Time series estimation of the environmental Kuznets curve on CO_2 emission

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Hyangsuk Cho+ and Kwangsuck Lee++

<Abstract>

The environmental Kuznets curve (EKC) represents an inverted U-shaped relationship between environmental degradation (such as carbon dioxide emission per capita) and economic growth (defined as per capita GDP). Accordingly, pollution levels rise as income level increases in the early stages of economic development, but reach a certain threshold where pollution begins to fall. Most of previous studies on this subject are based on estimating parametric quadratic or cubic stationary regressions.

In this study, however, we examine the EKC hypothesis for CO_2 emission based on the unit root test and panel cointegration analysis for the different income groups of countries. We have three panels such as 48 high income countries, 38 middle income countries, and 41 low income countries. Verifying the EKC hypothesis using unit root and panel cointegration tests, we investigate the existence of EKC phenomenon among different income groups through an error-correction model. Our results show that there is cointegration relationship between CO_2 emission per capita and GDP per capita. More importantly, we examine the EKC hypothesis using ECM. We find the income elasticity in the long run is smaller than the short run only in high-income countries group. Also we divided country groups based on per capita forest area and tested the EKC hypothesis for the groups. It shows the forest area has a decisive effect on explaining the EKC.

+ Department of Economics, Sungkyunkwan University, Seoul, 110-745, Korea
(e-mail: chs0618@gmail.com))

++ Department of Economics, Sungkyunkwan University, Seoul, 110-745, Korea
(e-mail: kwanglee@skku.edu)

I. Introduction

Global warming has been highlighted as an important issue in recent years. Since carbon dioxide (CO_2) emission is considered the main cause of global warming, the individual countries have attempted to take various measures to reduce CO_2 emissions. Achieving sustainable economic growth has become one of the most important challenges facing the current economic society as well. In this regard, it is meaningful to test the environmental Kuznets curve (EKC) hypothesis for CO_2 emissions. A typical macroeconomic variable related to environmental degradation such as greenhouse gas is income. Thus, as EKC hypothesis suggests, the existence of an inverted U-shaped relationship between environmental pollutants and income has long been an empirical task.

Many previous studies on EKC employed parametric quadratic or cubic model. However, recent studies have focused on the non-stationary of time series in the regression models, which requires different methods in the estimation of the environmental Kuznets curve. In this paper, focusing on nonstationrity of time series variables, we estimate the relationship between the CO2 emissions and income in the framework of an error correction model.

This paper consists of two different tests of EKC hypothesis. In the first test, the country groups are classified by income levels such as high income, middle income and low income countries. Then, we estimate the relationship between CO_2 emission and income by each group. In the second test, we analyze whether EKC would be influenced by per capita forest area.

II. Literature Review

The EKC hypothesis appeared in the early 1990s with Grossman and Krueger (1995). They analyze the relationship between environmental pollutants and income as was announced the inverted U-shape of the Environmental Kuznets Curve, this has been going after active research in this regard. After that, there is a variety of literature that analyzes the EKC hypothesis.

Holtz-Eakin and Selden(1995) estimated the relationship between per capita income and carbon dioxide emissions using global panel data, and found that the emissions increase monotonically with income or have high turning points with large standard errors. Heil and

Selden (2001) using a panel data from 135 countries over the period 1951-1992, found a monotonous increasing relationship between CO_2 emissions and income per capita.

Friedl and Getzner(2003) examined whether an Environmental Kuznets Curve holds for a single country rather than concentrating on panel or cross-section data. They found that a N-shaped relationship between GDP and CO_2 emissions. Galeotti et al. (2006) examined the relationship between income per capita and carbon dioxide emissions per capita using per capita income squared and per capita income cubed for the OECD and non-OECD countries. They found an EKC evidence only for the OECD countries. Zhao et al.(2013) tested the EKC hypothesis for carbon dioxide emissions by taking the first-order derivative of the quadratic EKC equation. In this study, they found the long-term carbon dioxide emissions rarely supported the EKC hypothesis, but the carbon dioxide emissions in short-term widely supported the EKC hypothesis.

Recent studies utilizing econometric method can be characterized by nonstationary time series approach. Kanjilal and Ghosh (2002) tested the cointegration and Granger causality between industrial CO_2 emissions and GDP for India.. Perman and Stern (2003) used a panel cointegration approach to estimate the EKC hypothesis for a panel consisting of 74 countries. Lee and Lee(2009) investigated EKC hypothesis by using augmented Dickey-Fuller test on the carbon dioxide emissions per capita and real GDP per capita within seven regional panels for 1971-2003. Narayan and Narayan(2010) examined the Environment Kuznets Curve hypothesis for 43 developing countries using the panel cointegration and the panel long-run estimation techniques.

III. Empirical results

Unlike the previous studies, our EKC test focuses on the panel groups with different income levels. Also, we classify the countries within each of the income group according to the forest area per capita. By doing this, some policy implications might be drawn with regard to the natural resource management such as forest preservation. Methodologically, we use the nonstationary regression models as introduced below.

1. Methodology

1) Unit root test

In this study, we use two unit root tests which include Breitung and IPS. The Breitung test assumes that the error term is uncorrelated across both i and t and the IPS test allows for heterogeneous panels with serially uncorrelated errors assuming the number of time periods, T, is fixed. Most economic variables that exhibit strong trends such as GDP are not stationary. By specifying the following the equation, we will test whether the CO2 emission and GDP data are nonstationary :

$$\Delta \ln(y_{it}) = \alpha_i + (\rho_i - 1)\ln(y_{it-1}) + e_{it} \quad , \qquad i = 1,2,\dots,N,\ t = 1,2,\dots,T \qquad (1)$$

$$\text{Ho: } (\rho_i - 1) = \gamma_i = 0\ ,\ \forall\, i$$

2) Cointegration test

If these variables are nonstationary, cointegration relationship can be expressed as follows:

$$\Delta\ln(y_{it}) = \alpha_i + \sum_{j=1}^{p}\pi_j \Delta\ln(y_{it-j}) + \sum_{k=1}^{q}\delta_j \Delta\ln(\ x_{it-k}) + \varphi_i \ln(y_{it-1}) - \varphi_i \ln(\beta_i x_{it-1}) + e_{it} \qquad (2)$$

$$H_0: \varphi_i = 0\ ,\ for\ all\ i\ ,$$
$$H_1: \varphi_i < 0,\ \ at\ least\ one$$

3) Error Correction Model

If the cointegration relationship exists, error correction model can be expressed as follows:

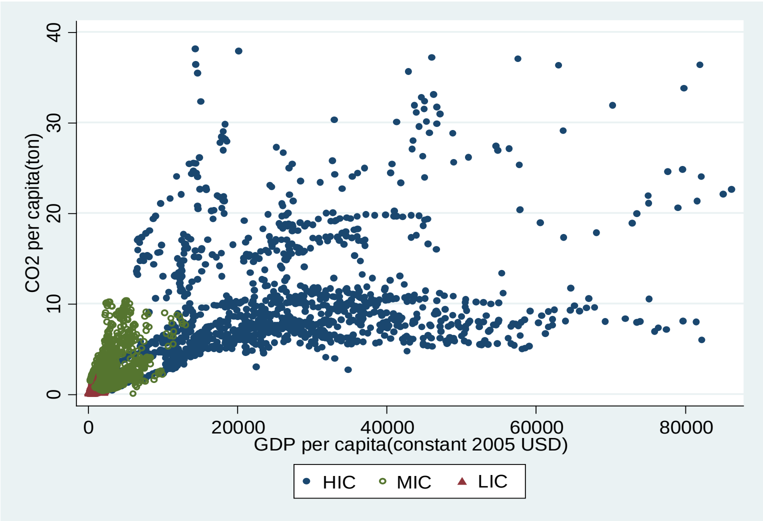
$$\Delta\ln y_{it} = \alpha_i + \varphi_i(\ln(y_{it-1}) - \theta_i - \beta_i ln(x_{it-1})) + \sum_{i=1}^{p}\pi_i \Delta\ln(y_{it-k}) + \sum_{i=1}^{p}\delta_i \Delta\ln(x_{it-k}) + e_{it} \qquad (3)$$

for t=1,⋯, T ; i=1,⋯N, where T refers to the number of observations over time and N refers to the number of individual countries in the panel. We define $\ln y$ as the natural logarithm of GDP per capita and $\ln x$ the natural logarithm of carbon dioxide emission per capita. The parameter φ_i determines the speed at which the system corrects back to the equilibrium relationship $\ln(y_{it-1})$- $\beta_i ln(x_{it-1})$ after sudden shock.

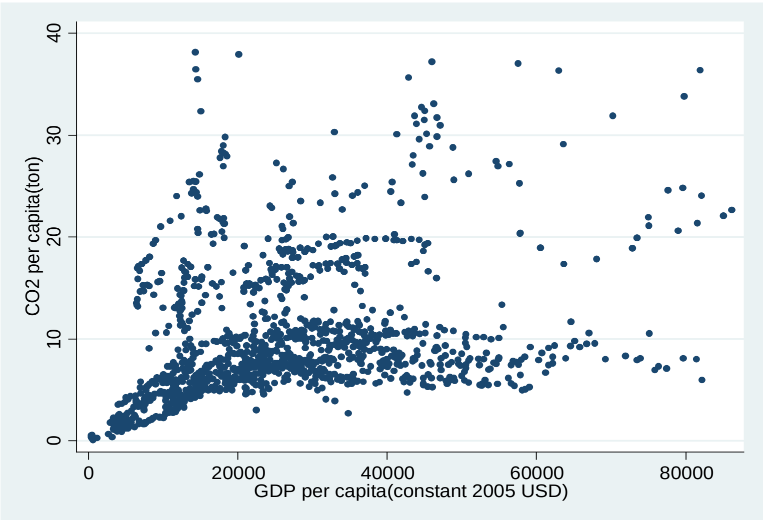
2. Data

We use the dataset of 127 countries during 1980-2010 periods. The figures below show the relationship between per capita CO_2 emission and per capita GDP by different income groups which are clustered by the World Bank classification.

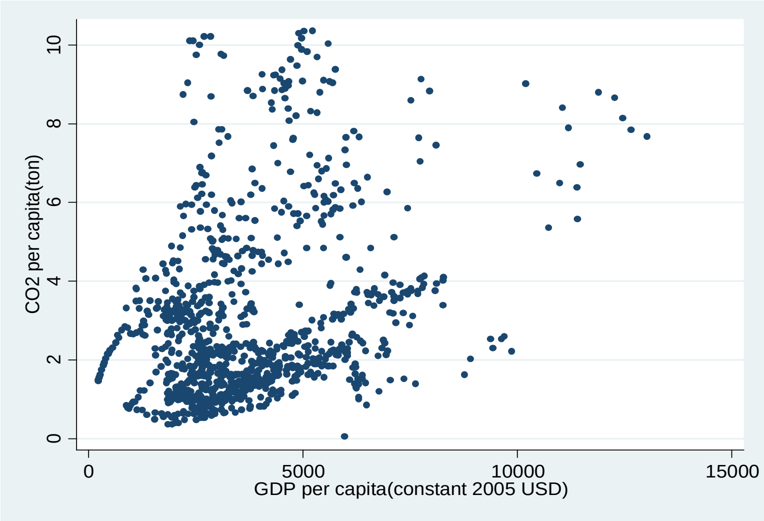
1) All countries (127 countries)



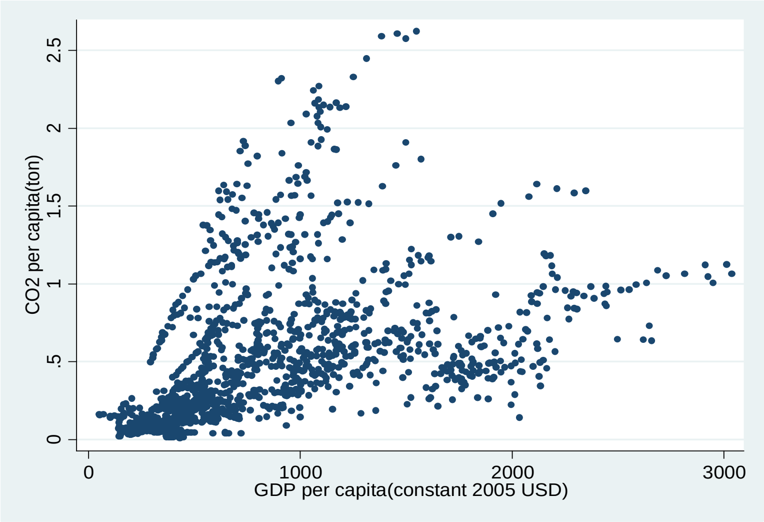
2) High income group (42 countries)



3) Middle income group (34 countries)



4) Low income group (51countries)



3. Test results by income groups

We first confirm that the variables are

The test results of nonstationarity using two different unit root test are reported in Table 1 for different income groups. Among the total 127 countries, we have a panel of 42 high income countries, a panel of 34 middle income countries, and a panel of 51 low income countries. The Breitung test indicates that GDP and carbon dioxide emission are nonstationary. But, IPS test shows that GDP is nonstationary but carbon dioxide emission is stationary except for low income countries data.

Table 1. Unit root test

	Breitung test		IPS	
	lnGDP	$lnCO_2$	lnGDP	$lnCO_2$
All countries	11.1423	4.5637	0.4999	-1.6183^{*}
High income countries	5.9879	1.5960	2.0312	-1.5092^{*}
Middle income countries	5.4410	2.2448	-0.7942	-1.3690^{*}
Low income countries	8.4804	1.3178	-2.2616	-2.7951

Note[1]: In square brackets, the vales denote t-statistics. * indicates that rejects the null hypothesis at the 10% level.

Note[2]:[Breitung test] Ho: Panels contain unit roots, Ha: Panels are stationary

[IPS test] Ho: All panels contain unit roots, Ha: Some panels are stationary

Then we estimated the cointegration between carbon dioxide emissions and GDP as shown in Table 2 which reports that most of their test statistics support cointegration relationship between GDP and carbon dioxide emissions. It means there are long run relationships between the two variables.

Table 2. Cointegration test

	Gt	Ga	Pt	Pa
All countries	-2.132^{***}	-8.888^{***}	-21.729^{***}	-7.948^{***}
High income countries	-2.240^{***}	-9.397^{**}	-14.420^{***}	-11.039^{***}
Middle income countries	-2.237^{***}	-8.491^{*}	-7.646	-5.343^{*}
Low income countries	-2.088^{**}	-8.312^{*}	-15.228^{***}	-7.966^{***}

Note[1]: In square brackets, the vales denote t-statistics. *, ** and *** indicates that rejects the null of no cointegration at the 10%, 5%, and 1% level.

Note[2]: Gt(Group-mean test) Ga(Group-mean test) Pt(Panel test) Pa(Panel test)

The long-run and short-run income elasticity together with the one-period lagged error correction term for each of the 127 countries is reported in Table 3. The results for the all countries reveal that the error correction term is statistically significant at 1 percent level, implying that a long-run relationship exists between income and carbon dioxide emissions. In the short-run, income influences significantly on CO_2 emissions except for the middle income group, while in the long run, the influence is positive and statistically significant at 1 per cent level in the all income groups.

Table 3. Error correction model result: long-run and short-run elasticity

	Short-run	Long-run	ECT
All countries	0.148***	0.154***	-1.143***
	(0.0477)	(0.0139)	(0.0111)
High income countries	0.286***	0.108***	-0.153***
	(0.0864)	(0.0182)	(0.0186)
Middle income countries	0.0750	0.155***	-0.185***
	(0.0913)	(0.0313)	(0.0222)
Low income countries	0.149***	0.186***	-0.236***
	(0.0747)	(0.0263)	(0.0178)

Note: *t*-values are in parentheses. *, ** and *** indicates statistical significance at the 10%, 5%, and 1% level.

In sum, the unit root test shows that CO_2 emission per capita and GDP per capita are nonstationary and the results for the cointegration test reveal that two variables have long-term relationship. However, according to the ECM results, only for the high income countries, the income elasticity for CO_2 emission in the long run is smaller than that of the short run. This implies that Environmental Kuznets curve appears only for high income country group.

4. Empirical Results considering per capita forest area

In this section, we try to test the EKC hypothesis by using additional information on the forest area of each income group. The countries are divided by the ranks of per capita forest area: such as upper 50% and lower 50% groups.

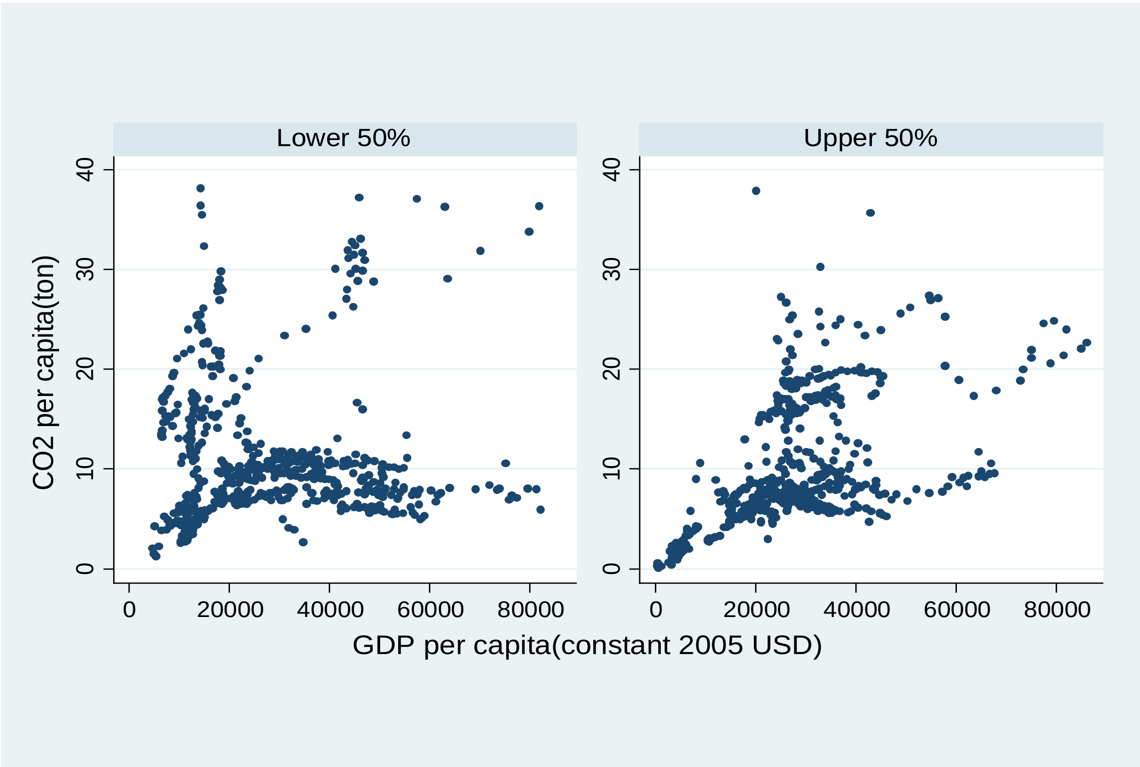
1) High income countries (38 countries)

The 38 high income countries are divided by the ranks of per capita forest area: such as 17 countries as upper 50% group and 21 countries as lower 50% group. Table 4 shows the results indicating that, for the upper 50% group, per capita GDP has a positive and statistically significant effect on CO_2 emission both in the short- and long-run. Its long-run income elasticity for CO_2 emission is lower than that of the short-run. However, for the lower 50% ranking group, its effect is verified only for the short run. The long-run income elasticity for CO_2 emission in this group is estimated with negative value.

Table 4. Error correction model result in high income countries

	Short-run	Long-run	ECT
Upper 50% group	0.225*	0.0393**	-0.0631***
	(0.131)	(0.0163)	(0.0171)
Lower 50% group	0.403***	-0.0275***	-0.0190**
	(0.114)	(0.00771)	(0.00885)

Note: *t*-values are in parentheses. *, ** and *** indicates statistical significance at the 10%, 5%, and 1% level.



3) Middle income countries (34 countries)

Middle income countries are divided by 17 countries as upper 50% ranking group and another 17 countries as lower 50% ranking group of the per capita forest area. The ECM results as seen in Table 5 indicate that only for the upper 50% group, the log-run income elasticity for CO_2 emission appears smaller than the short run elasticity.

Table 5. Error correction model result in middle income countries

	Short-run	Long-run	ECT
Upper 50% group	0.419*	0.175**	-0.202***
	(0.235)	(0.0694)	(0.0391)
Lower 50% group	-0.105*	0.103***	-0.127**
	(0.0559)	(0.0211)	(0.0174)

Note: *t*-values are in parentheses. *, ** and *** indicates statistical significance at the 10%, 5%, and 1% level.

4) Low income countries (49countries)

Low income countries are grouped by 27 countries as upper 50% ranking group and 22 countries as lower 50% ranking group with regard to per capita forest area. Same as middle income countries, the results show that only for the upper 50% ranking group, the income elasticity for CO_2 emission in the long run is estimated to be smaller than that in the short run.

Table 6. Error correction model result in low income countries

	Short-run	Long-run	ECT
Upper 50% group	0.233**	0.140 ***	-0.251***
	(0.104)	(0.0378)	(0.0252)
Lower 50% group	-0.0632	0.262***	-0.213***
	(0.110)	(0.0426)	(0.0252)

Note: *t*-values are in parentheses. *, ** and *** indicates statistical significance at the 10%, 5%, and 1% level.

In sum, the upper 50% ranking group of per capita forest area shows the smaller income elasticity for CO_2 emission in the long run compared to its short-run estimates. The same results are found in all the different income groups. This would indicate that the forest resource has a decisive implication on examining the EKC.

IV. Concluding Remark

Environmental issues are not limited to certain countries. These issues involve the entire human population. Greenhouse gas emission affects our environment more closely as climate change progresses. The relationship between economic growth and carbon dioxide emissions, termed as the Environmental Kuznets curve hypothesis, has been examined in a variety of literature. In this paper, we test the EKC hypothesis by considering the countries' income level and per capita forest area. The main implication of our work is that Environmental Kuznets curve on CO_2 emission appears only in high income countries. In addition, higher level of per capita forest area has a decisive effect on explaining the EKC. According, we could expect that the EKC on CO_2 emission can be more clearly shaped in the higher income countries with more per capita forest area.

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