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The role of economic growth and energy consumption on CO_2 emissions in E7 countries

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Abstract. *The purpose of this study is to analyze the relationship between carbon emissions, financial development, total energy consumption and economic growth by using panel data analysis in E7 countries (Brazil, China, Indonesia, India, Mexico, Russia and Turkey) for 1990-2014 period. The result of the panel analysis suggests that there is no long-term relationship between carbon emissions and financial development. A 1% increase in total energy consumption increases carbon emissions by 1.840%. A 1% increase in economic growth leads to an increase of 0.243% in carbon emissions over the long-term. To this end, it would be beneficial for policy makers to consider alternative growth models, along with alternative energy sources, to prevent environmental pollution.*

Keywords: energy consumption, CO_2 emissions, economic growth, E7 countries.

JEL Classification: C32, O44, Q54.

1. Introduction

Energy plays an important role in economic development as it is a vital factor in directing all economic activities. Energy is seen as one of the potential inputs in various units of economic activity, that is, it primarily helps to reduce the energy demand of households and trading companies for consumption and production purposes (Shahbaz et al. 2016). Energy demand in many countries worldwide are significantly increasing due to rapid urbanization and population growth. The United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) predicts that energy demands in developing countries will grow by around 87% by 2030 (UNEP, 2011). For this reason, rapid economic growth will continue due to the presence of large industries that require more energy consumption, despite causing environmental degradation. No consensus has yet been reached as to whether energy consumption is a factor that increases economic growth or is a consequence of it (Hamrita and Templet, 2016).

Lately, many countries have been striving to generate more energy to meet energy demand while at the same time implementing policies that reduce greenhouse gas emissions in the atmosphere. The International Energy Agency reports that the current trend in energy supply and use is unsustainable from economic, environmental and social aspects and that carbon dioxide emissions associated with energy will increase by two quarters in 2050, and that increased petroleum demand will increase security concerns in oil-producing countries unless decisive and lasting measures are taken (Apergis et al., 2010: 2255). Therefore, the socio-economic importance of energy demand has been discussed by many researchers and developers. In this respect, it shows that developing countries should be cautious about using energy efficiently and using different energy sources (e.g. renewable and non-renewable). Otherwise, developing countries will face greater challenges, both in short and long run, because they increase CO_2 emissions due to increased energy consumption, as real output and energy use are largely dependent on each other and affect each other significantly within the economy (Shahbaz et al., 2016).

In this context, the consequences of these challenges are multilayered for developing or industrialized countries worldwide. For example, increased CO_2 emissions in developing countries lead to climate change (i.e. rising sea levels, cyclones, drought and floods) that cause global warming at regional and global levels. At the same time, developing countries are also experiencing a decline in environmental quality due to increased CO_2 emissions, climate change and global warming. Environmental degradation does not only prevent the sustainability of persistent economic development in the long run, it also affects the life quality and standard of the people in the economy (Shahbaz et al., 2016).

The United Nations' Fourth Assessment Report on climate change predicts that the temperature will rise by 2-4.2 degrees on average by 2100. Many experts have attributed the main source of global warming to the rapid increase in the global economy to the depletion of a significant portion of the energy, and that the greenhouse effect is caused by six different gas releases that affect the world's climate change. At the 1997 Kyoto Protocol, between 2008 and 2012, a reduction of greenhouse gas emissions by 5.2 per cent was requested compared to 1990 values. The protocol came into operation in 2005. CO_2 emissions arise from the burning of fossil fuels and provide the greatest contribution to greenhouse gas emissions alone. Among the many pollutants that cause climate change, CO_2 accounts for 58.8 percent of all greenhouse gases. Since the 1970s, the rapid economic growth trend in the world has been influential in the development of this progress, and as a result, effect of CO_2 emissions has been increasing. For this reason, predictions and analysis of CO_2 emissions suggest that energy consumption and economic growth constitute the most important component of clean energy economics (Pao et al., 2012: 400, Halicioglu, 2009).

It can be said that climate change should be regarded as an urgent and serious environmental problem in the fields of energy and ecological economy. According to the latest statistics from the Intergovernmental Panel on Climate Change (IPCC, 2006), CO_2 emissions are among the most important determinants of greenhouse gas emissions, accounting for 76.7% of the world's total greenhouse gas (GHG) emissions. Other factors leading to greenhouse gas emissions are fossil fuels, deforestation and other sources; 56.6%, 17.3% and 2.8%, respectively. This means that carbon dioxide is responsible for 76% of the greenhouse effect. Hence, increasing CO_2 emissions per capita is often used as a representative determinant of environmental pollutants and is often associated with per capita income. Increasing CO_2 emissions are one of the major factors leading to global warming and climate change, and in recent years it has been a serious problem worldwide (Raza et al., 2015).

The purpose of this study is to examine the effect of the relationship between carbon emissions, financial development, total energy consumption and economic growth of the E7 countries (Brazil, China, Indonesia, India, Mexico, Russia and Turkey) by using panel data analysis method for the years 1990-2014. E7 is a group of developing countries with the fastest growing population and integrated with the international economy, with the goal of becoming one of the strongest economies in the world like the G7 countries. The main reasons for choosing this period and sample are; the fact that data from the 80s are not available for some of these countries and that E7 countries have stepped in among the world's strongest economies with huge developments in the last 20 years. The gap between these countries and the G7 countries (America, Japan, Germany, England, Italy, France, Canada) are closing more and more every day. The report published by the international consulting firm PricewaterhouseCooper (PwC) underlines that these countries could pass 75 percent of the economies of the G7 countries, which are so-called industrialized countries in 2020 (PwC, 2010). Again, PricewaterhouseCooper (PwC) has found the weight of the global economy has been shifting towards China, India and other major emerging economies. China and India are at the forefront of innovation and this acts as an engine for growth in other E7 countries. Technological progress, innovation and energy play an important role especially in China's growth performance (Göçer, 2013: 122).

No empirical study has been found in the literature on these countries and time period. Working in this context is expected to contribute to the literature. In the second part of the study which includes a current topic, a brief literature review is given. In the third chapter, panel cointegration results are discussed by giving information about data and data sources. In the last section, policy recommendations and conclusions are presented.

2. Brief review of literature

Increasing global warming and climate change threats have brought global focus on the relationship between economic growth, energy consumption and carbon emissions. There are many researches on economic growth and energy consumption. However, economic theories do not express the existence of a clear relationship between energy consumption, CO_2 emissions and economic growth. Empirical research with these variables has been one of the most important areas of energy economics in the last two decades. In these surveys, developing countries have often achieved high growth rates by increasing their energy consumption quantities at the expense of neglecting effective technologies (Tiwari, 2011: 95).

The relationship between economic growth and carbon emissions, like economic growth and energy consumption in the literature, is generally studied within three study groups. The first group studies focus on the relationship between carbon emissions and economic growth. In these studies, the validity of the Environmental Kuznets Curve (EKC) hypothesis is tested for countries. Kuznets' study (1955), Kuznets Curve, which shows the relationship between income distribution and economic growth as income increases, income distribution first deteriorated and then improved, started to be applied to environmental quality and per capita income relation in the 1990s. The environmental Kuznets Curve hypothesis explains the relationship between the deterioration of environmental conditions and per capita income and shows that the level of carbon emissions will decrease at the beginning of the economic development process and is then represented by an inverted U-shaped curve (Dinda, 2004: 433). There are detailed researches about this hypothesis (Dinda, 2004; Stern, 2004). In the first group of studies, the studies on EKC were based on Grossmann and Krueger (1991), Shafik and Bandyopadhyay (1992), Panayotou (1993), Beltratti (1997), Bulte and van Soest 1995) and Stokey's (1998) studies. In some of the related studies, it has been found that some of them support the Environmental Kuznets Curve hypothesis, whereas some does not (Panayotou, 1997; Bruyn, Van den Berg and Opschoor, 1998; Coondoo and Dinda, 2002; Lindmark, 2002; Lise, 2006; Akbostancı et al., 2009; Choi et al., 2010; Acaravcı and Öztürk, 2010; Fodha and Zaghdoud, 2010; Orubu and Omotor, 2011; Farhani and Rejeb, 2012).

The second group of studies examine the relationship between energy consumption and economic growth. Findings from studies show mixed results. In these researches it is shown that increasing economic growth will require more energy consumption. It is also stated that the same level of effective energy use will further increase the level of economic development. It has also been studied whether the economic growth stimulates energy consumption or whether alone energy consumption is a stimulus to economic growth indirectly via total demand due to increased total efficiency and technological development. Numerous researches have been found in the literature using cointegration techniques and causality tests. (Erol and Yu, 1987; Brown and Yücel, 2002; Glasure and Lee, 1997; Oh and Lee, 2004; Lee, 2005; Shiu and Lam, 2004; Lee and Chang, 2005; Soytaş and Sarı, 2009; Wolde-Rufael, 2009; Oztürk et al., 2010; Apergis and Danuletiu, 2012; Esseghir and Khouni, 2014; Naser, 2015; Doğan and Değer, 2016; Doğan and Değer, 2018).

The third group of studies examine the dynamic relationship between carbon emissions, energy consumption and economic growth and a combination of the two previous approaches. Say and Yücel (2006), studied the relationship between energy consumption, economic growth and carbon emissions in Turkey. In the study they conducted for the period of 1970-2002, there was a strong correlation between energy consumption and carbon emissions. Soytaş et al. (2007) examined the dynamic relationship between energy consumption, CO_2 emissions and economic growth in the US and found that CO_2 emissions are the reason for the increase in income and energy consumption, and that these two increase CO_2 emissions. Chang (2010) has studied the relationship between economic growth, energy consumption and CO_2 emissions for the Chinese economy and has come to the conclusion that economic growth is the cause of energy consumption that would lead to CO_2 emissions. Niu et al. (2011) showed that there is a positive relationship between energy consumption and CO_2 emissions in the economies of 8 Asian countries. Despite the fact that developing countries have much lower per capita CO_2 emissions and energy efficiency than developed countries, the amount of energy per unit in these countries is much higher than in developed countries. Wang et al. (2011) studied the relationship between CO_2 emissions, energy consumption and economic growth, for the 1995-2007 period in 28 provinces of China using panel cointegration and vector error correction methods. Model estimation shows that CO_2 emissions, energy consumption and economic growth are cointegrated. They found that economic growth and energy consumption were the reason for long-term CO_2 emissions, and that CO_2 emissions and economic growth were the long-term reason of energy consumption. A similar study for China was conducted for Pao et al. (2012). In the study using cointegration method, it has been found that there is a long-term relationship between CO_2 emissions, energy consumption and real GDP, which indicates CO_2 emissions are insensitive to the increase in real production (inelastic), but flexible to energy consumption. Thus, it has been shown that energy consumption is more important than real production when determining CO_2 emissions.

Arouri et al. (2012) studied the relationship between CO_2 emissions, energy consumption and real GDP in 12 Middle East and North African countries during the period 1981-2005 using panel unit root tests and cointegration techniques. According to the results, in the long run, energy consumption has a significant positive effect on CO_2. Salahuddin and Gow (2014) investigated the experimental relationship between economic growth, energy consumption and CO_2 emissions in the Gulf Cooperation Council (GCC) countries. They found that both short and long-term energy consumption and CO_2 emissions and economic growth and energy consumption are positively correlated. Saidi and Hammami (2015) studied the impact of energy consumption and CO_2 emissions on economic growth in 58 countries. Using the model of isochronous equations determined by the GMM estimator, they have reached the conclusion that the energy consumption on the economic growth is positive and the CO_2 emission is the negative effect. Farhani (2015) examined the relationship between renewable energy consumption, economic growth and CO_2 in 12 MENA countries between 1975 and 2008 using panel cointegration technique. Panel FMOLS and DOLS calculations show that only CO_2 emissions are effective on renewable energy consumption. Wang et al. (2016) studied the relationship between economic growth, energy consumption and CO_2 emissions by using Chinese data, adopting the cointegration approach. The results of the cointegration tests show that there is a long cyclic cointegration relationship between the variables. Furthermore, impact response analysis found that the effect of a shock on economic growth or CO_2 emissions on energy consumption was only marginally significant.

3. Empirical analysis

3.1. *Data set*

E7 countries that have taken their place among the powerful economies, especially in the recent years, have been used in this study. In this study, carbon emission, financial development, total energy consumption and economic growth data for 1993-2014 period are used. For total energy consumption, the sum of oil, natural gas, coal and hydro energy data is used, and this data is obtained from the BP world energy statistics database. Carbon emissions, financial development and economic growth data are taken from the Penn World Table (Version 8.1) database.

3.2. *Cross sectional dependency tests*

In panel data analysis, if there is cross sectional dependency between the series and this test is not applied, the results that will occur in the analysis will not be consistent (Breusch and Pagan, 1980; Pesaran, 2004). Due to this situation, in this study, the presence of the cross sectional dependence must be tested before performing the analysis. According to the results to be obtained, it will be decided whether to use first or second-generation panel unit root analysis and cointegration analysis.

In our study, the cross sectional dependency between the series are examined by using CD tests developed by Pesaran (2004). The Pesaran (2004) CD test can be used in conditions where the cross sectional dimension is larger than the time dimension, and the time dimension is larger than cross sectional dimension (N > T, T > N). The CD test deviates where the mean of country is different than zero, but the panel average is zero. The LM test introduced by Pesaran and Yamagata (2008) corrects this deviation by adding the variance and the mean to the test statistic. The LM test is as follows:

$$\text{CDLM1} = T \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij}^{2} \sim X^2 \frac{N(N-1)}{2} \quad (1)$$

The corrected version is:

$$LM_{adj} = \left(\frac{2}{N(N-1)}\right)^{1/2} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij}^{2} \frac{(T-K-1)\hat{\rho}_{ij}^{2} - \hat{\mu}_{Tij}}{\upsilon_{Tij}} \sim N(0,1) \quad (2)$$

In the equation, $\hat{\mu}_{Tij}$ represents the mean, whereas υ_{Tij} represents variance.

The test statistic obtained from the equation shows the standard normal distribution asymptotically (Pesaran et al., 2008).

Hypotheses are:

H_0= There is no cross sectional dependence;

H_1= There is cross sectional dependence.

According to the test results, when the probability value is below 0.05, H_0 hypothesis is rejected at the 5% significance level, and it is determined that there is cross sectional dependency between units forming the panel (Pesaran et al., 2008).

In this study, the cross sectional dependency of the series and the cointegration equation are checked via LM_{adj} test separately with the help of Gauss codes, and the results are given below.

Table 1. *Testing Cross Sectional Dependency*

Variables	CO_2		FD	ENERGY	GDP	Cointegration Equation
Tests		Test statistics and p-value				
LM (Breusch and Pagan, 1980)	34,725(0,030)		56,307(0,000)	37,348(0,015)	43,044(0,003)	31,066(0,073)
CDLM1 (Pesaran, 2004)	2,118(0,017)		5,448(0,000)	2,522(0,006)	3,402(0,000)	1,553(0,060)
CDLM (Pesaran, 2004)	-2,303(0,011)		-1,298(0,097)	-2,161(0,015)	-1,843(0,033)	-0,082(0,467)
LM_{adj}(Pesaran et al., 2008)	-1,112(0,867)		-1,422(0,923)	1,217(0,112)	2,655(0,004)	5,623(0,000)

The values on table shows that since the results of the variables and the cointegration equation is less than the probability value 0.05, H_0 hypotheses are rejected, and it is determined that there is no cross sectional dependency in the series and the cointegration equation. That is, carbon emissions, financial development, total energy consumption and economic growth shocks in one country are also affecting other countries. Also, after determining that there is cross sectional dependency, it is decided to apply second generation panel unit root tests and cointegration analysis. While identifying the cointegration relationship between the series, cointegration analyses that takes cross sectional dependency into account are required to be used. Hence, after this part of the study, second generation panel unit root, panel cointegration and long-term panel analysis will be carried out.

3.3. Panel unit root analysis

The most important point when applying panel unit root analysis is to check whether the cross sections forming the panel are independent of each other.

First generation panel unit root tests are based on the result that the cross sectional units forming the panel data analysis are independent of each other, that is, a shock affecting a panel forming country group affects the entire cross section evenly. However, it is known that the world system is globalizing, and the countries are not independent of each other. Therefore, it is more probable that a shock that occurs in each cross sectional unit forming the panel data analysis will affect the other units at different levels. In order to eliminate this problem, second generation panel root tests which removes the cross sectional dependency between the cross sectional units are developed.

In this study, since CSD is identified between the countries forming the panel test, one of the second-generation panel unit root tests, CADF test (Pesaran, 2007) is carried out. While testing for each individual country forming the panel, CADF test also provides results for the panel as a whole. Another feature of the CADF test is that it can also be used in T > N and T < N condition. The results are compared with the CADF (Pesaran, 2007) critical table values to determine the presence of the unit root. The hypothesis for the unit root test is built as below:

$$Y_{i,t} = (1 - \emptyset_i)\mu_i + \emptyset_i y_{i,t-1} + u_{i,t} i = 1,2,,,,,,,,, Nvet = 1,2,,,,,, T \quad (3)$$

$$u_{it} = \gamma_i f_t + \varepsilon_{it} \quad (4)$$

f_t is the unobservable common effect of each country forming the panel, while ε_{it} represents the error term for each country. Therefore, the unit root hypothesis is;

$$\Delta y_{it} = \alpha_i + \beta_i y_{i,t-1} + \gamma_i f_t + \varepsilon_{it} i = 1,2,,,,,,,,, Nvet = 1,2,,,,,, T$$

$H_0: \beta_i = 0 \; for \; all \; i$ (The series are non-stationary.)

$H_0: \beta_i < 0 \, , i = 1,2,,,,,,,,, N_1, \beta_i = 0 \; i = N_1 + 1, N_2 + 2,,,,,, N.$ (The series are stationary.)

In addition, the CIPS (Cross-Sectionally Augmented IPS) which is the unit root test statistics for the entire panel can be found by calculating the average of unit root test statistics of the cross section, or the countries (Pesaran, 2007). CIPS statistics;

$$CIPS = N^{-1} \sum_{i=1}^{N} CADF_i \quad (5)$$

The results of unit root tests for each individual country (CADF) and for the entire panel (CIPS) and the critical values provided by Pesaran (2007) are given on the table below.

Table 2. *Panel unit root test*

Countries Variables	Test Statistics							
	CO_2	ΔCO_2	FD	ΔFD	GDP	ΔGDP	ENERGY	ΔENERGY
Brazil	0,7248	-0,9391	-3,9902**	-4,3673*	-4,8112*	-5,3795*	-0,7326	-1,8496
China	-3,0751***	-2,5288	-2,2515	-2,7820	-0,3324	-0,5937	-2,0082	-1,7580
Indonesia	-2,0163	-2,2329	-1,4435	-3,1580***	-1,9795	-8,2865*	-2,1993	-2,4804
India	-2,1754	-1,9295	2,2251	-0,8087	-2,5635	-2,4967	-3,5246**	-3,0476***
Mexico	-1,8773	-4,0348**	-2,6152	-11,2938*	-1,7367	-1,5073	0,4436	-2,8632
Russia	-2,2938	-5,7932*	-1,1505	-2,5391	-2,0393	-1,7282	-4,9847*	-1,1779
Turkey	-1,8229	-2,3101	-2,5630	-6,3400*	-2,1819	-5,2929*	-4,0320**	-2,6470
Panel (CIPS)	1,7909	-2,8240*	-1,6841	-4,4698*	-2,2349	-3,6121*	-2,4340**	-2,2605***

Note: * denotes to the stationarity of the series at the significance level. *%1, **%5 and ***%10 refer to the stationarity at the significance level. For the countries, only intercept critical values are %1; -4.35 %5; -3.43 %10; -3.00; and for the panel, they are %1; -2.60 %5; -2.34 %10; -2.21. Δ denotes the differences of the variables. As test model, stationary model is selected for all the variables.

According to the Pesaran (2007) CADF unit root test analysis that is used to control the stationarity of the series, it is found that CO_2, FD and GDP series are non-stationary, and they only become stationary at 1% significance level after their differences are calculated. Also, the energy series stationary, and the series are stationary at 10% significance level after their first differences are calculated.

3.4. Homogeneity test for cointegration coefficients

Homogeneity test is used to determine whether the slope coefficient in the cointegration equation is homogeneous or not. The test is first developed by Swamy (1970) and then developed by Pesaran and Yamagata (2008).

$$Y_{it} = \alpha + \beta_i X_{it} + \varepsilon_{it} \quad (6)$$

The cointegration equation above tests for whether β_i slope coefficient differs among cross sections. Hypotheses of the homogeneity test are;

$H_0: \beta_i = \beta$ *Slope coefficients are homogeneous.*

$H_0: \beta_i \neq \beta$ *Slope coefficients are not homogeneous.*

Pesaran and Yamagata (2008) developed two different test statistics to test the hypotheses:

For Large Samples: $\hat{\Delta} = \sqrt{N}\left(\frac{N^{-1}\tilde{S}-k}{2k}\right) \sim X_k^2$

For Small Samples: $\hat{\Delta}_{adj} = \sqrt{N}\left(\frac{N^{-1}\tilde{S}-k}{v(T,k)}\right) \sim N(0,1)$

In the above equations, N, S, k and $v(T,k)$ denote the number of cross sections, Swammy test statistics, the number of explanatory variables and standard error, respectively.

Table 3. *Results of the homogeneity test*

$CO2_{it} = \beta_{0i} + \beta_{1i}ENERGY_{it} + \varepsilon_{it}$	Test Statistics	Probability Value
$\hat{\Delta}$	11,267	0,000
$\hat{\Delta}_{adj}$	12,124	0,000
$CO2_{it} = \beta_{0i} + \beta_{1i}FD_{it} + \varepsilon_{it}$	Test Statistics	Probability Value
$\hat{\Delta}$	9,630	0,000
$\hat{\Delta}_{adj}$	10,363	0,000
$CO2_{it} = \beta_{0i} + \beta_{1i}GDP_{it} + \varepsilon_{it}$	Test Statistics	Probability Value
$\hat{\Delta}$	11,370	0,000
$\hat{\Delta}_{adj}$	12,235	0,000

H_0 hypothesis is accepted because the calculated probability values of the tests are greater than 0.05. In the cointegration equation, it is determined that the constant term and slope coefficients are homogeneous. The interpretations of cointegration equation for the panel are valid and reliable (Pesaran and Yamagata, 2008).

3.5. Durbin-Hausman panel cointegration test

When panel data analysis is conducted, cointegration method is frequently used in empirical analyzes to test the long-term relationship between variables in the analysis (Pedroni, 1999; Pedroni, 2004; Westerlund 2007; Westerlund and Edgerton, 2007; Westerlund, 2008).

Durbin-H panel cointegration analysis developed by Westerlund (2008) analyzes the cointegration relationship between carbon emissions, energy consumption, financial development and economic growth series. Since the cross sectional dependency of the series is tested, the presence of panel cointegration is tried to be analyzed via Westerlund (2008) Durbin-H method.

Durbin-H method allows for panel cointegration analysis if dependent variable is I(1), and independent variables are I(1) or I(0) (Westerlund, 2008). The hypotheses of the test are as follows:

$H_0: \emptyset_i = 1$ There is no cointegration relationship (i =1, 2,…, n).

$H_1: \emptyset_i < 1$ There is cointegration relationship (i = 1, 2,…, n).

According to the results of the analysis, the hypothesis is rejected or accepted. The values of the analysis are compared with the critical values of the normal distribution table. When the test statistics obtained from this result is greater than 1,645 (5% significance level), H_0 is rejected and the presence of cointegration relation is accepted.

In the Westerlund (2008) Durbin-H cointegration method, the cointegration relationship is tested for the group and the panel separately. In the Durbin-H group test, autoregressive parameters are allowed to differentiate between sections. In this test, the rejection of the *H0* hypothesis implies the presence of a cointegration relationship at least for some of the sections. On the other hand, for the Westerlund (2008) Durbin-H panel cointegration test, the autoregressive parameter is assumed to be the same for all sections. Under this assumption, when *H0* hypothesis is rejected, it is accepted that there is a cointegration relationship for all sections. (Dilorio and Fachin, 2008; Bayar et al., 2011).

The panel data model can be stated as below;

$$y_{it} = \alpha_1 + \beta_1 x_{it} + z_{it} \quad (7)$$

$$x_{it} = \delta X_{it-1} + w_{it} \quad (8)$$

The sets of equations that allow cross sectional dependence of the distribution of z_{it} can be shown as follows.

$$z_{it} = \lambda_i' F_t + \varepsilon_{it} \quad (9)$$

$$F_{it} = p_i F_{it-1} + u_{jt} \quad (10)$$

$$e_{it} = \emptyset_i e_{it-1} + v_{it} \text{ (Her j için } p_i\text{<1)}$$

Here, F_t is a F_{jt}k dimensional common factor vector (j = 1,…, k), and λ_i is the compatible vector of the factor loadings.

Durbin-H group and panel (DH_g, DH_p) statistics are as below.

$$DH_g = \sum_{i=1}^{n} \widehat{S_t}\,(\widetilde{\emptyset}_t - \widehat{\emptyset}_t)^2 \sum_{t=2}^{T} \hat{e}_{it-1}^2 \text{ and } DH_g = \hat{S}_n\,(\widetilde{\emptyset} - \widehat{\emptyset})^2 \sum_{i=1}^{n} \sum_{i=2}^{T} \hat{e}_{it-1}^2 \quad (11)$$

Westerlund (2008) Durbin-H test is analyzed and the obtained values are given in the table below.

Table 4. *Results of the Durbin-Hausman Panel Cointegration Test*

	Statistical value	Probability value	Critical value	Result
Durbin-H group statistics	2,678	0,004	1,645	There is cointegration relationship
Durbin-H panel statistics	2,590	0,005	1,645	There is cointegration relationship

3.6. Estimation of long-term cointegration coefficients

In this chapter of the study, the CCE method developed by Pesaran (2006), which pays regard to the cross sectional dependency, will be used in estimating the long-term cointegration coefficients after the cointegration relation between the series are estimated.

$$CO2_{it} = \beta_{0i} + \beta_{1i} FD_{it} \beta_{2i} GDP_{it} \beta_{3i} ENERGY_{it} + \varepsilon_{it} \quad (12)$$

The long-term cointegration estimator developed by Pesaran (2006) provides results that enable consistent and asymptotic normal distribution even when the time dimension is greater or less than the cross sectional dimension and calculates long-term values for each cross sectional unit separately (Pesaran, 2006). The results of the estimations made via CCE method are given in Table 5.

Table 5. *Estimation of long-term cointegration coefficients*

Countries Variables	FD	t-statistic	GDP	t-statistic	Energy	t-statistic
Brazil	-0,0016	0,351	-0,023	0,778	1,810	0,001*
China	0,008	0,475	0,719	0,074***	1,937	0,334
Indonesia	0,0007	0,862	0,081	0,532	2,013	0,183
India	-0,008	0,051***	0,015	0,872	1,439	0,000*
Mexico	-0,001	0,807	0,178	0,055***	2,048	0,000*
Russia	0,012	0,593	0,533	0,010*	2,264	0,123
Turkey	0,012	0,042**	0,200	0,071***	1,307	0,180
Panel	0,003	0,278	0,243	0,021**	1,840	0,000*

Note: *, ** and *** denote statistical significance at the 1, 5 and 10% level of significance, respectively.

As shown in the table, a 1% increase in economic growth in the panel leads to an increase of 0.224% in carbon emissions. A 1% increase in total energy consumption causes a 1.88% increase in carbon emissions. The table also presents that there is no long-term relationship between financial development and carbon emissions. The sample of E-7 countries, which includes the most developing countries in recent years, shows that the economic growth and the increase in total energy consumption affect the carbon emissions in a positive and statistically significant way. This indicates that these countries making economic progress will need more energy to sustain their development, and in this case, they will cause more carbon emissions. These findings are consistent with the studies of Say and Yücel (2006) and Salahuddin and Gow (2014).

4. Conclusion and policy implications

The relationship between economic growth, energy consumption and carbon emissions has become a frequently discussed topic in recent years. The use of fossil fuels due to high economic growth in the world, and thus the emitted greenhouse gases leading to global warming and climate change has increased the importance of countries to use energy more efficiently, to consider domestic and renewable resources and to utilize their own resources more effectively. Especially for developing countries, the relationship of economic growth, energy consumption and CO_2 emissions has become significant in the energy and environmental policies of governments. In this context, this paper analyzes the effects of the relationship between carbon emissions, financial development, total energy consumption and economic growth in E7 countries (Brazil, China, Indonesia, India, Mexico, Russia and Turkey) for 1993-2014 period. Firstly, in order to test for cross sectional dependency of the series, CD tests developed by Breusch and Pagan (1980); Pesaran (2004) and Pesaran, Ullah and Yamagata (2008) are applied, and it is determined that there is cross sectional dependency between the countries. Hereupon, the stationarity of the series is examined via CADF unit root test which is one of the second-generation unit root tests and is developed by Pesaran (2007). The series are determined to be stationary when their first difference is calculated. Then, Durbin-H cointegration test is performed, and it is found that the series move together in the long run. After testing the presence of cointegration between the series, the panel is tested for long-term cointegration estimator, CCE method, developed by Pesaran (2006). The findings of the analysis suggest that there is no long-term relationship between carbon emissions and financial development. Also, if the total energy consumption goes up by 1%, carbon emissions go up by 1,840%. A 1% increase in economic growth leads to a long-term increase of 0.224% in carbon emissions. The results of this study are compatible with the other studies given in the literature, and they suggest that there is a long-term relationship between carbon emissions, energy consumption and economic growth. It has also been determined that increases in energy consumption and increases in economic growth of E-7 countries, which are said to make significant economic development in the coming years, has led to more increase in carbon emissions.

Increasing CO_2 emissions makes it crucial to reduce energy consumption based on fossil fuels with diversified policies on energy resources. Active precautions should be taken to increase the use of clean energy resources such as wind, solar energy, natural gas and nuclear energy. In order to decrease the level of CO_2 emissions in the atmosphere, it will be effective to consider alternatives such as adopting technologies that help increasing the efficiency of energy conversion or use, transferring to renewable fuels that emit little or no CO_2, promoting the use of nuclear energy and focusing on carbon capture and storage.

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