IJED : Vol. 13, No. 2, July-December 2016

GROWTH AND POLLUTION– TESTING THE ENVIRONMENTAL KUZNETS CURVE FOR A LARGE PANEL OF COUNTRIES

Semih Emre Cekin*

Abstract: *We test the validity of the Environmental Kuznets Curve (EKC) hypothesis using a large panel of countries that spans close to 40 years of data. Estimating the link between* CO_2 *emissions and per-capita incomes using Panel Data methodologies, our results show that there is a non-linear relationship between income levels and pollution levels. Our results further show that turning points for the estimated EKC are higher than what was reported in previous work. Our findings support the idea that the implementation of efficient public policies is inevitable, and that we cannot wait for the EKC to "take effect" to solve the problem of climate change.*

KeyWords: *Environmental Kuznets Curve,* CO_2 *Emissions, Panel Data*

JELCodes: *C33, Q53, Q56*

I. INTRODUCTION

For decadeseconomists have sought to understand the relationships between economically relevant variables and how they interact over time. Simon Kuznets' seminal analysis (1955) on the relation between income levels and inequality was dubbed the "Kuznets Curve". According to this acclaimed hypothesis, countries suffer high income inequality levels over the initial stage of development and eventually experience a decrease in income equality.

The understanding that the persistent growth of countries with large populations does not come without side effects sparked the interest of some economists to analyze relationships between income levels and economic degradation.

In what was subsequently dubbed the "Environmental Kuznets Curve" (EKC), Grossman and Krueger (1993) analyzed the relationship between economic development (using per capita GDP) and environmental quality by focusing on the level of urban air pollution to get estimates on the turning points for the concentration of Suspended Particular Matter (SPM) and Sulfur Dioxide (SO_2) in the atmosphere. Their findings suggest that the EKC has a turning point at $4000-$5000, i.e. environmental degradation decreases after these income levels.

* College of Business, Governors State University, University Park, IL 60484

By employing random and fixed effects models, Seldon and Song (1994) suggested that for the case of the air pollutants NO and $SO_{2,}$ the turning point of the EKC is above \$8000.

In their analysis, Copeland and Taylor (1994) analyzed the EKC with a different approach. They suggested that free trade has three types of effects on countries: the technology effect, scale effect and composition effect. The first effect suggests thatfree trade induces people's understanding of the environment and people require management and controlpolicies and thus, increases in income increase the demand for environmental protection.The second effect can lead to the deterioration of the environment since free trade can lead to increases in the volume of world trade, and each country increases its output level. The third effect puts forward the "pollution haven" hypothesis, namely the idea that developing countries tend to attract pollution-intensive industries, and developed countries are likely to avoid such industries to attract foreign direct investment. A possible decrease in pollution levels depends on the relative size of the technology and composition effects.

Since then, a number of researchers – including Kaufmann *et al.* (1998), List and Gallet (1999), Stern and Common (2001) , Huang, Lee and Wu (2008) - have analyzed the relationship between environmental degradation and economic growth and found different answers on the turning points for the EKC. In a recent work, Apergis (2016) challenges existing methodologies and finds that the EKC hypothesis is valid for some countries, but not for others.

This paper attempts to contribute to the existing literature by considering a large(r) number of countries and a large time span. We believe that this allows for a thorough understanding of how robust the relationship is over a long period of time and over a variety of countries that exhibit different stages of development.

I. EMPIRICAL ANALYSIS

The EKC is estimated with a random effects model and with a pooled OLS model: the log of per capita CO_2 emissions (*l_co2*) is regressed on the log of per capita GDP (*l_gdppc*), its squared, the Birth Rate[1] (*Birth_rate*), Life expectancy (*Life_exp*), measure of openness (*Openc*), its squared and a regional dummy[2]. The regression to be estimated takes the following form:

$$(\text{l\_co2})_{it} = \beta_0 + \beta_1(\text{l\_gdppc})_{it} + \beta_2(\text{l\_gdppc})_{it}^{\ 2} + \beta_3(\text{Birth\_rate})_{it} + \beta_4(\text{Life\_exp.})_{it} + \beta_5\,(\text{Openc})_{it} + \beta_6(\text{Openc})_{it}^{\ 2} + \beta_7(\text{RegionDummy})_i + \alpha_i + \varepsilon_{it} \quad (1)$$

The squared terms are added to analyze an inverted shape for the EKC. To get a "reasonable" shape for the EKC, one should have $\beta_1 > 0$ and $\beta_2 < 0$. The variables Life Expectancy and Birth Rate are included to control for the level of development of a country. To understand how trade openness relates to CO_2 emissions and whether it also exhibits an inverted U-shape, trade openness and its square are added as independent variables. The turning point for the EKC is calculated as $\tau = \exp(-\beta_1/2\beta_2)$.

II. DATA

The data consists of an annual panel data set that includes 111 countries, spans the period from 1971 to 2008 and includes the variables CO_2 emissions per capita, GDP per capita, Real GDP per capita, Export to GDP ratio, Life expectancy and Birth rates. The major source of data for the series is the World Development Indicators (WDI) of the World Bank and the International Energy Agency (IEA). The series on openness were taken from the Penn World Tables for the aforementioned period. The choice of the range and length of the data was based on availability of data and also to exclude the effects of the Great Recession and the subsequent increase in oil prices. Table I provides summary statistics for the data set used.

III. RESULTS

Quadratic Representation

Table II summarizes the regression results for equation (1), i.e. the quadratic specification, with the two methods that we utilized.

According to both models, the estimation coefficients on per capita GDP and its squared both exhibit the expected signs. Also, the EKC is suggested to have an inverted U-shape and a turning point at $23,573 and $19,079 respectively. These numbers stay in contrast to previous research, which suggest turning points at much lower thresholds. Possible reasons for this contrast lie in the fact that in this work many more countries are considered than in previous work. The pooled OLS model suggests that countries with higher birth rates and African and Asian countries exhibit lower per-capita CO_2 emissions; developed countries and Middle Eastern countries on the other hand exhibit higher emissions. The coefficient that captures the effect of emerging economies is not statistically significant. Finally, the results suggest that openness of countries has a non-linear effect on pollution: the coefficients suggest that as countries become more open, they tend to emit more CO_2.

The results of the Random Effects model exhibit similar signs and magnitudes in comparison to the pooled OLS model. Whereas countries with higher birth rates, African countries and Asian countries exhibit lower CO_2 emission levels, South American, Middle Eastern and Developed countries exhibit higher emission levels. Also, openness has a non-linear effect on emissions, similar to the pooled OLS model.

To explore the possibility of a cubic specification, a model in which cubed per-capita GDP also enters the equation is presented next.

Cubic Representation

Equation (1) that was estimated above has a quadratic form, which implies that the relationship between CO_2 emissions and per-capita GDP can be represented by a parabola. Another shape for the EKC that one can explore is a cubic representation, in which the relationship between CO_2 emissions and per-capita GDP has an "N-shape". In this cubic representation, if $\beta_1 > 0$, $\beta_2 > 0$ and $\beta_3 < 0$, the implication is that at low levels CO_2 emissions are low, then increase with higher income levels and then decrease at very high income levels. The equation for the cubic representation takes the following form:

$$(\text{l\_co2})_{it} = \beta_0 + \beta_1(\text{l\_gdppc})_{it} + \beta_2(\text{l\_gdppc})_{it}^2 + \beta_2(\text{l\_gdppc})_{it}^3 + \beta_4(\text{Birth\_rate})_{it} + \beta_5(\text{Life\_exp.})_{it} + \beta_6(\text{Openc})_{it} + \beta_7(\text{Openc})_{it}^2 + \beta_8(\text{RegionDummy})_i + \alpha_i + \varepsilon_{it} \quad (2)$$

As with our quadratic representation, we present both the pooled OLS model and the Random-effects model in Table II.

Most coefficient estimates of the cubic representation are statistically significant and imply that an N-shaped EKC is also an appropriate representation of the relationship between income levels and CO_2emission levels. And as described above, since $\beta_1 > 0$, $\beta_2 > 0$ and $\beta_3 < 0$, the estimated form of the EKC is N-shaped. Also, the specification exhibits lower turning points in contrast to the quadratic representation and implies the same qualitative signs for the remaining coefficients: whereas countries with higher birth rates and African countries exhibit lower emission levels of CO_2, South American, Middle Eastern, Developed and Emerging economies have higher per-capita emission levels. Although one would expect the Developed country dummy to have a negative sign, it is strongly positive and statistically significant. Although this seems to be contradictory to our finding of the existence of a EKC, it can be explained by the fact that developed countries have overall larger per-capita emission numbers in our samples than developing or emerging economies. When we analyze the idiosyncratic movement of the relationship between emissions and income levels however, the non-linear shape of the EKC exists for developed countries as well.

Overall, the results provide evidence for the existence of a so-called Environmental Kuznets curve. There is also mixed evidence regarding the relationship between various development measures and CO_2 emissions.

IV. CONCLUSION

This paper addressed the topic of EKC by considering an annual data set over a large period of time and covering a wide range of countries. The findings suggest that there exist a significant relationship between income levels and environmental degradation measured as per capita emissions of CO_2 - one of the main Greenhouse gases. Analyzing whether this relationship is non-linear, we found evidence that both a quadratic as well as a cubic representation are reasonable specifications.

The results further suggest that the variables Birth rate and openness of a country are significantly related to the aforementioned measure of pollution. The coefficient on Life expectancy is not significantly related to CO_2emissions. The dummies for the different regions considered suggest that for developed countries there is a significant positive relation between economic growth and CO_2 emissions whereas for African countries, this relation is negative. Turning points, i.e. the points at which emission levels reach a peak and decrease thereafter, vary between the models and specifications we consider, and are higher than some of the numbers found in the literature so far. Whereas our estimate of the turning point is more comparable to e.g. Cole (1997), Apergis and Ozturk (2015) estimate the turning point at the \$9000-\$12000 range for a set of 14 Asian economies for 1990-2011. The difference between our estimate and the previous literature can partly be explained by the fact that we analyze a significantly higher number of countries and a longer time period.

Our results carry relevance for the climate debate of the past years; CO_2 is one of the main Greenhouse gases, and the reduction of emissions is presented as one of the main goals in many multilateral climate meetings. According to our results, the turning point ranges from a low of about $16,341 to a high of $23,573. One implication is that many countries that are classified as extremely poor will still have to go through the second stage of development which comes with high pollution. Also, it will take many years, if not decades, until $16,341 of per-capita GDP is reached for many other countries. It is thus relevant that political and institutional changes are implemented without waiting for many countries to go through the EKC cycle.

References

Apergis, N. (2016), Environmental Kuznets curves: New evidence on both panel and country-level CO 2 emissions. *Energy Economics*, *54*, 263-271.

Apergis, N., & Ozturk, I. (2015), Testing environmental Kuznets curve hypothesis in Asian countries. *Ecological Indicators*, *52*, 16-22.

Cole, M. A., Rayner, A. J., & Bates, J. M. (1997), The environmental Kuznets curve: an empirical analysis. *Environment and development economics*, *2*(04), 401-416.

Copeland B.R. and M.S. Taylor (1994), North-South trade and the environment. *Quarterly Journal of Economics* 109(3), 755-787.

Grossman G.M. and A.B. Krueger (1993), Environmental impacts of the North American Free Trade Agreement, in Peter Garber (Ed.), The U.S.-Mexico Free Trade Agreement. MIT Press, Cambridge.

Huang W.M, G.W.M. Lee and C.C. Wu (2008), GHG emissions, GDP growth and the Kyoto protocol: a revisit of Environmental Kuznets curve hypothesis, *Energy Policy* 36, 239–47.

List, J. A. and Gallet, C. A., (1999), The environmental Kuznets curve: does one size fit all? Ecological Economics, 31: 409-424.

Kaufmann, R. K., Davidsdottir, B., Garnham, S., and Pauly, P., (1997), The determinants of atmospheric SO2 concentrations: reconsidering the environmental Kuznets curve, Ecological Economics, 25: 209-220.

Kuznets S. (1955), Economic Growth and income inequality, *American Economic Review* 45(1), 1-28.

Seldon 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.

Stern, D. I. and Common, M. S., (2001), Is there an environmental Kuznets curve for sulfur? Journal of Environmental Economics and Environmental Management, 41: 162-178.

APPENDIX

Table I
Summary Statistics, using all observations 1971-2008

Variable	*Mean*	*Median*	*Minimum*	*Maximum*
co2	4.41715	1.74378	0.0112416	79.9433
Birth_rate	28.8929	28.5245	6.90000	55.9700
ExpoGDP	34.6055	28.1255	0.182969	234.352
Life_exp	64.2090	67.3217	26.8187	82.5876
gdppc	6218.14	1588.29	57.6420	118841.

Variable	*Std. Dev.*	*C.V.*	*Skewness*	*Ex. kurtosis*
co2	6.36542	1.44107	3.53313	22.8274
Birth_rate	12.9715	0.448954	0.119416	-1.28855
Openc	26.4443	0.764164	2.70688	11.6737
Life_exp	11.3214	0.176321	-0.511653	-0.850530
gdppc	10592.4	1.70347	3.02907	13.1986

Table II
Estimation Results for Cross sectional and Random Effects Model

	Quadratic Specification		*Cubic Specification*	
	Cross-Section	*Random Effects*	*Cross-Section*	*Random Effects*
Constant	-12.95***	-5.638***	-9.111***	-3.851***
	(0. 310)	(0.276)	(0.968)	(0.571)
GDP per capita	2.951***	1.268	1.506***	0.467**
	(0.072)	(0.046)	(0.399)	(0.223)
(GDP per capita)^2	-0.147***	-0.065***	0.026*	0.041**
	(0.004)	(0.003)	(0.011)	(0.018)
(GDP per capita)^3	-	-	-0.007***	-0.004***
			(0.002)	(0.001
Birth Rate	-0.005**	-0.007***	-0.009***	-0.006***
	(0.002)	(0.001)	(0.002)	(0.001)
Life Expectancy	-0.003	0.002	-0.005**	0.0001
	(0.003)	(-0.127)	(0.0025)	(0.001)
Openness	0.003***	0.003***	0.011***	0.007***
	(0.0005)	(0.0005)	(0.001)	(0.0008)
(Openness)^2	-3.78e^{-06}**	-2.594***	-4.31e^{-05}**	-2.48e^{-05}***
	(1.70e^{-06})	(4.38e^{-06})	(6.09e^{-06})	(4.39e^{-05})
Africa Dummy	-0.601***	-0.702***	-0.343***	-0.701***
	(0.034)	(0.177)	(0.042)	(0.178)
S. America Dummy	-0.053	0.456**	0.243***	0.461**
	(0.035)	(0.186)	(0.039)	(0.187)
Asia Dummy	-0.102**	-0.159	0.118***	-0.128
	(0.040)	(0.19)	(0.041)	(0.192)

contd. table

	Quadratic Specification		*Cubic Specification*	
	Cross-Section	*Random Effects*	*Cross-Section*	*Random Effects*
Emerging Dummy	0.062	0.359*	0.147***	0.386*
	(0.046)	(0.208)	(0.044)	(0.210)
Developed Dummy	0.625***	1.619***	0.807***	1.601***
	(0.041)	(0.163)	(0.041)	(0.164)
Middle East Dummy	0.686***	0.842***	0.668***	0.820***
	(0.043)	(0.195)	(0.043)	(0.197)
Turning Point	$23,573	$19,079	$20,594	$16,341

*** Denotes significance at the 1% level
** Denotes significance at the 5% level
* Denotes significance at the 10% level

Countries considered

Algeria, Argentina, Australia, Austria, Bangladesh Barbados, Belgium, Benin, Bolivia, Botswana, Brazil, Burkina Faso, Burundi, Cameroon, Canada, Central African Republic, Chad, Chile, China, Colombia, Congo, Dem. Rep., Congo, Rep., Costa Rica, Cote d'Ivoire, Cuba, Cyprus, Denmark, Dominican Republic, Ecuador, Egypt, Arab Rep., El Salvador, Fiji, Finland, France, Gabon, Gambia, Germany, Ghana, Greece, Guatemala, Guinea-Bissau, Guyana, Honduras, Hong Kong SAR, Hungary, Iceland, India, Indonesia, Iran, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kenya, Korea, Rep., Kuwait, Luxembourg, Madagascar, Malawi, Malaysia, Mali, Malta, Mauritania, Mauritius, Mexico, Morocco, Myanmar, Nepal, Netherlands, New Zealand, Nicaragua, Niger, Nigeria, Norway, Oman, Pakistan, Papua New Guinea, Paraguay, Peru, Philippines, Portugal, Rwanda, Saudi Arabia, Senegal, Sierra Leone, Singapore, South Africa, Spain, Sri Lanka, Sudan, Suriname, Swaziland, Sweden, Switzerland, Syrian Arab Republic, Thailand, Togo, Tonga, Trinidad and Tobago, Tunisia, Turkey, Uganda, United Arab Emirates, United Kingdom, United States, Uruguay, Vanuatu, Venezuela, Zambia, Zimbabwe.

Notes

1. Which is the fertility rate of an average woman (given as births per thousand).
2. The regions considered are Africa, South/Latin America, Asia, Emerging, Developed (categorized according to World Bank classifications) and Middle Eastern Countries.