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Re−examining the pollution−income relationship: a random coefficients approach

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Abstract

This paper re−examines the pollution−income relationship using a random coefficients model to allow for greater cross−country heterogeneity. The existence of a common pollution−income relationship across countries is rejected and hence little support for the environmental Kuznets curve is found.

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1. Introduction

A large body of literature has developed in recent years examining the relationship between per capita income and pollution. Early papers by Shafik (1994) and Grossman and Krueger (1995) found evidence of an inverted U-shaped relationship between income and pollution which has since become known as the environmental Kuznets curve (EKC). More recent papers have subjected the EKC to increased scrutiny, questioning which pollutants the relationship might hold for, examining the effects of additional independent variables and comparing results found for OECD-only samples to those from 'world' samples (see for example, Ekins 1997, Stern 2001, Cole 2003). However, the vast majority of EKC studies have used, and continue to use, econometric models with very restrictive assumptions. More specifically, they restrict the coefficients on per capita income to be the same for every country and every time period. Given the great diversity of physical, social, political and economic characteristics across countries, this restriction may appear unreasonable. This short paper therefore adopts an alternative, less restrictive, random coefficients approach which allows for cross-country heterogeneity in the shape of the pollution-income relationship.[1] This approach is used to examine the relationship between income and three common air pollutants, namely sulfur dioxide, nitrogen oxides and carbon dioxide. Tests of parameter constancy across countries are also performed. Results are compared to those from a more restrictive fixed effects specification.

2. Methodology

The standard methodology for estimating EKCs is based around a model of the form:

$$E_{it} = \alpha_i + \sum_{j=1}^{k} \beta_j x_{itj} \tag{1}$$

where E is pollution per capita in country i (i = 1…m) and year t, α_i is a country specific intercept and x_{itj} refers to explanatory variable j in country i and year t. In this fixed effects model, a separate intercept is estimated for each country but all countries (and time periods) share the same values of β_j. Thus, if the explanatory variables are per capita income and per capita income squared and an inverted U-shaped EKC results, then each country will have the same shaped EKC, but the fixed effects will allow the EKC to vertically shift up or down for different countries.

It could, of course, be argued that it is unrealistic to believe that the shape of the relationship between income and pollution will be the same for each country. Given the differences in economies, political structures, geography, culture and climate that exist across countries there is no reason to believe that the same income-pollution relationship will be experienced by, for example, countries as diverse as Switzerland and Cameroon.

[1] A similar approach is adopted by Koop and Tole (1999) to examine the relationship between income and deforestation.

A solution is to utilise the random coefficients model, as depicted by equation (2);

$$E_{it} = \alpha_i + \sum_{j=1}^{k} \beta_{ij} x_{itj} \qquad (2)$$

in which $\beta_i = (\alpha_i, \beta_{i1}, \ldots, \beta_{ik})'$ is assumed to be drawn from some common distribution;

$$\beta_i = \beta + v_i$$

with $E(v_i) = 0$, $E(v_i v_i') = \Omega$ and $E(v_j v_i') = 0$ for $i \neq j$.

When utilising this methodology, the parameter vector β can be interpreted as providing the average pollution-income relationship. However, the pollution-income relationship experienced by individual countries can differ from this average relationship. If Ω is small then countries deviate little from the mean and hence equation (1) would provide a suitable estimation of the income-pollution relationship. However, if Ω is large then it implies that cross-country heterogeneity is large and hence it becomes inappropriate to assume that the parameter vector β is the same for all countries as equation (1) implies.

Equations (1) and (2) are estimated for three air pollutants, sulfur dioxide (SO_2), nitrogen oxides (NOx) and carbon dioxide (CO_2). The Appendix provides data definitions and sources.

3. Results

Table 1 presents estimates of equation (1), a fixed effects specification and hence the estimated coefficients are restricted to be the same for all countries. In all specifications, the independent variables consist only of per capita income (Y) and per capita income squared (Y^2) thereby testing the basic, parsimonius, EKC relationship common to much of the EKC literature.

For each pollutant, results are estimated using the full sample, OECD countries only, and non-OECD countries only. Considering SO_2 results, an inverted U-shaped relationship is estimated for the full sample, with a turning point broadly in line with those of previous studies.[2] Very similar results are found using the OECD-only sample, but this finding is not replicated for the non-OECD sample where the linear income term is negative and not statistically significant. For NOx, the results again differ across samples. The full sample provides a very high turning point level of income well beyond that found by previous studies, whilst the OECD-only sample finds a much lower turning point.[3] In the non-OECD sample Y^2 is not statistically significant, resulting in a very high turning point. For CO_2, a pollutant with no local impact, turning points in the literature have typically been much

[2] To put these turning points in context, the income range of the full sample is \$49.30 (Liberia, 1995) to \$58,500 (Luxembourg, 2000), all in 1995 US dollars. The income range within the OECD sample is \$2,143 to \$58,454 and within the non-OECD sample is \$49.3 to \$28,282.

[3] Previous studies that test NOx emissions tend to utilise only OECD data.

higher than those estimated for pollutants with a local impact such as SO_2 and NOx. In this study, the only inverted-U shaped relationship is found using the OECD-only sample with an out of sample turning point estimated. To conclude, the traditional fixed effects estimator provides some support for the existence of an EKC relationship, although this is shown to be very sensitive to the choice of sample. Only the OECD-only sample provides results for all pollutants which broadly match those of previous studies.

Table 1. Results from Fixed Effects Estimation (Equation 1).

	SO_2	NOx	CO_2
		Full Sample	
ln$Y$	1.06***	1.81***	0.31**
	(4.0)	(3.3)	(2.2)
$(\ln Y)^2$	-0.06***	-0.076**	0.021*
	(-3.0)	(2.2)	(1.9)
n	1851	104	1851
R^2	0.96	0.99	0.96
Turning Pt.	$15,986	$151,777	-
		OECD only	
ln$Y$	10.26***	8.21*	4.82***
	(6.2)	(1.7)	(5.4)
$(\ln Y)^2$	-0.53***	-0.44*	-0.21***
	(-6.0)	(1.6)	(-4.2)
n	487	52	487
R^2	0.91	0.98	0.93
Turning Pt.	$16,012	$10,800	$114,663
		Non-OECD only	
ln$Y$	-0.15	1.39*	-0.14
	(-0.7)	(1.9)	(-0.8)
$(\ln Y)^2$	0.04**	-0.05	0.06***
	(2.4)	(-1.5)	(3.6)
n	1364	52	1364
R^2	0.96	0.99	0.95
Turning Pt.	-	$635,543	-

*, ** and *** denote significance at 90%, 95% and 99% confidence levels, respectively. Turning points expressed in 1995 US$. T-statistics reported in parentheses.

Table 2 provides the results from the random coefficients estimations based on equation (2). Again, the full sample, OECD-only sample and non-OECD only samples are used. To allow a more thorough investigation of the pollution-income relationship, estimations are carried out using only linear income terms, in addition to the combined use of income and income squared.

Table 2. Results from Random Coefficients Estimation (Equation 2)

	SO_2		NOx		CO_2	
			Full Sample			
Ln*Y*	-0.16	4.72	0.62**	39.86*	0.88**	3.19
	(-0.71)	(0.2)	(3.1)	(2.2)	(6.24)	(0.2)
$(\ln Y)^2$		-0.18		-2.19*		-0.11
		(-0.09)		(2.3)		(-0.1)
N	1851	1851	104	104	1851	1851
Turning Pt.	-	\$370,782	-	\$8,887	-	\$3,033,518
Parameter	1.8e+5	2.1e+5	13923.1	7.3e+6	2.3e+5	2.3e+5
Constancy?	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
			OECD only			
Ln*Y*	-1.84**	42.47	0.29	68.59*	0.53**	16.43
	(-3.5)	(1.0)	(1.4)	(2.1)	(3.2)	(1.2)
$(\ln Y)^2$		-2.26		-3.61*		-0.81
		(-1.1)		(-2.1)		(-1.2)
N	487	487	52		487	487
Turning Pt.	-	\$12,032	-	\$13,508	-	\$24,423
Parameter	52961.1	43698.6	4127.1	1.0e+6	63558.8	68036.4
Constancy?	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
			Non-OECD only			
Ln*Y*	0.41*	-7.80	0.89**	17.93*	1.01**	0.39
	(2.2)	(-0.2)	(2.6)	(2.2)	(5.5)	(0.01)
$(\ln Y)^2$		0.52		-1.13*		0.022
		(0.2)		(-2.0)		(0.01)
N	1364	1364	52	52	1364	1364
Turning Pt.	-	-	-	\$2,713	-	-
Parameter	1.1e+5	1.3e+5	9201.1	23047.3	1.3e+5	1.5e+5
Constancy?	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

*, ** and *** denote significance at 90%, 95% and 99% confidence levels, respectively. Turning points expressed in 1995 US\$. T-statistics reported in parentheses. Parameter constancy refers to a test of the null that parameters are constant across countries (with probability in parentheses).

Considering first the quadratic specification, only NOx provides evidence of a statistically significant inverted U-shaped relationship with per capita income. The random coefficients methodology therefore implies that, for NOx, the *average* pollution-income relationship does form an EKC with a within-sample turning point. For SO_2 and CO_2 no such evidence of an EKC is found. For CO_2, the average relationship is found to be positive and statistically significant for all three samples. For SO_2, a negative linear relationship is found for the OECD, with a positive relationship for non-OECD countries, both being statistically significant.

However, in order to know how meaningful these average relationships are the extent to which individual countries deviate from the average must be known. Table 2 therefore presents the results of tests of parameter constancy. Referring back to equation (2), this test is algebraically equivalent to testing $H_0 = \beta_{1j} = \beta_{2j} = ... = \beta_{mj}$. In all cases, the null of parameter constancy is rejected implying that the distribution of β_i has very large variance (i.e. Ω is large). This finding therefore indicates that the average pollution-income relationship tells us little about this relationship in individual countries (i.e. β_i is very different to β) and hence the notion of a 'one size fits all' EKC is questionable at best.[4]

4. Conclusion

This short paper has argued that the traditional manner in which the pollution-income relationship is estimated rests on the very restrictive assumption of constant coefficients across countries. Given the great diversity of economies, political structures, geography, culture and climate that exist across countries there is no reason to believe that the same income-pollution relationship will be experienced by all countries. This paper begins by using this restrictive (fixed effects) model to examine the relationship between income and three common air pollutants. The results provide some support for the EKC relationship although, as we may expect, they show sensitivity to the use of different samples. The paper therefore re-examines the income-pollution relationship by adopting a random coefficients model that allows for a greater degree of cross-country heterogeneity. Of the three pollutants examined, only nitrogen oxides provides an average pollution-income relationship that is statistically significant and hence supportive of the EKC. However, for *all* pollutants, and for the full sample, OECD-only sample and non-OECD sample, the income-pollution relationship is found to vary widely across countries. This suggests that the assumption of constants coefficients across countries in the traditional fixed effects specification is inappropriate. More fundamentally it suggests that there is no income-pollution relationship that is common to all countries and hence the very existence of meaningful EKCs is questionable.

[4] Perhaps surprisingly, re-estimating the models in Table 2 for specific regions did not provide more compelling results. Thus, the null of parameter constancy was rejected even for individual regions.

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Appendix

Variable	Data Coverage and Source
SO_2 Emissions	110 countries, 1984-2000, Source: Stern (2005)
NOx Emissions	26 countries, 1975, 80, 85, 90: Source UNEP (1993)
CO_2 Emissions	110 countries, 1984-2000: Source World Bank (2004)
Per Capita Income	World Bank (2004)