Revisiting Carbon Kuznets Curves with Endogenous Breaks Modeling: Evidence of Decoupling and Saturation (but few Inverted-Us) for Individual OECD Countries

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Overview

Whether pollution first rises with income and then falls after some threshold level of income/development is reached, thus forming an inverted U-shaped relationshipð also called an Environmental Kuznets Curve (EKC)ð is one of the most popular questions in environmental economics (e.g., see review by Stern 2004). Such EKC analyses typically employ panel data and most often focus on emissions per capita. Those emissions are modelled as a quadratic (or sometimes cubic) function of GDP per capita; an EKC between emissions per capita and income is said to exist if the coefficient for GDP per capita is statistically significant and positive, while the coefficient for its square is statistically significant and negative.

Not surprisingly, the large EKC literature has generated substantial criticism. Stern (2004) argued that many EKC studies risked spurious findings by ignoring that variables like emissions per capita and GDP per capita are likely nonstationary; later, Muller-Furstenberger and Wagner (2007) argued further that even the EKC studies that did recognize the stationarity properties in the data still risked spurious findings by performing nonlinear (quadratic) transformations of a nonstationary variable (GDP per capita). Lastly, the polynomial of GDP per capita model (either quadratic or cubic) used in the EKC literatures has been criticized for being highly inflexible and for rendering unimportant feasible emissions-GDP relationships for which it cannot test (Lindmark 2004). For example, the typical polynomial model does not allow for the possibility (i) that GDP elasticities are significantly different across development levels but still (forever) positiveð i.e., a saturation effect or S-curve; or (ii) that at high levels of GDP per capita the relationship with emissions is insignificantð i.e., a decoupling of the emissions-GDP relationship.

This paper tests for a so-called carbon Kuznets curve (CKC) by examining the CO_2 emissions per capita-GDP per capita relationship individually, for several OECD countries. A reduced-form, linear model that allows for multiple endogenously determined breaks is used to address the econometric and modeling issues mentioned aboveð the linear model with multiple breaks is highly flexible and can approximate complicated nonlinear relationships without presuming a priori any particular relationship; hence, no nonlinear transformations of potentially nonstationary variables are necessary. Lastly, by focusing on the time-series data of single countries, we address the crucial question of a specific countryõs evolution of its income-environment relationship (as recommended by, e.g., Stern et al., 1996).

Methods

We analyze the CO_2 emissions per capita and real GDP per capita relationship for 23 advanced/OECD countries using data that covers 1950-2010. This paper adopts the more flexible Harvey et al. (2013) procedure for testing for unit-roots and breaks. If both series are determined to be I(1), then we estimate the relationship using Kejriwal and Perron (2010). Kejriwal and Perron updated the Bai and Perron (1998, 2003) method of endogenous breaks to be valid for I(1), cointegrated regressors.

If only one of the two series is determined to have a unit root, we conclude that the GDP-emissions relationship for that country is already (i.e., as of prior to 1950) described as decoupled, and we do not analyze those series further. Lastly, since all of the series are highly trending, we interpret the rejection of the unit root null as a finding of trend stationary. If both GDP and carbon emissions are determined to be trend stationary, we estimate the relationship between them using the Bai and Perron (1998, 2003) method since that method is robust to trending regressors.

Results

The unit root test results suggest that for most countries the two series are I(1). Yet, for Australia, Denmark, Finland, France, and Sweden, the two series are of different order of integration; hence, for those countries, decoupling of income and emissions had (arguably) already occurred, and we do no further analysis on them.

Moving to the estimations with endogenous breaks, if we focus on the sign and significance of the income termôs coefficient, by far the most common income-emissions relationship is that of saturationð a statistically significant, declining, but still positive income elasticity; that relationship is the clear case for eight countriesð Austria, Canada, Greece, Ireland, Italy, Japan, Netherlands (when only one break is allowed), and New Zealand. Since carbon emissions are so associated with energy consumption, perhaps a saturation pattern is to be expected.

US displays decoupling of income and emissions beginning in 1970ð as the income elasticity is no longer significant. Similarly, Hungary displays saturation beginning in 1963, followed by decoupling in 1990; so does Netherlands beginning in 1982 for saturation and in 1997 for decoupling, when two breaks are considered for that country. Previously, we mentioned five countries for which income and emissions had different orders of integration; if we judge those five countries as evidencing decoupling, too, then saturation and decoupling are the primary post-1950 income-emissions relationships, i.e., the case for 15 of the 23 OECD countries studied. Only four countries (Belgium, Germany, Switzerland, and UK) show clear evidence of a carbon Kuznets curveð a significant, negative relationship between income and emissions, and for two of those countries, Belgium and Switzerland, the downturn occurred rather recently (and thus, at a high income level), in 1997 and 1993, respectively.

The income-emissions regimes of four other countries deserve further discussion. Considering one break (in 1989), Poland displays a CKC; however, when a second break is allowed (in 1999), Polandôs income-emissions relationship takes on an N-shape. That first break in 1989 is associated with the fall of the Berlin Wall and reintegration of East and West Europeð a time of great structural change for Eastern European countries. Hence, for Poland the regime of 1989-1999 was more of a period of structural change/adjustment than a transition period to a less carbon intensive path, and so post-1999, Poland has resumed its rather carbon/energy intensive economic development. For Portugal and Spain, despite evidence of breaks, both countries have maintained a high, positive, and near proportional relationship between income and emissions; hence, one might surmise that neither Spain nor Portugal have experienced an income-emissions transition or regime change. Norwayôs income-emissions relationship accelerated in 1970, and while it declined relative to that high elasticity, that relationship still has been more than proportional from 1990ð effectively a U-shaped relationship.

Conclusions

For only four countries did the emissions-income relationship become negativeð i.e., a CKC. Indeed, the primary emission-income relationship determined here (i.e., for 15 of 23 countries studied) was either (i) decouplingð where income no longer affected emissions in a statistically significant way, or (ii) saturationð where the emissions elasticity of income is declining, less than proportional, but still positive.

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