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The Environmental Kuznets Curve for Water Quality: An Analysis of its Appropriateness Using Unit Root and Cointegration Tests

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–Introduction. –I. The Environmental Kuznets Curve. –II. Methodology and results. –Conclusions. –Appendix. –References

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Introduction

The Environmental Kuznets Curve (EKC) hypothesis posits that there is an inverted U-shaped relation among various indicators of environmental degradation (pollution or resource depletion) and *per capita* income. Among the interpretations suggested for this hypothesis is that economic growth gives rise to changes in economic structure and technology, as well as to improvements in regulation and an enhanced environmental awareness that offset the impact of growth on the environment.

This hypothesis has brought back interest in the discussion about economic growth's impact on the environment. In that sense, several economists assume that growth itself will lead to revert the environmental impacts made on the first stages of development and to environmental improvements in developed countries. Thus, they have stated that growth, far from being a threat for environmental quality, is necessary for its improvement and conservation.

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Despite the EKC has faced considerable criticism on both theoretical and empirical grounds, it has become one of the 'stylized facts' of environmental and resource economics. However, cointegration analysis may prove useful to test the validity of such stylized facts when the data involved contain stochastic trends (Perman and Stern, 2003). The present study is focused on this alternative.

In order to do that, the EKC hypothesis is studied for Biochemical Oxygen Demand (BOD) with the aim to confirm whether that there is a long-run relationship between this water pollution indicator and income for every country. The panel studied includes 46 countries from 1980 to 2000. Besides per capita GNP, explanatory variables include a foreign trade intensity coefficient. Contrasts of unit roots and cointegration were individually applied to each country and to the panel data; afterwards, a number of models were adjusted with the introduction of deterministic trends and time dummy variables.

This paper is made up of four parts. In the first one, some potential explanatory factors for the EKC hypothesis are indicated, the main econometric aspects and the criticism, and studies related to BOD as well. Then the econometric approach used is described. The results obtained are analysed in the third part. To end, some conclusions and suggestions are outlined to feed further research.

I. The Environmental Kuznets Curve

The Environmental Kuznets Curve hypothesis was introduced in the early nineties with Grossman and Krueger's work (1991) about the potential impacts of NAFTA, and with Shafik and Bandyopadhyay's background study for the World Development Report in 1992. These studies showed the existence of an inverted U-shaped relationship between several pollutants and per capita income; that is, environmental quality initially deteriorates, but once countries reach a given income level, environmental degradation tends to decline. Panayotou (1993) called this relationship EKC because of its similarity with the relationship between income level and inequality in income distribution suggested by Simon Kuznets (1955). Since then, this term has become a reference point in the literature on growth and the environment.

In that sense, the EKC hypothesis has been useful to support the general proposition that economic growth will lead to remediate the environmental impacts of the first stages of development and to improve environmental quality in developed countries. Thus, some economists use it to support the statement that economic growth is a remedy to pollution and depletion of natural resources (Beckerman, 1992). Accordingly, they suggest fostering economic growth on the grounds that such an approach will drive the implementation of effective environmental policies (World Bank, 1992).

However, this assertion is preliminary due to the lack of unequivocal evidence regarding environmental degradation patterns throughout the economic development process, as well as to the lack of consensus on the determining factors of the EKC. Additionally, there are several aspects impeding to draw clear policy conclusions from this empirical hypothesis, which are mainly related to the EKC appropriateness for several kinds of environmental pressure and for all countries (individually and collectively) (de Bruyn and Heintz, 1999; Dinda, 2004).

A. Some suggested explanations

According to Barbier (1997), the explanations of the EKC have been focused on several underlying and dissimilar relations, including the effects of changes in the economic structure on the use of the environment, the links between the demand for environmental quality and income, and the types of environmental degradation and ecological processes. Some of the major explanations given to this empirical hypothesis are exposed in the following.

1. Scale, composition and technique effects

Economic growth affects the environmental quality through three different mechanisms, that is, the scale, composition and technique effects (Grossman and Krueger, 1991). The scale effect is reflected in a positive relation between environmental degradation and income; hence, environmental quality is expected to worsen as economic activity increases. However, with the increase in per capita income, changes in production mix may take place, leading an economy to less intense polluting sectors (for example, from industry to services). Similarly, growth may induce the adoption of technologies to enhance productive efficiency, in that they should use less polluting inputs per unit of output, or reduce polluting discharges per unit of input.[1] Under this scenario, environmental quality may suffer from degradation with income unless the scale effect is offset by a combination of the composition and the technique effects.

2. The impact of regulation

Grossman and Krueger (1995) interpret the EKC as a sign that environmental policy is carried out more effectively in a developed economy than in a developing one, as economic growth fosters demand for environmental quality

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[1] The adoption of technologies may also be the result of changes in underlying variables related to economic development, such as more stringent environmental regulation and/or higher educational level of the population. In a similar way, it may be directed by the market (partly fostered by the benefits of environmental conservation).

and provides the resources to perform environmental protection measures (see also Panayotou, 1997). This explanation is further developed by Dasgupta *et al.* (2002), who indicate that evidence available suggests that regulation is the determining factor to explain pollution reduction as countries grow beyond the middle income status.

3. Foreign trade

Foreign trade causes contradictory impacts on the environment. As trade volume increases (especially exports), economy size increases, which damages environmental quality; however, trade could also lead to environmental improvements through the effects on the composition of economic activity and technology, mainly through consequences on the distribution of polluting industries.

Foreign trade benefits the decrease in production of pollution-intensive goods in one country as this production increases in the other(s). This composition effect is ascribed to two related hypotheses, namely, the *displacement hypothesis* and the *pollution haven hypothesis*. The displacement hypothesis refers to a situation where changes in the developed countries' productive structure are not accompanied by equivalent changes in the consumption structure. In this case, the EKC would refer to the displacement of dirty industries towards developing economies (de Bruyn and Heintz, 1999).

On the other hand, the pollution haven hypothesis refers to the possibility that multinational firms, particularly those carrying out highly polluting activities, relocate their plants in countries having less stringent environmental regulations. According to this hypothesis, lower environmental standards should become a source of comparative advantage and, therefore, of changes in trade patterns (Stern *et al.,* 1996). This hypothesis suggests primarily that highly regulated countries will 'lose' all the dirty industries that poor countries will get (Dinda, 2004).

However, if the validity of these hypotheses is proved, the estimated turning points of the EKC would be unrealistic since even with an increase in their income level, developing countries will not have the environmental rewards available to developed economies because of relocation (Stern, 1998).

B. Econometric aspects and criticisms

Most of the EKC analyses use panel data (Stern, 1998). For their estimation, a statistical reduced-form relation is employed, in which the chosen environmental degradation indicator is modelled as an inverted U-shaped function of per capita income, and thus the logarithm of the dependent variable is associated to the square of the income log.[2] Using this methodology, the regression model assumes the following static form:

$$\ln\left(\frac{E}{P}\right)_{it} = \alpha_i + \gamma_t + \beta_1 \ln\left(\frac{GDP}{P}\right)_{it} + \beta_2\left[\ln\left(\frac{GDP}{P}\right)\right]^2_{it} + \varepsilon_{it} \qquad (1)$$

where *E* refers to environmental degradation, *GDP* represents the income level, *P* is the population level, and ln indicates natural logarithms. Variables are expressed across a series of countries ($i = 1, \ldots, N$) and time periods ($t = 1, \ldots, T$). The first two terms on the right hand side are the intercept parameters, which change among the various countries *i* and years *t*. They allow for specific effects across countries(α_i) and through time (γ_i) with the aim to register common stochastic *shocks*. Random disturbances ε_{it} are assumed to be independent across countries, with variances that may differ across each of these.

If the EKC hypothesis is met, then equation (1) has a common form, with $\beta_1 > 0$ and $\beta_2 < 0$ for all *i*, and the income level at the turning point, where environmental quality is not affected by income, is given by

$$\tau = \exp\left(\frac{-\beta_1}{(2\beta_2)}\right) \qquad (2)$$

Comparing the estimated per capita income level associated to the turning point with the income levels observed in the data set can indicate whether the turning point falls in or out of the actual income range. This can shed light on the reliability of the EKC estimations (Barbier, 1997).

Most of the literature on the EKC has shown weak results from the econometric view. Concerning this, one of the more relevant aspects deals with the use of a reduced-form statistical relation, which eliminates the need of data on other variables that could affect the relation between per capita income and the pollution level, on the grounds that one equation captures the influence of income on technology, product mix and environmental policy, as well as the incidence that changes in these factors have on environmental pressure. The use of a reduced-form model has the advantage of providing a direct estimation of the net effect of income on environmental pressure (Correa Restrepo, 2004); however, it does not shed light on the nature of the estimated relation and, in particular, on coefficients analysis (Grossman and Krueger, 1995). Hence it is purely descriptive and does not allow observing the influence of growth on pollution patterns (de Bruyn *et al.,* 1998; de Bruyn and Heintz, 1999; Panayotou, 1997).

[2] Note that this functional specification does not allow for incorporation of null or negative values of the environmental degradation indicators.

Another controversial aspect has to do with the validity that estimated EKC relations on samples of countries may have for individual nations (de Bruyn *et al.,* 1998). In that sense, some economists argue that the importance given to this hypothesis is based on the scarce attention that studies have paid to the statistical properties of the data, like serial correlation or stochastic trends in time series, and to the carrying out of model adjustment tests, such as the possibility of biases due to the omission of variables. Not long ago research reports having diagnosis statistics on series integration or cointegration among variables were quite reduced, and thus these are not clear as to what can be inferred on issues such as the significance of additional variables included in a reduced-form regression (e.*g*., economic openness indicators, among others) (Stern, 2004; Perman and Stern, 2003).

Perman and Stern (2003) find, using diagnosis tests for cointegration and unit roots in panel data relating sulphur emissions and income, that data are integrated in the time series dimension, that there are more than one cointegrating regression, and that these are not commonly of the EKC type for every country. These authors examine each individual country on the sample and find out that only some cointegrating relations estimated are consistent with the EKC hypothesis (typically, relations are U-shaped or monotonically rising in income). Based on these results, they suggest applying such diagnosis tests in studies related to other environmental indicators.

C. Empirical evidence and Biochemical Oxygen Demand

A number of models including explanatory variables other than income have been built with the aim to study the effect of underlying or approximate factors such as 'political freedom' (Torras and Boyce, 1998), economic structure (Panayotou, 1997; Suri and Chapman, 1998) or trade (Shafik and Bandyopadhyay, 1992; Suri and Chapman, 1998). Also, population density has been considered (Selden and Song, 1994) as well as lagged income (Grossman and Krueger, 1995), among others. The inclusion of these variables is intended to improve the adjustment of estimations and to provide additional insights on pollutants behaviour as economies develop[3] (de Bruyn and Heintz, 1999).

The literature on the EKC for water pollution, and particularly for pollution related to the oxygen regime (dissolved oxygen, Chemical Oxygen Demand, Biochemical Oxygen Demand), is scant and shows conflicting patterns. As for BOD, Grossman and Krueger (1995) and Correa Restrepo (2004) report

[3] Compared to the values estimated without their inclusion, such variables capture some part of the polluting effects associated to income and, as a consequence, can alter the turning points.

an EKC, but Shafik and Bandyopadhyay (1992) and Torras and Boyce (1998) find monotonically decreasing and N-shaped patterns, respectively. Despite the results are contradictory, all these studies are carried out following similar methodologies (regressions with panel data using ordinary or generalized least squares, *per capita* income measured in terms of purchasing power parity) and neglect the econometric diagnosis statistics.

The present study takes into account the criticisms mentioned in section I.A. and Perman and Stern's (2003) suggestion concerning the estimation of a regression relating water pollution by BOD with income, including additionally a variable of foreign trade intensity. With this, we intend to contribute to a rigorous analysis of the validity of the EKC for various environmental degradation indicators.

II. Methodology and results

Static estimations were made for each country; panel data estimations with fixed and random effects; a dynamic error correction model for each country, which was additionally adjusted presuming the existence of a single EKC for all countries. Deterministic trends or time dummy variables were added to the earlier models. Prior to model estimation, unit root contrasts were made for each series employing individual and panel data tests, as well as individual and panel cointegration contrasts. Finally, the proposed models were validated. The software used is EViews 5.1.

A. The data

The sample used was defined under data availability criteria. Annual data for 46 countries in the period 1980-2000 were considered (see descriptive statistics in Appendix 1). Still, the panel is unbalanced as some data are missing (not more than two per time series), an unbalance corrected using smoothing methodologies.[4] The countries considered are classified as high, middle and low income, as we wanted to comprise a heterogeneous group,[5] which is in accordance with the estimation method used. The main aspects of the variables used in the model are explained as follows.

1. The dependent variable

Biochemical Oxygen Demand (BOD) is the water pollution indicator most used by regulatory agencies.[6] It measures the oxygen dissolved that micro-

4 The BOD series were corrected with the non-seasonal Holt-Winter smoothing method, while the series for economic openness and per capita GDP were corrected through autoregressive processes.

5 For each country's descriptive statistics, see Appendix 2. We thank a referee for suggesting us this point.

6 As a matter of fact, developing countries have traditionally started industrial pollution control programs by regulating emissions of this pollutant.

organisms require for the decomposition process of organic matter in water bodies.[7] We use the BOD series featured on the World Development Indicators (World Bank, 2005), which refers to polluting emissions (in kg/day).

2. The explanatory variables

–Gross Domestic Product *per capita*

As indicated before, income is the (more) relevant explanatory variable in the EKC hypothesis. This variable is represented by *per capita* Gross Domestic Product in terms of purchasing power parity (PPP). The series were taken from the World Development Indicators published in 2005 (World Bank 2005).

–Foreign trade intensity

Trade intensity, defined as the ratio of exports plus imports and GDP, is a coefficient used to measure openness to foreign trade. Like the previous variables, the data were taken from the World Development Indicators published in 2005 (World Bank, 2005). It is worth noting that even though this indicator has been quite used in the literature on the EKC that considers foreign trade (Grossman and Krueger, 1991; Shafik and Bandyopadhyay, 1992), it has been strongly criticized as it gives an account of trade policy orientation rather than of observed trade (Stern, 1998; Suri and Chapman, 1998).

As the values of the variables to be used are all positive and given the general functional specification of the EKC (equation (1)), we take the logarithm of the various variables. For the sake of simplicity, the natural logs of BOD, GDP per capita and foreign trade intensity are denoted as Y, X and W, respectively. The square of X is called Z.

B. Econometric Procedures and Analysis of Results

1. Unit root tests

The implementation of unit root tests for both each series and the panel data is mainly due to the proven fact that individual tests have low power when they are applied to short series, while panel tests increase the power of contrasts (Perman and Stern, 1999). However, individual tests are useful to support the results obtained with panel tests.

–Individual unit root tests

Dickey-Fuller (ADF), Phillips-Perron (PP) and Kwiatowski *et al.* (KPSS) tests were applied. For that, the optimal lag length was chosen attending to the Schwarz's information criterion, as well as a consistent estimator of the variance

[7] There are other indicators of water pollution by organic compounds. One of them is Chemical Oxygen Demand (COD), which measures the dissolved oxygen required by a chemical oxidant to decompose the organic material contained both in natural and waste waters.

using the Newey-West method. Table 1 shows the number of countries for which the three contrasts used allow to conclude that the series are stationary at five and ten percent levels of significance.

When a trend is not included in the contrast, ADF and PP tests show similar results: most series have a unit root. On average, the null hypothesis has been rejected only for two countries under all variables. Following the same specification, the null hypothesis of stationarity is more often not rejected on the KPSS test (for the natural log of BOD, the stationarity hypothesis can not be rejected in 17 countries). When the tests include an individual trend, ADF and PP results show more rejections of the unit root null hypothesis (four on average) compared to the results of the same tests with no trend. The KPSS test shows a higher number of non rejections for the null hypothesis of stationarity.

Table 1. *Number of countries having stationary variables*

Contrast \ Variable	Y		X		Z		W	
	5%	10%	5%	10%	5%	10%	5%	10%
ADF intercept	2	2	1	1	1	1	0	3
ADF intercept and trend	1	5	4	7	5	7	4	10
PP intercept	1	2	1	1	1	1	1	3
PP intercept and trend	3	5	0	1	0	1	5	10
KPSS intercept	17	12	12	10	12	10	7	3
KPSS intercept and trend	31	25	35	23	36	23	19	15

Source: authors' estimations.

In sum, the unit root individual tests allow us to state that most series corresponding to the various countries in the sample are integrated of order one –*i.e.* I(1). Note that, when analyzing the series in first differences, these proved to be stationary.

–Panel unit root tests

Two approaches are employed: common (Levin and Lin; Hadri) and individual (Im, Pesaran and Shin). The individual approach considers heterogeneity among the panel individuals, while the common approach does not. Following Perman and Stern (2003), we call Levin and Lin's statistic panel statistic, and Im, Pesaran and Shin`s statistic group statistic. Hadri's test statistic is considered separately. Table 2 shows a clear trend on all contrasts to not rejecting the hypothesis of existence of stochastic trends in all series, except for *X* and *Z*, for which the non-trended panel statistic allows rejecting the null hypothesis.

Table 2. *Panel unit root test*

Test statistic	Y	W	Conclusion
Panel: Non-trended regression	-1,24419	9,07357	Null hypothesis is not rejected
Panel: Trended regression	-1,15442	-1,45807	Null hypothesis is not rejected
Group: non-trended	2,99601	12,4402	Null hypothesis is not rejected
Group: trended	0,39648	-0,5772	Null hypothesis is not rejected
Hadri Z-stat	17,5953	18,4388	Null hypothesis is rejected
Hadri Z-stat (intercept and trend)	11,5083	11,6185	Null hypothesis is rejected
Test statistic	X	Z	Conclusion
Panel: Non-trended regression	-3,14789	-2,02594	Null hypothesis is rejected
Panel: Trended regression	0,16871	0,11612	Null hypothesis is not rejected
Group: non-trended	5,71509	6,28117	Null hypothesis is not rejected
Group: trended	-0,51765	-0,74196	Null hypothesis is not rejected
Hadri Z-stat	19,9084	20,0428	Null hypothesis is rejected
Hadri Z-stat (intercept and trend)	10,6786	10,4283	Null hypothesis is rejected

Source: authors' estimations.

In Hadri's stationarity test, the null hypothesis is rejected for all series, which shows that the series analyzed have a unit root. Thus, there is strong evidence that all the series included in the panel are integrated of order one. Individual series analysis, besides, helps to validate the insight on the existence of a unit root in the panel.

2. Cointegration tests

The previous results make further tests required in order to find a long-run relation connecting the series, that is, to ensure that we are not in the presence of a spurious relation.

–Individual cointegration tests

The Engle and Granger procedure is followed. The analysis is applied on two groups of models. In the first group, we take the variables in deviations from their transversal means or time *dummies*, while these are not contained in the second group. Perman and Stern (1999) indicate that these *dummies* can be used as *proxies* of common effects on time. Their inclusion is meant to eliminate dependence between country-related errors.

Table 3 shows the results obtained for each of the estimated models. Individually, there is no strong evidence supporting the existence of cointegration, as statistically speaking the higher number of significant long-run relations is ten. Only two countries (Bolivia and Sri Lanka) show evidence of cointegration in all the four models at ten percent level of significance.

Table 3. *Individual cointegration tests*

Individual cointegration	5%	10%
With *dummies* and intercept	5	9
With *dummies,* intercept and trend	1	6
Without *dummies* and intercept	4	7
Without *dummies,* intercept and trend	5	10

Source: authors' estimations.

In the following section, the results from some panel cointegration tests are analyzed.

–Panel cointegration tests

Several approaches to prove the existence of a potential cointegration relation have emerged recently. These approaches are based on the traditional ones to individual cointegration. In this paper, we follow Pedroni's (1999) approach, as he takes up again the residuals-based conceptualisation posited by Engle and Granger, and formulates seven test statistics that allow assuming heterogeneity in the panel. This author proposes two approaches to contrast cointegration: panel and group statistics. The panel statistics are made on the *within* dimension, that is, fixed effects are presupposed. The group statistics are made on the *between* dimension, that is to say, the mean for each individual in the panel is obtained before adding on the N dimension.

The results from Pedroni's cointegration tests are shown in table 4. It can be seen that the various tests allow rejecting the no-cointegration null hypothesis. This result is important as, unlike the individual cointegration tests, it shows a long-run relation among the variables. Note that the no-cointegration hypothesis is not rejected only in the test with the time non-trended dummies *rho* panel statistic. This is evidence supporting the heterogeneity present among the panel individuals.

These results beg some questions regarding the existence of a long-run relation of the EKC type common to all countries, which will be discussed in the following section.

Table 4. *Data panel cointegration test**

	Time and trended *dummies*	Time non -trended *dummies*	Trended, non -time *dummies*
v Panel	40 ,4849 (0 ,0000)	14 ,7094 (0 ,0000)	-8,0670 (0,0000)
rho Panel	-1,6593 (0,0970)	0,2045 (0,8378)	4,7891 (0,0000)
t Panel NP	-9,8690 (0 ,0000)	-4,8123 (0 ,0000)	2,7324 (0,0062)
T Panel P	-181,693 (0,0000)	-151,8015 (0,0000)	-439,565 (0,0000)
rho Group	4,6275 (0 ,0000)	3,566580 (0,0004)	5,0845 (0 ,0000)
t group NP	-2,5715 (0 ,0101)	-2,4419 (0,0146)	-2,186 (0,0287)
t group P	-4,8394 (0,0000)	-3,9835 (0 ,0000)	-4,7569 (0,0000)

* Probability values in parentheses Note: P: parametric; NP: non-parametric
Source: authors' estimations.

3. Estimation of models

The econometric work is primarily based on the estimation of a dynamic model. However, various static models were adjusted. The static model for each country has the form

$$Y_{it} = \alpha_i X_{it} + \beta_i Z_{it} + \theta_i W_{it} + \varphi_i + \varepsilon_{it} \quad (3)$$

Where i =1, 2,…, 46 and t = 1980, 1981, …, 2000. Each transversal unit/variable is related to its respective parameter. This model was adjusted with a deterministic trend or with time *dummies*. The assumptions on the disturbance term are the classical ones. The methodology used was ordinary least squares. Fixed and random effects models are given by

$$Y_{it} = \alpha X_{it} + \beta Z_{it} + \theta W_{it} + \varepsilon_{it} \quad (4)$$

Where the disturbance term has the form $\varepsilon_{it}=\varphi_i+\eta_{it}$. It is assumed that η_t is not correlated with the explanatory variables. φ_i is called the country's individual effect i, constant in time. In the fixed effects model φ_i is considered a parameter, while it is treated as a random variable in the random effects model. Under the classical assumptions, the model with fixed effects is estimated by ordinary least squares, whereas generalized least squares is used for estimating the model with random effects.

Given that the variables are integrated of order one, previous static relations being spurious is at risk. Similarly, the model residuals are very likely to be correlated even though estimations are consistent but biased. The estimations can be improved using error-correction dynamic models wherein, assuming that the variables are cointegrated, classical inference is valid. Moreover, since lags are introduced in the regressors, problems such as correlation of residuals may possibly be amended. The error-correction model is as follows:

$$\Delta Y_{it} = \alpha_i (Y_{it-1} - \beta_{1i} X_{it-1} - \beta_{2i} Z_{it-1} - \beta_{3i} W_{it-1}) + \gamma_i \Delta_{it-1} + \theta_i \Delta X_{it-1} + \varphi_i \Delta Z_{it-1} + \lambda_i \Delta W_{it-1} + \mu_i + \eta_t + \varepsilon_{it} \quad (5)$$

A single lag is used for all variables, as otherwise the number of parameters would be too large; also, the model is adequate in this situation. This is a very general model, as all the parameters associated to the distinct variables are different for each transversal section. a_i is the error-correction coefficient related to country *i,* and reports on the speed of adjustment towards equilibrium. To have a long-run relation, it has to be the case that $-1 < \alpha_i < 0$.

μ_i is the fixed effects parameter, which varies among the different countries. η_t is the intercept related to year *t*. With η_t, which implies introducing time dummy variables in the model, we seek to control the common effect associated to time; thus, by taking into account the presence of μ_i and the lags in the model, we can assume that the disturbance terms ε_{it} are independently distributed through time and across countries, with zero mean and constant variance per country. We can add a deterministic trend associated to each country to the previous model.

Among the existing possibilities, two models were selected. The first model includes a deterministic trend within the long-run relation, but no time dummies; in the second one, the roles of those variables are interchanged. The second model was estimated after extracting from each datum the transversal mean of the corresponding year. The estimation of these models, called non-restricted models, allows studying in a clearer statistical way whether the EKC actually exists for every country. Also, it is possible to estimate the average of each long-run parameter from the average of the corresponding estimates, and to calculate a common estimate of the turning point for all countries based on that information.[8]

One way to study the EKC hypothesis is to subject the previous model, in both versions, to the restriction $\beta_{1i} = \beta_1, \beta_{2i} = \beta_2, \beta_{3i} = \beta_3, i = 1, 2, \ldots, n$, called a restricted model, and to analyze whether data do not allow to reject such a restriction. Non rejection of the null hypothesis implies that there exists a single long-run relation and, therefore, it would validate the EKC hypothesis. The estimation methodology used was weighted least squares, as it enables one to take into account the likely heteroscedasticity of the disturbance term in each country. The basis on which to contrast the EKC hypothesis is the likelihood ratio, asymptotically chi-square distributed with q degrees of freedom, where q is equal to the number of restrictions.

The static models for each country were adjusted so that one would be trended and the other would have time but not trended dummy variables. These models show strong correlation problems in residuals (high R-square and Durbin-Watson statistic close to zero). In the trended model, 26 countries

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[8] Pesaran and Smith (1995) show that the estimator obtained using this procedure (mean group estimator, MG) consistently estimates the parameter average.

meet the EKC hypothesis, while in the other case the models corroborating this hypothesis amount to 33. Both fixed and random effects models meet the EKC assumptions, but as the static models, they are not statistically valid.

In tables 5 and 6, the main results for the dynamic models are presented. At the individual level, it can be noticed that there are 30 countries that verify the EKC hypothesis, which is similar to the results obtained for the static models. However, these results are invalid, because only 4 countries in the non-dummies trended model meet all of the necessary hypotheses (speed of adjustment between -1 and 0 and statistically significant, statistically significant parameters with appropriate signs). Also, we may conclude that for 11 countries, the long-run relation is valid. In the model with dummies, 3 countries corroborate all hypotheses, and 4 show cointegration.

Table 5. *Non-dummies trended models*[a]

	Non-restricted model	Restricted model	Fixed effects	Random effects
X	20,1423 [b]	7,1340 (7,8126)	6,2893 (14,8265)	6,0335 (14,5764)
Z	-0,78384 [b]	-0,387 (-7,6116)	-0,3361 (-14,2073)	-0,3211 (-13,8397)
W	-0,01234 [b]	0,4162 (5,8442)	-0,0934 (-1,9664)	-0,1394 (-1,9664)
i	-0,7733 [b]	-0,2004		
Turning point	380233,4 [b]	10073,84	11573,27	12034,24
Ln L	0,9996	1,6844		
LR	598,4638	Invalid model		
Static EKC	26			
Dynamic EKC	30			
EKC	Exists	Exists	Exists	Exists
Valfa	33			
Cointegration	11			
Kuznets	4			

[a] T Values in parentheses [b] Mean group estimate (MG) *Source:* authors' estimations.

Table 6. *Non-trended with dummies models*[a]

	Non-restricted model	Restricted model	Fixed effects	Random effects
Z	4,048 [b]	17,5453 (7,7030)	6,2893 (14,8265)	6,0335 (14,5764)
X	-0,1564 [b]	-0,9399 (-7,311)	0,3361 (-14,2073)	-0,3211 (-13,8397)
W	-0,9065 [b]	2,3728 (6,2347)	0,0934 (-1,96640)	-0,1394 (-1,9664)
i	-0,6298 [b]	-0,0147		
Turning point	416467,2 [b]	11311,40	11573,27	12034,24
ln L	1,0876	1,7018		
LR	536,8340	Invalid model		
Static EKC	33			
Dynamic EKC	30			
EKC	Exists	Exists	Exists	Exists
Valfa	34			
Cointegration	4			
Kuznets	3			

[a] T Values in parentheses [b] Mean group estimate (MG) *Source*: authors' estimations.

The null hypothesis of existence of a unique EKC for all 46 countries in both types of models is rejected with a probability value of zero. This allows us to assert that, for these data, parameters are not homogeneous in the long run and, therefore, the EKC does not exist for this set of countries. Also, it can be inferred that the static results, which have traditionally shown fixed or random effects, are spurious; that is, the results of the two last columns in tables 5 and 6 do not have any statistical validity.

The results obtained for the income level associated to the turning point in the restricted models and in the estimations with random and fixed effects are convincing because of their relative similarity and because they are located within the set of values of per capita income for all of the countries. However, individually, income associated to the turning points in the four models mentioned falls in the range of income for six nations only. As we have said, these conclusions are void of statistical validity.

Conclusions

The EKC hypothesis posits the existence of a U-shaped relation between environmental degradation and per capita income. This hypothesis has been criticized because several authors have assumed that it entails economic growth as a precondition to implement environmental effective policies, and thus to revert the impacts caused to the environment during the first stages of development (Beckerman, 1992; World Bank, 1992). Besides, the importance given to the EKC hypothesis is supported by the limited or void attention given to the econometric diagnosis statistics that studies on the topic usually exhibit (Stern, 2004). In particular, it is believed that what has been traditionally done (estimations with panel data on static models with random or fixed effects) poses specification problems due to the presence of first-order integrated series; also, because homogeneity is assumed in the parameters for different countries, which can be incorrect.

The results obtained in this study show evidence that all the series exhibit stochastic trends both on the individual and on the panel level. As for cointegration, it does not appear among the series for most of the countries taken individually, though it does appear for the panel data. Nonetheless, the different estimates show that, even if there is a long-run relation among BOD, per capita GDP (linear and squared) and foreign trade intensity, this is not an EKC for the set of nations considered.

Even more, models under restrictions and estimates with random and fixed effects are not statistically valid. This is remarkable given the relative consistency that these estimates show in favour of the EKC hypothesis and because of the income levels associated to the turning points obtained. However, individual results support conceptual criticism on the EKC hypothesis since most of the countries have not yet achieved the per capita income levels that allow them improvements in water quality, which contributes to worsen global environmental degradation (Stern *et al.,* 1996; Arrow *et al.,* 1995).

Following the explanations to the EKC posited on the literature, and since such hypothesis reports a relation between the income level and environmental pressure exclusively, an additional variable has been tried in order to consider the incidence of foreign trade. But such a variable, a foreign trade intensity coefficient, has turned out to be not very significant from the statistic perspective and with little relevance for the analysis. This rather confirms the criticism that the inclusion of this variable has received in some studies on the EKC (Stern, 1998; Suri and Chapman, 1998), and raises the need to include other trade indicators capable of giving an account of relocation of polluting activities. This consideration can be generalized as these indicators allow considering other underlying or proximate factors, thereby providing sound explanations about changes in water quality as economic development unfolds.

The results obtained match up Perman and Stern's (2003) on sulphur dioxide (an indicator of atmospheric pollution). Then it can be said that, to make appropriate analyses of the EKC hypothesis, unit root and cointegration contrasts should be applied at the individual and panel levels. In this sense, we suggest to continue the use of such procedure when addressing relations between economic growth and environmental quality.

Yet it should be noted that the lack of data, mainly for the time interval considered, plays down power to the unit root and cointegration tests presented here. Similarly, hypothesis tests on unit roots and panel cointegration continue to be incipient. Another limitation has to do with the lack of randomness in the selection of countries comprising the panel, so inferences can not be made on the basis of actual estimations to countries not included in the sample.

In brief, theoretical and econometric criticisms on the EKC, partly supported by the results achieved throughout this study, suggest the need to reformulate the relation between economic growth and water degradation and, in general, between growth and environmental quality. It is obvious that the EKC may be configured from innumerable possible results derived from economic growth. Therefore, instead of ascribing the EKC to a single factor, appropriate attention should be paid to the other elements that make up the system economy-environment. In this sense, further research needs to give priority to the identification of the more relevant aspects when explaining such a relation, since this would be the only way to formulate policies able to influence it.

Appendix 1. Panel descriptive statistics

Variable		Mean	Std. Dev.	Min.	Max.	No. of obs.
Y	overall	11,32047	1,496965	7,175161	14,82456	N = 966
	between		1,495484	8,036924	14,743	n = 46
	within		0,225351	10,4587	12,11529	T = 21
X	overall	8,962864	1,071977	6,193291	10,93787	N = 966
	between		1,070177	6,312048	10,33318	n = 46
	within		0,166105	8,304044	9,629311	T = 21
W	overall	-0,58912	0,620335	-2,12193	1,055724	N = 966
	between		0,591678	-1,854	0,733963	n = 46
	within		0,204909	-1,20176	0,235386	T = 21

Source: authors'estimations based on World Bank (2005).

Appendix 2. *Descriptive statistics of the countries included in the sample*

Country	*Y*				*X*				*W*			
	Mean	Std. Dev.	Min.	Max.	Mean	Std. Dev.	Min.	Max.	Mean	Std. Dev.	Min	Max.
Australia	11,9180	0,31204	11,5196	12,2321	9,9583	0,12676	9,7563	10,1728	-1,1080	0,21308	-1,4061	-0,7819
Austria	11,4249	0,09109	11,2996	11,5937	10,0123	0,13221	9,8200	10,2398	-0,3475	0,15527	-0,5379	0,0116
Bolivia	9,1039	0,21600	8,7414	9,4540	7,7121	0,05888	7,6252	7,8136	-0,9818	0,19265	-1,3349	-0,6802
Botswana	8,0369	0,40635	7,1752	8,4478	8,5172	0,28985	7,9347	8,9260	0,1036	0,11449	-0,0745	0,2470
Bulgaria	11,7414	0,22535	11,3933	11,9866	8,7185	0,10416	8,5683	8,9262	-0,0273	0,26408	-0,6400	0,2771
Canada	12,6365	0,05374	12,5275	12,7216	10,0378	0,09608	9,8838	10,2357	-0,5400	0,23762	-0,8926	-0,1462
Chile	10,9728	0,27935	10,4720	11,2720	8,7301	0,26775	8,3483	9,1266	-0,8187	0,17732	-1,0870	-0,5359
Colombia	11,4891	0,09822	11,3445	11,6497	8,6414	0,09915	8,4932	8,7755	-1,1790	0,24456	-1,4484	-0,8481
Denmark**	11,2348	0,13987	11,0566	11,4281	10,0987	0,10318	9,9185	10,2866	-0,5356	0,15884	-0,7918	-0,1955
Ecuador*	10,1897	0,16269	9,9353	10,4726	8,1264	0,02683	8,0713	8,1761	-0,5336	0,12974	-0,7361	-0,3441
Egypt**	12,1835	0,08894	12,0381	12,3469	7,9595	0,11192	7,7365	8,1703	-0,7179	0,17601	-0,9370	-0,3172
Ethiopia§†	9,8800	0,07311	9,7264	10,0067	6,4336	0,08273	6,1951	6,5423	-0,9639	0,09485	-1,0854	-0,7960
Finland	11,2431	0,13494	11,0667	11,4332	9,9197	0,10869	9,7277	10,1323	-0,6770	0,19012	-0,8508	-0,2649
France	13,1954	0,37344	12,5385	13,5005	9,9658	0,10114	9,8016	10,1393	-0,9727	0,18707	-1,1936	-0,5824
Greece**	10,9208	0,17728	10,6257	11,0868	9,5549	0,06320	9,4708	9,7240	-0,9931	0,22721	-1,2737	-0,5153
Hong Kong	11,1703	0,38786	10,4459	11,5520	9,8434	0,24569	9,3946	10,1575	0,5684	0,40980	-0,0107	1,0557
Hungary	11,9767	0,21691	11,6398	12,2155	9,2675	0,08409	9,1481	9,4498	-0,2686	0,28272	-0,5332	0,4172
India	14,1910	0,09322	14,0372	14,3474	7,4188	0,22426	7,0721	7,7896	-1,7622	0,24952	-2,0089	-1,2540
Indonesia	12,9956	0,45184	12,2738	13,5316	7,7233	0,27601	7,2874	8,1017	-0,2780	0,12998	-0,4566	0,0000
Ireland	10,5460	0,09319	10,4444	10,8025	9,6434	0,32685	9,2280	10,3099	0,0315	0,29506	-0,3653	0,5974
Italy	12,9361	0,13035	12,7862	13,1242	9,9474	0,11980	9,7528	10,1241	-0,9396	0,20620	-1,1969	-0,5871
Japan	14,2000	0,04272	14,1024	14,2705	9,9841	0,15476	9,7294	10,1649	-1,8540	0,12412	-2,0039	-1,6006
Jordan	9,1332	0,49733	8,3298	9,9280	8,3439	0,08815	8,1995	8,4985	0,2415	0,15025	-0,0419	0,5166
Kenya	10,6074	0,20151	10,1974	10,8786	6,9621	0,03889	6,8976	7,0365	-0,6903	0,16948	-0,9314	-0,4521
South Korea	12,6956	0,10741	12,5244	12,8555	9,0832	0,39554	8,4244	9,6292	-0,7854	0,26439	-1,0863	-0,2422
Luxembourg	8,9007	0,16598	8,6744	9,1524	10,3332	0,30030	9,9147	10,9379	0,7340	0,11875	0,5935	1,0399
Malawi**	9,2018	0,14753	8,9506	9,4486	6,3120	0,06087	6,1933	6,4130	-0,1752	0,12505	-0,4360	0,1320
Malaysia*	11,5897	0,32837	11,1991	12,1346	8,6813	0,26487	8,3056	9,0997	0,3753	0,29407	-0,0183	0,8280
Mauritius*	9,6163	0,26287	9,1296	9,8394	8,7552	0,27377	8,3161	9,1719	0,1451	0,16784	-0,1423	0,2947

Continúa...

Continuación. Appendix 2.

Country	*Y*				*X*				*W*			
	Mean	Std. Dev.	Min.	Max.	Mean	Std. Dev.	Min.	Ma				
Mexico	12,1756	0,29438	11,7762	12,5984	8,9671	0,05465	8,8814	9,0960	-1,2717	0,43196	-1,7891	-0,4472
Morocco	10,8765	0,46210	10,1886	11,3939	8,0737	0,08774	7,8991	8,1792	-0,6348	0,17263	-0,8765	-0,3349
Netherlands	11,8113	0,08072	11,7013	12,0162	9,9730	0,13375	9,7929	10,2120	-0,0647	0,16664	-0,2793	0,2602
New Zealand	10,8761	0,09973	10,7386	11,0130	9,7612	0,07819	9,6126	9,9040	-0,7048	0,17936	-0,9529	-0,4478
Norway	10,9364	0,11607	10,6587	11,1257	10,2022	0,16330	9,9582	10,4669	-0,4093	0,08833	-0,5151	-0,2617
Portugal	11,6954	0,18526	11,4547	11,9251	9,4640	0,17397	9,2227	9,7611	-0,6896	0,25612	-1,0624	-0,2968
Puerto Rico††	9,8990	0,15125	9,6400	10,1054	9,6371	0,25651	9,2798	10,0183	0,4122	0,13944	0,2325	0,6429
Senegal	9,1077	0,20655	8,7876	9,4144	7,2375	0,04003	7,1714	7,3047	-0,2901	0,05231	-0,3747	-0,1682
South Africa	12,3538	0,11486	12,1245	12,4754	9,2121	0,08056	9,1151	9,3895	-0,8624	0,16604	-1,0615	-0,5983
Spain	12,7128	0,07054	12,6046	12,8380	9,6340	0,15761	9,4201	9,9019	-1,0559	0,32930	-1,5139	-0,4703
Sri Lanka†	10,9625	0,35669	10,3090	11,3958	7,7869	0,21081	7,4517	8,1479	-0,3578	0,10151	-0,4743	-0,1206
Sweden	11,6007	0,09801	11,4506	11,7787	9,9185	0,09800	9,7493	10,1075	-0,5400	0,19253	-0,7863	-0,1462
Syria**	9,9159	0,33437	9,3215	10,5514	7,9841	0,09915	7,8317	8,1581	-0,7008	0,13800	-0,9382	-0,3884
United Kingdom	13,4722	0,13439	13,2579	13,7794	9,8825	0,13756	9,6628	10,1136	-0,8738	0,16998	-1,0803	-0,5414
United States	14,7430	0,06242	14,4926	14,8246	10,2302	0,13231	10,0015	10,4375	-1,7889	0,25372	-2,1219	-1,3341
Uruguay	10,2627	0,23200	9,7027	10,5793	8,9373	0,12103	8,7515	9,1391	-1,2536	0,23725	-1,5204	-0,9091
Venezuela**	11,4086	0,08343	11,2695	11,5389	8,7050	0,05283	8,6303	8,8178	-1,0635	0,14979	-1,3763	-0,7907

* BOD data completed with Holt-Winter smoothing method § GDP data completed by AR process † Trade openness index data completed by AR process

Source: authors'estimations based on World Bank (2005).

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