Is the carbon Environmental Kuznets Curve hypothesis relevant for Genuine Income?

Frederic ANG

Division of Bioeconomics, KULeuven – Research Group of Environmental Economics, Hasselt University

frederic.ang@ees.kuleuven.be and frederic.ang@uhasselt.be

(1) Overview

This paper presents the first study that examines the Environmental Kuznets Curve (EKC) hypothesis for not only GDP, but also genuine income (GI), in which depreciation of natural and produced capital is subtracted from GDP. GDP is a sound indicator of the total national economic activity, but an inadequate measure of sustainable economic performance (particularly in resource-intensive countries) (Neumayer, 2010). From the perspective of the policy maker interested in the sustainable improvement of living standards, GI may be a more apt independent variable to test the EKC hypothesis. Concretely, we test whether CO_2-eq emission per capita is an inverted U-shape function of GDP per capita, on the one hand, and GI per capita, on the other hand. We use several econometric workhorse models for a balanced panel dataset of 153 countries from 1993 to 2008. Additionally, we separately consider the top 20 of oil-producing countries. Our study shows that the evidence of a carbon EKC with significant in-sample turning points could (arguably) exist for GDP, but disappears for GI.

(2) Methods

To estimate the carbon EKC models, we estimate the quadratic models following the overview of Stern (2010), because all workhorse models are presented in this paper. The models use the following structure:

$$\ln(C/P)_{it} = \beta_0 + \beta_1 \ln(Y/P)_{it} + \beta_2[\ln(Y/P)_{it}]^2 + \alpha_i + \gamma_t + \varepsilon_{it} \quad (1)$$

where C is CO_2-eq emissions, P is population, Y is the economic indicator. i indexes countries, and t time periods. ε_{it} is an independently and identically distributed error term. α_i and γ_t vary across countries and time periods, respectively. We use the independent variables $Y/P = GDP/P$ and its adjusted counterpart $Y/P = GI/P$. If $\beta_1 > 0$ and $\beta_2 < 0$, an inverted U-shape relationship is inferred.

The turning point income τ, where CO_2-eq emission is supposed to be at its maximum, can be inferred in the following way (Stern, 2004):

$$\tau = \exp(-\beta_1/(2\beta_2)) \quad (2)$$

We estimate (1) for pooled OLS (and a first-differenced (FD) counterpart to take into account possible autocorrelation), Fixed Effects (FE), Random Effects (RE), and Between Effects (BE).

The data on GDP (in constant 2000 US$), population, and depreciation on natural and produced capital are collected from the website of the WB (2013). We use a balanced panel dataset of 153 countries from 1993 to 2008 (n = 2448). To gain insight on the performance of resource-intensive countries (where GI is a very relevant indicator of sustainable economic performance), we separately consider the results of the top 20 of oil-producing countries according to the Central Intelligence Agency (2013).

(3) Results

The turning points of all **GDP** models are generally high for the **full sample**. Only the pooled OLS (with trend and without trend), the FE (with time effects and without time effects), and the BE models yield an inverted U-shape curve with an in-sample turning point. Combining a turning point of 31,101$ significant at the 1% level, the FE estimation with time effects provides the most convincing confirmation of the carbon EKC hypothesis. The significant turning points of the OLS without time trend (51,275$), OLS with time trend (51,688$), FE with time effects (49,395$), and BE quadratic (49,011$) are in-sample, but very high. The turning point of the RE model without time effects (66,426$) is significant at the 5% level, but is effectively out-of-sample. Moreover, the turning point of its counterpart with time effects (182,888$) is even higher, and solely significant at the 10% level. The turning points of the FD OLS estimations are extremely high and insignificant both without and with time trend (724,757$ and 1,188,509$, respectively).

None of the **GI** models show an in-sample turning point for the **full sample**. The turning points of nearly all models are much higher than the GDP turning points. The BE model shows a turning point of 41,100$ at the 10% level. The OLS FD model with time trend yields a turning point of 41,829$ insignificant from zero, as shown by the very high standard error (108,518$). The turning points of the OLS without time trend (58,281$) and OLS with time trend (58,567$) are significant at the 1% level. The time trend does not play an essential role for the OLS estimation, while it seems to be more important for its differenced counterpart. The turning points of the remaining models are extremely high and effectively insignificant from zero.

The evidence of a carbon EKC with a significant in-sample turning point erodes for **GDP** when the **top 20 of the oil-producing countries** is considered. Solely the OLS FD models without time trend (22,870$) and with time trend (18,481$) and the FE model with time effects (51,110$) yield in-sample turning points. However, all turning points, including the former, are insignificant from zero. For this subset, there is thus no evidence that GDP growth is a reasonable strategy to decrease CO_2-eq emission. The turning points of the BE regression (336,118$) and especially the RE regression (2.02E+11) are extremely high. Moreover, the BE quadratic model does not yield any coefficients that are significant at the 10% level. The rather similar coefficients of the quadratic OLS model provide a turning point of 500,436$. All time trends are insignificant at the 10% level and thus do not play an essential role.

The lack of significant in-sample turning points in the sample comprising the **top 20 of the oil-producing countries** is even more clear for **GI**. The turning points of the OLS FD without time trend (6,350$) and with time trend (1,802$) are considerably lower than their GDP counterpart and within the sample. However, these are again very imprecisely estimated and in fact insignificant from zero. All remaining turning points are also insignificant and either much higher than the corresponding GDP estimates or even non-existent due to a positive quadratic term. The turning points of the OLS quadratic without and with time trend are 1.15E+09$ and 2.11E+09$, respectively. Both the FE and RE models show positive quadratic variables, suggesting a monotonically increasing relationship between GI and CO_2-eq emission. The BE quadratic estimates are insignificant from zero and indicate a very high, insignificant turning point of 795,867$. Including time effects gives turning points that are very high and insignificant for the FE model (211,159$), and extremely high and insignificant for the RE model (2.47E+28$). The time trends are only significant (at the 10% level) in the OLS FD model with trend.

(4) Conclusions

The pooled OLS, FE and BE models yield a significant in-sample turning point if GDP is used as an independent variable for the full sample. On the other hand, all models seem to suggest that growth of GI, which arguably is a better policy indicator than GDP, may monotonically increase CO_2 emission in our full sample. The additional analysis of a subset of the top 20 of oil producing countries in which individual country effects may not play a less prominent role, does not give evidence of an inverted U-shape relationship with a significant in-sample turning point. This remarkable outcome is even more apparent for GI than for GDP. Oil-dependent economies, which already emit a very high level of CO_2-eq, seem thus unable to decrease this level by growing either GDP or GI. In our opinion, these results are remarkable, given that many studies validate the EKC hypothesis for CO_2 emission (e.g., Grossman and Krueger, 1995; Selden and Song, 1994).

Several environmental economists have pointed out that pooled OLS, FE, RE, and BE models may result in estimates biased toward the validation of the EKC hypothesis (e.g., Vollebergh et al., 2009; Wagner, 2008). Our study shows that, even in these favorable conditions, the evidence of a carbon EKC with significant in-sample turning points erodes heavily for GI. The EKC hypothesis thus seems progressively to be vulnerable to not only econometric, but also conceptual criticisms.

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