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Carbon Emissions and Economic Development in East Asia: A Macroeconometric Inquiry

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Abstract

The main objective of this study is to analyze econometrically the Environmental Kuznets Curve relationship for carbon dioxide emissions in East Asia. Panel data regressions were used to test the East Asian EKC for the period 1980 to 2000. It has been found that the CO2 EKC for East Asia does exist. Various socioeconomic variables also contribute to environmental degradation.

Keywords: Carbon Emissions, EKC, Degradation

1. Introduction

Significance and Objectives

The rapid economic growth of East Asian countries has brought about an increasing scale of carbon emissions. There is a growing question of whether or not development can coexist with environmental quality. To test the relationship between economic growth and environmental degradation, the Environmental Kuznets Curve (EKC) could be used. Thus, the main objective of this study is to analyze empirically the potential Environmental Kuznets Curve relationship for carbon dioxide (CO2) emissions in East Asia. The EKC hypothesis postulates an inverted U-shaped relationship between environmental quality indicators and per capita income (Dinda, 2004). During initial stages of economic development, pollution appears inevitable. However, further income increases will produce incentives for environmental conservation (Bhattarai and Hammig, 2004). Besides national income growth, social and political factors could also influence the extent of pollutant emissions (Stern, 2003). Thus, another objective of this study is to identify other possible socioeconomic determinants of carbon dioxide emissions in East Asia.

Literature Review

Several studies on economic growth and environmental quality have shown that some pollutants such as nitrous oxides and sulfur dioxide follow an inverse U-shaped functional relationship with economic growth (Bhattarai and Hammig, 2004). The first EKC study by Grossman and Krueger (1991) investigated the potential impact of NAFTA. They pointed out an inverted-U relationship between pollutant emissions, e.g., sulfur dioxide, and income per capita (Dinda, 2004). However, evidence of a Kuznetian relationship has not yet been consistently observed for other pollutants such as carbon dioxide (Stern, 2003).

To the author's knowledge, there seems to be only one study which conducted to examine empirically the existence of an Environmental Kuznets Curve in East Asia. For instance, employing Ordinary Least Squares estimation, Iwami (2004) examined the effects of income, energy efficiency, and industrial structure on pollutant emissions. For both sulfur dioxide and carbon dioxide emissions, it was observed that the linear and squared income, and energy efficiency have significant effects.

Scope and Limitations

This study specifically verifies the Environmental Kuznets Curve hypothesis for eight East Asian countries (Japan, South Korea, Singapore, China, Philippines, Thailand, Malaysia, and Indonesia). Furthermore, due to data unavailability, this paper analyzes pollutant emissions only for the years 1980 to 2000. Lastly, only one measure of environmental quality, CO2 emissions, is examined.

2. Materials and Methods

Empirical Model

As the EKC theory suggests, a measure for environmental degradation is assigned as the dependent variable while among the explanatory variables is per capita income. Thus, using the specification suggested by Bhattarai and Hammig (2004) in their study of deforestation EKC, the basic multivariate model used in this study is as follows:

$$\text{POLLUTION} = F(Y, Y^2, I, X, P)$$

where POLLUTION = pollutant emissions per capita
Y = GDP per capita
I = institutional variables
X = macroeconomic policy variables
P = population variables

Functional Specifications

In this study, the relationship between economic development and pollutant emissions is analyzed using pooled cross-section and time series data for the regressions, i.e., panel data analysis. Following the basic model above, the fully specified empirical models adopted in this study are the following:

$$\ln\text{POLLUTION}_{it} = \beta_0 + \beta_1 \ln Y_{it} + \beta_2(\ln Y_{it})^2 + \alpha_i + \upsilon_{it} \quad (1)$$

$$\ln\text{POLLUTION}_{it} = \beta_0 + \beta_1 \ln Y_{it} + \beta_2(\ln Y_{it})^2 + \beta_3\text{FDI}_{it} + \beta_4\text{ILIT}_{it} + \beta_5\text{DEM}_{it}$$
$$+ \beta_4\text{ENERit} + \beta_7\text{POP}_{it-1} + \beta_8\text{DEBT}_{it} + \beta_9\text{ECONGROWTH}_{it-1}$$
$$+ \beta_{10}\text{TRADE}_{it} + \beta_{1i}\text{MANUFACTURE}_{it} + \alpha_i + \upsilon_{it} \quad (2)$$

where

Symbol	Variable
$POLLUTION_{it}$	Pollutant emissions per capita: Carbon dioxide and sulfur dioxide emissions per capita for country i at period t
Y_{it}	GDP per capita
Y^2_{it}	GDP per capita-squared
FDI_{it}	Ratio of FDI to GDP
$ILIT_{it}$	Illiteracy Rate
DEM_{it}	Democracy Index (Political Institutions score: sum of political rights and civil liberty scores)
$ENER_{it}$	Energy Efficiency measured as the ratio of GDP to Energy Use
POP_{it-1}	Population Growth Rate (one-year lag)
$DEBT_{it}$	Total Debt divided by the GDP
$ECONGROWTH_{it-1}$	Economic Growth Rate (one-year lag)
$TRADE_{it}$	Importance of trade measured as the ratio of total exports and imports (goods and services) to GDP
$MANUFACTURE_{it}$	Manufacturing Industry (value-added) as percentage of GDP
α_i	Unobserved Heterogeneity (Unobserved Time-Constant Factors Which Affect the Dependent Variable)
υ_{it}	Error Term

The Data

The relationship between pollutant emissions (dependent variable) and income is examined. The eight East Asian countries included in this study are as follows: China, Indonesia, Japan, Malaysia, Philippines, Singapore, Thailand, and South Korea.

Carbon Dioxide Emissions

Cross-country statistics on pollutant emissions for 1980 to 2000 were obtained. For national carbon dioxide emissions (metric tons of CO2 per capita), data sets were collected from the Carbon Dioxide Information Analysis Center's (CDIAC) Trends Database on Global, Regional, and National Fossil Fuel CO2 Emissions. CO2 emissions statistics were estimated using data from the combustion of fossil fuels, gas flaring, and the production of cement.

Income

Purchasing power parity-adjusted Gross Domestic Product (GDP) per capita, in constant 2005 international US Dollars, is used as national income measure. These data are obtained from the World Bank Development Indicators website.

Institutions

The political institutions variable, DEM, is an index which measures democratic access (political rights and civil liberties), as compiled and reported by Freedom House. According to Freedom in the World (2008), the indicators were drawn from the Universal Declaration of Human Rights. DEM is created by adding each country's political rights and civil liberties indices. With the addition of the two indices, the DEM variable's value ranges from 2 to 14. A higher value implies less political and economic freedom, which could indicate poor regulation of environmental policies and programs.

Other Variables

The macroeconomic variables selected for the empirical model are foreign direct investment as percentage of GDP, foreign debt as percentage of GDP, manufacturing value-added as percentage of GDP, energy efficiency as measured by GDP per unit of energy consumed, and terms of trade of goods and services. Structural factors like annual growth of GDP and illiteracy rates were also included. For population factors, population growth rate is used as an explanatory variable in the model. Most of the data for these variables were obtained from the World Bank Development Indicators website and the United Nations Statistical Database.

Econometric Techniques

The relationship between economic development and carbon emissions is analyzed using panel data analysis. Panel data analysis is employed due to the following reasons: 1) it allows bigger sample size; 2) it allows the study of dynamic as well as cross-sectional aspects of the problem; and 3) it controls for individual country and time invariant variables.

Since this study uses time series data from 1980 to 2000, econometric tests for serial correlation (Durbin-Watson test) and heteroskedasticity (Breusch-Pagan test) are used to obtain fully corrected models. In addition, for panel analysis, the Hausman test is employed.

3. Results and Discussion

Hausman Test

For the dependent variable, CO2, the null hypothesis is strongly rejected. This implies that the difference between random and fixed effects coefficients is systematic. Therefore, the fixed effects model should be used to obtain better estimation.

Serial Correlation and Heteroskedasticity

To conduct correction procedures for obtaining consistent and unbiased estimates, Equation 2 is first tested for serial correlation and heteroskedasticity. Unfortunately, it was found out that the model suffers from serial correlation and heteroskedasticity problems.

Fully Corrected Model

Instead of merely using Ordinary Least Squares estimation, Weighted Least Squares estimation, together with Prais-Winsten regression, is employed to correct for the serial correlation and heteroskedasticity issues of the fixed effects model.

Pooled data results for CO2 pollutant emissions are shown in Table 1 for the full sample of eight East Asian countries for the time period 1980-2000.

Table 1 Fully Corrected Fixed Effects Estimation of Factors Affecting Annual Per Capita CO_2 Emissions, 1980-2000

Independent Variable	Model 1	Model 2
	Coefficient *p-value*	
Y	1.46003**** *0.011*	2.501731**** *0.000*
Y^2	-.03338 *0.311*	-.09610**** *0.001*
FDI		-.00539 *0.227*
TRADE		.00027 *0.651*
MANUFACTURE		.01142**** *0.001*
ENER		-.17526**** *0.000*
POP		.02658** *0.097*
DEBT		-.00576* *0.119*
ECONGROWTH		.00053 *0.723*
ILIT		-.00499 *0.414*
DEM		.00010 *0.983*
Constant, β_0	-8.97518**** *0.000*	-12.65106**** *0.000*
Adjusted-R^2	0.7127	0.7614
Number of Observations, n	168	168

Note: **** denotes that coefficients are significant at the 1% level, *** at 5% level, ** at 10% level, * at 15% level.

Based on Table 1's Models 1 and 2 results, the factors which have a significant effect (at the 1% to 15% level of significance) on per capita CO2 emissions are the following: Y, Y2, MANUFACTURE, ENER, POP, and DEBT. Overall, the results in Table 1 strongly confirm the Environmental Kuznets Curve hypothesis. Significant positive per capita GDP terms, Y, and negative quadratic GDP terms, Y2 are observed. Such might indicate that at the early stages of development, as industrialization progresses, environmental deterioration increases due to greater use of resources. In addition, early stages of growth are characterized by more pollutant emissions, employment of inefficient technologies, and ignorance of the environmental consequences of growth. But, once economic development continues, people eventually shift to cleaner technologies and acquire more information on how to improve environmental quality.

Meanwhile, the significance of other variables shows other socioeconomic factors' effect on East Asian carbon dioxide emissions. For instance, MANUFACTURE is highly significant at the 1% level. As expected, it has a positive sign. A high share of the manufacturing industry value-added in GDP is associated with increased energy consumption, a process which is pollution-intensive. Furthermore, the positive relationship of pollution and manufacturing can also be a result of the failure to focus on environment protection because expanding the economy through rigorous manufacturing is being prioritized. Meanwhile, energy efficiency, ENER, is statistically significant and negative. This implies that as GDP per unit of energy increases, pollutant emissions decrease.

The population growth variable, POP, is positive and statistically significant at the 1% level. Such result is quite obvious. As the population grows, escalation of commercial activities such as transportation, production of commodities, etc. that result to higher pollution levels are induced.

DEBT has a negative and significant coefficient. This is consistent with the debt-for-nature swap programs in developing countries. Since CO2 is a stock pollutant which accumulates over time, it might be that governments tend to be more forward-looking. Such an attitude induces the need for debt-for-nature policies. Debt-for-nature swap programs are commonly suggested by international organizations as a tool for conservation efforts (Bhattarai and Hammig, 2004). Accordingly, these programs provide a financing mechanism for long-run environmental protection.

The lagged annual economic growth rate, ECONGROWTH, is positive but insignificant. It is probable that the previous year's economic growth rate does not have a significant effect on this year's pollutant emissions because the effect of changes in national income on air pollution is more immediate.

The DEM coefficient is positive but insignificant for CO2 emissions. For the East Asian region, a country's degree of democratic freedom does not have sufficient impact on pollution abatement. Democracy may lead to more equitable distribution of resources and more access on information, but this does not necessarily translate into higher pollution control efficiency. In addition, ILIT, the measure of illiteracy rate of a country's adult population, is also insignificant. This only signals that higher literacy does not automatically translate into greater advocacy for sustainable development.

The FDI coefficient is noticeably significant. However, the insignificant negative correlation might slightly indicate that multinational businesses located in low-income countries are often environmentally friendlier than domestically owned firms (Dinda, 2004).

Lastly, though TRADE's coefficient is positive for the CO2 equation as well, it is not highly significant. This, however, could slightly imply a possible relationship between trade liberalization and worsening environment conditions.

4. Conclusion

Summary

It is hoped that this study, an inquiry into the relationship between CO2 emissions and GDP for a sample of East Asian countries, has provided empirical evidence to support the Environmental Kuznets Curve hypothesis. It has been shown, using fully corrected fixed effects models, that for the period 1980 to 2000, the inverted U-shaped Environmental Kuznets Curve does exist. The results imply that pollution increases as income rises but, after reaching a certain income level, a decrease in pollution is anticipated. It has also been empirically shown that economic and demographic variables also contribute to environmental degradation. Possible determinants for per capita CO2 emissions are the following: GDP per capita, GDP per capita-squared, manufacturing intensity, energy efficiency, population growth, and debt share in GDP.

Recommendations

This paper recommends other paths of future research to analyze further the existence of the Environmental Kuznets Curve. It is suggested that other environmental measures like water quality, biological oxygen demand, nitrous oxide, and heavy metal concentration be empirically examined. Another recommendation is the exploration of the role of other socioeconomic variables such as income inequality and vehicle ownership. Some macroeconomic variables like research expenditures and exchange rate can also be used. The use of other measures of development, e.g. the Human Development Index, is also recommended. Finally, to provide stability to empirical findings, the time period considered in this research may also be expanded. The number of countries covered can also be increased. It might be possible that the whole Asian region's Environmental Kuznets Curve be investigated. Furthermore, other regressions may be obtained by grouping countries according to the level of income.

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