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TESTING ENVIRONMENTAL KUZNETS CURVE IN THE SELECTED TRANSITION ECONOMIES WITH PANEL SMOOTH TRANSITION REGRESSION ANALYSIS

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Abstract

The Environmental Kuznets Curve (EKC) introduces an inverted U-shaped relationship between environmental pollution and economic development. The inverted U-shaped curve is seen as complete pattern for developed economies. However, our study tests the EKC for developing transition economies of European Union, therefore, our results could make a significant contribution to the literature. In this paper, the relationship between carbon dioxide (CO₂) emissions, gross domestic product (GDP), energy use and urban population is investigated in the Transition Economies (Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia). Environmental Kuznets Curve is tested by panel smooth transition regression for these economies for 1993 – 2010 periods. As a result of study, the null hypothesis of linearity was rejected and non-remaining nonlinearity test showed that there is a smooth transition exists between two regimes (below \$5176 GDP per capita is first one and above \$5176 GDP per capita is second one) in the related period for these economies.

Keywords: panel data models, panel smooth transition regression model, transition economies, environmental Kuznets curve.

JEL Classification: C23, C24, P20, P28

Introduction

There are several factors exist that effect the environment adversely while economic growth continues. The main factor of this degradation is Greenhouse gases (GHGs) among the others. According to IPCC report (IPCC, 2014), human-induced CO₂ emissions merely holds more than 75% of the GHG emissions. Thus the main concern of this paper is the relationship of CO₂ emissions and income.

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The Environmental Kuznets Curve (EKC) proposes an inverted-U shaped relationship between various indicators of environmental pollution and economic activity (Apergis and Payne, 2009). Accordingly, environmental deterioration increases in the first stage of economic growth until threshold or turning point, and then in the second stage, it begins to decrease. This pattern could be seen as the path of the developed economies. However, the findings for the developing economies' path is still ambiguous in the literature. In our study, this unclear relationship is going to be evaluated by an unusual non-linear model. Therefore, our findings could make an important contribution to the literature. In order to assess this relationship in Transition Economies, recently developed Panel Smooth Transition Regression (PSTR) by Fok, Dijk, and Franses (2005) and Gonzalez, Terasvirta and Dijk. (2005) is implemented to data for 1993-2010 period.

In the study, each countries' path is going to be evaluated separately. In this way, it is aimed to observe the path of the individual countries in order to obtain their curve with their threshold income level. The threshold value enables us to understand their paths better. In order to do that non-linear relationship is going to be evaluated first and then the number of transition functions is going to be defined which enables us to determine the number of regimes in the related period.

The paper is organized as follows; section two outlines the related literature, section three describes our data and model specification, section four presents our empirical results, and finally section five describes conclusion.

1. Literature Review

Numerous studies have been conducted in different types of techniques so far in order to shed light on CO₂ – income relationship. On the basis of this relationship, in several cases, a number of empirical studies have identified a U-shaped curve; Kahuthu (2006) by Panel Data Analysis; Jalil and Mahmud (2009) by ARDL Model; Musolesi, Mazzanti and Zoboli (2009) by Panel Bayesian Estimation; Nasir and Rehman (2011) by Cointegration; Rehman, Nasir, and Kanwal (2012) by Panel Model; Kiviyiro and Arminen (2014) by ARDL Model; *López-Menéndez*, Pérez and Moreno (2014) by Panel Model; Shahbaz, et al. (2014) by ARDL Model; Heidari, Katircioğlu, and Saeidpour (2015) by Panel Smooth Transition Regression. Main results of these studies can be thought supportive for the EKC theory. It would outline methodologies and their main results of these studies (table no.1).

Table no. 1: Literature Review

Authors	Methodology	Main Result(s)
Bertinelli and Strobl (2005)	Semi Parametric Regression Estimator	A bell-shaped link between CO ₂ and GDP/capita.
Azomahou, Laisney and Van (2006)	Nonparametric Panel Approach	There is a stable relationship between CO ₂ emissions per capita and GDP per capita over time during the period of the study.
Galeotti, Lanza and Pauli (2006)	Estimation of alternative functional forms	Cointegrated relationship between per capita emissions and income.
Kahuthu A. (2006)	Panel Data Analysis	CO ₂ emissions and GDP per capita seems to have changed from a linear shape to an inverted-U one.

Authors	Methodology	Main Result(s)
Huang, Lee, and Wu (2008)	Quadratic Model	Exhibit a quasi-L-shape or hockey-stick-curve trend.
Aslanidis and Iranzo (2009)	Panel Smooth Transition Regression	There is no evidence of environmental Kuznets curve
Halicioglu F. (2009)	ARDL Model	The elasticity of CO ₂ emissions with respect to income in the long run is found to be 12.31-1.66y.
Jalil and Mahmud (2009)	ARDL Model	The positive sign with income and negative sign with the quadratic term of income confirms the existence of EKC for CO ₂ emission in the case of China.
Lee and Lee (2009)	Panel Cointegration	Real GDP and CO ₂ emissions in these countries are a mixture of I(0) and I(1) processes.
Musolesi, Mazzanti and Zoboli (2009)	Panel Bayesian Estimation	More industrialized countries show evidence of EKC in quadratic specifications. A less-developed country consistently shows that CO ₂ emissions rise positively with income.
Fodha and Zaghoud (2010)	Johansen Cointegration Approach	There is a monotonically increasing linear relationship between per capita CO ₂ emissions and per capita GDP.
He and Richard (2010)	Parametric Cubic Models	Per capita GDP and per capita CO ₂ emissions exhibit monotonically increasing but that the slope of that function changes often over time.
Hossain S. Md. (2011)	Johansen Panel Cointegration	There is a short run casual relationship from economic growth and trade openness to CO ₂ emissions.
Nasir and Rehman (2011)	Johansen Cointegration and VECM	The EKC is only a long-run phenomenon in case of Pakistan.
Pao and Tsai (2011)	Multivariate Granger Causality	CO ₂ emissions appear to be GDP elastic if GDP is less than 1.174, with GDP being inelastic if GDP is greater than 1.174.
Sharma S. S. (2011)	Panel Model	GDP per capita has positive effect on CO ₂ emissions.
Arouri et al. (2012)	Panel ECM and Cointegration	Real GDP exhibits a quadratic relationship with CO ₂ emissions for MENA region.
Borhan, Ahmed and Hitam (2012)	Simultaneous Equation Models	Simultaneous relationship exists between CO ₂ of air pollution and income.
Rehman, Nasir and Kanwal (2012)	Panel Model	An inverted-U shaped relationship between per capita income (GDP) and the CO ₂ emissions.
Bassetti, Benos and Karagiannis (2013)	Panel Model	The results do not support theoretical models predicting that a country can be caught simultaneously in a poverty and environment trap
Mosheim R. (2013)	Panel Model	There is a support for the pattern that a greater degree of income equality leads to better environmental outcomes.

Authors	Methodology	Main Result(s)
Wang C. (2013)	Decomposition Technique	Output growth is a major source for increases in carbon dioxide emissions while decline in energy intensity is the main contributor to the reduction of emissions.
Azlina, Law and Mustapha (2014)	Multivariate Cointegration	There is no casual evidence of an effect of income on emission.
Boutabba M. A. (2014)	ARDL Model	The long-run and casual relationships between per capita CO ₂ emissions, financial development, per capita real GDP, the square of per capita real GDP, per capita energy use and trade openness.
Kiviyiro and Arminen (2014)	ARDL Model	The results support the EKC hypothesis could be an inverted-U shaped.
Lopez-Menendez., Pérez and Moreno, (2014)	Panel Model	The existence of an EKC could be assumed for these countries.
Shahbaz et al. (2014)	ARDL Model	Economic growth is granger cause of CO ₂ emissions.
Zeb et al. (2014)	Johansen Cointegration	There is a long run relationship among ERS, CO ₂ , NRD, GDP and Poverty.
Heidari, Katircioğlu and Saeidpour (2015)	Panel Smooth Transition Regression	Nonlinear relationship among CO ₂ emissions, energy consumption and GDP per capita.

On the other hand, several studies do not find any supportive results for the EKC or they presented ambiguous results. Additionally, Aldy (2004) stated that, estimated EKC_s are changing for panel of 48 states in the U.S. and carbon dioxide emissions – income relationship could be spurious. Moreover, Bertinelli and Strobl (2005) investigated 122 countries for 1950-1990 periods by semi-parametric regression estimator and found just a little evidence in favor of the EKC.

2. Data and Model Specification

2.1. Data

With the aim of evaluation the linkage between income and carbon dioxide emissions, annual data is used on 11 Transition Economies from 1993 to 2010. All variables are collected from World Development Indicators of the World Bank. Selected Transition Economies which are the members of European Union consist of Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia. The descriptive statistics of variables are demonstrated in below (table no. 2).

Table no. 2: Summary statistics of the variables (logarithmically)

	lnCO _{it}	lnGDP _{it}	lnURPO _{it}	lnENUSE _{it}
Mean	0.80	3.76	6.57	3.42
Median	0.79	3.75	6.48	3.41
Maximum	1.15	4.43	7.38	3.65
Minimum	0.42	3.03	5.96	3.17
Std.Dev.	0.18	0.33	0.42	0.12
Skewness	0.11	-0.20	0.26	0.02
Kurtosis	-0.84	-0.73	-0.92	-0.99

The table summarizes descriptive statistics of the variables. Each variable has 198 observations from 1993 to 2010. Carbon dioxide emission (lCO_{it}) variable is measured in terms of metric tons per capita as a dependent variable in the model, real GDP per capita ($lGDP_{it}$) is measured in current US dollars prices, urban population ($lURPO_{it}$) variable represents the number of people who live in urban areas, finally, kilogram of oil equivalent energy use ($lENUSE_{it}$) is used as a transition variable in the PSTR model.

2.2. Model Specification

In order to evaluate the relationship between our variables in the panel context, resolving the heterogeneity and time variability problems is vital. PSTR approach is an appropriate one for overcoming these two problems simultaneously. Following González et al. (2005), PSTR model with two extreme regimes and a single transition function can be written as shown below;

$$y_{i,t} = \mu_i + \beta_0' x_{i,t} + \beta_1' x_{i,t} g(p_{i,t}; \gamma, c) + u_{i,t} \quad (1)$$

where:

$$\begin{aligned} i &= 1, \dots, N; \\ t &= 1, \dots, T; \end{aligned}$$

where:

N and T represent the total number of countries and the size of related period, respectively.

The dependent variable y_{it} is a scalar, x_{it} is a k -dimensional vector of time-varying exogenous variables, μ_i represents the fixed individual effect, and u_{it} are the errors. Transition function $g(p_{it}; \gamma, c)$ is a continuous function of the transition variable p_{it} and is normalized to be bounded between 0 and 1, and these extreme values are associated with regression coefficients β_0 and $\beta_0 + \beta_1$ (Nieh and Yao, 2013).

According to the study of Granger and Teräsvirta (1993) and Gonzalez, Terasvirta and Dijk (2005) the following logistic transition function is defined as follows:

$$g(p_{i,t}; \gamma, c) = [1 + \exp(-\gamma \prod_{j=1}^m (p_{i,t} - c_j))]^{-1} \text{ with } \gamma > 0 \text{ and } c_1 \leq \dots \leq c_m \quad (2)$$

where:

$c = (c_1, \dots, c_m)'$ is an m-dimensional vector of the location parameters;
 γ is the slope of transition function which determines the smoothness of the transitions (Nieh and Fan, 2012).

And considering the two most common cases in practice in order to capture nonlinearity, correspond to $m = 1$ (logistic) and $m = 2$ (logistic quadratic) (Coudert, Courharde and Mignon, 2014). For every value of m, when $\gamma \rightarrow \infty$, the PSTR becomes a panel transition regression (PTR) model. Conversely, when $\gamma \rightarrow 0$, the transition function is constant and the PSTR estimation becomes a panel with fixed effects (Wu, Liu and Pan, 2013). Also the three regime smoothing transition regression can be demonstrated as below;

$$y_{i,t} = \mu_i + \beta_0' x_{i,t} + \beta_1' x_{i,t} g_1(p_{i,t}; \gamma_1, c_1) + \beta_2' x_{i,t} g_2(p_{i,t}; \gamma_2, c_2) + u_{i,t} \tag{3}$$

Similarly, parameters c_1 and c_2 are the thresholds giving the location of the transition function and parameters γ_1 and γ_2 are the slope parameters of the transition functions respectively (Giovanis, 2012).

In addition, it is possible to specify the PSTR model to more than two regimes:

$$y_{i,t} = \mu_i + \beta_0' x_{i,t} + \sum_{j=1}^r \beta_j' x_{i,t} g_j(p_{i,t}^{(j)}; \gamma_j, c_j) + u_{i,t} \tag{4}$$

where:

$r + 1$ is the number of regimes;
 $g_j(p_{i,t}^{(j)}; \gamma_j, c_j), j = 1, \dots, r$, are the transition functions (Béreau, Villavicencio and Mignon, 2010).

3. Empirical Results

The estimation of PSTR model consists of a few stages. Firstly, a linearity test is applied to the model and then if linearity is rejected, the most appropriate number of transition function is determined by no-remaining non-linearity test as a second stage. Finally, PSTR model is estimated by nonlinear least squares.

As a first and second stage of PSTR model, we apply linearity and no-remaining non-linearity tests to our model. As a result of these tests' results (table no. 3), it is easily noticeable that we strongly reject the null hypothesis for linearity test and we cannot reject the null hypothesis of no-remaining non-linearity test and we decided that there is a one transition between two extreme regimes.

Table no. 3: Linearity and no-remaining non-linearity tests

	m=1			m=2		
	LMF	LMw	LR	LMF	LMw	LR
$H_0: r = 0$ vs. $H_1: r = 1$	94.059 (0.000)	119.849 (0.000)	184.067 (0.000)	55.647 (0.000)	128.396 (0.000)	206.997 (0.000)
$H_0: r = 1$ vs. $H_1: r = 2$	1.017 (0.386)	3.337 (0.343)	3.366 (0.339)	0.115 (0.995)	0.776 (0.993)	0.778 (0.993)

Note: r, m represents the number of transition functions and the number of location parameters respectively. P-values are in the parentheses.

After this stage, in order to determine the number of location parameters, Akaike and Schwarz information criterions are calculated based on Jude (2010). Consequently, the most suitable model consists of one transition function and one location parameter for the related period according to results (table no.4).

Table no. 4: Determination of the number of location parameters

PSTR Model (m, r)	(1, 1)	(2, 1)
RSS	0.09	0.09
AIC	-7.569	-7.558
SIC	-7.436	-7.408

Note: r, m represents the number of transition functions and the number of location parameters respectively.

The main results of the final PSTR model are reported using a specification of one smooth transition function and one location parameter (table no.5). As a result of our model, the value of slope parameter is equal to 2.8337 which indicates that a smooth and continuous transition function exists between two extreme regimes. The threshold value of our model is equal to -3.714 which its antilog is equal to 5176\$. These value separates two extreme regimes from each other. The first regime is experienced until GDP per capita of 5176\$, and second regime is observed after this value. Moreover these results coincide with the literature. Grossman and Krueger (1995) stated that for different pollutants, the turning point is expected to occur until 8000\$ GDP per capita. Conversely, our results show that EKC does not exist in the related period for our sample countries. The reason for that GDP per capita has negative effect on CO₂ emissions per capita in the first regime while urban population and energy use variables have positive effect. In the second regime, the scenario is totally opposite. Thus, it is concluded that a U-shape EKC is valid for Transition Economies which is the member of European Union in the 1993-2010 period according to PSTR model results.

Table no. 5: Estimation results of two-regime PSTR model

Coefficients	Dependent variable CO _{it}	
	Regime 1	Regime 2
$\beta_{GDP_{it}}$	-8.3030* (-445.3)	
$\beta_{URPO_{it}}$	1.6547* (10.8)	
$\beta_{ENUSE_{it}}$	0.1969* (1995.7)	
$\tilde{\beta}_{GDP_{it}}$		8.3030* (446.2)
$\tilde{\beta}_{URPO_{it}}$		-1.6547* (11.7)
$\tilde{\beta}_{ENUSE_{it}}$		-0.1969* (-inf.)
γ	2.8337	
c	-3.714	

Note: () 1%, significance levels. The values in parentheses are t-statistics.*

Time series plots of CO₂ and GDP per capita variables are demonstrated for 11 transition economies (figure no.1). Vertical axis refers to CO₂ emissions per capita and horizontal one stands for GDP per capita.

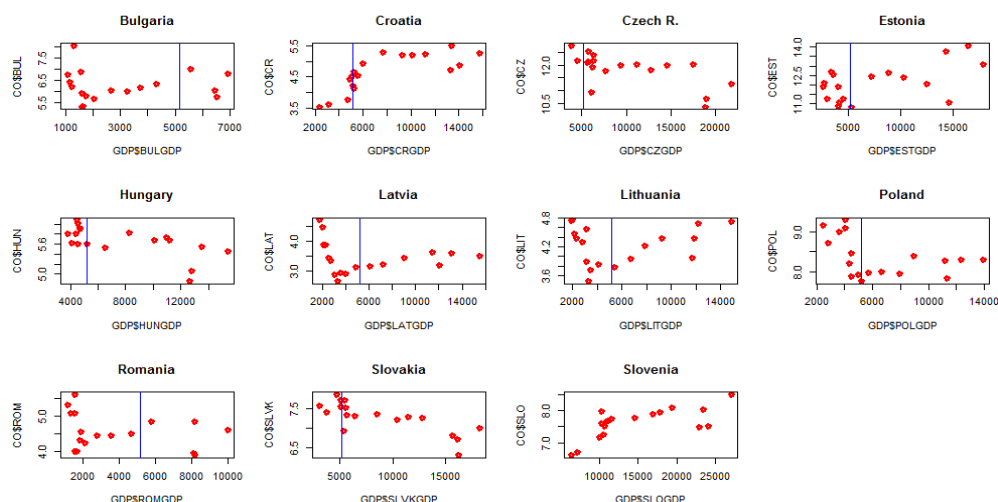


Figure no. 1: CO₂ – GDP per capita

Note: Vertical line represents threshold value

On the one hand, we concluded that the EKC does not exist in the related period for these economies nevertheless, after or around threshold value, the majority of sample countries tend to exhibit an increasing pathway for an inverted U-shape while progressing through higher income levels such as; Bulgaria, Croatia, Estonia, Latvia, Lithuania, Poland and Slovenia. Other economies are following a decreasing trend or ambiguous period after threshold value while their economies are growing.

Conclusions

In this paper, the PSTR model is employed to investigate the transition dynamics of CO₂ emissions per capita and GDP per capita by using eleven Transition Economies data for the period from 1993 to 2010. In order to explain the heterogeneity in time and country between CO₂ emissions per capita and other variables, energy use is used as a transition variable in the model.

Our PSTR model results demonstrate that an obvious non-linear relationship exists between CO₂ emissions per capita and GDP per capita in the selected eleven Transition Economies. The existence of the non-linear relationship is consistent with the literature (Heidari, Katircioğlu and Saeidpour, 2015). However, the EKC is not validated by the estimation results of PSTR model, there is an ordinary U-shaped relationship in the related period. Turning point of this curve is estimated to be 5176\$ GDP per capita which is the appropriate value with the literature (Grossman and Krueger, 1995). Individual country analysis showed that particularly Bulgaria, Romania, The Czech Republic, Hungary and Slovakia followed an inverted U-shaped path in the related period. They showed a decreasing trend after the threshold value, therefore, these countries paths could be seen in line with the EKC theory. On the contrary, Croatia, Latvia, Lithuania, Poland and

Slovenia's paths could be interpreted as U-shaped period. In addition, Estonia has an ambiguous period for the EKC theory.

The regression coefficients support that as GDP per capita increases, CO₂ emissions per capita decreases in the first regime, afterwards CO₂ emissions per capita tend to move in accordance with GDP per capita in the second regime which means they increase simultaneously after threshold value of 5176\$ GDP per capita. Consequently, there is a U-shaped relationship between economic growth and carbon dioxide emissions for these eleven Transition Economies in the related period. However, considering additional variables that may affect the dependent variable could enable more accurate results for further studies.

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