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Economic growth and CO2 emissions: the ECM analysis

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Abstract. Our paper uses the panel data approach to investigate the relationship between CO2 emissions and economic growth for 18 EU Member Countries from 1995 to 2012. The economic growth of countries impels an intensive use of energy which results in growing CO2 emissions, so the pollution is directly linked with economic growth and development. Using basic ECM estimation we verified that the long-run relationship between GDP and CO2 emissions is negative, because the development of new low-carbon technologies enables in the long-run reaching the same production level at lower CO2 emissions and that the short-run relationship between GDP and CO2 emissions is positive, because the fast increase in production can be reached due to more intensive energy use by the existing technologies, then the capacity increases as well CO2 emissions.

Keywords: energy consumption, economic growth, panel data analysis, ECM, CO2 emissions

JEL Classifications: C23, Q43, O40

INTRODUCTION

The relationship between economic growth and CO2 emissions has been the subject of intense research over the past few decades. Many countries are facing a major challenge, namely, to ensure stable economic growth and to protect the environment. The increase of CO2 emissions is the major factor in the climate change threat. Economic growth of countries impels an intensive use of energy which results in growing CO2 emissions, so pollution is directly linked with economic growth and development. On the other hand, economic growth and development result in introduction of new energy-saving and low-carbon technologies that displace the old, energy- and carbon-intensive ones. Taking all of the above into account we can hypothesize that:

Long-run relationship between GDP and CO2 emissions is negative, because the development of new low-carbon technologies enables reaching in the long-run the same production level at lower CO2 emissions – Hypothesis1, Short-run relationship between GDP and CO2 emissions is positive, because fast increase in production can be reached due to more intensive energy use by the existing technologies, then the capacity increases as well the CO2 emissions – Hypothesis2.

To verify the hypothesis of the study we examined the relationship between CO2 emissions and economic growth for 18 countries of the European Union, for the period 1995–2012. To this end, we used, as an investigating technique, the basic ECM estimation, which follows the spirit of the analysis. This approach ensures reaching the aims of the study, because ECM estimation can verify long-run as well as short-run relationships between the analyzed time series. First, we performed the panel unit root tests to obtain the order of data integration. Second, we estimated long-run equation and to check the correctness of the results we used the cointegration tests. Next, we used the EGLS technique for panel data to estimate the model which provides information on the existence of a short-run relationship between the analyzed economic aggregates.

The remainder of the paper is organized as follows. Section 1 is introduction. Section 2 is a short literature review. Section 3 presents the data used in our model. Section 4 describes the model and the econometric methodology used in the analysis. Section 5. reports the empirical results for the order of integration. Section 6. reports the empirical results for the GDP model estimation. Finally, conclusions are made in Section 7.

LITERATURE REVIEW

The relationship between CO2 emissions and economic growth is of great interest in the economics literature in last decades. The articles on this topic was published by Coondoo, Dinda (2002). They examined the causality relationships between CO2 emissions and income using panel data representing 88 countries and the time period 1960–1990. Their analysis do not provide much evidence for the existence of a causal relationship between income and carbon emissions. Lise (2006) concluded that the relation between CO2 emissions and income in Turkey is linear rather than quadratic and does not support the EKC hypothesis. Richmond and Kaufmann (2006) employed simple OLS in levels and found that there is no significant relationship between economic growth and CO2 emissions. In contrast, Ang (2008) found a long-run positive dependence between pollution and energy consumption using a VAR approach for EKC model. Furthermore, Soytas and Sari (2009) investigated the long-run Granger causality relationship between economic growth, CO2 emissions and energy consumption in Turkey. The empirical findings suggest the existence of Granger causality running from carbon emissions to energy consumption, but only one way and in this direction. Similarly, Akbostanci, Turut-As¸ ik, and Tunc (2009) studied the relationship between income and environment in Turkey using time series and panel data for the periods1968–2003 and 1992–2001. They indicated a increasing relationship between CO2 emissions and income. On the other hand, Menyah and Rufael (2010) found a unidirectional relationship between energy consumption and economic growth, in the case of South Africa, where the causality runs from energy consumption to economic growth. Similarly, Apergis and Payne (2010) observed that energy consumption and economic growth Granger causes CO2 emissions and at the same time causality is found between energy consumption and CO2 emissions and between energy consumption and economic growth. Fodha and Zaghdoud (2010a,b) investigated the relationship between economic growth and pollutant emissions degradation based on the EKC hypothesis for Tunisia during the period 1961–2004 using time series data and cointegration analysis. The results provide support for a unique and robust long-run relationship between the per capita emissions of pollutants and per capita GDP, indicating that there is a monotonically increasing linear relationship between per capita CO2 emissions and per capita GDP. Chang (2010) investigated the causal relationships between CO2 emissions, energy consumption and economic growth based on the panel data for 28 China provinces over the period 1995–2007. The results of the study demonstrate bi-directional causality running: from GDP to CO2 emissions and the consumption of crude oil and coal; and from electricity consumption to GDP. Furthermore, increased GDP growth or energy consumption stimulates CO2 emissions. Recently, Pao, Tsai (2011) and Zamula, Kireitseva (2013) found a strong positive bi-directional causal relationship between energy consumption, CO2 emission, foreign direct investment, and growth in the BRIC countries and Ukraine. Niu, Ding, Niu, Li, and Luo (2011) revealed that there are long-term equilibrium relationships between energy consumption, GDP growth and CO2 emissions for the eight Asia-Pacific countries. Causality runs from energy consumption to CO2 emissions, GDP is responsible for the increase in energy consumption, and there is strong causality between GDP and CO2 emissions over the long run in developed countries, in contrast to the developing countries where the relationship is not present. Finally, Narayan and Popp (2012) tested the Environment Kuznets's Curve (EKC) hypothesis for 93 countries for the period from 1980 to 2004. They examined the long-run impact of energy consumption on real GDP and established the sign of the long-run causality effect.

THE DATA

The data for calculation was taken from Eurostat databases. The financial data was adapted to reality with the use of Eurostat price indices. Then data were converted to their logarithms which allowed us to present the relationships between variables in an additive equation. The research covers the period from the 1995 to 2012 for 18 countries of the European Union member countries (Belgium, Denmark, Germany, Ireland, Spain, France, Italy, Luxembourg, Netherlands, Austria, Portugal, Finland, Sweden, United Kingdom, Czech Republic, Hungary, Poland, Slovakia). In total, we are working with 324 observations in one panel which ensures the statistical validity of our results and enables us to draw conclusions and policy implications.

EMPIRICAL MODEL

In the presented study, we use the panel data approach to investigate the long-run relationship between economic growth and CO2 emissions. We propose a framework based on the conventional Error Correction Model (ECM) developed by Engle and Granger in 1987, where we treat the relation between economic growth and CO2 emissions as a long-run dependence and Energy Consumption (E), Capital (K) and Total Employment (L), as exogenous inputs in short-run GDP equation. That is:

It is assumed: $GDP \sim I(1),\ CO2 \sim I(1)$

$$GDP_{i,t} = \beta_0 + \beta_1 CO2_{i,t} + \mu_{i,t} \quad (1)$$

let $\mu_{i,t} = Z$, when $Z \sim I(0)$ the variables GDP and CO2 are assumed to be cointegrated. Then we can estimate a short-run GDP equation:

$$\Delta GDP_{i,t} = \beta_0 + \beta_1 \Delta GDP_{i,t-1} + \beta_2 \Delta CO2_{i,t-1} + \beta_3 \Delta E_{i,t} + \beta_4 \Delta K_{i,t} + \beta_5 \Delta L_{i,t} + \beta_6 Z_{i,t-1} \quad (2)$$

where: $\Delta GDP \sim I(0),\ \Delta CO2 \sim I(0),\ \Delta E \sim I(0),\ \Delta K \sim I(0),\ \Delta L \sim I(0),$

when Z appears to be significant variable with coefficient β_6 of negative value (-1; 0), that means that the estimated system drives-back to the long-run sustainability.

The panel estimation procedure adopted in this study uses a three-step procedure. First, panel unit root tests are applied to test the degree of integration of the variables. We performed the panel unit root tests proposed by Levin, Lin, Chu (2002) and Im, Pesaran, Shin (2003) and panel unit root tests Fisher-ADF and Fisher-PP proposed by Maddala and Wu (1999), and by Choi (2001). Once the order of integration has been established, the issue arises whether there exists a long-run equilibrium relationship between the two analyzed variables – GDP and CO2. After establishing the long-run dependence, the short-run equation was estimated by using panel EGLS. The empirical study was made using EViews software.

TESTING FOR THE ORDER OF INTEGRATION

The analyzed time series were examined by unit root tests to establish the order of integration.

Table 1 reports the results of testing for unit roots in the level variables as well as in their difference.

Table 1

Test results for panel unit roots

	Method			
Variable	Levin, Lin & **Chu** t*	Im, Pesaran and Shin W-stat	ADF - Fisher Chi-square	PP - Fisher Chi-square
GDP	-1,2489	2,8301	17,6791	6,9420
ΔGDP	-9,7020***	-4,8018***	82,7704***	152,198***
E	-0,2861	1,9652	34,4074	48,1705
ΔE	-16,2912***	-14,8262***	208,939***	267,709***
K	-0,4823	0,2332	48,5901	21,9383
ΔK	-7,5568***	-5,7004***	91,2134***	124,125***
L	2,3001	2,5974	33,7115	12,3229
ΔL	-6,2376***	-5,1379***	85,0943***	67,1087***
CO2	0,0220	2,2977	31,2678	36,0739
ΔCO2	-17,7651***	-16,1163***	219,513***	263,815***

*** denotes that we can aknowledge the stationarity for 5% significance level

Source: own calculation.

In the case of the level of variables the null hypothesis that variables assume common and individual unit root process cannot be rejected, after applying the first difference, all of the variables meet the requirements of the EGLS estimation. So, we can acknowledge that the level of variables are integrated of order one process ~I(1).

PANEL GDP ESTIMATION RESULTS

In studying the long-run GDP – CO2 emissions dependence we applied panel least squares method. There was estimated GDP equation, taking into consideration one way model with fixed cross-section effects. The results of modeling the GDP equation are reported in Table 2.

Table 2

Long-run GDP equation

Variable	Coefficient	Std. **Error**	t-Statistic	Prob.
C	18.20048	0.778292	23.38517	0.0000
LCO2	-0.501796	0.065506	-7.660280	0.0000
Weighted Statistics				
R-squared	0.994333	Mean dependent var	17.46065	
Adjusted R-squared	0.993999	S.D. dependent var	9.694478	
S.E. of regression	0.145666	Sum squared resid	6.471697	
F-statistic	2973.258	Durbin-Watson stat	0.175026	
Test results for Z unit root				
Variable	Levin, Lin & Chu t*	Im, Pesaran and Shin W-stat	ADF - Fisher Chi-square	PP - Fisher Chi-square
Z	-5,824***	-2,369***	54,400***	72,544***

Source: own calculation.

The results of the estimation of long-run GDP equation allow to state, that there is a significant statistical relationship between economic growth and the CO2 emissions, so we found existence of cointegration relationships. To confirm the results of the estimation we performed eight panel cointegration test.

Table 3

Residual Cointegration Test

Test equation	GDP (CO2)	
	Statistic	Prob.
Pedroni Panel v-Stat.	**24.05125**	**0.0000**
Pedroni Panel rho-Stat.	1.272434	0.8984
Pedroni Panel PP-Stat.	-0.742555	0.2289
Pedroni Panel ADF-Stat.	**-2.565815**	**0.0051**
Pedroni Group rho-Stat.	1.695368	0.9550
Pedroni Group PP-Stat.	**-1.977897**	**0.0240**
Pedroni Group ADF-Stat.	**-3.122985**	**0.0009**
Kao Residual Cointegration Test	**-2.142997**	**0.0161**

Source: own calculation.

Five statistics significantly reject the null-hypothesis of no cointegration, with the exception of the panel rho-statistic, pp-statistic and group rho-statistic for all sample countries. In general, the majority of the statistic tests, taking into consideration the 5% significance level, reject the null hypothesis of no cointegration. The analyzed variables move together in the long-run, so one can state that there is a long-run relationship between energy consumption and CO2 emissions.

The next step was to estimate the short-run panel EGLS equation with endogenous variables GDP(-1), CO2(-1) and exogenous inputs Energy Consumption (E), Capital (K),Total Employment (L) and with the variable Z. The results of modeling the short-run GDP equation are reported in Table 4, which presents the econometrical tests of the estimated model as well.

Table 4

Short-run GDP equation

One Way Fixed - Panel EGLS (Cross-section weights)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.018497	0.001075	17.20215	0.0000
ΔGDP(-1)	-0.016821	0.038169	-0.440697	0.6598
ΔCO2(-1)	0.035200	0.017664	1.992760	0.0473
ΔE	0.107758	0.022487	4.792033	0.0000
ΔK	0.264320	0.015186	17.40500	0.0000
ΔL	0.027507	0.058351	0.471401	0.6377
Z(-1)	-0.028033	0.006454	-4.343360	0.0000
	Effects Specification			
Cross-section fixed (dummy variables)				
	Weighted Statistics			
R-squared	0.819810	Mean dependent var		0.025288
Adjusted R-squared	0.804112	S.D. dependent var		0.031101
S.E. of regression	0.013822	Sum squared resid		0.050436
F-statistic	52.22273	Durbin-Watson stat		1.887716
Prob(F-statistic)	0.000000			
	Unweighted Statistics			
R-squared	0.769325	Mean dependent var		0.022684
Sum squared resid	0.053463	Durbin-Watson stat		1.835715
Test cross-section fixed effects				
Effects Test		Statistic	d.f.	Prob.
Cross-section F		5,403318	17,264	0,0000
Normality Test of Residuals		Statistic		Prob.
Jarque-Bera		1,962165		0,374905

Source: own calculation.

The calculated one way fixed effects short-run equation using panel EGLS (Cross-section weights) meets the assumptions of regression. The estimated DW test statistic for the model is 1.8357, so we can assume that the residuals are uncorrelated and the heteroscedasticity of residuals is not present. Furthermore, we conducted a test for the normality of residuals as well, the Jarque-Bera statistic does not reject the hypothesis of normal distribution. The p-value is 0.374, so it indicates that there is no reason to reject the null hypothesis and allows us to accept the normality of residuals distribution. In addition, we used stationary variables for the estimation of the equations.

For the independent variables ΔCO2(-1), ΔE, ΔK the panel EGLS estimator produce similar results in terms of the sign and statistical significance, whereas the magnitudes of the estimated coefficients are slightly different. For the variable Z(-1) (the residuals from the long-run equation) the estimator produce a negative statistical significant coefficient. All the coefficients are statistically significant at the 5% level of significance. We found a positive relationship between CO2 emissions, energy consumption, gross fixed capital and economic growth in the short-run. The panel EGLS results suggest that in the short-run a 1% increase in energy consumption increases GDP by 0.10%, a 1% increase in CO2 emissions increases GDP by 0.035% in next year, a 1% increase in gross fixed capital increases GDP by 0.26%. In case of the total employment the panel estimator produce similar result in terms of the sign, but it has no statistical significance. For Z variable the coefficient is negative with the value (-0.028), this means that the mechanism of error correction is running well, and the system can return to the long-term steady trajectory.

CONCLUSIONS

In this paper, we investigated the long-run relationship between economic growth and CO2 emissions for 18 EU countries during the period 1995-2012 using the ECM estimation, panel unit root tests, panel cointegration test and EGLS estimator.

The estimation of GDP long-run equation indicated that that the CO2 emissions are negative related to the economic growth, what was confirmed by panel cointegration test results. The economic growth and the CO2 emissions are cointegrated for the whole panel of countries. So the first hypothesis of the study - The long-run relationship between GDP and CO2 emissions is negative, because the development of new low-carbon technologies enables in the long-run to reach the same production level at lower CO2 emissions – cannot be rejected. The negative relationship is for sure caused by energy-saving and low-carbon technological development of the EU economies. The final GDP short-run equation stands in line with the second hypothesis of the study - The short-run relationship between GDP and CO2 emissions is positive, because the fast increase in production can be reached due to more intensive energy use by the existing technologies, then the capacity increases as well the CO2 emissions, so the hypothesis as well the first one cannot be rejected. The evaluated regression model of GDP includes not only endogenous CO2 emission variable but growth rates of Energy Consumption, growth rates of Gross Fixed Capital in real prices and the significant correction mechanism as well. The finding of the study suggests that energy consumption is an integral part of economic growth, so the economic growth of analyzed European countries is energy-dependent. The energy consumption produces wastes, namely pollutions with CO2 emissions. To sum up, the empirical results of the study we can state that the ongoing policy of the pollution treatment of analyzed European Union countries is working, but it is a question – How it is working? Perhaps to slow.

The study should be counted as a preliminary study for further reflection on the subject. In this study we have not incorporated the analysis of the fastness of CO2 emission reductions in the analyzed countries. Such ability of faster introduction of CO2 emission reductions seems to be an interesting subject for further research.

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