Received 5 December 2018
Revised 3 May 2019
Accepted 24 June 2019

Investigating energy consumption and economic growth for BRICS-T countries

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Abstract

Purpose – The purpose of this paper is to explore the relationship between energy consumption and economic growth for Brazil, Russia, China, India, South Africa and Turkey (BRICS-T) countries. In this context, this study investigates energy consumption and real output in BRICS-T countries through panel cointegration.
Design/methodology/approach – The data include energy consumption and real output for BRICS-T countries and period of 1990–2014. The variables are transformed into natural logarithm. To analyze these data, this study employed Pedroni cointegration test, the second-generation panel cointegration test, Westerlund and Edgerton (2008) test and FMOLS test.
Findings – Results indicate that there is a bi-directional causality relationship between energy consumption and economic growth for BRICS-T countries. An increase in GDP leads to an increase in energy consumption and an increase in energy consumption leads to an increase in GDP.
Research limitations/implications – This study used data that include the period of 1990–2014 for BRICS-T countries. So, further studies can use different periods of data or different countries.
Originality/value – This study provides important evidence that countries with strong growth performance need to follow bi-directional energy policies to increase both energy investments and ensure energy savings.

Keywords Economic growth, Energy consumption, Panel cointegration, BRICS-T

Paper type Research paper

1. Introduction

Brazil, Russia, China and India (BRIC) are emerging economies at regional and international levels in recent years. Jim O'Neil determined term of BRIC by 2001 and now this term is used commonly. Economic size, strong economic growth rates and international political forces are major characteristics of BRIC countries (Morazan *et al.*, 2012, p. 6). Although Brazilian and Russian economies have been declining for past few years, BRIC countries continue to be influential in global markets due to their economic and demographic scales (O'neill *et al.*, 2005, p. 7). According to World Bank Data, the group, which is also referred to as BRICS with the participation of South Africa in 2011, has 41.7 percent of total world population, has 29.5 percent of total surface of Earth and has 22 percent of total revenue. The economic size of the countries also increases the share of world energy consumption. The energy consumption rate of countries that consuming 36 percent of the total primary energy has increased by 16 percent over the past decade (BP, 2017).

It is thought that investigating the relationship between energy consumption and output is an important issue for policy makers. For example, the bi-directional relationship between energy consumption and real output shows that energy consumption and economic growth are related and policy makers should take care of this result. Also, while high levels of economic growth lead to energy demand, a shrinkage in energy demand may also effect economic growth negatively. In this context, countries should determine new strategies that

This study was presented in International Congress Of Energy Economy And Security – 2018 Spring in Istanbul, Turkey.

World Journal of Science, Technology and Sustainable Development
Vol. 16 No. 4, 2019
pp. 184-195

2042-5945
DOI 10.1108/WJSTSD-12-2018-0063

including both of preventing energy waste and increasing energy saving to support economic growth in the long term (Pao and Tsai, 2011, p. 7857). If there is a one-way relationship from energy consumption to real output, the implementation of energy-saving policies in this case may have a negative impact on the real output. When there is a one-way relationship from economic growth to energy consumption, energy-saving policies probably will not impact economic growth (Eggoh *et al.*, 2011, p. 7408).

BRICS countries which are Brazil, Russian Federation, India, China, South Africa and Turkey are also accepted as emerging countries recently, according to their rapid economic growth performances. The Brazil, Russia, China, India, South Africa and Turkey (BRICS-T) country group's growth performances seem stronger than the growth performances of the leading industrialized countries in the world. As it is seen in the literature, relatively high growth rate requires high energy consumption. In this point, this study will investigate the relationship between energy consumption and economic growth for BRICS-T countries.

2. Literature review

The literature provides many studies about the relationship between energy consumption and real output/growth. Most of these studies used time series approach as an econometric method. In these studies, there is no consensus on the direction of energy consumption and economic growth. (Kraft and Kraft, 1978; Masih and Masih, 1996; Soytas and Sari, 2003; Akinlo, 2008; Warr and Ayres, 2010; Pathan and Abbasi, 2014). Using the time series method can reduce the effectiveness of relatively short data range tests (Narayan and Smyth, 2008, p. 2332; Eggoh *et al.*, 2011, p. 7408). Panel data method gives more accurate and reliable statistical results when the time dimension is relatively small (Constantini and Martini, 2010, p. 593). There are various types of panel cointegration methods applied in the literature to test the relationship between energy consumption and economic growth. Pedroni (1999, 2000, 2004) has been extensively used to measure energy consumption and product dependence, but complex results have been achieved in relation to the direction. For example, Apergis and Payne (2009) conclude that there was a one-way relationship between energy consumption and growth for six Central American countries between 1980 and 2004 periods. In another study of Apergis and Payne (2010), there was a long-term balance relationship between real GDP and energy consumption in nine South American countries between 1980 and 2005. Similar results have been found in the short-term and long-term energy consumption for the developing countries with the existence of a causality relation to GDP between 1975 and 2001, by Lee (2005). Al-Mulali (2011) concluded that there was a long-term cointegration relationship between oil consumption and GDP in the MENA countries by the cointegration test results of Pedroni (1999, 2004) and Kao (1999). At the same time, it has been determined that there was a long-term and short-term bi-directional relationship between the variables. Al-Mulali and Binti Che Sab (2012) tested the total primary energy consumption and GDP growth data of sub-Saharan countries for the 1980–2008 period with the Pedroni (Engle–Granger based) cointegration test and panel granger causality tests. According to panel cointegration test results, there was a bi-directional causality relation with the existence of a long-term cointegration relation among the variables. The fact that Pedroni (1999, 2000, 2004) neglects cross-sectional dependency did not seem to be realistic when the links between economies were taken into consideration (Dobnik, 2011, p. 6). Accordingly, it is not appropriate for this study to assume that BRICS country economies are not related. This study will prefer to use the most appropriate method through data set, with the superior aspects of the panel series compared to the time series.

On the other hand, factors that cause structural breakdowns such as economic crisis, energy crisis and structural adjustment policies can affect the relationship between energy and output (Eggoh *et al.*, 2011, p. 7409). For this reason, new econometric techniques have been developed which take into account both cross-sectional dependency and structural breaks, thus providing more reliable results. The cointegration tests developed by Westerlund (2006, 2007) and Westerlund and Edgerton (2008) are some of these methods. These tests take into account the multiple structural endogenous breakdowns that can differ between countries and the strong dependency between countries (Eggoh *et al.*, 2011, p. 7408). Narayan and Smyth (2008) investigated the relationship between energy consumption and real GDP in G7 countries through Pedroni (1999) and Westerlund (2006) tests. In the study of Pedroni's (1999) cointegration, Westerlund's (2006) multiple structural breaks cointegration test and Granger's causality tests are used. According to the Pedroni (1999) test results, no correlation was found between the variables; however, when the structural break was allowed, the existence of cointegration between the variables was tested. According to the Granger causality test, a bi-directional causality was determined between variables. Eggoh *et al.* (2011) tested the data between economic growth and energy consumption of 21 African countries between 1970 and 2006 with the panel cointegration of Pedroni (1999, 2004) and Westerlund (2006, 2007) and Granger causality; and cointegration and bi-directional causality between variables were determined. Dobnik (2011) found the existence of a long-run equalization relationship between variables in the study used Westerlund and Edgerton's (2008) method to test the relation between real GDP and energy consumption for 23 OECD countries between 1971 and 2009. According to panel causality test results, there is a bi-directional relationship between variables. Jalil (2014) tested the long-term relationship between economic growth and energy consumption of 29 net energy importer countries and 19 net energy exporter countries between 1970 and 2012 using the panel cointegration method of Westerlund (2007) and Westerlund and Edgerton (2008). Both in two methods and in two groups of countries, there is a long-term cointegration relation. According to the results of the Granger causality test, there is a one-way economic growth from the energy consumption in the energy importer countries, and a two-way relationship in the energy exporting countries. Studies on BRICS countries are included in the literature; however, these studies are more limited. Pao and Tsai (2011) tested energy consumption and real GDP data for BRIC (except Russia) countries between 1990 and 2005 with Pedroni and Kao Panel cointegration and Granger Panel causality tests. In the study, where the cointegration relation was found, in short-term one-way and in long-term bi-directional causality from energy consumption to real output has been determined. Sebri and Ben-Salha (2014) tested their causality relationship between economic growth and renewable energy consumption in the BRICS countries during the period of 1971–2010 with the ARDL bounds testing approach to cointegration and vector error correction model (VECM). According to ARDL estimates, there was a long-run equalizing relation between the variables. According to the VECM results, there was a bi-directional and positive relationship between renewable energy consumption and economic growth. In the study of BRICS countries testing the panel causality method for electricity consumption and economic growth between 1990 and 2010, Cowan *et al.* (2014) reported that there was a bi-directional relationship between electricity consumption and growth in Russia, a one-way relationship from economic growth to electricity consumption in South Africa, and there was no relation between the variables in Brazil, China and India. Khobai (2017) tested the relationship between electricity consumption and economic growth with Kao (1999) panel cointegration and Johansen Fisher panel methods for BRICS countries during the period 1990–2014, and reached a long-term relationship between variables. Also, according to the VECM, there was a one-way relationship from long-term economic growth to electricity consumption.

3. Data and methodology

When the studies investigate the relationship between energy consumption and output, it is seen that there are some methodological problems. Particularly, the short-time period prevents the use of time series methods which require a relatively long number of observations.

Another inability to use time series methods is the annual collection of data such as energy use and produce, carbon emissions, etc., and thus the number of observations is limited. In this context, panel data methods should be used. Panel data methods give stronger results than time series methods. Panel data analysis reduces the effects of links between explanatory variables (colinearity), thereby increases the degree of freedom and the effectiveness of estimates. As a result, more reliable and stable parameter estimates can be obtained. Finally, panel data analysis can reduce the problems caused by substandard distributions and unit root analysis because of its relatively long time dimension.

Literature gives also studies that prefer non-linear models, as studies refer to linear models. On the other hand, there is no strong knowledge that non-linear models should be preferred in the literature. Non-linear approaches are loosely based on the theoretical grounds (see Mitic *et al.*, 2017). In this study, the relations between the series are being investigated by linear methods.

One of the major problems in panel data analysis is the interdependence between individual units (countries). This problem is called cross-sectional dependence (CSD). CSD can lead to reduced test statistics effectiveness and improper evaluations. The Breusch–Pagan Lagrange multiplier (LM) test and Pesaran CD tests are commonly used to investigate cross-sectional dependency. In this study, two different test statistics were used to investigate the cross-sectional dependency: Breusch–Pagan LM and Pesaran CD tests.

The basic hypothesis and test statistic suggesting that there is no cross-sectional dependency for the Breusch–Pagan LM test are as follows (Baltagi, 2001):

$$H_0 \colon \sigma_\mu^2 = 0,$$

$$\mathrm{LM} = \left(\mathrm{NT}/2(T-1)\right)\left[\left(\sum_{i=1}^{N} e_i^2 / \sum_{i=1}^{N}\sum_{t=1}^{T} e_{it}^2\right) - 1\right]^2.$$

In the basic hypothesis, the Peseran CD test statistic, which assumes that there is no cross-sectional dependency, is calculated as follows:

$$\mathrm{CD} = \sqrt{\frac{2T}{N(N-1)}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}\right)} \Rightarrow N(0,1).$$

The stationarity of the series has a preference in the choice of prediction models. After investigating cross-sectional dependency in this study, the stationarity of the series will be investigated. The most commonly used methods the LLC and IPS tests are used for investigating stationarity. LLC test allows autocorrelation between the series, while it does not offer individual autocorrelation. IPS test allows for a series of individual autocorrelation coefficients. The superiority of the IPS test comes from applying the ADF unit root test separately for each series. However, these analysis methods assume that the series do not have cross-sectional dependency. O'Connell (1998, p. 16) also showed that the possibility of the rejection of the basic hypothesis in the panel unit root tests increases when there is cross-sectional dependency between the series. In this context, Pesaran (2007) proposes a unit root test, the CADF (cross-sectionally Augmented Dickey fuller test) panel unit root test, which considers the cross-sectional dependency. It is a test that allows standard ADF regression to be used to examine stationarity conditions of cross-sectionals and panel data that can be used in both $T > N$ and $N > T$ situations where the first differences of cross-sectionals and the delayed values are widened by the cross-section averages. Breitung test is another test statistic that can produce robust *t*-statistics in the case of CSD. The coefficient ρ is assumed to be constant between units. However, it is also suitable for heterogeneous panels. For unit effects and models with trend, Breitung is stronger than LLC, HT and IPS tests. Also Breitung test has been shown to be stronger than other tests for small samples.

3.1 Panel cointegration tests

Panel data analysis is preferred in this study because it has a relatively long number of observations and reduces the problems associated with estimates made by time series and cross-sectional series methods. As stated by Al-Mulali (2011), if the panel data methods are preferred, the problems caused by time series methods can be overcome: unobserved heterogeneity, declining degrees of freedom and stable of parameter estimates. In this study, first, Pedroni cointegration analysis was used. The Pedroni cointegration test is based on the Engle–Granger co-integration test. This test develops several within dimension and between tests, which have no cointegration as their null hypotheses and heterogeneous intercepts and trend coefficients across cross-sections. Autoregressive parameters vary in the group statistics over the cross-section. If the null is rejected, at least one individual holds cointegration. For this reason, group tests offer an additional source of heterogeneity among panel members. In Fisher's ADF test, the null hypothesis of a unit root (no cointegration) for all three cross-sections is set against the alternative hypothesis of some cross-sections without a unit root (cointegration):

$$y_{it} = \alpha_i + \delta_i t + \gamma_t + X_{it}\beta_i + e_{it}. \tag{1}$$

In Equation (1), y_{it} and X_{it} are the variables; $i = 1, \ldots, N$ are the individuals; and $t = 1, \ldots, T$ is the time dimension. If the error terms are stationary, then a cointegration relation exists between the series (e_{it}, $I(0)$); if the error terms are not stationary, then (e_{it}, $I(1)$) cointegration relation does not exist. In other words, when the error terms are not stationary, the relation of the false regression is mentioned. The α_i and δ_i parameters allow each individual (country) to have specific fixed effects and deterministic trends. In the investigation of the cointegration relation, error terms are obtained in Equation (1) and the stationarity state of the error terms is investigated. Equation (2) is used to investigate the stationarity of error terms:

$$e_{it} = \rho_i e_{it-1} + u_{it}, \tag{2}$$

or:

$$\hat{e}_{it} = \rho \hat{e}_{it-1} + \sum_{p=1}^{P_i} \varphi_{ip} \Delta \hat{e}_{it-p} + u_{it}^{*} \tag{3}$$

The basic hypothesis (H_0: $p_i = 1$) which claims that cointegration relation is absent is being tested. The Pedroni test is included in the first-generation analysis methods as well as expressing the cointegration relation. First-generation (Konvansiyonel) panel data methods have some weaknesses. First of all, due to the structural break in the panel data analysis, the estimation results of relations between the series tend to accept false regression. This problem does not occur in panel sets with a very short-time dimension, it especially increases when the time dimension increases. If the cointegrated vector has structural breaks, traditional tests tend to accept false regression relationships. Another important problem of panel data tests is the cross-sectional dependency. Cross-sectional independence is an important assumption. Where this assumption is not met, first-generation tests tend to accept the basic hypothesis. First-generation test methods with simplification assumptions for these problems can lead to incorrect results. Second-generation tests take these issues into account (see Groen and Kleibergen, 2003; Banerjee and Carrion-i-Silvestre, 2006; Westerlund, 2006). Westerlund and Edgerton (2008) have developed a test that permits CSD for panel data analysis, multiple structural breaks of the cointegrated vector both at intercept and trend, and for error terms to have heteroskedastic and serially correlated errors. In this study, Westerlund and Edgerton (2008) methodology as well as Pedroni cointegration methodology are used. Westerlund and Edgerton (2008) developed a panel cointegration test derived from LM-based unit-root tests by Schmidt and Phillips (1992), Ahn (1993) and Amsler and Lee (1995). This test allows heteroskedastic and serially correlated errors, individual-specific intercepts and time trends, CSD and unknown breaks in both the intercept and trend of the cointegrated regression.

3.2 Westerlund and Edgerton (2008) panel cointegration test methodology

y_{it} variable can be computed as follows:

$$y_{it} = \alpha_i + \theta_i t + \delta_i D_{it} + x'_{it}\beta_i + (D_{it}x_{it})'\gamma_i + z_{it}, \tag{4}$$

$$\mathrm{x}_{it} = \mathrm{x}_{it-1} + w_{it}. \tag{5}$$

The k-dimensional vector x_{it} variable is modeled according to the pure random walk process. In the equation, D_{it} is the dummy variable representing the structural break ($D_{it} = 1 \rightarrow t > T_i$ and otherwise 0). In this case, α_i and β_i represent the intercept and trend in the pre-break period. δ_i and γ_i show the intercept and trend change in the break period. It is assumed that z_{it} has the following data generation process that allows for the use of unobserved common factors and CSD:

$$z_{it} = \lambda'_i F_t + v_{it}, \tag{6}$$

$$F_{jt} = \rho_i F_{jt-1} + \mu_{jt,} \tag{7}$$

$$\phi_i(L)\Delta v_{it} = \phi_i v_{it-1} + e_{it}, \tag{8}$$

here, $\phi_i(L)$: $1 - \sum_{j=1}^{P_i} \varphi_{ij} L^j$ is a scalar polynomial in the lag operator L. And F_t is the $\mathrm{F}_{jt}(j = 1, \ldots, r)$ r-dimensional vector of unobserved common factors. If $\rho_i < 1$ is for all j_i, the stationarity of F_t is ensured. In this case, the order of the integration of the composite regression error will depend only on the idiosyncratic disturbance. As a result, the $\phi_i < 0$ relation in Equation (4) is cointegrated and in the case of $\phi_i = 0$ it means fake relation.

If the cointegration relationship between the series is to be determined, the relationship between the series and their magnitude must be investigated. As Pedroni (1999, 2001) showed, if there is a long-term cointegration relationship between series, estimators of panel regressors would be inconsistent and biased, and he proposed an FMOLS (Fully-Modified OLS) method in the presence of a cointegration relationship.

4. Empirical findings

This study explained the relationship between energy consumption and economic growth for BRICS-T countries through data from period of 1990–2014. Our panel data set is strongly balanced. Energy use series are in kg of oil equivalent per capita. Energy use refers to the use of primary energy before transformation to other end-use fuels. GDP per capita is gross domestic product divided by midyear population (see World Bank definition). GDP per capita series are in constant $2010. Our data were obtained from World Bank website. Our data have been obtained from the World Bank website. Descriptive statistics is seen in Table I.

In terms of energy consumption per capita, Russia has the highest average. The second place is in South Africa. Turkey, Brazil and China are the countries of energy consumption, which are seen to be close to each other. On the other hand, India differs from this country group. India's energy consumption is relatively low according to other countries. In terms of GDP per capita, Russia and Turkey have the highest average. Brazil and China are close to

Table I. Descriptive statistics

	South Africa	Brazil	China	India	Russia	Turkey
Energy consumptions						
Min.	2,292.2	933.9	736.9	351.3	3,981.5	947.8
Max.	2,963.4	1,484.9	2,236.7	637.4	5,928.7	1,585.4
Avg.	2,584.4	1,142.4	1,282.6	454.9	4,698.6	1,234.5
SD	166.1	167.3	530.5	86.8	515.3	207.5
GDP Per capita						
Min.	5,517.5	7,796.8	730.8	530.9	5,505.6	6,708.9
Max.	7,627.9	11,912.1	6,108.2	1,646.8	11,615.7	13,312.0
Avg.	6,473.5	9,473.0	2,645.5	929.7	8,475.0	9,076.8
SD	782.9	1,340.8	1,667.2	348.3	2,146.4	1,974.1

each other. South Africa and India have a relatively low average per capita income according to other countries.

Cross-sectional dependency of the series was analyzed before the stationarity of the series was investigated. The results can be seen in Tables AI and AII. According to the results, the basic hypothesis cannot be rejected. There is cross-section dependency. After investigating the cross-sectional dependency of the series, stationarity conditions of the series will be investigated.

In Table II, it can be seen that the real product and energy consumption series are not stationary at the level. It was observed that the first differences of the series provided stationarity. In the case of cross-sectional dependency, the results obtained for unit root analysis may lose its validity. For this reason, the stationarity of the series was reconsidered with CADF and Breitung test statistics. In Table III, it can be seen the CADF and Breitung test results. It is seen from the CADF test results that the null hypothesis cannot be rejected and it is decided that the real product series are not stationary at the both models and the energy consumption series are not stationary at the trend and intercept model. However, energy consumption series are stationary at the intercept model. Breitung test is another test statistic that can produce robust t-statistics in the case of CSD. It is seen from the Breitung test results that both the real

Table II. Panel unit root test results

	Intercept		Trend and intercept	
Method	Statistic	Prob.	Statistic	Prob.
LNEN unit root test results				
Levin. Lin and Chu t	1.577	0.9427	−0.75805	0.2242
Im. Pesaran and Shin W-stat.	3.318	0.9995	0.13723	0.5546
LNGDP unit root test results				
Levin. Lin and Chu t	−0.04776	0.4810	−1.89501	0.0290
Im. Pesaran and Shin W-stat.	4.16061	1.0000	−2.23415	0.0127

Table III. CADF and Breitung panel unit root test results

	LNGDP CADF results				LNEN CADF results			
	Intercept		Trend and intercept		Intercept		Trend and intercept	
Method	Statistic	Prob.	Statistic	Prob.	Statistic	Prob.	Statistic	Prob.
CADF	−0.924	0.178	0.154	0.561	−2.179	0.015	1.209	0.887
Breitung	6.904	1.000	0.948	0.828	4.577	1.000	0.6866	0.7538
First differences test results								
CADF	−1.462	0.072	−0.229	0.409	−1.554	0.060	−0.149	0.441
Breitung	−2.749	0.003	−2.845	0.002	−4.2511	0.000	−3.961	0.000

product series and the energy consumption series are not stationary at the level (see Table II). According to the first differences panel unit root test results for CADF for Breitung test, the null hypothesis is rejected and it is decided that the series are stationary at the intercept model. In the analysis results, both conventional tests and the CADF and Breitung tests show that the series are stationary at the same level (I(1)); in other words, series can be cointegrated in the long run. First, the Pedroni cointegration test was applied to find the cointegration relations between the series. The results of Pedroni cointegration test can be seen in Table IV.

It is seen that there is no long-term relationship between energy consumption and real output in Table IV. According to the panel v-statistic test results where the real product series are dependent variables, there is a causality relation from the energy consumption to the output. However, since the Pedroni test is a first-generation test statistic that does not consider cross-sectional dependency or cointegration-related breaks, we used the second-generation prediction method, Westerlund and Edgerton (2008) panel cointegration methodology to overcome these problems mentioned above. Test results are shown in Table V.

In Table V, it is seen that there is no cointegration relation between the series consistent with the Pedroni test results as we consider, real output is our dependent variable according to the first model without break. Level break and regime break models were predicted up to five breaks. For level break model test results, there is a long-run cointegration relationship between the series. However, according to regime break model test results there is not a long-run cointegration relationship between series.

On the other hand, when the dependent variable is energy consumption; according to three models (without break, level break and regime break), there is a cointegration relation between the series. Also, it is seen that there is a bi-directional relationship between energy consumption and real output, unlike the first-generation analysis, Pedroni cointegration analysis. Pedroni (1999, 2001) recommends the FMOLS model if the cointegration relationship between the series is available (Table VI).

According to Table V, it can be said that an increase of 1 percent in output brings about an increase of 0.6 percent of energy consumption, while an increase of 1 percent in energy consumption leads to an increase of 0.9 percent in output.

	Statistic	Prob.	Statistic	Prob.
Dependent variable: LNEN				
Within-dimension				
Panel v-statistic	−1.354	0.912	−0.616	0.731
Panel ρ-statistic	0.451	0.674	−0.655	0.256
Panel PP-statistic	−1.044	0.148	−1.610	0.053
Panel ADF-statistic	0.692	0.755	0.076	0.530
Between-dimension				
Group ρ-statistic	0.453	0.674		
Group PP-statistic	−0.721	0.235		
Group ADF-statistic	0.518	0.697		
Dependent variable: LNGDP				
Within-dimension				
Panel v-statistic	9.969548	0.0000	3.445498	0.0003
Panel ρ-statistic	0.274549	0.6082	−0.062374	0.4751
Panel PP-statistic	−0.513910	0.3037	−0.941115	0.1733
Panel ADF-statistic	0.001904	0.5008	0.177867	0.5706
Between-dimension				
Group ρ-statistic	0.929467	0.8237		
Group PP-statistic	−0.742901	0.2288		
Group ADF-statistic	−0.466649	0.3204		

Table IV. Pedroni panel cointegration test results

5. Conclusion

This study aims to investigate the relationship between energy consumption and economic growth for BRICS-T countries through data from the period of 1990–2014. In the analysis, the cross-sectional dependency of the series was investigated through Breusch–Pagan LM and Pesaran tests. According to the test results, there is cross-sectional dependency. Thus, the stationarity of series is investigated with CADF and Breitung panel unit root tests taking cross-sectional dependency into consideration. On account of existence of cross-sectional dependency problem in the study, Westerlund and Edgerton (2008) test, which considers heteroskedastic and serially correlated errors, individual-specific intercepts and time trends, CSD and unknown breaks in both the intercept and trend, was preferred. According to Westerlund and Edgerton (2008) panel cointegration test results, bi-directional causality relationship between energy consumption and output was determined. According to FMOLS, an increase of 1 percent in output brings about an increase of 0.6 percent of energy consumption, while an increase of 1 percent in energy consumption leads to an increase of 0.9 percent in output.

This study provided similar result to Al-Mulali and Binti Che Sab (2012) that there was a bi-directional causality relationship between energy consumption and economic growth. Studies including BRICS countries are so limited that this study contributed the related literature. This study also gave consistent findings with Sebri and Ben-Salha (2014) in the context of research area as BRICS countries.

BRICS-T countries with high growth rates have significant effects on climate change. The results obtained from this study show that there is a bi-directional relationship between real production and energy consumption. In other words, the growth increases the global carbon emission via energy consumption also energy consumption increases the growth rate. This poses a threat to climate change and it is important to cooperate with BRICS-T countries in the fight against climate change. Adequate allocation of resources, use of renewable energy sources and investment in new technologies are important. In this context, environmentally friendly production techniques, energy inputs and projects as well

	$Z_\tau(N)$		$Z_\phi(N)$	
Model	Value	*p*-value	value	*p*-value
Dependent variable: LNEN				
No break	−3.396	0.000	−5.042	0.000
Level break	−3.603	0.000 (4 breaks)	−2.377	0.009 (4 breaks)
Regime shift	−5.456	0.000 (4 breaks)	−4.884	0.000 (4 breaks)
Dependent variable: LNGDP				
No break	0.314	0.623	0.979	0.836
Level break	−2.918	0.002 (4 breaks)	−2.609	0.005 (4 breaks)
Regime shift	−1.216	0.112 (4 breaks)	−1.603	0.054 (4 breaks)

Table V. Westerlund and Edgerton (2008) panel cointegration test results

Variable	Coefficient	SE	*t*-Statistic	Prob.
Dependent variable: LNGDP				
LNEN	0.899	0.110	8.172	0.000
R^2	0.997235	Adjusted R^2		0.996982
Dependent variable: LNEN				
LNGDP	0.615	0.077	7.917	0.000
R^2	0.996954	Adjusted R^2		0.996675

Table VI. FMOLS test results

as emission trade scheme, environmental tax and environmental pollution are needed in order to achieve sustainable development.

This study can guide the way in which the relationship between output and energy consumption will be made for different country groups and regions within the scope of energy economy literature.

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Further reading

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Appendix 1

Cross-section dependence test
Series: LNEN
Null hypothesis: no cross-section dependence (correlation)
Sample: 1990–2014
Periods included: 25
Cross-sections included: 6
Total panel observations: 150
Note: non-zero cross-section means detected in data
Cross-section means were removed during computation of correlations

Test	Statistic	df	Prob.
Breusch–Pagan LM	201.8722	15	0.0000
Pesaran scaled LM	33.02260		0.0000
Bias-corrected scaled LM	32.89760		0.0000
Pesaran CD	12.01894		0.0000

Table AI. Cross-section dependence test for LNEN

Appendix 2

Cross-section dependence test
Series: LNGDP
Null hypothesis: no cross-section dependence (correlation)
Sample: 1990–2014
Periods included: 25
Cross-sections included: 6
Total panel observations: 150
Note: non-zero cross-section means detected in data
Cross-section means were removed during computation of correlations

Test	Statistic	df	Prob.
Breusch–Pagan LM	307.8083	15	0.0000
Pesaran scaled LM	52.36378		0.0000
Bias-corrected scaled LM	52.23878		0.0000
Pesaran CD	17.43983		0.0000

Table AII. Cross-section dependence test LNGDP

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