Fact or Fiction: The Relationship between Carbon Linkage and Carbon Dioxide Environmental Kuznets Curve

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IPDC, 2014

Outline

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2. Empirical results
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   - de-factor EKC curve

Grossman and Krueger (1991,1995) found that the emissions of greenhouse gas have inverted U-shape relationship with per capita GDP. This hypothesis is called environmental Kurzets curve (EKC) hypothesis. If EKC hypothesis exist among all countries, the hypothesis may use to regulate the greenhouse gas reduction.

Some greenhouse gases are in the atmosphere:

1. SO2
2. NO
3. CO2

There are three characteristics in CO2 emissions:

- Different regions with different emissions (regional convergence)
- The developing countries have high CO2 emissions than underdeveloped countries
- Carbon leakage

The study makes three major contributions

- Construct the EKC according to the regions that countries are located in.
- Estimate the accurate EKC relationship with the common correlated effects
- Explain the reasons of cross-sectional dependence with carbon leakage

The traditional panel EKC model

$$\ln e_{it} = \alpha_i + \theta_i t + \beta_1 \ln y_{it} + \beta_2 \ln y_{it}^2 + u_{it} \quad (1)$$

The major concerns of choosing econometric methods

- Whether the series of CO2 emissions and per capita GDP are both stationary?
- The cross-sectional dependence exist in the errors.

When the panel EKC model exists cross-sectional dependence, the standard estimations of panel model, like Fixed of random effects, will generate the inconsistent estimates. We need to use different procedure.

The data on CO2 emissions was obtained from the Carbon Dioxide Information Analysis Center (CDIAC), and GDP per capita was obtained from the Penn World Table Version 6.2. This study collected data related to GDP and CO2 emissions of each country from the period 1972 to 2003. The 94 countries included in this study are located in Africa, America, Asia, and Europe.

The econometric methods:

- African Countries: Panel cointegration with cross-sectional independence (Kao and Chiang 1999).
- American, Asian and European countries: Panel regression with cross-sectional dependence (Pesaran 2006)

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Because the CO2 emissions are with cross-sectional dependence in three regions, we need to eliminate the cross-sectional dependence

$$\ln e_{it} = \alpha_i + \theta_i t + \beta_1 \ln y_{it} + \beta_2 (\ln y_{it})^2 + \beta_3 \overline{\ln e_t} + \beta_4 \overline{\ln y_t} + \beta_5 \overline{(\ln y_t)^2} + e_{it}. \quad (2)$$

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If a cross-sectional correlation exists in both CO2 and GDP series, biases will occur in the estimation of the parameters. We use the two-stage methods proposed by Wagner (2009).

$$\begin{aligned} \ln e_{it} &= \kappa_{1i} + \tau_{1i} t + \tau_{11} \overline{\ln e_t} + \tau_{12} \Delta \overline{\ln e_t} + \eta_{1it}, \\ \ln y_{it} &= \kappa_{2i} + \tau_{2i} t + \tau_{21} \overline{\ln y_t} + \tau_{22} \Delta \overline{\ln y_t} + \eta_{2it}. \end{aligned}$$

We then extract the residuals $\hat{\eta}_{1it}$ and $\hat{\eta}_{2it}$ and use the two variables for estimation in the EKC model.

$$\hat{\eta}_{1it} = \alpha_i + \beta_1 \hat{\eta}_{2it} + \beta_2 \hat{\eta}_{2it}^2 + e_{it} \tag{3}$$

Table: LM_{adj} statistic

	Asia	Africa	Europe	America
ln e_{it}	5.9633*	0.1848	11.976*	4.2011*
ln y_{it}	6.2531*	-0.2171	26.003*	7.0116*

[a] $*$ implies rejection of the null hypothesis at 5%.
[b] The critical value is ± 1.96.

Table: IPS and Kao statistics for EKC curve of African countries

IPS statistic		
ln e_{it}	−1.4244	0.0772
ln y_{it}	−0.1824	0.4276
Kao panel cointegration statistics		
DF_{ρ}	−30.8275	0.0000*
DF_{t}	−19.9752	0.0000*
ADF	−7.5987	0.0000*

[a] IPS regression includes intercept and deterministic trend.
[b] $*$ implies rejection of the null hypothesis at 5%.

Table: CIPS unit root statistics for different regions

	$\ln e_{it}$		$\ln y_{it}$	
	Statistics	p-value	Statistics	p-value
Asia	-3.0711	0.0011*	-5.7512	0.0000*
Africa	-3.5475	0.0002*	-6.3964	0.0000*
Europe	-7.3312	0.0000*	-2.0659	0.0194*
America	-16.614	0.0000*	-11.5145	0.0000*

[a] Equation includes intercept and deterministic trend.

[b] $*$ implies rejection of the null hypothesis at 5%.

Table: EKC estimation results

	Africa	Asia	Europe	America
t	-0.0044	-0.0007	-0.0001	0.0004
t-statistics	-0.9204	-0.0256	-0.0193	0.0807
$p(N)$-value	0.1787	0.4898	0.4923	0.4678
$\ln y_{it}$	-4.2323	2.5968	18.3459	9.7162
t-statistics	-3.4633	8.2460	20.2908	14.1225
$p(N)$-value	0.0003*	0.0000*	0.0000*	0.0000*
$(\ln y_{it})^2$	0.3327	-0.1138	-0.9075	-0.5275
t-statistics	4.0125	-6.0906	-19.9403	-13.3523
$p(N)$-value	0.0000*	0.0000*	0.0000*	0.0000*
$\overline{\ln y_{it}}$		1.0795	0.9491	1.0616
t-statistics		2.4418	5.6184	7.6228
$p(N)$-value		0.0073*	0.0000*	0.0000*
$\overline{\ln y_{it}}$		-2.7251	-17.9068	-7.1034
t-statistics		-0.5468	-4.6415	-0.5345
$p(N)$-value		0.2923	0.0000*	0.2965
$\overline{(\ln y_{it})^2}$		0.1176	0.8859	0.3805
t-statistics		0.3247	4.6940	0.4971
$p(N)$-value		0.3727	0.0000*	0.3096
R^2	0.1301	0.5378	0.4680	0.3878
Adj R^2	0.1200	0.5339	0.4622	0.3843

[a] Kao (1998) panel cointegration regression without cross-sectional dependence is used for African countries.
[b] EKC equation includes fixed effects.
[c] $*$ implies rejection of the null hypothesis at 5%.

Table: Estimation results with de-factored observations

	Asia	Africa	Europe	America
ln y_{it}	0.4710	-0.0929	0.3792	0.1248
t-statistics	3.2219	-0.7118	4.2687	2.2029
$p(N)$-value	0.0006*	0.2383	0.0000*	0.0138*
$(\ln y_{it})^2$	4.0910	2.0049	3.5555	0.8487
t-statistics	2.8952	1.8021	1.7245	1.0995
$p(N)$-value	0.0019*	0.0358*	0.0423*	0.1358
R^2	0.0312	0.0071	0.0405	0.0069
Adj R^2	0.0281	0.0033	0.0365	0.0048

[a] EKC equation includes fixed effects.
[b] $*$ implies rejection of the null hypothesis at 5%.

The outcomes of this research show when the authors control for the cross-sectional dependency of EKC curves in the four regions, the relationship between CO2 and income still maintains an inverted U-shaped curve in the American, Asian, and European regions, but not in Africa.

The results of de-factor EKC curves demonstrates after controlling for cross-sectional correlations in CO2 emissions caused by Carbon leakage, and in GDP per capita caused by the international division of labor. These outcomes display that under the premise that greenhouse gasses are inferior goods, pursuing growth in per capita GDP, thereby increasing production in all industries in a country, will be accompanied by an increase in CO2 emissions.