675.

Lawn, P.A., 2003. Environmental macroeconomics: extending the IS-LM Model to include an 'Environmental Equilibrium' curve. Australian Economic Papers 42 (1), 118–134.

Leitao, A., 2010. Corruption and the environmental Kuznets Curve: empirical evidence for sulfur. Ecological Economics 69, 2191–2201.

Levin, A., Lin, C.-F., James Chu, C.-S., 2002. Unit root tests in panel data: asymptotic and finite-sample properties. Journal of Econometrics 108 (1), 1–24.

López, R., Galinato, G., 2007. Should governments stop subsidies to private goods? Evidence from rural Latin America. Journal of Public Economics 91, 1071–1094.

Lopez, R.E., Palacios, A., 2010. Have government spending and energy tax policies contributed to make Europe environmentally cleaner? Working Papers 94795. University of Maryland, Maryland.

Lopez, R., Galinato, G.I., Islam, F., 2011. Fiscal spending and the environment: theory and empirics. Journal of Environmental Economics and Management 62, 180–198.

Maddison, A., 2010. GDP and Population Online Data. http://www.ggdc.net/MADDISON/oriindex.htm.

Mankiw, G.N., Romer, D., Weil, D.N., 1992. A contribution to the empirics of economic growth. Quarterly Journal of Economics 107 (2), 407–437.

Martin, C.W., Plumber, T., 2003. Democracy, government spending, and economic growth: a political–economic explanation of the Barro-effect. Public Choice 117, 27–50.

Pedroni, P., 2004. Panel cointegration: asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. Econometric Theory 20, 597–625.

Perman, R., Stern, D.I., The Environmental Kuznets Curve: Implications of Non-stationarity, Working Paper in Ecological Economics no. 9901, Centre for Resource and Environmental Studies, Australian National University, Canberra.

Pesaran, M.H., Smith, R., 1995. Estimating long-run relationships from dynamic heterogeneous panels. Journal of Econometrics 68 (1), 621–634.

Pesaran, M.H., Shin, Y., Smith, R., 1997. Pooled estimation of long-run relationships in dynamic heterogeneous panels. Cambridge Working Papers in Economics no. 9721. University of Cambridge.

Pesaran, M.H., Shin, Y., Smith, R., 2004. Pooled mean group estimation of dynamic heterogeneous panels. ESE Discussion Papers 16. University of Edinburgh, Edinburgh.

Polity IV Project, 2010. Polity IV Data Series. http://www.systemicpeace.org/polity/polity4.htm.

Sim, N.C.S., 2006. Environmental Keynesian macroeconomics: some further discussion. Ecological Economics 59, 401–405.

Stern, D.I., 2005. Global sulfur emissions from 1850 to 2000. Chemosphere 58, 163–175.

Welsch, H., 2004. Corruption, growth and the environment: a cross-country analysis. Environment and Development Economics 9, 663–693.

World Bank, 2011. World Development Indicators. http://data.worldbank.org/data-catalog/world-development-indicators.