Economic Development, Trade and Environmental Quality: Environmental Kuznets Curve Hypothesis in a Threshold Model

Savas Alpay

Department of Economics, Bilkent University, Bilkent, 06533 Ankara, Turkey

Abstract

The proposed inverted U-type relationship between environmental degradation and per capita income (known as EKC hypothesis) has been re-examined in this paper. Previous studies on EKC hypothesis are criticised due to their assumption of the quadratic or cubic specification of pollution with respect to income per capita; it is unclear why the specific reduced-form equation employed in their estimations exists. An important contribution of our study is to overcome this problem by employing the threshold estimation method developed by Hansen (1996, 2000), which can directly and rigorously test EKC. We find no evidence for EKC hypothesis between pollution and income; increases in income reduce the load on the environment, but they do not lead to improvement in environmental quality. Most importantly, for the first time in the literature we take openness to trade as the threshold variable, rather than GDP per capita, and test for an EKC-type behavior. Our results present a weak support for the hypothesis that higher openness lead to improved environmental conditions.

Key Words: Economic Development, Environmental Kuznets Curve, Openness to Trade, Threshold Model

1 INTRODUCTION

The impact of economic growth on environment has received an increasing attention in the last part of the previous century. Starting with Grosmann and Krueger (1991), empirical tests of this relationship have been carried out in a specific format: different indicators of environmental degradation have been assumed to be an ad hoc polynomial function of income per capita, and then it has been tested whether there would be a decline in environmental degradation for income levels higher than a threshold. This search for an inverted-U type relationship between pollution and income, i.e. the Environmental Kuznets Curve hypothesis (EKC) has been at the center of discussion on the interaction between economic growth and environment.

One of the most extensive studies on EKC by Grosmann and Krueger (1995) has analyzed the impact of economic growth on a wide range of pollutants including sulfur dioxide, suspended particles, smoke, dissolved oxygen, biological oxygen demand, and fecal coliform. Global Environmental Monitoring System (GEMS) data covering almost 40 countries between 1977 and 1986 have been utilized. Their findings in most cases were supportive of EKC, but not supportive of a common threshold level for income after which a decline in environmental degradation would be observed. Besides studies by Grossmann and Krueger, Shafik and Bandyopadhyay (1992), Panayotou (1993, 1997), Shafik (1994), Selden and Song (1994), Holtz-Eakin and Selden (1995), Suri and Chapman (1998), Kaufmann et al. (1998), and Agras and Chapman (1999) have presented tests of EKC. The results were mixed both in terms of an empirical support for EKC and the threshold level. The estimated turning points or threshold levels were substantially different across these studies ranging from

$2,894 (Panayotou, 1993) to $12,346 (Kaufmann et al. 1998). This large variation may be attributable to the differences in the source of data, inclusion of additional variables into the model, the use of emission or concentration of sulfur. Usually panel data from the Global Environmental Monitoring System's (GEMS) tracking of urban air quality in different cities in the developing and developed world has been used (Grossman and Krueger 1991, 1995, Panayotou 1997, Shafik 1994, Torras and Boyce 1997); OECD data was the next most commonly used data set (Cole et al. 1997, Selden and Song 1994). Technology level (Cole et al. 1997), locational dummies (Grossman and Krueger 1991, 1995, Shafik 1994), population density (Grossman and Krueger 1991, 1995, Panayotou 1997, Selden and Song 1994), GDP/area, imports/GDP, exports/GDP (Kaufmann et al. 1998, and Suri and Chapman 1998) were among the additional variables included in the models.

The impact of trade linkages among countries have been studied only in a few studies in the context of EKC. As indicated by Rothman (1998), international trade provides the means through which domestic consumption and production can become disassociated; thus, it is perfectly possible for a country to reduce its environmental degradation by shifting all or some of its dirty industries to other countries (Diwan and Shafik 1992). Therefore, the role of trade in the analysis of EKC-type behavior between economic growth and environmental degradation should not be neglected. The downward movement in the environmental degradation, if exists, may be due to increasing volume of trade, and not due to the increasing income. Shafik and Bandyopadhyay (1992), Antweiler et al. (1998), Kaufmann et al. (1998), Suri and Chapman (1998) and Agras and Chapman (1999) consider the environment--trade linkage in EKC-type modelling. They have included the ratios of imports and exports of all manufactured goods to domestic production of manufactured goods in their model to estimate the impact of openness to trade on the environment (Antweiler et al. also included other measures such as black market premium, average tariffs, average quota and Sachs and Warner dummy). Overall, these studies show that trade variables have significant impact on the environmental quality: higher openness lead to lower emissions with the exception of Shafik and Bandyopadhyay (1992). Additionally, the existence of EKC-type behavior becomes less likely with the inclusion of trade variables into the model. However, these studies use trade as an explanatory variable, and treat only GDP per capita as the threshold (regime switching) variable.

Our goal in this paper is two-fold. Firstly, all these studies on EKC hypothesis are criticised due to their ad hoc assumption of the quadratic or cubic specification of pollution with respect to income per capita. It is unclear why the specific reduced-form equation employed in their estimations exists. Our first contribution is to overcome this problem by employing the threshold estimation method developed by Hansen (2000). This new method models threshold directly and it is easier to interpret economic relationships compared to a polynomial model. Threshold model is a simple, parsimonious non-linear model. It is easy to understand, and compared to other non-linear models its application is simple. This allows for non-linearities in conditional expectation function. It is also a sub-case of more complicated Markov Switching models.

Secondly, none of the empirical studies in this literature have tested for the explicit impact of trade on the environmental quality in a framework similar to that of economic development. As indicated by Diwan and Shafik (1992), Rothman (1998), trade makes the separation (disassociation) of domestic consumption and production decisions possible; thus, a country can secure sustainable development (in terms of its environmental quality) at the expense of unsustainable development in other countries. We believe that empirical investigation of this is quite important, and we will present an explicit test of the hypothesis that there is an inverted-U type relationship between pollution and trade liberalization; that is to say, we will test the existence of an Environmental Kuznets Curve hypothesis between pollution and more openness. This approach is distinguished from earlier studies incorporating openness to trade variables into the EKC studies as they do so by only using these variables as one of the many independent variables but not the *threshold* variable.

Our empirical analysis with the new threshold estimation does not support the existence of EKC type behavior between economic development and environmental quality. Although a threshold exists in most cases, the impact of income on the level of emissions remains positive; only, its impact becomes smaller after the threshold. Furthermore, the threshold level changes from year to year, ranging from $ 2883 to $ 10423 in case of sulfur emissions.

As regards to the role of openness to international markets, our findings present partial support for the hypothesis that higher openness lead to improved environmental conditions. A weak EKC-type behavior between openness to trade and environmental quality has been shown for sulfur emissions; however, for dissolved oxygen indicator, no evidence exists.

In section 2, we briefly present a discussion of threshold estimation technique employed in this paper. Section 3, presents our data sources, model and estimation; section 4 summarizes main findings.

2 ECONOMETRIC MODEL

We consider the following threshold regression model by Hansen (2000):

$$Y_i = \beta_1 + \beta_{21} X_i \, 1_{(Xi \leq \lambda)} + \beta_{22} X_i \, 1_{(Xi > \lambda)} + \beta_3 Z_i + \epsilon_{it}$$

where X_i is the threshold variable, the variable that causes the regime shift, Z_i represents the rest of the independent variables, λ is the threshold level, and $1_{(.)}$ is the indicator function ($1_{(.)}$ is 1 if the condition in (.) is satisfied, otherwise it is zero).

We test

$H_0 : \beta_{21} = \beta_{22}$

against a regime shift, i.e. $\beta_{21} \neq \beta_{22}$. We use a supLm test for threshold models introduced in Hansen (1996). Since the threshold is unidentified under the null we compute p-values by using a bootstrap as in Hansen (1996). First we fix the regressors under the null then we generate bootstrap dependent variable from the normal distribution $N(0, \hat{e}_i^2)$. The residuals $\hat{e}_i$'s are the LS residuals from the unrestricted model. Hansen (1996) shows that this bootstrap method yields asymptotically correct p-values. This procedure handles heterokedasticity as well.

The next step is the estimation if a threshold is found to be present in data. Estimation is done by simple least squares (LS) regression. Firstly, we transform the model into a matrix form:

$Y = X \beta_{22} + X_{\lambda} \Delta + Z \Phi + \epsilon$

where $\Delta = \beta_{21} - \beta_{22}$ and $\Phi = (\beta_1 , \beta_3')'$.

X_{λ} is a nx1 vector where the ith element is $X_i 1_{(Xi \leq \lambda)}$. X is n dimensional vector . Z is nx(k-1) matrix .

We use Hansen's LS methodology of estimating thresholds. First set

$S_n (\Phi, \Delta, \beta_{22}, \lambda) = (Y - X \beta_{22} - X_{\lambda} \Delta - Z \Phi)' (Y - X \beta_{22} - X_{\lambda} \Delta - Z \Phi)$

Then given λ, the above equation is linear in Φ, Δ, and β_{22}. We first find conditional LS estimates for these parameters given the threshold parameter λ. Then we set

$$S_n(\lambda) = S_n(\hat{\Phi}(\lambda), \hat{\Delta}(\lambda), \hat{\beta}_{22}(\lambda), \lambda)$$

Then, we determine the unique estimate of λ by minimizing

$$\hat{\lambda} = \underset{\lambda \in \Lambda}{\arg\min}\, S_n(\lambda)$$

where Λ is a compact space . Given the solution to above minimization problem, the slope estimates are computed by plugging $\hat{\lambda}$ into the values for conditional slope estimates found above, namely $\hat{\Phi}(\hat{\lambda})$, $\hat{\Delta}(\hat{\lambda})$, and $\hat{\beta}_{22}(\hat{\lambda})$. For the details of the limit law of the threshold, the slope parameters and also for the corresponding confidence intervals, see Hansen (2000). Note that we use heteroskedasticity robust confidence regions for our parameters.

3. MODEL and ESTIMATION

After introducing the new econometric technique that we will employ in our paper, we will now introduce the basic model used in EKC studies in the literature. We will refer to Grosmann and Krueger (1995) seminal study. Grosmann and Krueger estimated the following reduced-form equation:

$$Y_{it} = G_{it}\ \beta_1 + G^2_{it}\,\beta_2 + G^3_{it}\,\beta_3 + \breve{G}_{it}\,\beta_4 + \breve{G}^2_{it}\,\beta_5 + \breve{G}^3_{it}\,\beta_6 + X_{it}\,\beta_7 + \epsilon_{it}$$

where Y_{it} is a measure of water or air pollution in station i in year t, G_{it} is GDP per capita in year t in the country in which station i is located, $\breve{G}_{it}$ is the average GDP per capita over the prior three years, X_{it} is a vector of other covariates (like temperature, population density, location dummies), and ϵ_{it} is the error term.

Grosmann and Krueger (1995) used the panel data from the Global Environmental Monitoring System's (GEMS) tracking of urban air quality in different cities in the developing and developed world, and the panel data from the GEMS monitoring of water quality in river basins around the globe. Estimation has been done by using generalized least squares (GLS) method to account for any other characteristics that are not included in their list of regressors. Their analysis included fourteen different indicators of environmental degradation such as sulfur dioxide, smoke, heavy particles, the state of the oxygen regime in river basins, fecal contamination of river basins, and contamination of river basins by heavy metals such as lead, cadmium and arsenic.

They find no evidence that economic growth harms the natural habitat steadily. Rather, they determine an inverted-U type relationship between economic development (measured by GDP per capita) and environmental degradation for most of the environmental indicators they have used: economic development brings an initial phase of deterioration which is followed by a subsequent phase of improvement. Thus, their results support the Environmental Kuznets Curve hypothesis. The turning point of the inverted-U is less than \$8000 per capita in most cases. More specifically, for a country with a per capita income of \$10000, the hypothesis that further growth will generate environmental degradation can be rejected at the 5 percent significance level for many of the pollution measures they have used.

We have used the same GEMS data as in Grosmann and Krueger (1995). The panel data from the Global Environmental Monitoring System's (GEMS) tracking of urban air quality in different cities in the developing and developed world includes data collected from 42 different countries. Water quality data, especially on rivers, includes a large number of stations in 58 different countries.

Our estimated model is almost same as the one in Grossman and Krueger (1995) with the exception of the removal of ad hoc cubic specification of income terms. Incorporating the threshold technique introduced above, our estimated model is:

$$Y_i = D_i \beta_1 + G_i 1_{(Gi \le \lambda)} \beta_{21} + G_i 1_{(Gi > \lambda)} \beta_{22} + CO_i \beta_3 + R_i \beta_4 + CC_i \beta_5 + I_i \beta_6 + \epsilon_i$$

for each of the years analysed.

Y_i is a measure of water or air pollution in station i , D_i is population density, G_i is GDP per capita in the country in which station i is located; CO_i is coastal dummy;

R_i, CC_i and I_i are other location dummies indicating residential, center of city, and industry, respectively; ϵ_i is the error term. Location dummies are removed in case of pollutants where they are not relevant (such as biological oxygen demand and fecal contamination). All these variables are included in the Grosmann and Krueger (1995) model above under X_{it}. In the first stage of our estimation, we will try to identify whether a threshold exists with respect to income variable. If a significant threshold exists, then the coefficients in the above model is estimated both before and after the threshold GDP level. Given the requirements of the threshold model we are employing, we can not pool the cross section and time series data, and thus, we separate the data across years, and repeat the estimation for each year. Because of the lack of enough observations, we could not obtain threshold estimates for some of the years and for some of the pollutants used by Grosmann and Krueger (1995) (for a reliable threshold estimation, one needs at least 100 observations). Estimation results are as follows:

Table I. Threshold estimation for sulfur dioxide emissions.

Year	Beta Before Threshold, β_{21}	Beta After Threshold, β_{22}	Threshold	Number of Observations
1977	45.587 (1.233)*	2.676 (1.339)*	2883 [a]	123
1978	11.248 (1.902)	1.461 (0.349)	4422 [a]	126
1979	3.331 (1.180)	-0.084 (0.560)	10423 [b]	127
1982	10.261 (2.154)	1.20 (0.483)	4591 [a]	142
1984	15.675 (3.927)	0.390 (0.551)	3526 [b]	145

* Standard errors in parenthesis.

[a] Significant at 0.001.

[b] Significant at 0.01.

As clearly seen in Table I, a significant threshold exists for all years used in the estimation; however, there is hardly any evidence for EKC-type behavior. With the exception of 1979, the effect of GDP on pollution level is positive both before and after the threshold level. Although, the positive impact shows significant decline, there is no reversal in the impact of GDP on pollution level.

We have also applied threshold estimation for some other pollutants for which Grossmann and Krueger (1995) identified EKC type behavior. In case of biological oxygen demand (BOD), no significant threshold exists for the years 1982—1985 (for other years number of observations were not adequate). Another indicator of water quality is dissolved oxygen. We could test for threshold for three different years. In 1981 and 1982 there exist a significant threshold; however, only in 1982 we get barely an EKC-type behavior (in 1981, coefficients of income term before and after the threshold were both positive). For 1985, no threshold was present. Finally, we have also managed to check the existence of EKC for the fecal coliform. For 1981, 1983, and 1985 we were not able to get a significant threshold. For 1980, we identified a significant threshold, but no EKC-type behavior. Only for 1982, there was a significant threshold and EKC-type behavior.

3.1 EKC in Openness to Trade?

An interesting critique of EKC hypothesis is that it is not the economic development that brings a decline in the pollution level after a threshold but the openness to international markets. As suggested in Rothman (1998), one possible consequence of international trade is the change in the composition of the production. In particular, with trade polluting industries may be moving to less developed countries from more developed ones. If this is the case, then environmental degradation is being displaced from one country to the other, rather than getting reduced, and maybe increasing on the global scale. Moreover, this way of reducing environmental degradation will obviously not be available to the latest-developing countries (Ekins 1997).

We would like to apply the threshold estimation technique to this issue as well. Towards that end, we have obtained openness-to-trade indices for the countries included in Grossmann and Krueger (1995) study. This index is defined as the ratio of sum of exports and imports to GDP; it is also known as trade intensity and used in earlier studies as well (see, for example Antweiler et al. 1998). Then, we have estimated the following model with the threshold technique: (for each of the years analysed)

$$Y_i = D_i\ \beta_1 + G_i\,\beta_2 + CO_i\,\beta_3 + R_i\,\beta_4 + CC_i\,\beta_5 + I_i\,\beta_6 + OP_i\,1_{(OPi \le \lambda)}\,\beta_{71} +$$

$$OP_i\,1_{(OPi > \lambda)}\,\beta_{72} + \epsilon_i$$

where Y_i , D_i , G_i , CO_i , R_i , CC_i , and I_i are as defined above; OP_i is the openness index in the country in which station i is located. Note that there is an important distinction between this equation and the previous equation we have estimated other than the inclusion of openness index in the former: the threshold variable is now changed to openness index from GDP per capita. If we can detect a significant reversal in the sign of openness index then one can talk about an EKC hypothesis in the level of openness to trade as opposed to per capita income. We have tested for the threshold in openness for sulfur dioxide emissions and dissolved oxygen only due to data limitations. In the case of dissolved oxygen, we have identified a significant threshold for openness index for 1979 and 1980; the threshold for 1981 and 1982 was not statistically significant; however, in all cases, no evidence exists for the EKC type behavior between environmental quality and openness to international markets. Estimation results for sulfur emissions are shown in Table II below:

Table II. Threshold estimation for sulfur dioxide emissions. (Threshold for Openness)

Year	Beta before Threshold, β_{71}	Beta after Threshold, β_{72}	Threshold	Number of Observations
1977	0.01 (0.006)*	-0.077 (0.011)*	28.42 [b]	118
1981	0.137 (0.023)	-0.0015 (0.005)	24.21 [a]	132
1983	0.036 (0.012)	-0.005 (0.006)	10.76 [c]	110
1984	0.561 (0.111)	-0.0007 (0.007)	19.5 [b]	112
1985	0.281 (0.070)	-0.007 (0.006)	16.43 [b]	97

* Standard errors in parenthesis.
[a] Significant at 0.001.
[b] Significant at 0.01.
[c] Significant at 0.05.

As seen above in Table II, there is somewhat strong evidence for the existence of a threshold in openness index. We also have a weak support for EKC hypothesis in openness, that is to say, upto a certain openness level the impact of higher trade liberalization on the environment is negative, and after that level, higher liberalization results in lower environmental degradation; however, note that coefficients after the threshold are not significant with the exception of year 1977 due to relatively high standard errors.

4. CONCLUSIONS

Understanding the impact of economic development and trade liberalization policies on the environmental quality is becoming increasingly important as general environmental concerns are making their way into main public policy agenda. This is especially important nowadays as the environmental consequences of human activities exceeded certain limits and can not be considered as negligible. On the other hand, economic development and trade liberalization are among the top priority policies in most of the developing countries. Thus, it is worth studying environmental consequences of economic development and more openness to trade.

Interactions between economic development and environmental degradation have been subject to a good deal of studies. Although no firm conclusions have been achieved unequivocally regarding the impact of higher economic development on the level of different pollutants, an inverted U-type relationship, known as Environmental Kuznets Curve hypothesis (EKC), has been commonly proposed, especially for sulfur dioxide emissions. Empirical studies indicating evidences for EKC have been subject to an important modelling criticism: the ad hoc choice of a second or third order polynomial specification of the pollution with respect to income has no sound theoretical background (this was inevitable as the researchers would like to test the existence of a threshold in income). Our first contribution in this paper is the removal of this ad hoc modelling. We employ a recently developed econometric technique by Hansen (2000) for the estimation of thresholds in the data. The threshold econometric model, a sub-case of more complicated Markov Switching models, is simple to apply, easy to understand. It is essentially running two separate linear regressions before and after the threshold, if a threshold exists in the data.

As a general conclusion, our estimation results do not support the existence of EKC type behavior between economic development and environmental quality. Although we have used the same data set as in Grosmann and Krueger (1995), our findings are not supportive of theirs: a threshold exists in most cases, but the impact of income on the level of emissions does not show a reversal in sign; at best, the positive impact becomes smaller. Increases in income reduce the load on the environment, but they do not lead to improvement in environmental quality.

A neglected issue in this literature is the role of trade liberalization policies in the framework of EKC hypothesis. International trade makes the separation of consumption and production activities possible, and thus, pollution intensive industries can move across countries. Then, one may talk about two possible sources for an improvement in environmental conditions: higher openness to trade and/or higher income. Our second contribution is the explicit test of the hypothesis that higher openness lead to improved environmental conditions, in other words, a test of EKC behavior between openness to trade and environmental quality; this has not been shown before. Our findings present some weak support for this hypothesis for sulfur emissions; however, for dissolved oxygen indicator, no evidence exists. Thus, we may suggest that our estimations present a weak support for the hypothesis that sustainable development (as regards to environmental quality) in some countries is being achieved at the expense of unsustainable development in some others. Such a trend, if exists, can not be sustained globally. We suggest the investigation of this interaction between openness and environmental quality more extensively by using more up to date and better data sets. Our future work will try to address whether improvement in environmental conditions is due to economic development (higher income), or openness to international markets or both.

REFERENCES

Agras, J. and Chapman, D., 1999, A Dynamic Approach to the Environmental Kuznets Curve Hypothesis, *Ecol. Econ.* 28, 267-277.

Antweiler, W., Copeland, B.R., and Taylor, M.S., 1998, "Is Free Trade Good for the Environment" *NBER Working Paper Series*, No: 6707, NBER, Cambridge MA.

Cole M.A., A.J. Rayner, and J.M. Bates, 1997, The Environmental Kuznets Curve: An Empirical Analysis, *Environment and Development Economics* 2(4), 401-416.

Diwan, I., and Shafik, N., 1992, "Investment, Technology and the Global Environment: Towards International Agreement in a World of Disparities", in Low, P. (Ed.), International Trade and the Environment, World Bank, Washington, DC.

Ekins, P., 1997, The Kuznets Curve for the Environment and Economic Growth: Examining the Evidence, *Environment and Planning A* 29, 805-830.

Grossman, G.M. and Krueger, A.B., 1991, Environmental Impacts of North American Free Trade Agreement, *NBER Working Paper Series*, No: 3914.

Grossman, G.M., and A.B. Krueger, 1995, "Economic Growth and the Environment", *Quarterly Journal of Economics*, 110, 353-77.

Hansen, B.E. (1996), "Inference when a nuisance parameter is not identified under the null hypotheses", *Econometrica*, 64, 413-430.

Hansen, B.E. (2000), "Sample Splitting and Threshold Estimation" , *Econometrica*, 68, 575-603.

Holtz-Eakin, D.and T.M. Selden (1995), "Stoking the Fires? CO_2 Emissions and Economic Growth", *Journal of Public Economics* 57, 85-101.

Kaufmann, R.K., Davidsdottir B., Garnham S., Pauly P., 1998, “The Determinants of Atmospheric SO_2 concentrations: reconsidering the environmental Kuznets curve”, *Ecological Economics*, 25, 209-230.

Panayotou T., 1993, “Empirical Tests and Policy Analysis of Environmental Degradation at Different Stages of Economic Development”, Working Paper WP238, Technology and Employment Programme, International Labour Office, Geneva.

Panayotou T., 1997, Demystifying The Environmental Kuznets Curve: Turning A Black Box Into A Policy Tool , *Environment and Development Econ.* 2(4), 465-484.

Rothman, D.S., 1998, “Environmental Kuznets Curves-Real Progress or Passing the Buck? A case for Consumption-Based Approaches”, *Ecological Economics* 25, 177-194.

Sachs, J.D., and Warner, A., 1995, “Economic Reform and the Process of Global Integration”, *Brookings Papers on Economic Activity*, 1, 1-119.

Selden, T.M. and D. Song, 1994, “Environmental Quality and Development: Is There a Kuznets Curve for Air Pollution Emissions?”, *Journal of Environmental Economics and Management* , 27, 147-162.

Shafik and Bandyopadhyay (1992), “Economic Growth and Environmental Quality: Time Series and Cross-Country Evidence”, World Bank Policy Research Working Paper, WPS 904, Washington DC: World Bank.

Shafik N., 1994, “Economic Development and Environmental Quality: An Econometric Analysis”, *Oxford Economic Papers*, 46, 757-773.

Suri, V., Chapman, D., 1998, Economic Growth, Trade and Energy: Implications for the Environmental Kuznets Curve, *Ecol. Econ*. 25, 195-208.

Torras M. and J. K. Boyce, 1996, Income, inequality, and pollution: a reassessment of the environmental Kuznets curve, *Ecological Economics*, special issue on EKC.