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EKC: Static or Dynamic?

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Abstract

This paper tests the robustness of the Environmental Kuznets Curve (EKC) hypothesis, using dynamic model specification for the long panel data set rather than static model. The monotonic income - CO₂ emission relationship exists in most of the under developed or developing economies but EKC exists mostly in developed economies.

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Key words: EKC, Dynamic model, CO₂ Emission.

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1. Introduction

This paper investigates the robustness of the Environmental Kuznets Curve (EKC), an inverted-U shaped relationship between environmental quality indicators¹ and the level of economic activity or income. Several earlier studies (See, Grossman and Krueger 1995, Selden and Song 1994, de Bruyn et al. 1998, Holtz-Eakin and Selden 1995, Cole et al. 1997, Dinda et al. 2000, Shafik 1994, etc.) have attempted to test the EKC hypothesis empirically with the help of panel data. Most of these studies have used static model for estimation purpose. Little attention has been given in the model specification, especially dynamic model specification in the EKC literature.

In re-examining the EKC relationship, this study improves over the previous literature in two aspects. Firstly, proper selection of a model and appropriate method of estimation are important for panel data. A dynamic model helps to draw a valid inference about the parameters of the EKC relationship. Finally, we re-examine the validity of EKC relationship between CO₂ emission and income using a cross-country panel data covering 88 countries, which are taken from all the continents of the world over the period 1960 - 1990.

In the next section, we select an appropriate model, the empirical results are analyzed in section 3, and a summary of the findings is given in the final section.

2. Methodology and Model selection

The basic simple EKC model, is used by most of the earlier studies, is given as:

$$y_{it} = \alpha_i + \phi T + \beta_1 x_{it} + \beta_2 x_{it}^2 + \varepsilon_{it} \quad (1)$$

Where y_{it} denotes the environmental quality indicator of i th individual at time t ; x is income per capita (PPP at a constant price, 1985), α_i is the country specific effect, T is the time trend and ε_{it} is

¹ It is defined as the level of concentration of pollution or flow of emissions, depletion of resources etc.

disturbance term. Note that this model has an individual effect (α_i) that allows for the intercept of the Kuznets curve to vary in every country. Despite the inclusion of fixed country effects, the β s, which measures the effect of the explanatory variables, is the same for each country for each time period. The parameter β s can be thought of as the average income - emission relation, but individual country may differ from this average. Actually, equation (1) is a static model. It means that due to any shock, all adjustment takes place within the time period in which it occurs. Here adjustment process is actually instantaneous. On the contrary, a slow adjustment process exists in reality and a statistical sound approach is required to estimate a dynamic model (see Greene 1998) in panel data set up. The earlier EKC models are mis-specified because the dynamic nature of the model has not been taken into consideration for the estimation purpose in case of long time series data in panel set up. Now, we consider the following dynamic model:

$$y_{it} = \alpha_i + \phi T + \eta y_{it-1} + \beta_1 x_{it} + \beta_2 x_{it}^2 + \varepsilon'_{it} \quad (2)$$

This dynamic relationship is characterized by the presence of a lagged dependent variable among the regressors. Thus, autocorrelation effect can be removed from error terms.

3. Data and discussion of results

For the present study, we have used cross-country panel data on per capita GDP (PCGDP, measured at 1985 US dollar) compiled by Summers and Heston (Mark 5.6) and corresponding per capita CO₂ emission (PCCO₂, measured in metric tons) are taken from Carbon Dioxide Analysis Information Center (CDAIC) of Oak Ridge National Laboratory (ORNL), USA. Given these basic data, we have compiled a cross-country bi-variate panel data set of yearly observations covering 88 countries spread over the globe for the time period 1960 - 1990.

Now, we see the results of static model (1). The estimated *turning point* for the global EKC is \$31147 (at US 1985 Prices) per capita income which is the out of sample range, that imply a monotonic income-emissions relation. This estimated *turning point* is nearly same as that of Holtz-Eakin and Selden (1995) (i.e., \$35428 per capita). The estimates are consistent with an inverted-U shape for the CO₂ emission-income relation (i.e., $\beta_1 > 0$ and $\beta_2 < 0$). In most of the developed countries, CO₂ emission starts to decline after oil shock (see, Moomaw and Unruh (1997)). Incorporating dummy (d=1 for post oil shock period, i.e., 1975 -1990, and zero otherwise, i.e., 1960 - 1974) in model 1 and 2, we also try to examine the oil shock effect which is the major cause of reducing CO₂ emission in post oil shock period. We also examine the EKC relationship between income and emission for individual countries. Table 1 presents the results of individual EKC regressions. In case of with and without trend, the statistically significant EKCs exist in 34 and 36 countries out of 88, respectively. The relationship of CO₂ emission with per capita income has been found to be monotonic in most of the under developed and developing economies but EKC exists mostly in developed economies (see table 1).

It should be noted that OLS is known to be generally inefficient for panel data regression estimation. In this case, all the data are pooled and ignore the individual effect or country specific effect. This country specific effect may be unique for each country. We consider that country effect may be a random variable. Here, Random Effect (RE) model estimation is important. In case of panel data set up, within method/Fixed Effect (FE) and/or Random Effect (RE) model estimations are better than Pooled/OLS estimation. The Hausman χ^2 test statistic helps to select the appropriate model among FE and RE models. In this study, the FE turned out to be the appropriate choice. Sum of squared residuals is the minimum in case of FE model estimation for both equation (1) and (2). Note that adjusted R² is also the maximum only in case of FE compare to RE model for both equations. From this FE model, the estimated *turning point* for model (1) is \$13860 per capita, which is within the sample range and implies no more monotonic emission-income relation. In this case, our estimated turning point is nearly same as the findings of Agras and Chapman (1999) and it is surprisingly low, especially compared to estimates of other studies (Shafik (1994), Holtz-Eakin and Selden (1994)). In

general for the world, these results reject the monotonic relationship of carbon dioxide emission with per capita income. The estimated *Turning Point* of global EKC model differs from OLS to FE or RE model estimations (See Table 2).

In general, the valid inference can be drawn about the parameters of the EKC relationship between PCGDP and PCCO₂ when a more completely specified dynamic model (i.e., equation (2)) is chosen. Now, for the model (2), we obtain the *turning point* at \$10931 per capita in FE model estimation and in OLS at \$ 9836 per capita, which is far below that of model (1). The model (1) is mis-specified because the dynamic effect has not been considered in long panel data. The dynamic effects have been incorporated in the model (2). The results are drastically changed if the model is properly selected or specified. See the table 2, how the estimated results differ due to mis-specification of models. The result of dynamic model is consistent and efficient for EKC relationship.

4. Conclusion

Our findings are briefly: It makes an important difference for estimation and inference techniques in case of dynamic model rather than static model in case of panel data. The EKC relations exist for the world as a whole, and Carbon dioxide emission is no longer monotonic with per capita income. The FE estimation of dynamic model is consistent and efficient for global EKC relation. The individual EKC relation exists mostly for developed economies.

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Table 1: Results of individual EKC regression: with and without trends.

	OECD		Non-OECD	
	With trend	Without trend	With trend	Without trend
$\beta_1 > 0$ and $\beta_2 < 0$ (EKC)	20/27	18/27	14/61	18/61
$\beta_1 < 0$ and $\beta_2 > 0$ (U-shaped)	2/27	1/27	5/61	4/61

Table 2: Estimated EKC results for Static and Dynamic models.

Variables	Static Model			Dynamic Model		
	OLS	FE	RE	OLS	FE	RE
Constant	-0.2349** (-5.87)	-	-0.027 (-1.49)	-0.013 (-1.72)	-	-0.0195 (-1.75)
GDP	3.71E-4** (19.6)	4.0E-4** (23.1)	3.86E-4** (25.96)	2.14E-5** (5.74)	5.82E-5** (6.57)	2.88E-5** (5.9)
GDP ²	-5.95E-9** (-4.71)	-1.44E-8** (-16.9)	-1.4E-8** (-17.2)	-1.09E-9** (-4.64)	-2.66E-9** (-6.36)	-1.44E-9** (-5.04)
Trend	-7.8E-5** (-2.6)	-2.33E-3* (-2.17)	9.9E-5 (0.83)	-3.03E-6 (-0.54)	-1.06E-3* (-2.08)	-7.93E-7 (-0.1)
CO _{2t-1}	-	-	-	0.9785** (276.4)	0.8783** (98.6)	0.9627** (197.8)
Adjusted R ²	0.5917	0.9374	0.9348	0.9865	0.9871	0.9863
SSR	2334	346.7	360.8	75.04	69.09	73.49
Turning Point	31147	13860	13766	9836	10931	9973
F-test (A,B=A ₁ ,B)		173.7			2.52	
p-value		0			0	
Hausman χ^2			26.88			141.05
p-value			0			0

Note: Figures in parentheses are t-ratios. SSR= Sum of Squared Residuals. * and ** denote the significance level at 5% and 1%, respectively.