

Halkos, George

Conference Paper

Economic Development and Environmental Degradation: Testing the Existence of an Environmental Kuznets Curve At Regional Level

46th Congress of the European Regional Science Association: "Enlargement, Southern Europe and the Mediterranean", August 30th - September 3rd, 2006, Volos, Greece

Provided in Cooperation with:

European Regional Science Association (ERSA)

Suggested Citation: Halkos, George (2006) : Economic Development and Environmental Degradation: Testing the Existence of an Environmental Kuznets Curve At Regional Level, 46th Congress of the European Regional Science Association: "Enlargement, Southern Europe and the Mediterranean", August 30th - September 3rd, 2006, Volos, Greece, European Regional Science Association (ERSA), Louvain-la-Neuve

This Version is available at:

<https://hdl.handle.net/10419/118411>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

Economic development and environmental degradation: Testing the existence of an Environmental Kuznets Curve at regional level

George E. Halkos
Department of Economics
University of Thessaly

Abstract

This paper uses a dynamic panel data for 23 OECD and 50 non-OECD countries for the time period 1960-1990 in order to estimate the relationship between economic development (in the form of GDP) and environmental pollution (in the form of sulphur emissions). Panel data econometric techniques are applied for performing our empirical estimation. The analysis shows significant differences between the most industrialized countries and the rest of the countries considered. This implies that policies to control pollution have to take into consideration the specific economic situation as well as the structure of the industrial and the business sectors in each region. Finally, in terms of policy implications, the study discusses the main abatement options for sulphur reduction.

1. Introduction

Kuznets (1965, 1966) showed that during the various economic development stages, income disparities first rise and then begin to fall. The environmental Kuznets curve (hereafter EKC) hypothesis proposes that there is an inverted U-shape relation between environmental degradation and per-capita income. Environmental damage seems to be lower in the most developed countries compared to many middle-income countries and higher in many middle-income countries compared to less developed countries. It is worth mentioning that an alternative form of the EKC hypothesis suggests that environmental degradation as a function of income is not a stable relationship but may depend on the level of income. This is because in this alternative form, there may exist one relationship for poor and another for rich countries. On the aggregate this would give an inverted U-like curve.

A number of authors have estimated econometrically the EKC using OLS analysis. The use of OLS is not likely to yield accurate estimates of the peak levels. Additionally to the fact that the use of OLS is not an appropriate technique in modelling the EKC, most of the empirical studies do not present diagnostic statistics of the regression residuals. Due to this reason we cannot be certain that the peak levels provided -and the policy implications suggested - are accurate. Halkos and Tsionas (2001) using cross-sectional data obtained the following results:

$$\text{Deforestation} = -2.344 + 1.298 \log \text{GNP} - 0.243 [1/2(\log \text{GNP})^2]$$

(0.7824) (1.595) (2.189)

$$\text{Harvey test for heteroskedasticity } \chi^2(2) = 9.213,$$

$$\text{RESET test for misspecification } F(3, 55) = 3.03$$

$$\text{BP test for heteroskedasticity } \chi^2(2) = 1.427$$

$$\text{Jarque-Bera Test for Normality: } \chi^2(1) = 4.67$$

where t-ratios are presented in parentheses. These results indicate the existence of an EKC. However, the diagnostics imply the specification is totally unreliable as we see heteroskedasticity, misspecification and non-normality problems.

The EKC estimates for any dependent variable (e.g. SO₂, NO_x, deforestation, etc.) peak at income, levels which are around the world's mean income per capita. Income as expected is not normally distributed but skewed (with a lot of countries below mean income per capita). Arrow *et al.* (1995), Ekins (1997) and Ansuategi *et al.* (1998) provide a number of reviews and critiques of the EKC studies. Stern *et al.* (1996) identified a number of problems with some of the main EKC estimators and their interpretation. They mention among others econometric problems, the mean-median income problems, the interpretation of particular EKCs in isolation from other environmental problems, the assumption of unidirectional causality from growth to environmental quality and the reversibility of environmental change and the asymptotic behavior. Stern (1998) reviews these problems in details and shows where progress has been made in empirical studies.

In this paper, a dynamic panel data for 73 countries for the time period 1960-1990 is used in order to estimate the relationship between Gross Domestic Product (GDP) and pollution in the form of sulphur emissions. Our empirical estimation is performed using fixed and random effects. To control for non-observable specific effects Two Stage Least Squares (2SLS) is applied. A random coefficients model formulation is also applied assuming that each parameter is a random variable. Countries are heterogeneous with different stochastic regression coefficients, which arise from a k -variate normal distribution. In this way we find out if there is cross-country variation in the parameters

and if this variation is so large that aggregate summarization is not useful at all.

The paper is organised as follows: Section 2 discusses the existing theoretical and empirical work. Section 3 discusses the econometric models. The empirical evidence is presented in section 4 together with the data used. The final section concludes the paper.

2. Previous work

A number of possible explanations exist for the inverse U-shape relationship. Natural progression of economic development goes from clean agricultural to polluting industrial and to clean service economies. The improvement in environmental quality may be the result of the change in the technological mode of production (de Bruyn, 1997; Han and Chatterjee, 1997) or of the exportation of “dirty industry” to less developed or developing countries (Rock, 1996; Suri and Chapman, 1998).

In the formalization of the transition to the low-pollution state there is a group of authors that provide significant analyses of the role of preferences and regulation on the emissions profile of polluters (Lopez, 1994; McConnell, 1997; Stokey, 1998). A better institutional set up in the form of credible property rights; regulations and good governance may create public awareness against environmental degradation (Dinda *et al.*, 2000).

Another explanation relies on the fact that pollution will stop increase and start to decrease with economic growth because some constraints will become non-binding. Stokey (1998) shows that pollution increases linearly with income until the threshold is passed and cleaner technologies can be used. The implied pollution-income path takes the form of an inverse-V with a sharp peak, taking place at the point where a continuum of cleaner technologies becomes available. Jaeger (1998), similarly to Stokey, finds that the pollution income relationship is an inversed-V. Jaeger relies on the assumption that at low levels of pollution consumers’ taste for clean air is satisfied and marginal benefit of additional environmental quality is zero.

Finally, Andreoni and Levinson (2001) suggest another explanation due to the technological link between consumption of a desired good and abatement of its undesirable byproducts (pollution). Distribution issues may be considered another explanation. Torras and Boyce (1998) argue that the greater equality of incomes results in lower level of environmental degradation. This claim is challenged by Scruggs (1998). Table 1 presents the relevant EKC studies for sulphur.

3. Econometric methods

The model proposed here is a logarithmic quadratic estimated as:

$$\ln(S/c)_{it} = \alpha_i + \gamma_t + \beta_1 \ln(GDP/c)_{it} + \beta_2 (\ln(GDP/c))_{it}^2 + \varepsilon_{it} \quad (1)$$

where the α_i ’s are country specific intercepts and the γ_t ’s are time specific intercepts and the countries are indexed by i and time periods by t . S/c is sulfur emissions per capita in tons of sulfur and ε_{it} is a disturbance term. Both dependent (emissions per capita) and independent (PPP GDP per capita) variables are in natural logarithms.

Panel data methods are applied to estimate the above equation. The first method employed imposes the same intercept and slope parameter for all countries and it is therefore equivalent to OLS estimation (omitted for simplicity in some cases). The second method is the fixed effects (hereafter FE) allowing each individual country to have a different intercept treating the α_i and γ_t as regression parameters.

This practically means that the means of each variable for each country are subtracted from the data for that country and the mean for all countries in the sample

in each individual time period is also deducted from the observations from that period. Then OLS is used to estimate the regression with the transformed data.

The third model is the random-effects (hereafter RE) in which the individual effects are treated as random. In this model the α_i and γ_i are treated as components of the random disturbances. The residual from an OLS estimate of the model with a single intercept are used to construct variances utilized in a GLS estimates (for further details see Hsiao, 1986). If the effects α_i and γ_i are correlated with the explanatory variables then the random effects model cannot be estimated consistently (Hsiao, 1986, Mundlak, 1978). Only the fixed effects model can be estimated consistently.

Table 1: Sulfur emissions EKC Studies

Authors	Estimation Technique	Source of Sulfur data	Time Period	Additional Variables	Turning Point	Countries/cities
Grossman and Krueger, 1991	RE	GEMS	1977, '82, '88	Locational dummies, population density, trend	\$4772-5965	Up to 52 cities in up to 32 countries
Kaufmann <i>et al.</i> , 1998	RE, FE, OLS	UN	1974-89	GDP/Area, steel exports/GDP	\$14730	13 developed, 10 developing countries
Selden and Song, 1994	Random and Fixed Effects OLS	WRI – primarily OECD source	1979-87	Population density	\$10391-10620	22 OECD, 8 developing countries
Panayotou 1993, 1995	OLS	Own estimates from fuel use data	1987-88		\$3137	55 developed and developing countries
Panayotou, 1997	RE, FE	GEMS	1982-84	Population density, policy variables	\$5965	Cities in 30 developed and developing countries
Shafik, 1994	FE	GEMS	1972-88	Time trend, locational dummies	\$4379	47 Cities in 31 Countries
Cole <i>et al.</i> , 1997	Random and Fixed Effects, OLS	OECD	1970-92	Country dummy, technology level	\$8232	11 OECD countries
Stern and Common (2001)	Random and Fixed Effects	ASL	1960-90	Time and country effects	\$101166	73 developed and developing countries
Halkos (2003)	GMM, Random coefficients	ASL	1960-90	Time and country effects	\$2805-\$6230	73 developed and developing countries

To control for non-observable specific effects Two Stage Least Squares (2SLS) was applied but the results were insignificant. Due to exogeneity strict requirement for the efficiency of these methods we also control for endogeneity of GDP using the GDP variable lagged two periods as the instrumental variable (IV) and in order to achieve completeness.

Random coefficient model formulation is also used. This is known as Swamy's (1970) model and relies on the idea that the cross section coefficient vectors

are “drawn” from a distribution with a common mean (Hildreth and Houck, 1968; Judge *et al.*, 1988). The random coefficient model is given as

$$Y_{it} = X_{it}' \beta_i + \varepsilon_{it} \quad i = 1, \dots, N, \quad t = 1, \dots, T \quad (2)$$

where Y_{it} is the value of the dependent variable for country i and year t , X_{it} is a $k \times 1$ vector of explanatory variables, β_i is a $k \times 1$ vector of coefficients for country i , and ε_{it} is a disturbance term. We assume that

$$\varepsilon_{it} \sim IN(0, \sigma_i^2) \quad (3)$$

In this formulation, countries are heterogeneous in the sense that they have different regression coefficients. These coefficients are stochastic, and arise from a k -variate normal distribution with moments as above. That is, we assume that each parameter is a random variable. This assumption may be presented as:

$$\beta_{tk} = \bar{\beta}_k + u_{tk} \quad k=1, \dots, K \quad (4)$$

where $\bar{\beta}_k$ is a $k \times 1$ vector of mean coefficients; it is nonstochastic and a mean response coefficient. u_{tk} is a random disturbance with $E[u_{tk}] = 0$ and $\text{var}(u_{tk}) = \alpha_k^2$. We are interested in calculating the mean response vector $\bar{\beta} = (\bar{\beta}_1, \dots, \bar{\beta}_k)$ and the covariance matrix of the error vector $v_t = (u_{t1}, \dots, u_{tK})'$ which is given by $E(v_t v_t')$. If $X_t' = (1, X_{t1}, X_{t2}, \dots, X_{tk})$ then (2) can be expressed as

$$Y_t = X_t'(\bar{\beta} + v_t) = X_t' \bar{\beta} + X_t' v_t = X_t' \bar{\beta} + e_t \quad (5)$$

which is the usual linear model formulation with a heteroskedastic error term e_t with variance $\sigma_t^2 = X_t' \Sigma X_t$. So the model may be estimated using a two-step generalized least squares (GLS) procedure.

4. Empirical evidence

Our sample consists of the 73 countries (23 OECD and 50 non-OECD member countries), which have a full set of sulfur and purchasing power parity GDP per capita information for the period 1960-90 (A.S.L. and Associates, 1997; Lefohn *et al.*, 1999; Summers and Heston, 1991)¹. The database used has 2263 observations per variable. In terms of the raw data, it is observed that emissions increase with income, but there is some sign of a decrease at high-income levels. We have used emissions rather than concentrations as the latter depend on both emissions and geographic location and atmospheric conditions in the form of wind velocity etc. We may justify the use of emissions, as there is no reason to expect that developing countries differ in any systematic manner in the dispersion of pollutants.

We first present the results for the whole of the database and for the OECD and non-OECD countries as shown in Table 2. Both the fixed and random effects models indicate the presence of a Kuznets curve, and parameter estimates as well as t-statistics are quite similar. As we observe the implied turning points are extremely high for both the fixed and random effects for the whole dataset ($n=2263$) and they are equal to \$123571/c and \$91991/c respectively. Thus using the ASL database and fixed and random effect models produces a monotonic EKC for the total sample. The turning points for non-OECD countries and for the fixed and random effects models are much higher (\$501936 and \$361942 respectively).

Similarly, and from Table 3, the turning points for the OECD countries are inside the sample. Specifically for the fixed and random effects models they are equal to \$9152 and \$9166 respectively. Confirming the results derived in Stern and Common (2001), sulphur emissions per capita are a monotonic function of income per

capita, when they use a global sample and an inverted U-shaped function of income when they use a sample of high-income countries only.

Table 2: Fixed and Random Effects results for the World and non-OECD countries

Region	World n=2263		Non-OECD n=1550	
	Fixed Effects	Random Effects	Fixed Effects	Random Effects
Constant		-24.661 (-14.029)		-19.3753 (-7.724)
Ln GDP/P	4.1036 (6.141)	4.1146 (9.4749)	2.6725 (4.1386)	2.684 (4.191)
(ln GDP/P) ²	-0.175 (-4.999)	-0.18 (-7.706)	-0.1018 (-2.762)	-0.10485 (-2.784)
Adjusted R ²	0.144	0.155	0.143	0.151
P	0,873	0,882	0,852	0,86
AR(1)	88,3	89,7	71,59	73,71
Turning Point	123571	91991	501936	361942
Chow F Test	10.681 (0.016)	4.026 (0.04)		
Hausman Test		10.8 (P=0.0045)		13.54 (P=0.0011)

Figures in parentheses are t statistics. AR(1) is a t-test on the residual autocorrelation coefficient p.

The Hausman test shows that country intercepts and income are correlated in the global model. The test shows that the random effects formulation cannot be consistently estimated. This suggests that there are omitted variables, which are correlated with GDP. The Chow test shows that there are differences in the estimated parameters between high- and low-income countries. The reported tests for serial correlation show that there is significant residual serial correlation in the individual countries even after common time effects have been removed².

The F test performed in order to test for the significance of the FE shows that the null hypothesis (of non significance) is always rejected implying that the assumption of constant intercept may not always be valid for the different countries. That is, although the above-average (and the below-average) income countries exhibit identical patterns in terms of the relationship between GDP increases and sulphur emissions, there are differences in levels, as they start from different levels of sulphur emissions.

A high level of predictability is observed in both cases of FE and RE model formulation. At an income level of \$4135 (the lowest in the sample considered and for Portugal) the elasticity of emissions with respect to income was found to be 1,11. For an income level of \$5819 (Ireland) the elasticity of emissions with respect to income was found to be 0,6329, for an income of \$8838 (Austria) the elasticity is 0,049, for an income of \$9366 (Belgium) the elasticity is -0,0325 and for an income of \$11426 (Sweden) the elasticity is -0,31042³.

The fixed and random effect models allow for variation only in the intercept and impose slope homogeneity, whereas the random coefficients models allow for random countrywide variation in all slope coefficients. Considering now the empirical results derived for the random coefficients model we see a quite different picture. The parameter estimates for the full data set and for the random coefficients models are presented in Table 4. We have tried a number of random coefficients models that differ in two dimensions: whether the variables are used in logs, and whether a

quadratic income term is included. Income and income squared (in levels or logs) are not statistically significant. The reason is that there is huge cross-country variation in β_i 's implying that even if Kuznets curves do exist, their parameters are so extremely heterogeneous across countries that an aggregate summarization is not very useful at all.

Table 3. Fixed and Random Effects Results for the OECD countries

Regressors	OLS	FE	RE	TSLS
Constant	-69,711 (-11,582)		-59.59 (-18.4671)	
Ln GDP	14,261 (10,524)	12.245 (16.1613)	12.2196 (16.7735)	-1,636 (-1,382)
Ln GDP ²	-0,7716 (-10,12)	-0.6712 (-16.26)	-0.6697 (-16.282)	0,1318 (1,89)
R ² Adjusted	0,2998	0.311	0.332	
SE	0,565	0,29011	0,29122	0,3745
Sign. FE		2095,9		
P	0,99	0,911	0,908	
AR(1)	98,91	56,4	54,94	
Turning Point	10313	9152	9166	
Hausman test			0.25	

Table 4. Parameter estimates for the random coefficient models (t-statistics in parentheses)

	Random Coefficients			
	I	II	III	IV
Constant	0.013 (3.547)	0.0105 (1.919)	-11.43 (-0.944)	-85.09 (-1.39)
GDP	0.28 10 ⁻⁵ (0.947)	0.481 10 ⁻⁵ (1.144)		
GDP ²		-0.838 10 ⁻⁹ (-0.3882)		
LogGDP			0.748 (0.396)	20.953 (1.2154)
LogGDP ²				-1.382 (-1.118)

We tried separating the countries according to their geographical position into Southern and Northern countries as well as according to their income level. According to the latter distinction, we have defined the first group as above average income countries and the second as below average income countries. The turning points in this case were \$8203, \$8671 and \$7529 and \$9221 for the FE and RE and for the above- and below-average income countries.

5. Conclusions and Policy Implications

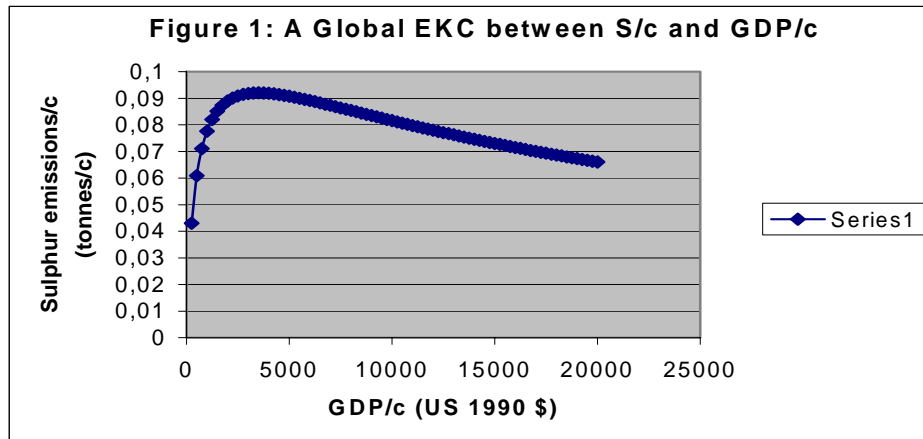
Like inequality, pollution tends to become worse before it becomes better along a country's development path. Our results indicate the existence of an inverted U-shaped relationship between economic development and pollution in the form of sulphur emissions as shown in Figure 1.

Specifically, using this panel database:

1. Using a random coefficients method does not support an EKC hypothesis. The main message from the random coefficients model is that income and its square (in levels or logs) do not appear to be statistically significant. The reason is that there is enormous cross-country variation in β_i 's. This result implies that even if

Kuznets curve do exist, their parameters are so extremely heterogeneous across countries that an aggregate summarization is not very useful at all.

2. Fixed and random effect models produces a monotonic EKC for global and non OECD samples with extremely high turning points and an inverted U-shaped with within the sample turning points for the case of OECD countries. Estimating an EKC using data for only the OECD countries leads to estimates where the turning point is not biased downwards relative to that estimated using data for the World as a whole.
3. The turning point occurs at \$9152 for the OECD countries, at \$501936 for the non-OECD countries and at \$123571 for the world in general.



A part of the steepness of the inverted U-shaped relationship between economic growth and pollution is due to policy distortions (under-pricing of natural resources, subsidies of energy and agrochemicals, etc), which are at the same time environmentally and economically destructive. Governments can flatten out their EKC by reducing or eliminating policy distortions, defining and applying property rights over natural resources, internalizing environmental costs to the sources that generate them.

The need for technology transfer to help developing countries to achieve sustainability emerges. The main idea is that abatement technologies in developed countries are cleaner and more advanced. As developing countries have no financial resources to import and use these technologies at commercial cost this implies that developed countries should transfer or facilitate the transfer of these technologies to less developed or developing countries. The impact of this technology transfer depends on the type of industrial activity. That is, in the energy sector these transfers will be more beneficial for the environment compared to other industries such as textiles, etc. It should be emphasized that transfer of information must accompany these technology transfers on know-how and skills to enable countries to design or modify their own technologies.

Desulphurization processes exist to reduce the sulphur content of the fuel in use. The extent of removal is dependent on the physical and chemical characteristics of the sulphur in the fuel. Control technologies can be classified into three categories: 1. pre-combustion (physical coal washing and oil desulphurization); 2. during-combustion (sorber injection and fluidized bed combustion); and 3. post-combustion (flue gas desulphurization, FGD). The choice of the technology will depend upon the characteristics of the fuel being burned and the standards for emissions, which must be met. Ease of disposition or ability to reuse waste products was found to be a secondary but important determinant of the technology used, especially as it affects the economics of certain processes. Table 5 presents information on the cost-effectiveness of the

available technologies as well as the applicability and the capital and operating and maintenance costs.

Table 5: Sulphur emission abatement options and costs (costs in \$ million 1985). Costs are based on a new 500 MW power plant, using hard coal of 2% sulphur content, 70% load factor and 5% retention factor.

Abatement Method	Applicability	Sulphur removal efficiency (%)	Capital Cost	Operating and Maintenance cost		Cost-Effectiveness \$/t SR
				FIXED	VAR	
Fuel switching (e.g. oil to gas)	All Users	Up to 99	-	-	-	(1)
Physical coal cleaning	All users	25	-	-	-	635-1625
Heavy fuel oil desulphurisation	All users	80	7.775	6.32	12.28	2100-2930
Sorbent injection	All users	50	0.344	0.22	2.59	485-750
Atmospheric Fluidised Bed Combustion	Power plants, industrial boilers	80	3.259	0.16	2.71	238-446
Circulating Fluidised Bed Combustion	New plants only	85	7.061	0.35	4.77	529-835
Flue Gas Desulphurization	Power plants, industrial boilers and process emissions	90	29.462	1.67	4.02	650-1200
Gas Oil Desulphurization	All users	90	1.918	1.93	2.2	2900-3740

Source: Halkos (1995)

ENDNOTES

1. Data are for the following countries:

OECD: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Greece, Ireland, Italy, Japan, Luxembourg, Netherlands, Norway, New Zealand, Portugal, Spain, Sweden, Switzerland, Turkey, UK, USA, West. Germany.

Non-OECD: Algeria, Argentina, Barbados, Bolivia, Brazil, Chile, China, Colombia, Cyprus, Czechoslovakia, Egypt, Ghana, Guatemala, Honduras, Hong Kong, India, Indonesia, Iran, Israel, Kenya, Korea, Madagascar, Malaysia, Mexico, Morocco, Mozambique, Myanmar, Namibia, Nicaragua, Nigeria, Peru, Philippines, Romania, South Africa, Saudi Arabia, Singapore, Sri Lanka, Syria, Taiwan, Tanzania, Thailand, Trinidad & Tobago, Tunisia, Uruguay, U.S.S.R., Venezuela, Yugoslavia, Zaire, Zambia, Zimbabwe

2. A model estimated in first differences reduces statistical problems but results in a monotonic EKC when estimated on both high and low income samples. Stern and Common (2001) provide the results in first differences where the turning points again differ substantially. They equal \$53590, \$586965 and \$21545 for the global, OECD and non-OECD samples respectively.

3. GDP may be an integrated variable at least in the case of the Western European countries (Stern, 1998; Perman and Stern, 1999). The Hausman tests reported in Table 2 show that there may be omitted variables correlated with GDP. If the EKC regressions do not cointegrate the estimates may be spurious and non-cointegration is very possible. The very high reported autocorrelation coefficients in Stern and Common (2001) imply this conclusion. Thus the regression results reported above may be spurious. Differencing the data will eliminate potential stochastic trends in the series.

References

- Andreoni J. and Levinson A., 'The simple analytics of the environmental Kuznets curve', *Journal of Public Economics*, 80, 2001, 269-286
- Ansuategi A., Barbier E.B. and Perrings C.A., The Environmental Kuznets Curve, in: Van den Bergh, J.C.J.M. and Hofkes, M.W. (Eds) *Theory and Implementation of Economic Models for Sustainable Development*, Kluwer. 1998
- Arrow K., Bolin B., Costanza R., Dasgupta P., Folke C., Holling C.S., Jansson B-O, Levin S., Maler K-G, Perrings C. and Pimentel D., Economic growth, carrying capacity and the environment, *Science*, 268, 1995, 520-521.
- A.S.L. and Associates, *Sulphur Emissions By Country And Year*, Report No: DE96014790, US Department of Energy, Washington DC, 1997.
- Cole M.A., Rayner A.J. and Bates J.M., The Environmental Kuznets curve: an empirical analysis, *Environment and Development* 2(4), 1997, 401-416.
- de Bruyn, S.M., Explaining the Environmental Kuznets Curve: structural change and international agreements in reducing sulphur emissions, *Environment and Development Economics*, 2(4), (1997), 485-503
- Dinda S., D. Coondos and M. Pal, 'Air quality and economic growth: an empirical study', *Ecological Economics*, 34, 2000, 409-423
- Ekins P., The Kuznets curve for the environment and economic growth: examining the evidence, *Environment and Planning A* 29, 1997, 805-830.
- Grossman G. and A. Krueger, *Environmental impacts of a North American Free Trade Agreement*, NBER Working Paper 3914, National Bureau of Economic Research, Cambridge MA., 1991.
- Grossman G. and A. Krueger, Economic growth and the Environment, *Quarterly Journal of Economics*, 110, 1995, 353-377
- Halkos G., An evaluation of the direct cost of abatement under the main desulphurization technologies, *Energy Sources*, 17(4), 1995, 391-412
- Halkos, G. and E. Tsionas, Environmental Kuznets Curve: Bayesian evidence from Switching Regime Models, *Energy Economics*, 23(2), March 2001, 191-209
- Halkos, G., Is there an Environmental Kuznets Curve for sulfur?, *Environment and Development Economics*, 8(4), 2003, 581-601,
- Han X. and Chatterjee L., 'Impacts of growth and structural change on CO₂ emissions of developing countries', *World Development*, 25, 1997, 395-407
- Hildreth, C. and J. Houck (1968), 'Some estimators for a linear model with random coefficients', *Journal of the American Statistical Association*, 63: 584-595

- Hsiao C., *Analysis of panel data*, Cambridge University Press, Cambridge UK, 1986
- Jaeger W., *A theoretical basis for the environmental inverted-U curve and implications for international trade*, Williams College, Working Paper, 1998
- Judge, G.G., R.C. Hill, W.G. Griffiths, H. Lutkepohl and T.C. Lee (1988), *Introduction to the Theory and Practice of Econometrics*, 2nd Ed., John Wiley & Sons, Inc.
- Kaufmann R.K., Davidsottir B., Garnham S. and Pauly P., The determinants of atmospheric SO₂ concentrations: reconsidering the Environmental Kuznets Curve, *Ecological Economics*, 25, 1998, 209-220.
- Kuznet S., *Economic Growth and Structural Change*, New York, 1965
- Kuznet S., *Modern Economic Growth*, Yale University Press, 1966
- Lefohn A. S., D.H. Janja and B.H. Rudolf, 'Estimating historical anthropogenic global sulphur emission patterns for the period 1860-1990', *Atmospheric Environment*, 33, 1999, 2435-2444
- Lopez R., The environment as a factor of production: the effects of economic growth and trade liberalization, *Journal of Environmental Economics and Management*, 27, 1994, 163-184.
- McConnell K.E., 'Income and demand for environmental quality', *Environment and Development Economics*, 2, 1997, 383-399
- Mundlak Y., On the pooling of time series and cross section data, *Econometrica*, 46, 1978, 69-85
- Panayotou T., *Empirical tests and policy analysis of environmental degradation at different stages of economic development*, Working Paper WP238, Technology and Employment Programme, International Labor Office, Geneva, 1993
- Panayotou T., Environmental degradation at different stages of economic development, in: I. Ahmed and J. A. Doeleman (eds.) *Beyond Rio: The Environmental Crisis and Sustainable Livelihoods in the Third World*, MacMillan, London, 1995
- Panayotou T., 'Demystifying the environmental Kuznets curve: turning a black box into a policy tool', *Environment and Development Economics*, 2(4), 1997, 465-484.
- Perman R. and Stern D.I., *The Environmental Kuznets curve: implications of non-stationarity*, Working Papers in Ecological Economics 9901, Center for Resource and Environmental Studies, Australian National University, 1999
- Rock M.T., 'Pollution intensity of GDP and trade policy: can the World Bank be wrong?', *World Development*, 24, 1996, 471-479

Scruggs L.A., 'Political and economic inequality and the environment', *Ecological Economics*, 26, 1998, 259-275

Selten T. and D. Song, Environmental quality and development: is there a Kuznets curve for air pollution emissions? *Journal of Environmental Economics and Management*, 27, 1994, 147-162.

Shafik N. and S. Bandyopadhyay, *Economic growth and environmental quality: time series and cross-country evidence*, Background paper for the World Development Report 1992, The World Bank, Washington DC, 1992

Shafik N., Economic development and environmental quality: an econometric analysis, *Oxford Economic Papers* 46, 1994, 757-773.

Rock M.T., Pollution intensity of GDP and trade policy: can the World Bank be wrong?, *World Development*, 24, 1996, 471-479

Stern D. I., M.S. Common and E.B. Barbier, Economic growth and the environmental degradation: the environmental Kuznets Curve and sustainable development, *World Development*, 24, 1996, 1151-1160.

Stern D.I., Progress on the environmental Kuznets curve? *Environment and Development* 3, 1998, 175-198.

Stern D. I. and M.S. Common , 'Is there an environmental Kuznets curve for sulphur?' *Journal of Environmental Economics and Management*, 41, 2001, 162-178

Stokey N.L., 'Are there limits to growth?', *International Economic Review*, 39, 1998, 1-31

Suri V. and Chapman D., 'Economic growth, trade and energy: implications for the environmental Kuznets curve', *Ecological Economics*, 25, 1998, 195-208

Summers R. and A. Heston, 'The Penn World Table (Mark 5): An expanded set of international comparisons, 1950-1988', *Quarterly Journal of Economics*, 106, 1991, 1-41.

Swamy, P.A.V.B. (1970), 'Efficient inference in a random coefficient regression model', *Econometrica*, **38**: 311-323

Torrás M. and J.K. Boyce, 'Income, inequality and pollution: a reassessment of the environmental Kuznets curve', *Ecological Economics*, 25, 1998, 147-160