***comparative analysis on environmental kuznets curve focusing on the turning point***

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## Overview

Climate change has emerged a serious problem. International organizations such as the Intergovernmental Panel on Climate Change (IPCC) have published the annual report. The Paris agreement was ratified successfully, though it has weak binding force for parties. The parties must reduce their carbon emissions by intended nationally determined contribution. The Paris agreement includes technology transfer business from developed to developing countries. Although this seems to imply international cooperation to solve the climate change problem, there exists another perspective. Developed countries attempt to share the responsibility on climate change to developing countries which may be caused by the development procedure of developed countries. Thus, it may be a role of developed countries to make policy implication as the precedents. By investigating the turning point of the Environmental Kuznets Curve (EKC) with developed countries data, we can forecast the time when developing countries will make an effort to carbon mitigation.

International Energy Agency (IEA) published the report covering the relationship between energy and climate change (IEA, 2015). The two-thirds of greenhouse gases emissions are related to energy production and consumption. Therefore, desirable energy roadmap can be a shortcut for sustainable development. Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) analysis, which is a model to investigate the determinants of economic degradation, is conducted to suggest energy policy direction.

In EKC study, the turning point denotes the point that the relationship between per capita income and per capita environmental degradation is going to be different. For instance, the zero gradient point is the turning point under the assumption of inverted U-shape curve of EKC. The purpose of this study is to make policy implication for developing countries by investigating the turning point of the EKC hypothesis and the determinants of each turning point. To accomplish this, we conduct the comparative analysis for the EKC hypothesis confirmation adopting two analysis framework which uses degradation intensity and per capita variable, respectively. Time series analysis for each country is also adopted to estimate the turning point of each country. Since the EKC hypothesis is based on the fact that environmental conservation efforts start to be made when a country’s economic level reaches a certain level, our empirical study is conducted for developed countries – OECD.

## Methods

In this paper, two EKC empirical frameworks are adopted. One is estimation with per capita variables. The other is based on degradation intensity. The estimation with per capita variables is a traditional EKC hypothesis confirmation which investigates the inverted-U shaped relationship between per capita income and per capita environmental degradation. In this analysis, we use the following equational framework:

 , (1)

where  indicates carbon emissions per capita as a dependent variable.  and  are per capita GDP and quadratic form of it, respectively.  denotes a vector of additional variables. In this analysis, the share of trade to GDP is chosen as an additional variable considering the adoption history of existing literature. Through the natural logarithm transformation, the following equation is constructed.

 , (2)

where  and indicate cross-section and time-series, respectively.  is an additional variable to control the heterogeneity across the cross-section.  denotes identically independent error term if this equation is estimated well based on stochastic assumption. In case that  is revealed as a negative value and statistically significant, inverted U-shape curve exists between per capita GDP and per capita carbon emissions. However, it is too early to say that the EKC hypothesis is confirmed.  must be a positive value. The EKC exists when maximum point of the curve is positive since per capita GDP cannot be negative. Furthermore,  also presents the scale effect.

However, according to Stern et al. (1996), environmental impact determined by production size and technology varies across panels of countries. Thus, we conducted pooled regression with degradation intensity data which is free from the mixed scale and technology effect. After then, time series analysis for each country is conducted to estimate EKC for a single country. Through the comparative analysis, we identify which model is more plausible and from the estimated EKC for each country, the determinants of turning point are investigated.

## Results

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| --- | --- | --- |
| Variables | FMOLS | DOLS |
| Coefficient (P-value) | Coefficient (P-value) |
| GDP | 9.6699 (0.0000) c | 12.2116 (0.0000) c |
| Quadratic GDP | -0.4609 (0.0000) c | -0.5871 (0.0000) c |
| Trade | -0.2357 (0.0000) c | -0.2165 (0.0006) c |
| Adjusted R-squared | 0.9570 | 0.9798 |
| Turning point | 35,963 USD | 32,857 USD |

Note: c indicates rejection of the null hypothesis at the 1% significance level.

The long-run equilibrium relationship among variables is confirmed. As a result of cointegrating equation estimation, the EKC hypothesis is confirmed with high statistical significance. For the comparative analysis, both results are statistically significant. The turning point is well estimated which is not greatly different from the results of time-series analysis. The turning point is strongly related to the size of the country and the speed of growth.

## Conclusions

We suggest two purposes of this study. One is to conduct a comparative analysis of two methods to estimate EKC. The other is to make policy implication for developing countries using the investigated determinants of a turning point in the robust framework. The empirical results of both models are statistically significant enough to be utilized as reference data for developing countries. The estimated turning point is about 35,963 USD. This implies that some of developing countries have not yet reached the turning point. Considering the turning points are different depending on country and strongly related to the size and the speed of growth, individual policy implications are necessary. The infrastructure and geopolitical condition must be considered. In the additional analysis for policy implication, STIRPAT analysis, it is definite that fossil fuel usage has quite a positive impact on carbon emissions, while renewable energy affects carbon mitigation relatively small. Therefore, developing countries must start by reducing fossil fuel usage. In this context, technology transfer of the Paris agreement may help developing countries switching their energy sources.

## References

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