Is There an Environmental Kuznets Curve: Empirical Evidence in a Cross-section Country Data

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Abstract: This paper tests the effect of gross domestic product (GDP) per capita on pollution, measured by carbon dioxide (CO_2) emissions per capita. World Bank 1992 study claims that pollution rises with income, but at a slower and slower speed and eventually declines. Using Ordinary Least Squares estimation procedure, we find a quadratic relationship ("inverted U-hypothesis") between CO_2 emissions per capita and GDP per capita in a cross-section of world countries with data from 2000, thus proving the existence of Environmental Kuznets Curve. The result is important because it may have important policy implications.

Keywords: Environmental Kuznets curve, pollution, inverted U-hypothesis

JEL Classification number: Q2

I. Introduction and literature overview

In this paper, we find econometric evidence that pollution rises with country per capita income but at a slower and slower pace. Using Ordinary Least Squares estimation procedure, we find a quadratic relationship ("inverted U-hypothesis") between CO_2 emissions per capita and GDP per capita in a cross-section of world countries with data from 2000, thus proving the existence of Environmental Kuznets Curve. The result is important because it may have important policy implications.

The possible reasons for the existence of the environmental Kuznets curve (EKC) are that in poor countries most of the output is produced in the agricultural sector. In middle-income countries, there is some industry present. Thus, the higher the level of production, the more pollution there will be. As the country grows, it will tend to switch to a cleaner technology, or cut back on polluting sectors to cleaner ones, such as services.

The EKC is a hypothesized relationship between various indicators of environmental degradation and income per capita. In the early stages of economic growth, pollution increases, but beyond some level of income per capita the trend reverses. Thus, at high-income levels economic growth leads to environmental improvement. This implies that the environmental impact indicator is an inverted U-shaped function of income per capita. An example of an estimated EKC is shown in Figure 1:

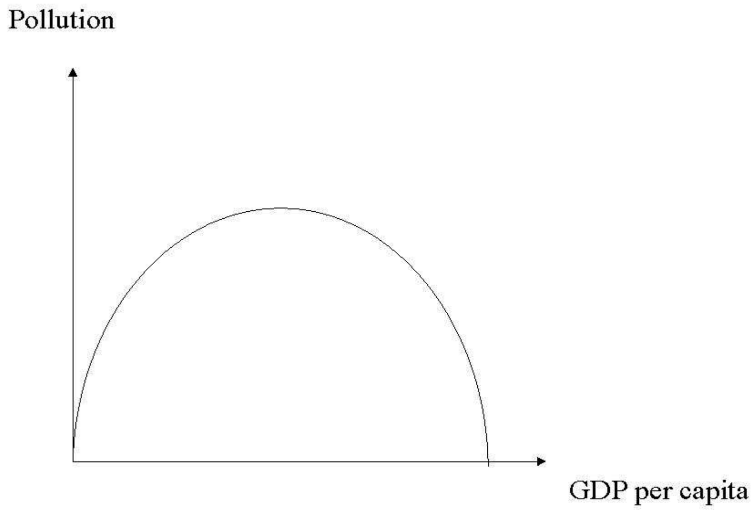

Figure 1: Inverted-U (quadratic) curve

. The EKC is named for Kuznets (1955) who hypothesized that income inequality first rises and then falls as economic development proceeds. In his paper he regressed Gini coefficient (a variable describing income inequality) on GDP per capita and its square term, and found them both significant in explaining inequality.

The EKC theme was popularized by the World Bank's *World Development Report 1992*, which argued that

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…[t]he view that greater economic activity inevitably hurts the environment is based on static assumptions about technology, tastes and environmental investments" (p.38), and that "As incomes rise, the demand for improvements in environmental quality will increase, as will the resources available for investment.(p 39)

So in a sense, clean air may be viewed as a luxurious good: when income rises above certain level, the demand for it rises. Thus, the pollution issue has important policy implications because of the existence of a certain threshold above which pollution starts declining. Wooldridge (2003) also notes that using more recent data can add constructively to a debate, which is the existence of EKC in our case.

The structure of the paper is the following: Part 2 describes the data and estimation procedure, Part 3 states the results, Part 4 discusses some caveats and possible critiques, and Part 5 concludes.

II. Data description and estimation procedure

Cross-sectional analysis using OLS was performed, since we want to estimate the effect of GDP per capita on pollution, measured by CO_2 emissions per capita. As non-linearities in the relationship were expected (see Figure 2), polynomials of GDP per capita were included as well.

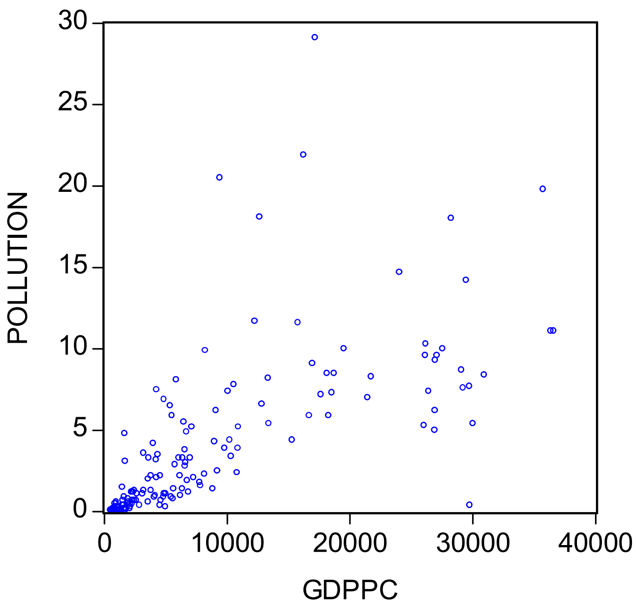

Figure 2: Scatterplot of CO_2 emissions per capita vs. GDPPC

That lead to the following final specification:

$$POLLUTION_i = \beta_0 + \beta_1 GDPPC_i + \beta_2 GDPPC_i^2 + u_i$$

where POLLUTION is CO_2 emissions in metric tons emissions per capita in 2000 and GDPPC is Purchasing Power Parity (PPP) GDP per capita in 2000, taken from UNDP Human Development Report

In order to make it easy to interpret coefficients, we multiplied pollution by 10^6. This corresponds to transforming the variable from measuring CO_2 emissions per capita.in metric tons to metric grams. In addition, when we initially estimated the regression by OLS, we performed White's test, which detected the presence of heteroscedasticity. To cure this problem, we re-estimated the equation, using White Heteroscedasticity-Consistent Standard Errors and Covariances. Adjusting for heteroskedasticity in the estimation significantly improved the goodness of fit of the regression.

When estimating the regression, the US was excluded, being an outlier. This is so because it is much bigger than other countries in terms of GDPPC and that constitutes a good reason to estimate the model without it. OLS Regression with US was estimated as well but the estimated curve did not have a downward sloping part. In other words, we do not have countries with high GDPPC and low pollution, a finding that does not match the data. Thus dropping the US from the regression made the OLS estimates change by a large amount. Without the outlier, we have countries with high GDP per capita and low pollution, which is what we see in the data.

III. Results

The RHS variables explain approximately 52.5% of the variation in pollution. The constant is negative. In the absence of any income, pollution will be negative. The latter does not make much economic sense, though. This is not a problem because the constant was included to make the unobserved factor zero in expectations.

GDPPC and its square term are both individually and jointly significant at 1 % level of significance. The marginal effect of GDPPC on pollution is the following:

$$\frac{\partial Pollution}{\partial GDPPC} = 796.6726 - 2 * 0.014383 * GDPPC$$

Thus,

$$GDPPC^* = \frac{796.6726}{0.028766} = 27694.93$$

There are 12 countries in our sample that have higher than the cut-off GDPPC and low pollution.

IV. Caveats and Possible Critiques

Among the possible critiques on econometric grounds are the issues of simultaneity, endogeneity, functional form specifications and a second group related to possible problems with data. In this section of the paper, we discuss them one by one:

Simultaneity: Some scholars propose in their studies that simultaneity might be an issue: in addition to the fact that pollution decreases with income, high income feeds back into lowering pollution. The author thinks that policy measures are mostly exogenously determined since pollution is an externality. Firms are not willing to incur higher production costs, because that drives down their profits. Eventually they do so because of government regulations or international arrangements, e.g. Kyoto Protocol.

Endogeneity: Technology may be correlated with income. However, since we use aggregate data, the assumption is that on average, all sectoral effects cancel each other. After all, technological change may be both good for the environment, such as pollution abatement technology.

Functional forms: We also tested for a linear dependence as well as a cubic one for a monotonic and N-shaped relation, but the result was a worse fit than the quadratic specification. Another model, log-log one, was discarded as well because the very transformation of the variables: that is, taking their natural logs, made their distributions look clearer. The estimated curve, however, was much more humped and gave a satiation point that was too low and not met in reality – it proposed that too many countries were already in the downward-sloping segment of the curve.

The shortcoming of the final specification –quadratic relationship of GDPPC with pollution - is that we eliminate all country-specific effects by assuming an identical relationship between pollution and income. Further extension of our study could be to do a time series on individual countries or panel regression.

For *data problems,* there are two major possible sources:

- <u>Measurement error:</u> Typically pollution is measured at location with pollution problems and where action is being undertaken. We use estimates rather than real data. This will make it pro-EKC. On the other hand, carbon dioxide emissions are not solely due to pollution, but also when exhaling, when organic substances disintegrate, etc. There is also lack of data on many pollutants and no comprehensive indicator of environmental quality.

In addition, most of the available data is from developed countries. A large contribution to global pollution, however, comes from many developing countries for which data is not available. Hence, the sample selection made in cross-country studies may underestimate the level of pollution. <u>So the direction of the asymptotic bias could be in any direction.</u>

- <u>Missing data</u>: some poor countries lack data on pollution. We cannot do anything about this, since it is completely at random. Our estimates will be less precise due to the reduced sample, but we do not introduce any bias (Wooldridge, 2003) There is no sample selection because we do not set any threshold for GDPPC.

Despite all the limitations discussed, however, the significance of the obtained results is unquestionable.

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V. Conclusion and further research

The evidence presented in this paper showed that EKC exists in a cross-section of countries in 2000. The statistical analysis, however, was not very robust. The research challenge now is to revisit some of the issues addressed earlier in the EKC literature using panel data and time series statistics. Rigorous answers to these questions are central to the debate on globalization and environmental policies.

Some scope for further research will be to build on the basic EKC model by introducing additional explanatory variables intended to model underlying or proximate factors such as “political freedom” or output structure or trade (as reviewed by Stern (2003)).

References

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Appendix

Regression Output

Dependent Variable: POLLUTION*1000000				
Method: Least Squares				
Sample: 1 162 IF GDPPC<50000				
Included observations: 155				
White Heteroskedasticity-Consistent Standard Errors & Covariance				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-663473.6	401403.5	-1.652884	0.1004
GDPPC	796.6726	149.4349	5.331237	0.0000
GDPPC^2	-0.014383	0.005019	-2.865885	0.0047
R-squared	0.524968	Mean dependent variation		4100645.
Adjusted R-squared	0.518717	S.D. dependent variation		4941955.
S.E. of regression	3428458.	Akaike info criterion		32.95228
Sum squared residuals	1.79E+15	Schwarz criterion		33.01119
Log likelihood	-2550.802	F-statistic		83.98916
Durbin-Watson statistic	2.094508	Prob.(F-statistic)		0.000000

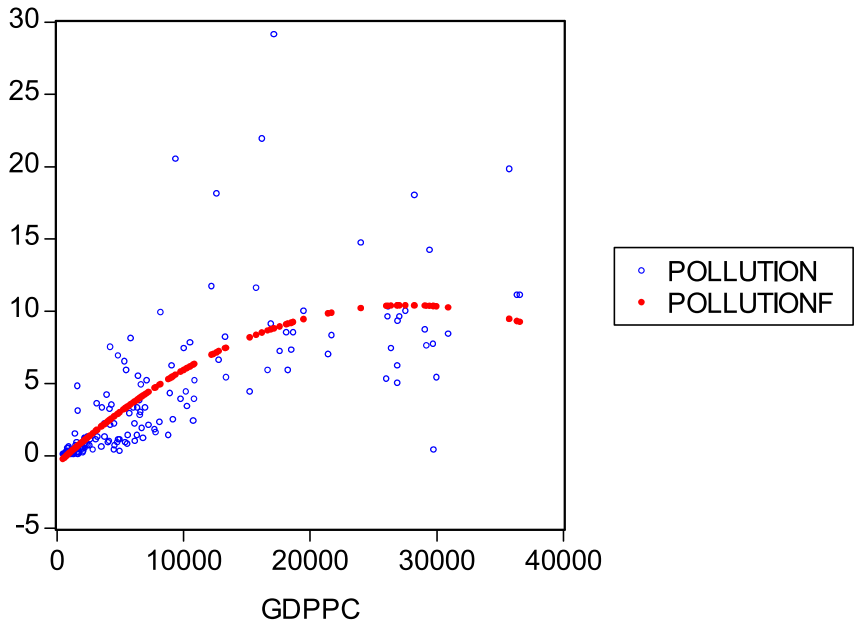

Figure 3: The fit of the in-sample forecasted pollution on the real pollution