

THE DISSOCIATION BETWEEN EMISSIONS AND ECONOMIC GROWTH: THE ROLE OF SHOCKS EXOGENOUS TO THE ENVIRONMENTAL KUZNETS CURVE MODEL

DÍAZ-VÁZQUEZ, M. Rosario *

Abstract

This analysis focuses on determining the role of those factors that are exogenous to the environmental Kuznets curve (EKC) model in counteracting the scale effects (effects of the increase in GDP *ceteris paribus*) on CO₂ and sulphur emissions. For this purpose, first, the EKC model is estimated and, second, the time-effects are analysed.

JEL classification: Q56, O57, C33

Keywords: development, environment, Kuznets, world, econometric model.

1. Introduction.

The environmental Kuznets curve (EKC) hypothesis states that the relationship between per capita income and environmental degradation may be graphically represented by an inverted-U curve. The shape of this curve implies that there is a positive relationship between environmental degradation and income, i.e. high income leads to greater degradation, up to a point at which incremental increases in income cause the curve to begin to slope downwards, implying improvements in the quality of the environment¹.

The main thrust of the empirical studies that analyze the EKC hypothesis focus on estimating econometric models that try to establish the relationship between per capita income and a given indicator of environmental degradation. If and when this relationship is represented by an inverted-U shaped curve, the second step is to calculate the turning point (TP), that is, the per capita income at which the curve reaches its maximum and a marginal change in the environmental indicator is zero. The equation most often used in order to estimate this relationship is as follows (Ekins, 1997):

(1)

$$f(E_{it}) = \alpha_0 + \alpha_1 g_1(Y_{it}) + \alpha_2 g_2(Y_{it}^2) + \alpha_3 g_3(Y_{it}^3) + \\ + \alpha_4 g_4(Y_{it-a}^n) + \beta \cdot B + \gamma t + \varepsilon_{it}$$

where E_{it} is the environmental indicator for the country i at the time t ; α, β, γ are the parameters that must be estimated; Y_{it} is the per capita income for the country i at the moment in time t , where Y_{it-a}^n is a polynomial of the lagged income; B is a vector of other explanatory variables which might possibly include dummy variables in order to capture specific demographics, the geography or specific years; ε is the random

* María-Rosario Díaz-Vázquez, Faculty of Economics and Business. University of Santiago de Compostela. E-msil: rosario.diaz@usc.es.

¹ Stern *et al* (1996), Ekins (1997), Barbier (1997), Stern (1998), Stagl (1999), Dasgupta *et al* (2002) and Stern (2004) offer an overview of the literature that is available within the field. Further, in 1997 the journal *Environment and Development Economics*, 2(4), dedicated a special edition to the issue, as did *Ecological Economics*, 25(2) in 1998

disturbance; and $f(.)$ and $g(.)$ are the functional forms that are predominantly, but not exclusively, logarithmic or lineal.

If $\alpha_3 \neq 0$, the income equation is cubic; if $\alpha_3 = 0$ and $\alpha_2 \neq 0$, the equation is quadratic; if $\alpha_3 = \alpha_2 = 0$ and $\alpha_1 \neq 0$, the equation is lineal. The shape of the curve generated by the given relationship will depend upon the signs and the relative values of α_1 , α_2 and α_3 .

It can be seen that equation (1) is in its reduced form, and this means that it reflects both the direct and the indirect relationships that exist between income and the environmental indicator. This makes it difficult to obtain conclusions as to a direct causal relationship using these equations. Consequently, the conclusion of certain authors that economic growth, without environmental policy, is enough to attain both economic and ecological objectives cannot be extrapolated directly from this studies.

It must be stated that not all reductions in pollution and contamination that occur concurrently with increases in per capita income are compatible with the EKC hypothesis. As Vogel (1999, p.26) points out: "Provided that these environmental turn-arounds in the course of a period of rising per capita income are a real and robust phenomenon, they must include a systematic component that is linked to typical characteristics of a developing and growing economy". Consequently, it is possible that there are both initial increases and subsequent reductions in contamination and these should not be placed under the umbrella of EKC, even though they may occur while levels of per capita income are increasing.

For this reason, our paper aims to evaluate the influence of both exogenous factors and income related factors in reducing emissions, in order to advance in the analysis of the nexus between economic growth and environment,

2. - Aim of the Analysis.

This analysis focuses on determining if variables that are exogenous to the EKC model have been more influent in counteracting the scale effect than income related variables. Scale effect is defined here as the increase in emissions due to the increase in economic activity, *ceteris paribus*.

To this end, the standard EKC model in reduced version was estimated using the available data and a time-effects analysis carried out.

The econometric analysis was based on the work of Stern and Common (2001). There were two reasons for this choice of reference:

- The authors highlight the fact that the basic EKC model in reduced form may be incorrectly specified. This is because, when focusing on GDP as the specific variable for explaining the evolution of the indicator that registers environmental deterioration, there arises the obvious risk that bias may occur due to the variables that have been omitted (p.162). This is why, besides estimating the standard EKC model in its logarithmic specification, they also carry out a first differences estimation which they consider to be preferable, although, not entirely, problem-free.
- A time effects analysis is included. The time effects take in the effects of the variables that have been omitted which vary over time, and the stochastic shocks that are common to all of the countries. This enables the analysis to provide

information as to the exogenous effects that might be affecting the evolution of the emissions.

While the Stern and Common model is used as a basis, it is extended in two directions:

- (i) The models provided here are estimated both for sulphur and CO₂ emissions, rather than for just sulphur.
- (ii) The chronological period of the sample has been enlarged. The former authors used the period 1960-1990² while this analysis utilizes the period 1950-1999.

As previously pointed out, the emissions of CO₂ and sulphur have been chosen as environmental indicators. The rationale for this choice was based on the fact that, there are long, complete sets of data that are readily available for both groups and that, although both pollutants have their origins in the combustion of fossil fuels, the environmental problems that they generate and their respective potential solutions are different since CO₂ produces climate change while sulphur produces acidification.

3. Data.

The CO₂ emissions data come from the *Carbon Dioxide Information Analysis Center* (CDIAC) from the *Oak Ridge National Laboratory* (ORNL) in the *U.S. Department of Energy*. The CO₂ emissions data from the ORNL include the emissions derived from the combustion of solid, liquid and gaseous fossil fuels, gas flaring and the production of cement (Marland *et al*, 2002). The data are expressed in terms of thousands metric tons of carbon. The series of ORNL data was used since it provided the most comprehensive chronological data. The sulphur emission data was taken from the Stern (2003)³ series and was expressed in terms of metric tons of sulphur per year.

The GDP and population data was taken from the University of Groningen and the Conference Board (2002). The GDP data are expressed in millions of U.S. dollars at 1990 prices, converted using “Geary-Khamis” purchasing power parities. The population data has been expressed in thousands of individuals. GDP/POP is therefore, expressed in thousands of dollars per capita.

The samples used to estimate the CO₂ emissions model are the following:
OECD94 (22 countries): Australia, Austria, Belgium, Canada, Denmark, Spain, United States, Finland, France, Greece, Netherlands, Ireland, Italy, Japan, Norway, New Zealand, Portugal, United Kingdom, Federal Republic of Germany, Sweden, Switzerland y Turkey.
Non-OECD (36 countries). *Africa*: Egypt, Ethiopia, Ghana, Kenya, Morocco, Niger, South Africa, Democratic Republic of the Congo. *Asia*: Myanmar, China, Hong Kong, India, Indonesia, Philippines, South Korea, Sri Lanka, Taiwan, Thailand. *East-Europe*: Bulgaria, Czechoslovakia, German Democratic Republic, Hungary, Poland, USSR. *Latín America*: Argentina, Brazil, Chile, Colombia, México, Peru, Venezuela. *Middle East*: Israel, Iran, Iraq, Saudi Arabia, Syria.

² They use data provided by ASL and Associates (Lefohn *et al*, 1999).

³ This work explains how the data series were elaborated and indicates where they may be found i.e. at the following address: <http://www.rpi.edu/~sternd/datasite.html> see 23-9-2003. This paper has been subsequently published in Stern (2005)

WORLD. Included all the OECD94 and non-OECD countries.

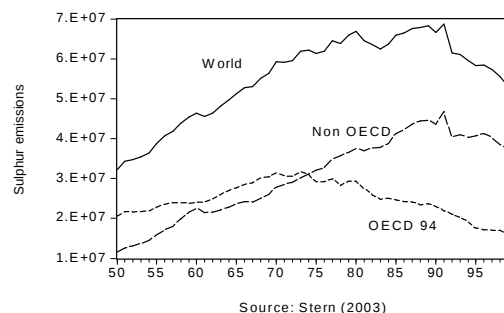
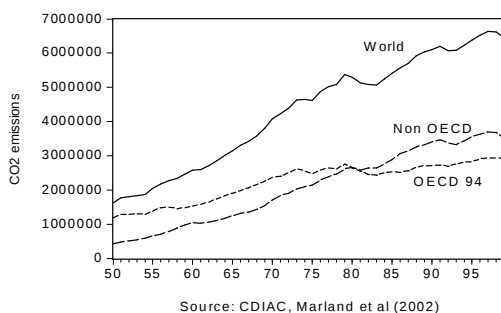
While the sample for both sulphur and the CO₂ emissions contain the same elements, there was no separate data available for sulphur from the Federal Republic and the Democratic Republic of Germany. Thus, it was decided that the OECD94-country sample should contain the unified data for Germany for the entire period in the case of sulphur.

The time-frame used, for the sample and all of the variables, was 1950-1999. Given the availability of data for CO₂ emissions for the Federal Republic of Germany and the Democratic Republic the period for these countries was limited to 1950-1990 and for the USSR from 1950 to 1991. With respect to USSR's sulphur emissions the data is only available up until 1980.

The countries that were chosen contained 83% of the world's population in 1998, 94% of GDP, 87% of the emissions of CO₂ and 88% of the sulphur emissions.

Figure 1 shows the uneven evolution of the CO₂ and sulphur emissions during the period analyzed. In figure 1, the world emissions correspond to the total world emissions and not the total of the countries cited. The non-OECD emissions have been calculated as the difference between the world total and those of the OECD94 sample.

Figure 1- CO₂ emissions (thousands of metric tons of carbon) and sulphur emissions (metric tons of sulphur).



In contrast to the world CO₂ emissions which, in general, have tended to rise throughout the period, sulphur emissions begin to decline after 1990. The same trajectories are observed in the non-OECD sample. In the OECD94 however, sulphur emissions begin to decline from 1973 onwards and CO₂ emissions tend to stabilize after 1979.

4. – Estimation of the EKC Model.

4.1. - Econometric Model

The model estimated by Stern and Common is the basic EKC model in its log quadratic specification. The model takes the following general form:

$$\ln\left(\frac{E}{POP}\right)_{it} = \alpha_i + \gamma_t + \beta_1 \ln\left(\frac{GDP}{POP}\right)_{it} + \beta_2 \left(\ln\left(\frac{GDP}{POP}\right)_{it}\right)^2 + \varepsilon_{it} \quad (2)$$

where E represent the contaminating emissions, POP the population, ε the random disturbance, α_i are country-specific intercepts, γ_t are time-specific intercepts, the sub index i is used for the countries and the sub index t for years. Specifically, Stern and Common estimate the model for the emissions of tonnes of sulphur.

These authors estimate model (2) for the samples: “world” and the sub-samples “OECD” and “non- OECD”.

Given that there is a possibility that the variables may not cointegrate, Stern and Common take a second step by opting to estimate the first differences model for the three samples. This procedure aims to eliminate the potential stochastic tendencies that might exist within the series⁴. In these cases, they also estimate the time effects.

They estimate the first differences model with two variants: in the first, they use a constant intercept which represents the mean rate of technical progress; second, they introduce the fixed time effects that allow the analysis to capture the other effects that are commonly related to time besides the technical change in the neoclassical sense. Given our interest in the evolution of the time effects, the analysis will focus on the latter of these variants. This model, according to the authors, provides better statistical properties than model (2).

$$\Delta \ln\left(\frac{E}{POP}\right)_{it} = \gamma_t + \beta_1 \Delta \ln\left(\frac{GDP}{POP}\right)_{it} + \beta_2 \Delta \left[\left(\ln\left(\frac{GDP}{POP}\right)_{it} \right)^2 \right] + \varepsilon_{it}, \quad (3)$$

Prior to presenting the results obtained, it must be underlined that the samples used do not coincide precisely with those used by Stern and Common. This difference resides, principally, in the sample in which the country members are non-OECD⁵.

4.2. Results of the estimation

Estimation of model (2) for the CO₂ and sulphur emissions

Tables 1 and 2 provide the results of the model (2) estimation of the CO₂ and sulphur emissions with fixed effects (OLS) and random effects. For the time effects a dummy variable was introduced for each year. The dummy variable for the year 1950 was eliminated in order to avoid perfect multicollinearity in the regressor matrix.

In order to facilitate the interpretation of the results, it was felt that it was necessary to stipulate the maximum level of per capita GDP for the sample, which was 28,083 1990 dollars reached by the USA in 1999.

⁴ It should be mentioned that the possibility of non-co-integration was subsequently analyzed by Perman and Stern (2003) who found that the variables used in model (2) could have been integrated variables. The use of some test for co-integration in panel data did not provide conclusive results given that some of these indicated co-integration for all of the countries and some accepted the hypothesis of non-co-integration. The existence of a common co-integration vector for all of the countries is strongly rejected (Stern, 2004).

⁵ The “OECD” of Stern and Common includes all of the countries in the OECD94 used in this sample together with Luxemburg. The differences are greater in the non-OECD, in which these authors include 50 countries

Table 1.- Regression results for CO₂ emissions: Model 2 with fixed and random effects.

DEPENDENT VARIABLE: ln (CO ₂ /POP)						
REGION	World n=2871		OECD94 n=1091		Non-OECD n=1780	
MODEL	Fixed effects	Random eff.	Fixed effects	Random eff.	Fixed effects	Random eff.
Constant		-2,2371 (-27,43)*		-3,2372 (-31,69)*		-2,2647 (-18,97)*
ln GDP/POP	1,3237 (38,95)*	1,5855 (52,07)*	2,6375 (36,11)*	2,7307 (40,49)*	1,0588 (24,13)*	1,4174 (36,24)*
(ln GDP/POP) ²	-0,1748 (-19,19)*	-0,1705 (-18,73)*	-0,4580 (-22,70)*	-0,4509 (-28,64)*	-0,0664 (-4,56)*	-0,0856 (-5,68)*
Adjusted R ²	0,96	0,96	0,94	0,94	0,95	0,94
Durbin-Watson	0,17	0,16	0,13	0,13	0,19	0,17
Turning Point	44.039	104.431	17.798	20.664	2.884.079	3.932.287
Hausman Test		77,9812 (0,0000)		17,8046 (0,0001)		226,6894 (0,0000)
Bartlett Test	2235 (0,000)		480,7 (0,000)		1217 (0,000)	
*1% level of statistical significance						
NOTE: Figures in parentheses are t statistics for regression coefficients and significance levels for the Hausman test statistics. Turning points are in real 1990 US dollars per head.						

Table 2.- Regression results for sulphur emissions: Model 2 with fixed and random effects.

DEPENDENT VARIABLE: ln (S/POP)						
REGION	World n=2830		OECD94 n=1100		Non-OECD n=1730	
MODEL	Fixed eff.	Random eff.	Fixed effects	Random eff.	Fixed effects	Random eff.
Constant		0,7893 (4,75)*		-1,2704 (-6,20)*		0,5002 (1,98)**
ln GDP/POP	1,5788 (21,43)*	1,6210 (25,44)*	3,9654 (26,44)*	4,4399 (31,09)*	1,0610 (11,05)*	1,1342 (14,17)*
(ln GDP/POP) ²	-0,3269 (-16,56)*	-0,3663 (-19,26)*	-0,9523 (-22,88)*	-1,0731 (-32,18)*	-0,0826 (-2,59)*	-0,1066 (-3,45)*
Adjusted R ²	0,87	0,87	0,82	0,80	0,86	0,87
Durbin-Watson	0,13	0,12	0,08	0,09	0,15	0,15
Turning Point	11.188	9.140	8.020	7.915	611.320	204.560
Hausman Test		61,2265 (0,0000)		106,9608 (0,0000)		9,0585 (0,0107)
Bartlett Test	3039 (0,000)		372,50 (0,000)		1868 (0,000)	
TP in SC (2001)	101.166	54.199	9.239	9.181	908.178	343.689
*1% level of statistical significance; ** 5% level of statistical significance.						
NOTE: Figures in parentheses are t statistics for regression coefficients and significance levels for the Hausman test statistics. Turning points are in real 1990 US dollars per head. We include the turning point estimated by Stern and Common (2001) (SC).						

Before going on to comment upon the values that can be seen in the tables, it must be underlined that the results of the Hausman test (Green, 1999) reveal that there is a correlation between the random disturbance and the regressors in the three samples of countries, both when the dependent variable is CO₂ and sulphur. It is ascertained

therefore, that the random effects model cannot be estimated consistently⁶. For this reason focus is placed upon the results of the fixed effects estimation.

Some of the most significant results of the estimation are as follows:

- The TP estimated, both for CO₂ and for sulphur, in the OECD94 countries falls within the income range, which contrasts with the non-OECD countries.
- There is variation among the TP estimated in the distinct samples. The results support the Stern and Common hypothesis that states that the sample with the greatest weight of low income countries, the non-OECD countries, provide higher estimates for the TP's. The analysis has tested that this remains true both for CO₂ and for sulphur.
- Given the same sample of countries, the TP's estimated for the CO₂ emissions are higher than those estimated for sulphur. This implies that, as expected, a global pollutant shows higher TP's than a local one.

At this juncture it must be highlighted that the estimation of model (2) has been carried out without taking into consideration the possible presence of heteroscedasticity and autocorrelation. In order to complete the analysis, the equality of variance hypothesis has been tested by running the Bartlett test (Judge et al, 1985; Socal and Rohlfs, 1995). This was rejected for all of the samples⁷. Further, the low scores for the Durbin-Watson statistic alert the analysis to the possible presence of first order autocorrelation, although such low values are probably pointing to the fact that the model is poorly specified⁸.

Estimation of model (3) for the emissions of CO₂ and sulphur

The analysis begins by estimating model (3) with OLS (results are not cited here). Since the Bartlett test rejected the equality of variances for all of the samples⁹, the model was estimated using GLS with *cross-sectional* weightings. Tables 3 and 4 provided the results of this estimation.

With respect to the results of the estimation for model (3), it may be observed that the quadratic term for per capita GDP in first differences is both negative and significant in every case with the exception of the non-OECD countries for CO₂, in which the result is non-significant. However, all of the estimated TP's fall outside of the income range being considered and, consequently, all of the estimated curves are monotonic and rising within this range.

⁶ Stern and Common carry out the estimation both with fixed effects (country and time) and with random effects. The random effects are utilized in spite of the following: first, the results of the Hausman test indicate that the effects are correlated with the explanatory variables, both in the sample "world" and in the non-OECD, and second, although in the OECD sample the random effects estimator is consistent, the non significance of the Hausman statistic is very sample-sensitive (for example, if Portugal and Turkey are removed, the statistic becomes highly significant).

⁷ In every case, the test was repeated using the Levene test (Levene, 1960) and the Brown-Forsythe test (Brown y Forsythe, 1974), leading to the rejection of the equality of variances hypothesis.

⁸ In face of these results, and while we accept that the specifications of the EKC are deficient, the estimation of model (2) has been carried out while taking into consideration that there is both autocorrelation and heteroscedasticity in the groups (results are not cited here). The conclusion to be drawn is that, testing of the EKC hypothesis is much more problematical when the model is estimated via GLS.

⁹ In every case, the test was repeated using the Levene test (Levene, 1960) and the Brown-Forsythe test (Brown y Forsythe, 1974), leading to the rejection of the equality of variances hypothesis

Table 3.- Regression results for CO₂ emissions: Model 3 with cross-section weights.

DEPENDENT VARIABLE: $\Delta \ln (\text{CO}_2/\text{POP})$			
REGION	World n=2812	OECD94 n=1069	Non-OECD n=1743
$\Delta \ln \text{GDP}/\text{POP}$	0,7886(12,93)*	1,5774(8,19)*	0,6629(9,61)*
$\Delta(\ln \text{GDP}/\text{POP})^2$	-0,0518(-2,98)*	-0,1877(-4,20)*	-0,0366(-1,55)
Adjusted R ²	0,20	0,32	0,17
Durbin- Watson	2,17	2,31	2,15
Turning Point	2.004.188	66.812	8.479.179
*1% level of statistical significance; ** 5% level of statistical significance; *** 10% level of statistical significance.			
NOTE: Figures in parentheses are t statistics for regression coefficients. Turning points are in real 1990 US dollars per head.			

Table 4.- Regression results for sulphur emissions: Model 3 with cross-section weights.

DEPENDENT VARIABLE: $\Delta \ln (\text{S}/\text{POP})$			
REGION	World n=2773	OECD94 n=1078	Non-OECD n=1695
$\Delta \ln \text{GDP}/\text{POP}$	0,7706(9,10)*	1,5870(5,12)*	0,6237(6,79)*
$\Delta(\ln \text{GDP}/\text{POP})^2$	-0,1031(-4,17)*	-0,1713(-2,34)**	-0,0884(-2,79)*
Adjusted R ²	0,14	0,31	0,08
Durbin- Watson	1,63	1,66	1,68
Turning Point	41.934	102.769	34.094
TP SC (2001)	33.290	55.481	18.039
*1% level of statistical significance; ** 5% level of statistical significance; *** 10% level of statistical significance.			
NOTE: Figures in parentheses are t statistics for regression coefficients. Turning points are in real 1990 US dollars per head. We include the turning point estimated, without cross-section weights, by Stern and Common (2001) (SC).			

For a more solid interpretation of the results it would be as well to refer to Suri and Chapman (1998, p.199). Here, they point out that the income variable GDP represents the scale effect, that is, the effect of an increase in economic activity on emissions *ceteris paribus*. GDP squared takes in all of the factors that are varying in the economy as GDP increases, including for example, output composition, environmental awareness and regulations. By taking all of the above into account, it may be affirmed, in accordance with the results obtained in model (3), that although the factors that vary in line with GDP are exerting a downward pressure on emissions – as it is confirmed by the negative sign of the coefficient estimated for the quadratic term for GDP- this effect will have been insufficiently strong to compensate for the predominantly upward thrust of the scale effect and thus it hasn't been able to change the increasing trend of the emissions, within the income range being considered.

In spite of the above, it still seems to be somewhat paradoxical that, both with respect to the results of the sample for sulphur and for those of Stern and Common, the TP estimated for the OECD94 are much higher than for the non-OECD. This might seem surprising since the sulphur emissions began to decrease previously in the OECD

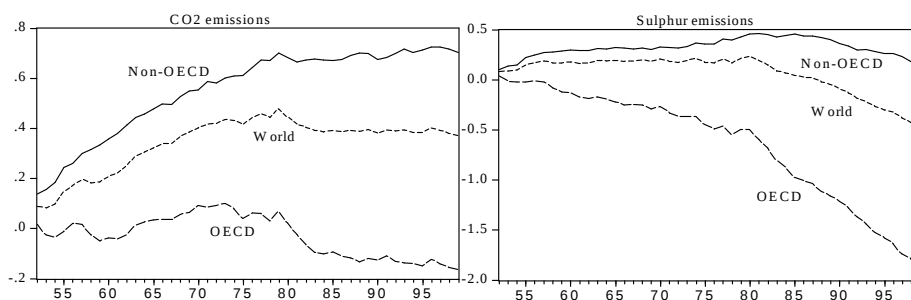
countries (figure 1). It is similarly surprising therefore that the TP estimated for sulphur in the OECD94 is far greater than the TP estimated for CO₂.

One possible explanation is that other factors, factors that are unrelated to increases in per capita income, have contributed to the reduction in sulphur emissions in the OECD94 but would not have the same effect on the non-OECD countries or upon the CO₂ emissions. Therefore, the following step in the analysis involves analyzing the information that the estimations carried out have offered with respect to the time effects, since these effects, as previously mentioned, take in the omitted variables that vary with time and the stochastic shocks common to all of the countries.

5. – Analysis of time effects.

Figure 2 shows the evolution of the time effects obtained through the estimations in model (3) (the “preferred” model).

Figure 2.- Time effects. Model 3 with cross-section weights.



Note: The time effects represented are the integrated annual coefficients of the dummy variables.

5.1.- Time effects for the emissions of CO₂.

In Figure 2.1, it can be observed that those time effects for CO₂ for the OECD94 are lower than for the non-OECD countries. Specifically, for the non-OECD, the time effects are always positive. They exhibit a tendency which is strongly ascendant but falls off in 1979, declines slightly and then, retakes the ascendant, although somewhat more gently. For the OECD94, these effects are constantly positive between the period 1963 and 1980 and clearly negative from that time onwards. The growing tendency that follows the time effects from 1959 stops in 1973. The sharpest reduction however, begins to take place from 1979 onwards.

Therefore, given that the years 1973 and 1979 signal periods in which there are the two oil crises, the time effects reflect the impact of these crises upon the evolution of CO₂ emissions. The estimated time effects suggest that there are variables that are omitted, which must have pushed the estimated curve upwards with respect to all of the samples right up until the 1970's. From here onwards, if the preferred model is adhered to, the results show that there will be factors that continue to exert a positive, yet greater stabilizing effect from 1979 onwards in the non-OECD; Quite the reverse is

true in the OECD94, the variables that have been omitted exert a negative impact on the emissions and this becomes noticeable in 1973 but intensifies after 1979.

5.2.- Time effects for the sulphur emissions.

In Figure 2.2, in which the estimated time effects for the preferred sulphur emissions model are displayed, it can be observed that, as with the case of CO₂, these effects are greater in the non-OECD than in the OECD94.

The time effects obtained for the non-OECD are positive throughout the whole period. They increase gradually until 1979 and then begin to decrease from 1985 onwards.

The estimated time effects for the OECD94 are negative throughout the period. The slope of the curve is markedly descendant and becomes even more so from 1979 onwards. Therefore, there must be factors that have displaced the curve downwards from the beginning of the period, although the effects intensify after 1979. In this year, two events with influence in sulphur emissions took place: the second oil crisis and the Convention on Long-range Transboundary Air Pollution (CLRTAP).

It now becomes possible to compare the time effects that come about as a result of the estimation of the preferred model for sulphur mooted in this analysis, with those obtained by Stern and Common (2001). These authors interpret the time effects obtained in the first differences estimation as the rate of technological change specific to each period.

With respect to OECD time effects, what they conclude coincides, essentially, with that obtained in the analysis contained here. In short, these conclusions state that the technical progress that leads to a decrease in emissions continues throughout the period of the sample. Nevertheless, there is one highly noteworthy difference between the two studies, both with respect to the results and their interpretation. The former authors find that there is a substantial technical improvement between the years 1981 and 1983, which they link exclusively to the CLRTAP. The analysis provided in this study however, provides a curve whose negative slope increases quite drastically from 1979 onwards. This means that it becomes less likely to be able to assign the vast weight of the change to the Convention without taking into consideration the oil crisis.

With regard to the time effect within the non-OECD countries, they observe that technical change is responsible for an increase in emissions until the mid-1970's and, subsequently, there is a slow decline in emissions. According to these authors, "this may provide support for the hypothesis that the energy crisis in 1973 had some effect on sulphur emissions but, ironically not for the developed countries studied by Moomaw and Unruh (1997) and Unruh and Moomaw (1998)" (Stern and Common, 2001, p.174). Our analysis does not share this conclusion for two reasons.

First, as expressed above, it is not feasible to simply ignore the impact of the crisis that took place in the 1970's, particularly with respect to the second shock, affecting the sulphur emissions in the OECD countries.

Second, the time effects with respect to sulphur emissions that are gleaned from the analysis presented here, point to the fact that the change in the technical progress in the non-OECD took place in the mid-1980's and not in the 1970's. The analysis indicates that technical progress would have previously affected the OECD emissions. This would seem to imply a subsequent technological diffusion of towards the non-OECD countries.

Further, it should be stressed that the works by Moomaw and Unruh focus on CO₂ emissions and not on sulphur, and it is important to underline that the results obtained here in our estimations of the time effects support the thesis on the impact of the oil crisis with respect to carbon emissions in OECD countries.

6. Conclusions

The main conclusion that may be obtained, both with respect to the results of the estimations and the analysis of the time effects of the preferred model, is that, although there may be factors related to the variation in income, which might be compensating for the scale effect, these are not strong enough to reduce the estimated TP to achievable levels of per capita income even for OECD94 countries.

On the contrary, the explanation for the reductions in the emissions that have been observed in some of the samples might, however, reside in the time effects. In the OECD94, these favour the reduction of emissions: in the case of sulphur, they cause a reduction right from the outset of the period and, in the case of carbon, from the crisis of the 1970's. In both cases the impact becomes more pronounced from 1979 onwards (second oil crisis and CLRTAP year). In the non-OECD countries the effects of the oil crisis also become evident since the growth of the time effects becomes less pronounced. Therefore, in short, exogenous shocks (such as oil crises or international agreements) seem to be linked to reductions in emissions.

In spite of the above, it must be remembered that, a single global EKC model in reduced form, even when this is a model in first differences, remains a misspecification (Stern y Common, p. 175). Hence, all of the results obtained must be interpreted with caution.

In an important critical revision of EKC literature, Stern *et al* (1996, p.1159), suggest that, "a more fruitful approach [than to estimate a single global EKC model in reduced version] to the analysis of the relationship between economic growth and environmental impact would be the examination of the historical experience of individual countries, using econometric and also qualitative historical analysis". For this reason, we consider of interest to study what happens in each of the countries individually.

References

- Barbier, E.B. (1997): "Introduction to the Environmental Kuznets Curve special issue", *Environment and Development Economics*, 2, 369-381.
- Brown, M. B. and Forsythe, A. B. (1974): "Robust Tests for the Equality of Variances", *Journal of the American Statistical Association*, 69, 364-367.
- Dasgupta, S.; Laplante, B.; Wang, H. and Wheeler, D. (2002): "Confronting the Environmental Kuznets Curve", *The Journal of Economic Perspectives*, 16(1), 147-168.
- Ekins, P. (1997): "The Kuznets curve for the environment and economic growth: examining the evidence", *Environment and Planning A*, 29, 805-830.
- Green, W.H. (1999): *Análisis econométrico*, Prentice Hall, Madrid, 3ª edición.
- Judge, G.G.; Griffiths, W.E.; Hill, R.C.; Lütkepohl, H; y Lee, T.C. (1985): *The theory and practice of econometrics*, John Wiley & Sons, 2nd edition.

- Lefohn A.S.; Husar, J.D. and Husar, R.B. (1999): "Estimating historical anthropogenic global sulfur emission patterns for the period 1850-1990", *Atmospheric Environment*, 33 (21), 3435-3444.
- Levene, H. (1960): "Robust Tests for the Equality of Variances", in: Olkin, I; Ghurye, S. G.; Hoeffding, W.; Madow, W. G.; y Mann, H. B. (eds.): *Contribution to Probability and Statistics*, Stanford University Press.
- Marland, G.; Boden, T.A. and Andres, R.J. (2002): "Global, Regional, and National Fossil Fuel CO₂ emissions". In *Trends: A Compendium of data on Global Change*. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., USA. Available from (3-12-2002): http://cdiac.esd.ornl.gov/trends/emis/meth_reg.htm .
- Moomaw, W.R. and Unruh, G.C. (1997): "Are Environmental Kuznets Curve misleading us? The case of CO₂ emissions", *Environment and Development Economics*, 2, 451-463.
- Perman, R. and Stern, D.I. (2003): "Evidence from panel unit root and cointegration tests that the Environmental Kuznets Curve does not exist", *Australian Journal of Agricultural and Resource Economics*, 47(3), 325-347.
- Sokal, R.R. and Rohlf, F.J. (1995): *Biometry*, W.H. Freeman.
- Stagl, S. (1999): *Delinking economic growth from environmental degradation? A literature survey on the Environmental Kuznets Curve Hypothesis*, Working Paper n° 6, Working Paper Series of the Research Focus Growth and Employment in Europe: Sustainability and Competitiveness, Wirtschaftsuniversität Wien.
- Stern, D.I.; Common, M.S. and Barbier, E.B. (1996): "Economic growth and environmental degradation: The Environmental Kuznets Curve and sustainable development", *World Development*, 24(7), 1151-1160.
- Stern, D.I. (1998): "Progress on the Environmental Kuznets Curve?", *Environment and Development Economics*, 3, 173-196.
- Stern, D.I. and Common, M.S. (2001): "Is there an Environmental Kuznets Curve for sulfur?", *Journal of Environmental Economics and Management*, 41, 162-178.
- Stern, D.I. (2003): *Global sulfur emissions in the 1990s*, Working Paper, Department of Economics, Rensselaer Polytechnic Institute, New York. Available from (11-12-2006): <http://www.economics.rpi.edu/workingpapers/rpi0311.pdf> .
- Stern, D.I. (2004): "The rise and fall of the Environmental Kuznets Curve", *World Development*, 32 (8), 1419-1439.
- Stern, D.I. (2005): "Global sulfur emissions from 1850 to 2000", *Chemosphere*, 58, 163-175.
- Suri, V. and Chapman, D. (1998): "Economic growth, trade and energy: implications for the Environmental Kuznets Curve", *Ecological Economics*, 25, 195-208.
- University of Gronigen and the Conference Board (2002): *GGDC Total Economy Database*, Available from (5-12-2002): <http://www.eco.rug.nl/ggdc>
- Unruh, G.C. and Moomaw, W.R. (1998): An alternative analysis of apparent EKC-type transitions, *Ecological Economics*, 25, 221-229.
- Vogel, M.P. (1999): *Environmental Kuznets Curves. A study on the economic theory and political economy of environmental quality improvements in the course of economic growth*, Springer, Berlin.