The Relationship between CO_2 Emission, Energy Consumption, Urbanization and Trade Openness for Selected CEECs

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Abstract

This paper investigates the relationship between CO_2 emission, real GDP, energy consumption, urbanization and trade openness for 10 for selected Central and Eastern European Countries (CEECs), including, Albania, Bulgaria, Croatia, Czech Republic, Macedonia, Hungary, Poland, Romania, Slovak Republic and Slovenia for the period of 1991–2011. The results show that the environmental Kuznets curve (EKC) hypothesis holds for these countries. The fully modified ordinary least squares (FMOLS) results reveal that a 1% increase in energy consumption leads to a %1.0863 increase in CO_2 emissions. Results for the existence and direction of panel Vector Error Correction Model (VECM) Granger causality method show that there is bidirectional causal relationship between CO_2 emissions - real GDP and energy consumption-real GDP as well.

Keywords: carbon dioxide emissions, energy consumption, environmental Kuznets curve, central and eastern European countries

1. Introduction

Since the initial study of Kuznets (1955) which argues that there is inverted U-shaped relationship between per capita income and income inequality, this phenomenon has been adapted to different connections. The most popular hypothesis based on Kuznets curve is that the relationship between per capita income and environmental degradation. Grossman and Krueger (1991) argues that the inverted U-shaped relationship is also exist between per capita income and environmental degradation which means as per capita income increases, environmental degradation also increases to maximum point but then decreases and the turning point is the critical high level of income.

Economists paid great attention to the environmental effects of economic growth recently. To test the validity of EKC hypothesis used different econometric methodologies and different factors. In this context, energy consumption indicator is used as an important indicator of economic development in the models. (Apergis and Payne, 2009, 2010) use this indicator in their study to test validity of EKC hypothesis for the Central American Countries and the Commonwealth of Independent States respectively. Lean and Smyth (2010) use this indicator for the Asian countries. Shahbaz, Lean, and Shabbir (2012) examines the relationship between CO2 emissions, energy consumption, economic growth and trade openness for Pakistan for the period of 1971–2009 utilizing bounds test for cointegration and Granger causality approach. The empirical results indicate that there is a long-run relationship among the variables and they provide evidence in favor of the EKC and they concluded that energy consumption increases CO_2 emissions. Pao and Tsai (2010) test the relationships between pollutant emissions, energy consumption and output for a panel of BRICS countries for the period of 1971–2005, except for Russia (1990–2005) utilizing panel co-integration and VECM granger methods and they found that that there was a two-way relationship between the energy consumption and CO_2 emission. Sharma (2011) examines the determinants of CO_2 emissions applying dynamic panel data for 69 countries for the period of 1985–2005. He found that that the energy and electricity consumption increases CO_2 emission in higher income countries levels.

To the best of our knowledge, there is no any study to examine the validity of EKC hypothesis with the role of urbanization and trade openness in Central and Eastern European Countries. In this study, it is aimed to fill the gap in the literature of energy and environmental economics. The other advantage of this paper is to use multivariate framework because the bivariate models may lead inconsistent results. The rest of the paper is organized as follows.

The second section presents the literature review for selected CEECs. The third section discusses data, methodology and empirical results. The fourth section concludes.

2. Literature Review for Selected Central and Eastern European Countries

CEECs often included in panel data studies. Kasman and Duman (2015) examine the relationship between energy consumption, carbon dioxide emissions, economic growth, trade openness and urbanization for new EU member and candidate countries for the period 1992 -2010 utilizing panel unit root tests, panel cointegration methods and panel causality tests. They found evidence in favor of EKC. The results show that the mean CO_2 emission ranges from 3.363 in Turkey to 12.273 in Estonia, as for the per capita energy consumption, Macedonia has the lowest energy usage, Slovenia has the highest per capita GDP, Macedonia is the poorest country in the panel and in realizing emissions per capita, Estonia has the highest volatility, and Macedonia has the lowest between fifteen countries.

Sadorsky (2014) tests the impact of urbanization on CO_2 emissions utilizing recently developed panel regression techniques that allow for heterogeneous slope coefficients and cross-section dependence for 16 emerging economies including Hungary for the period 1971-2009. They found that the average annual growth rate in CO_2 emissions for Hungary is −0.93%. The results present that the reduction of CO_2 emissions lead to reduce affluence, population, and energy intensity of emerging countries.

Poumanyvong and Kaneko, S. (2010) analyze the impact of urbanization on energy use and CO 2emissions taking into consideration of different levels of development for 99 countries for the period 1975– 2005 utilizing the Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) model. The results indicate that the relationship between urbanization and emissions is positive and different across the three income groups. Additionally, they found that while urbanization lessens energy use in the low-income countries, it increases energy use in the middle-and high-income countries including Albania, Bulgaria, Hungary, Poland, and Romania.

Atici (2009) tests the effect of gross domestic product per capita, energy use per capita and trade openness on CO_2 emission per capita for Bulgaria, Hungary, Romania and Turkey for the period of 1980 -2002. He found evidence in favor of the environmental Kuznets curve.

Archibald, Bochniarz, Gemma and Srebotnjak (2009) analyze the impact of institutional changes on environmental quality in EKC for 25 Central and East European countries (CEECs) and the countries of the Commonwealth of Independent States (CIS). They found some evidence in favor of the EKC using biological oxygen demand indicator for Central and East European countries (CEECs).

Tamazian and Rao (2010) test the EKC hypothesis applying panel data methods for 24 transition economies including Bulgaria, Croatia, Czech Republic, Hungary, Macedonia FYR, Moldova, Poland, Romania Slovak Republic, Slovenia for the period of 1993–2004. The results provide evidence for EKC.

Shahbaz, Mutascu and Azim (2013) examine the dynamic relationship between economic growth, energy consumption and CO_2 emissions utilizing ARDL bounds test for the period of 1980–2010 for Romania. The results show that there is a long run relationship between economic growth, energy consumption and energy pollutants. They found that reveals that EKC is valid for Romania.

Madr, Sauer and Lisa (2014) investigated the validity of EKC using selected air pollution indicators for the period of 1972–2008 for Czech Republic. They found that EKC is valid for Czech Republic

Al-mulali and Sheau-Ting (2014) investigated bi-directional long run relationship between trade-energy consumption, trade-CO_2 emission, exports-energy consumption, exports-CO_2 emission, imports-energy consumption, and imports-CO_2 emission for 189 countries from six different regions including Eastern Europe using FMOLS for the period of 1990–2011. The panel results show that all the regions, excluding Eastern Europe, show a long run positive relationship between the trade variables-energy consumption and between the trade variable- CO_2 emission. However, The FMOLS test results provide an evidence for the presence of a bi-directional long run negative relationship between the trade of goods and services and energy consumption and CO_2 emission for East European namely Belarus, Bulgaria, Estonia, Latvia, Lithuania, Macedonia, Moldova, Poland, Romania, Russia, and Ukraine.

3. Data, Methodology and Empirical Results

The study covers annually data for the period from 1991 to 2011 for selected 10 Central and Eastern European countries, including Albania, Bulgaria, Croatia, Czech Republic, Macedonia, Hungary, Poland, Romania, Slovak Republic and Slovenia. Following the study of Farhani and Ozturk (2015), CO_2 emission is described as a function of real GDP, the square of real GDP, energy consumption, urbanization and trade openness. The panel version of empirical model is written as follows;

$$co_{it} = a_0 + a_1 y_{it} + a_2 y_{it}^2 + a_3 ec_{it} + a_4 urb_{it} + a_5 tr_{it} + \varepsilon_{it} \quad (1)$$

where t indicates time period ,i indicates cross-section and ε_{it} refers to residual term. In addition, co_{it} is carbon dioxide emission per capita, y_{it} (y_{it}^2) is the real gross domestic product per capita (the square of real gross domestic product per capita), ec_{it} is energy consumption per capita, urb_{it} is urbanization and tr_{it} is trade openness.

The carbon dioxide emission is used as the dependent variable measured in metric tons per capita, real gross domestic product per capita is measured in millions of constant 2005 US dollars. The energy consumption is measured in kg of oil equivalent per capita, urbanization is measured using urban population as share in total population and trade openness is measured using the sum of real exports and real imports per capita in millions of constant 2005 US dollars. The data of CO_2 emissions, urbanization and trade openness is sourced from World Development Indicators. The real GDP data is sourced from Penn World Table 8.0. All variables are used in logarithmic form. Some results are expected such as the inverted U-shaped Kuznets curve can be supported when a_1>0 and a_2<0. In addition, it is concluded that the energy consumption of these countries is efficient in the case of a_3<0.

In order to determine the stationarity level of variables, we used two homogeneous unit root tests and two heterogeneous unit root tests. The null hypothesis of all tests indicates unit root process in the panel. The results of unit root test are shown in Table 1. According to obtained results, the null of unit root can't be rejected at 1 percent level for all variables. In differenced forms, all series have become stationary and the alternative hypothesis that stationarity process is strongly accepted.

Table 1. Unit root test results

	co_{it}	y_{it}	ec_{it}	urb_{it}	tr_{it}
Level					
Within dimension					
Breitung-t	-0.7532	-0.2029	-1.7108	-0.5317	-0.5300
	(0.2257)	(0.4196)	(0.0436)	(0.7026)	(0.2981)
Levin et al.	-1.1385	-0.6203	-0.9559	-1.0975	1.2435
	(0.1275)	(0.2675)	(0.1695)	(0.1525)	(0.8932)
Between dimension					
ADF Fisher-chi-square	24.4122	28.4125	28.9396	26.7892	20.6590
	(0.2249)	(0.1000)	(0.0890)	(0.1413)	(0.4174)
IPS W.	-0.6485	-1.0295	-1.3657	-2.5045	-0.0877
	(0.2583)	(0.1516)	(0.0860)	(0.0061)	(0.4651)
First differences					
Within dimension					
Breitung-t	-6.4117	-2.4202	-4.6435	-2.6271	-5.5210
	(0.0000)	(0.0078)	(0.0000)	(0.0043)	(0.0000)
Levin et al.	-11.4779	-5.2378	-9.0256	-3.2686	-9.9738
	(0.0000)	(0.0000)	(0.0000)	(0.0005)	(0.0000)
Between dimension					
ADF Fisher-chi-square	121.004	67.7218	110.295	44.9497	71.6196
	(0.0000)	(0.0000)	(0.0000)	(0.0011)	(0.0000)
IPS W.	-10.9601	-6.0140	-9.9489	-3.9553	-6.3665
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)

Note: The maximum lag lengths were selected automatically using with Schwarz Information Criteria. Numbers in brackets are p-values. Newey-West bandwidth selection with Bartlett kernel is used for LLC test.

The long-run relationship between variables is examined using with panel cointegration method developed by Pedroni (1999). Pedroni (1999) developed seven statistics to analyze the possible long-run relation and the test which is based on estimation of Eq. 1 with estimation of $\delta_i \varepsilon_{it-1} + \sum_{k=1}^{K_i} \delta_{ik} \Delta\varepsilon_{it-k} + v_{it}$ regression model. The null hypothesis of test indicates that there is no cointegration between variables.

Panel cointegration test results are presented in Table 2. The results show that two homogeneous statistics (Panel PP-statistic and Panel ADF-statistic) and two heterogeneous statistics (Group PP-statistic and Group ADF-statistic) are statistically significant at 1 percent level therefore the null of no cointegration can be rejected.

Table 2. Panel cointegration test results

	Statistics	*p*-values
Within dimension		
Panel ν-statistic	0.0678	0.4729
Panel ρ-statistic	-0.5509	0.2908
Panel PP-statistic	-4.7853***	0.0000
Panel ADF-statistic	-5.4079***	0.0000
Between dimension		
Group ρ-statistic	1.0725	0.8583
Group PP-statistic	-6.3093***	0.0000
Group ADF-statistic	-7.9920***	0.0000

Note: *,** and *** indicates statistically significance at 10, 5 and 1 percent level respectively.

The next step is to investigate the long-run coefficients of variables. The long-run coefficients are estimated with the fully modified ordinary least squares FMOLS and the dynamic ordinary least squares (DOLS), which Pedroni developed (2000, 2001). The panel FMOLS estimation may be written as $\hat{\beta}_{GFMOLS} = N^{-1}\sum_{i=1}^{N}\beta_{FMOLSi}$, where β_{FMOLSi} is acquired from the individual FMOLS estimation of Eq. 1, The associated *t*-ratio can be obtained as $t_{\beta_{GFMOLS}} = N^{-1/2}\sum_{i=1}^{N} t_{\beta_{FMOLSi}}$. The first step of the DOLS estimation procedure may be written as follows:

$$GDP_{it} = \beta_{0i} + \beta_{1i}FC_t + \beta_{2i}GC_t + \beta_{3i}TR_t + \sum_{k=-K_i}^{K_i} a_{ik}\Delta FC_t + \sum_{k=-K_i}^{K_i}\delta_{ik}\Delta GC_t + \sum_{k=-K_i}^{K_i}\gamma_{ik}\Delta TR_t + \varepsilon_{it} \quad (2)$$

where$-K_i$ refers to leads, and K_i refers to lags. Similar to the FMOLS test, DOLS estimation can be constructed as $\hat{\beta}_{GDOLS} = N^{-1}\sum_{i=1}^{N}\beta_{DOLSi}$, where β_{DOLSi} is obtained from the OLS estimation of Equation 2 for each of the member countries and a similarly associated *t*-ratio can be constructed as $t_{\beta_{GDOLS}} = N^{-1/2}\sum_{i=1}^{N} t_{\beta_{DOLSi}}$.

In Table 3, at a first glance, it seems the inverted U-shaped EKC hypothesis is supported in these economies because of the parameter of the real GDP is positive and the parameter of the square of real GDP is negative. According to FMOLS results, the increase in energy consumption by 1% will increase CO_2 emissions by 1.0863% and the increase in trade openness by 1% will decrease CO_2 emissions by 0.0686%. According to DOLS estimation results, the increase in energy consumption by 1% will increase CO_2 emissions by 1.1609%. In addition, the increase in urbanization and trade openness by 1% will decrease CO_2 emissions by 1.1042 and 0.0968 respectively.

Table 3. Panel long-run estimators results

	Group mean FMOLS		Group mean DOLS	
Variables	Coefficient	*t*-statistic	Coefficient	*t*-statistic
y_{it}	1.3687***	2.7408	2.5162***	3.2396
y_{it}^2	-0.0778***	-2.6645	-0.1474***	-3.3603
ec_{it}	1.0863***	3.3742	1.1609***	4.0078
urb_{it}	-0.4271	-1.0010	-1.1042**	-2.3847
tr_{it}	-0.0686***	-2.7101	-0.0968***	-2.9730

Note: *,** and *** indicates statistically significance at 10, 5 and 1 percent level respectively.

Table 4. Panel VECM Granger causality results

	Short-run causality					**Long-run causality**
	Independent variables					
	Δco	Δy	Δec	Δurb	Δtr	Ect(-1)
Δco	-	14.815***	2.071	3.660	11.247***	-0.0013***
Δy	7.735*	-	12.335***	1.607	5.355	-0.0054***
Δec	8.780**	6.894*	-	1.696	8.021**	-0.0011***
Δurb	5.324	1.007	2.832	-	5.449	-0.0017**
Δtr	3.313	18.843***	9.362**	4.261	-	-0.0397***

Note: *,** and *** indicates statistically significance at 10, 5 and 1 percent level respectively. The optimal lag length is selected with using Schwarz Information Criteria.

The validity of long-run relationship indicates possible causal connections between variables. In order to determine the directions of causal linkages, we used panel VECM Granger causality method. The panel VECM can be written as follows;

$$\Delta co_{it} = \delta_{1i} + \sum_{q=1}^{k} \delta_{11iq} \Delta co_{it-q} + \sum_{q=1}^{k} \delta_{12iq} \Delta y_{it-q} + \sum_{q=1}^{k} \delta_{13iq} \Delta ec_{it-q} + \sum_{q=1}^{k} \delta_{14iq} \Delta urb_{it-q} + \sum_{q=1}^{k} \delta_{15iq} \Delta tr_{it-q} + \varphi_{1i} \varepsilon_{it-1} + v_{1it} \quad (3)$$

$$\Delta y_{it} = \delta_{2i} + \sum_{q=1}^{k} \delta_{21iq} \Delta y_{it-q} + \sum_{q=1}^{k} \delta_{22iq} \Delta co_{it-q} + \sum_{q=1}^{k} \delta_{23iq} \Delta ec_{it-q} + \sum_{q=1}^{k} \delta_{24iq} \Delta urb_{it-q} + \sum_{q=1}^{k} \delta_{25iq} \Delta tr_{it-q} + \varphi_{2i} \varepsilon_{it-1} + v_{2it} \quad (4)$$

$$\Delta ec_{it} = \delta_{3i} + \sum_{q=1}^{k} \delta_{31iq} \Delta ec_{it-q} + \sum_{q=1}^{k} \delta_{32iq} \Delta co_{it-q} + \sum_{q=1}^{k} \delta_{33iq} \Delta y_{it-q} + \sum_{q=1}^{k} \delta_{34iq} \Delta urb_{it-q} + \sum_{q=1}^{k} \delta_{35iq} \Delta tr_{it-q} + \varphi_{3i} \varepsilon_{it-1} + v_{3it} \quad (5)$$

$$\Delta urb_{it} = \delta_{4i} + \sum_{q=1}^{k} \delta_{41iq} \Delta urb_{it-q} + \sum_{q=1}^{k} \delta_{42iq} \Delta co_{it-q} + \sum_{q=1}^{k} \delta_{43iq} \Delta y_{it-q} + \sum_{q=1}^{k} \delta_{44iq} \Delta ec_{it-q} + \sum_{q=1}^{k} \delta_{45iq} \Delta tr_{it-q} + \varphi_{4i} \varepsilon_{it-1} + v_{4it} \quad (6)$$

$$\Delta tr_{it} = \delta_{5i} + \sum_{q=1}^{k} \delta_{51iq} \Delta tr_{it-q} + \sum_{q=1}^{k} \delta_{52iq} \Delta co_{it-q} + \sum_{q=1}^{k} \delta_{53iq} \Delta y_{it-q} + \sum_{q=1}^{k} \delta_{54iq} \Delta ec_{it-q} + \sum_{q=1}^{k} \delta_{55iq} \Delta urb_{it-q} + \varphi_{5i} \varepsilon_{it-1} + v_{5it} \quad (7)$$

where Δ is the lag operator, k is the lag length and ε_{it} is the residual terms from the FMOLS estimation of Equation 1.

Table 4 represents the panel Granger causality test results. In the short-run, there is bidirectional causal relationship between CO_2 emissions and real GDP. Similarly, the bidirectional causality exists between energy consumption and real GDP. Moreover, the bidirectional causality relationship exists between real GDP and trade openness. In addition, there is unidirectional causality from trade openness to CO_2 emissions. On the other hand, there is no any causal linkage between urbanization and CO_2 emissions. Furthermore, all error correction terms are statistically significant therefore there are bidirectional causality linkages between real GDP and CO_2 emissions, energy consumption and CO_2 emissions, energy consumption and real GDP in the long-run.

4. Conclusions

This paper examines the relationship between CO_2 emission, energy consumption, urbanization and trade openness for 10 for selected Central and Eastern European Countries, including, Albania, Bulgaria, Croatia, Czech Republic, Macedonia, Hungary, Poland, Romania, Slovak Republic and Slovenia for the period of 1991–2011. Given the span of the dataset and the econometric techniques utilized, the results show that there exists a long-run cointegrated relationship between the variables. Additionally, we found evidence in favor of validity EKC hypothesis for these countries. The FMOLS results reveal that a 1% increase in energy consumption leads to a %1.0863 increase CO_2 emissions and a 1% increase in trade openness leads to % 0.0686 decrease in CO_2 emissions. DOLS estimation results show that 1% increase energy consumption causes % 1.1609 increases in CO_2 emissions. The direction of short-run and long-run causal relationship is tested utilizing panel VECM Granger causality method.

The direction of short-run and long-run causal relationship is tested utilizing panel VECM Granger causality method. The results show that there is bidirectional causal relationship between CO_2 emissions - real GDP and energy consumption-real GDP as well. As all error correction terms are significant, there exist bidirectional causality linkages between real GDP and CO_2 emissions, energy consumption and CO_2 emissions, energy consumption and real GDP in the long-run. Hence, the all results indicate that the policy makers in these countries should take action policies in reducing CO_2 emissions.

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