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DETERMINANTS OF ENERGY CONSUMPTION IN BRICS-T COUNTRIES: AN ECONOMETRIC ANALYSIS

With the emergence of globalization borders are fading out and economies are getting ever more interdependent with increasing trade volumes. As global population goes up, consumption demand reinforces increases in output. In this regard, energy can be regarded as one of the most critical inputs in the process of development and growth. Accordingly, the process of growth and industrialization has been gradually increasing the dependence of world economies on energy. Energy consumption has been steadily growing with each passing year, hence increasing the dependence on energy even further. This study examines the factors that determine energy consumption. For this purpose, the factors that determine energy consumption in BRICS-T countries (Brazil, Russia, India, China, South Africa, and Turkey) are analyzed for the period of 1992-2018. Foreign direct investments, energy prices and economic growth are taken to be the potential factors determining energy consumption. Error Correction Method (ECM) proposed by Westerland and LM Boostrap cointegration tests suggested by Westerland and Edgerton is used to test the existence of long term relationship between the series. Long term cointegration coefficients have been estimated using Common Correlated Effects Mean Group (CCEMG) estimator and Augmented Mean Group (AMG) estimator. The findings obtained from the analysis confirm

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that, firstly, all three variables (foreign direct investments, prices of energy, and economic growth) are critical and have a long-term relationship with energy consumption. Secondly, the series of foreign direct investments is significant in all countries subject to our panel data analysis. Economic growth series is only significant for Turkey and China. Energy prices series are found to be significant in Russia, S. Africa, and China.

Keywords: *Energy Consumption, GDP, FDI, Energy Prices, BRICS-T countries.*

1. INTRODUCTION

Energy is no doubt one of the most important factors for human beings to survive and meet their basic needs. Accordingly, the energy need is of vital importance in all the devices we use, from heating to enlightenment, transportation, communication, and industrial production. The invention of steam engines in the late 1700s and the subsequent Industrial Revolution that started in Europe rapidly increased the need and dependence on energy. Especially the spreading of the Industrial Revolution all over the world has been the beginning of an era that we can describe as the "energy age" with rapidly increasing mechanization. In addition to urbanization, population growth and industrialization, which increased rapidly with the Age of Enlightenment, the efforts of developing countries to accelerate economic growth resulted in a rapidly increasing production and consumption demand. As new technologies emerged, the demand for raw materials and energy has steadily increased at a global level. Until the 1970s, access to energy resources was relatively cheaper and they were abundant. However, oil prices rose rapidly as a result of oil shocks, hence restricting access to energy resources.

According to the 2018 report published by the British Petroleum (BP), global energy demand is increasing every year. Approximately 28% of the total energy demand is accounted for by coal, 34% oil and 24% natural gas, respectively. Accordingly, the greater part of global energy demand consists of non-renewable energy resources, which we can call *fossil fuels*. According to the energy scenarios conducted by the International Energy Agency (IEA), even though it is predicted that the share of fossil fuels in energy resources will decrease relatively by the 2040s, fossil fuels will remain as the dominant source of energy. On the other hand, the share of renewable energy resources is expected to be approximately 16.1% in the 2040s and this share is expected to continue to increase in the future.

Depending on various factors such as population growth, increasing welfare level of the countries, expanding world trade due to globalization and urbanization etc. global demand for heat and power seems highly likely to increase even further every coming year. By 2030, the world population is expected to increase by 2 billion with respect to today's population, and the number of vehicles in traffic in non-OECD countries is expected to reach approximately 550 million. In addition, it is predicted that the world energy demand, most of which are arising from developing countries, will be approximately 60% higher than that of today by the 2030s.

This study aims to examine the determinants of energy consumption in BRICS-T countries (Brazil, Russia, India, China, South Africa, and Turkey) based on a panel data covering the period 1992-2018. Foreign direct investments, economic growth and energy prices are taken as potential determinants of energy consumption in the study. The rest of the paper is organized as follows.

In the second and third sections, the determinants of energy consumption are examined theoretically and a thorough literature review is conducted, respectively. Section four consists of the data set and descriptive statistics of the study while the fifth section introduces the method and empirical results. In the conclusion, findings obtained are summarized and a comprehensive evaluation is presented.

2. THEORETICAL FRAMEWORK

Energy constitutes one of the basic production factors in achieving economic growth and social development of a country. It is inevitable for a country that wants to increase production to use energy as an input. Undoubtedly, achieving sustainable development requires increasing energy consumption. This occurs indirectly as a result of the increase in economic growth and increase in production factors (Bilginoğlu, 1991: 124-125). This creates a triple helix that increases production quantities, energy consumption and economic growth.

According to the Solow growth model, economic growth can only be achieved through technological development. The drawback of this model is that it cannot explain how technological progress will occur. According to an alternative growth model developed by Arrow (1962), only natural resources are seen as the source of economic growth. In this model, economic growth can be achieved by substituting unlimited natural resources and the capital produced by human beings. In the third group of Neoclassical growth models, both technology and natural resources are considered as the main factors of growth. All these models consider the contribution of energy to the economy as a cost of production. Therefore, in the Neoclassical growth models, energy is considered as an intermediate good, not a primary production input (Stern and Cleveland, 2004: 8-10).

However, Neoclassical economists' view, i.e. taking energy as a raw material or an intermediate good, is erroneous. Because it ignores a fundamental distinction between the function of energy and other raw materials used in the production process. The oil turns iron ore into iron, and then steel and ultimately thousands of finished steel products. Therefore, energy directs the business that transforms raw materials into final products (Alam, 2006: 6). From this point of view, the Neoclassicals' view that keep energy out of the economy are subject to criticism. Moreover, together with the mechanization process, the machinery brings along an acceleration in production and economic growth. Therefore, there is a direct relationship between energy and growth, while the concept of speed is completely related to energy (Alam, 2006: 4-6).

Ecological economists, therefore, strongly criticized both Neoclassical Growth Models and External Growth Models for not considering energy as a primary production factor and tried to develop alternative models that takes energy as a primary factor (Ayres, 2001: 820). Some scientists, such as Smile (1994) who study the relationship between economics and geography, and those who study economic history, for instance Wrigley (1988) and Allen (2009), agree that while energy is the most important factor of the industrial revolution, it also plays a vital role in economic growth.

One of the most fundamental or universal laws of economics is the *law of supply and demand*. It infers that, ceteris paribus, the price of a good falls as it becomes abundant, and price goes up as the good gets scarce. Conversely, when everything else is constant, if the price of a good increases, quantity demanded falls while it goes up when price decreases. In this context, price is a fundamental factor that balances supply and demand in the market (Acar, 2018). Price changes can affect the production (output) and consumption decisions of both producers and consumers in order to optimize the profits of producers and the general benefits of consumers. In addition, price is essential for determining the shortage of commodities in the market. Because an increase or decrease in the price of a commodity is one of the main factors taken as a signal for predicting supply and demand. Price is also an important tool for the efficient distribution of capital. A higher commodity selling price relative to cost gives investors a potential opportunity, indicating the need for new investment in production capacity. A lower commodity selling price will cause a decrease in investment (Secretariat, 2007: 41). Therefore, along with production and consumption, price affects many other decisions from investment to distribution of goods.

According to Hayek, price is seen as a label, a signal, a piece of information linked to the goods and services. Therefore, besides the production methods, the quantities to be produced and the options for consumption are based on the information carried by the prices (Osigwe and Arawomo, 2015: 408). Since price is the most important factor for energy demand and supply, it is inevitably an important factor affecting economic growth. In turn, growth rates can directly or indirectly affect energy consumption. It is a fact that the increase in energy prices, especially between 1973-1985, reduced the resource intensity of the industrial sector and energy consumption for production (Schafer, 2005: 431). On the other hand, with the decrease in energy prices experienced towards the end of the 1980s, there was an increase in the energy consumption of high-income and upper-middle income countries (Çermikli and Öztürkler, 2010: 11). Therefore, it would not be wrong to say that this inverse relationship is from energy prices to economic growth and energy consumption.

Foreign direct investments (FDI), when directed to a country with an effective and efficient planning, can create many positive effects on the economy: new employment possibilities, increase in production and exports, improvement in the balance of payments, higher income, economic development, and hence increase in welfare. The biggest effect of FDI is its contribution to the national income increase of a country (Görgün, 2004: 4). Borensztein *et al*. (1998) found that FDI lead to economic growth. According to this study, foreign direct investments depend on many factors: human capital, technology, exports and financial capital, and these factors can directly affect economic growth. Although it is possible to see some counter views in the literature, the dominant view is that the effect of FDI inflows on economic growth is positive.

In regards to the relationship between growth and energy consumption, energy is defined in a report published by the IEA (2016) as one of the most important factors for production and economic growth. An increase in energy consumption causes higher rates of growth, and a decrease in consumption causes a decrease in growth rates and a slowdown in the production process. In addition, a change in growth rates can show its effect on energy demand as an increase or decrease (Siddiqui, 2004: 176).

3. LITERATURE REVIEW

Asafu-Adjave (2000) examined the relationship between energy consumption and economic growth for India, Indonesia, the Philippines and Thailand for the period 1971-1995. A bi-directional causality from energy to income in India and Indonesia, and a causality from income to energy in Thailand and the Philippines has been identified. Wolde-Rufael (2005) investigated the relationship between energy consumption and economic growth in 19 African countries for 1971-2001 period where a bi-directional causality was determined. Lee (2006) investigated the relationship between energy consumption and economic growth in 11 industrialized countries. The results of the study covering the years between 1960-2001 confirm the existence of a significant relationship between these variables. Mahadevan *et al*. (2007) investigated the relationship between energy consumption and growth for 20 different energy importing and exporting countries for the period 1971-2002, where a bidirectional causality between energy consumption and economic growth in both energy exporting and energy importing countries was found.

Apergis and Payne (2009) identified a unidirectional causality from energy consumption to economic growth in six Central American countries for 1980-2004 period. Using data for a period between 1980-2007, Pao and Tsai (2011) examined the relationship between energy consumption and economic growth in the BRIC countries and found a significant relationship. Azam *et al*. (2015), in their study using data for a period between 1980 and 2012, confirmed the relationship between energy consumption and growth in Indonesia, Malaysia and Thailand. Baek (2016) investigated the relationship between energy consumption and growth for ASEAN countries for 1981-2010 period. This study also confirms a significant relationship between these variables.

In light of the above, one can say that, parallel to the theoretical expectations, most of the empirical studies confirm the positive relationship between growth and energy consumption. Table 1 below summarizes the literature on energy consuption and growth.

In regards to the relationship between energy prices and energy consumption, there are many studies in the literature that directly investigate this relationship. For instance, Yuan *et al*. (2010) investigated the relationship between energy prices and energy consumption for the period covering 1993-2007 for China. According to their findings, they concluded that high energy prices will reduce both energy consumption in the Chinese industry and household energy consumption.

Table 1.

THE LITERATURE ON THE RELATIONSHIP BETWEEN ECONOMIC GROWTH AND ENERGY CONSUMPTION

Author (s) / Year	Country (s)	Time / Period	Method	Research Subject	Result
Asafu-Adjaye, (2000)	India, Indonesia, Philippines, Thailand	1971-1995	Granger Cointegration Analysis	Relationship between energy consumption and economic growth	There is causality between energy consumption and economic growth.
Wolde-Rufael (2005)	19 African Countries	1971-2001	Toda-Yamamoto causality test	Relationship between energy consumption and economic growth	There is causality between energy consumption and economic growth.
Lee (2006)	G-11 Countries	1960-2001	Toda-Yamamoto and Granger causality test	Relationship between energy consumption and economic growth	There is causality between energy consumption and economic growth.
Mahadevan and Asafu-Adjaye, (2007)	20 countries	1971-2002	Error Correction Model	Relationship between energy consumption and economic growth	There is a bidirectional causality between energy consumption and economic growth.
Apergis and Payne (2009)	6 Central American countries	1980-2004	Pedroni panel cointegration test and error correction model	Relationship between energy consumption and economic growth	A unidirectional causality from energy consumption to economic growth.
Pao and Tsai (2011)	BRIC Countries	1980-2007	Panel Cointegration test	Relationship between energy consumption and economic growth	There is causality between energy consumption and economic growth.

Author (s) / Year	**Country (s)**	**Time / Period**	**Method**	**Research Subject**	**Result**
Azam *et al*. (2015)	Indonesia, Malaysia, Thailand	1980-2012	Least squares estimation method	Relationship between energy consumption and economic growth	A positive and statistically significant relationship was found on economic growth and energy consumption.
Baek (2016)	ASEAN Countries	1981-2010	PMG dynamic panel estimator	Relationship between energy consumption and economic growth	There is causality between energy consumption and economic growth.

Source: Prepared by the authors.

In another study investigating the relationship between energy consumption and energy prices, He *et al*. (2014) reveal that changes in electricity prices have a significant impact on energy consumption. Osigwe and Arawomo (2015) found a bidirectional causality between electricity prices and energy consumption in for Nigeria for 1970-2012. Chen *et al*. (2016) investigates the relationship between energy consumption and energy prices for 1982-2011. The findings show a positive and directly proportional relationship in the short term.

Table 2 summarizes the literature on energy prices and consumption.

Table 2.

LITERATURE ON THE RELATIONSHIP BETWEEN ENERGY PRICES AND ENERGY CONSUMPTION

Author (s) / Year	Country/ province (s)	Time / Period	Method	Research Subject	Result
Yuan *et al*. (2010)	China	1993-2007	Cointegration test, Granger causality analysis	Relationship between energy prices and energy consumption	Higher energy prices will reduce energy consumption in Chinese industrial sectors, but will not reduce economic output in the long run.
He *et al*. (2014)	Beijing	2010	CGE test	Relationship between energy prices and energy consumption	In sectors with high energy consumption, changes in electricity prices have a greater impact on energy consumption.
Osigwe and Arawomo (2015)	Nigeria	1970-2012	Granger causality test	Relationship between energy prices and energy consumption	A bidirectional causality has been determined between electricity consumption and electricity price.
Chen *et al*. (2016)	Taiwan	1982-2011	ARDL test	The impact of energy prices on energy consumption and energy efficiency	Energy use is inflexible in the short while it is flexible in the long run; price elasticity of energy efficiency was found to be more flexible in the long run.
Brini *et al*. (2017)	Tunisia	1980-2011	ARDL test	Relationship between renewable energy consumption and oil price	A unidirectional relationship has been found between renewable energy consumption and oil prices.

Source: Prepared by the authors.

Lastly, as far as the relationship between energy consumption and FDI is concerned, for example Omri and Kahouli (2014) examine this relationship in their study for 65 countries. Their analysis covering the period 1990-2011 reveals that there is a one-way causality from FDI to energy consumption. Similarly, Leitao (2015) looks into the relationship between energy consumption and foreign direct investment in Portugal between 1990-2011. Empirical results show a positive relationship between FDI and energy consumption.

Doytch and Narayan (2016) examine the link between foreign direct investment and energy demand for 74 countries in the period 1985-2012. Their findings indicate that FDI inflows in financial services increase non-renewable and renewable energy consumption. In the manufacturing sector, on the other hand, FDI seemed to reduce renewable energy consumption. Amri (2016) examined the relationship between energy consumption and FDI for 75 countries for 1990-2010 period. A two-way positive relationship is found between renewable energy consumption and FDI in the developed countries. Paramati *et al*. (2018) try to explain the main factors that determine energy consumption in seven neighboring market economies in Africa. The impact of FDI inflows on energy consumption is found to be reducing.

Table 3 summarizes the literature on FDI and energy consumption.

Table 3.

SUMMARY OF THE LITERATURE ON THE RELATIONSHIP BETWEEN FDI AND ENERGY CONSUMPTION

Author (s) / Year	Country (s)	Time / Period	Method	Research Subject	Result
Omri and Kahouli (2014)	65 countries	1990-2011	Panel Data Analysis	Relationship between energy consumption and FDI	A unidirectional causality from FDI to energy consumption.
Leitao (2015)	Portugal	1990-2011	Panel Data Analysis	Relationship between energy consumption and FDI	Positive relationship between FDI and energy consumption.
Doytch and Narayan (2016)	74 countries	1985-2012	Blundell – Bond Dynamic Panel Estimator	Relationship between energy consumption and FDI	While FDI inflows in financial services increase both non-renewable and renewable energy consumption. In the manufacturing sector, however, FDI reduces renewable energy consumption.
Amri (2016)	75 countries	1990-2010	Least Squares Estimator	Relationship between energy consumption and FDI	A bidirectional positive relationship between renewable energy consumption and FDI in developed countries.
Paramati *et al*. (2018)	7 African countries	1991-2012	Panel Data Analysis	Relationship between energy consumption and FDI	The effect of FDI inflows on energy consumption has been found to be reducing.

Source: Prepared by the authors.

4. DATA AND DESCRIPTIVE STATISTICS

BRICS-T countries that have shown a rapid economic growth in recent years, also called the *emerging economies* (Brazil, Russia, India, China, South Africa and Turkey) are examined in this study.

Four variables are used in the analysis, one being the dependent variable and three explanatory variables. Energy Consumption (ECON), used as the dependent variable refers to million tons of oil consumption for the countries subject to investigation. The relevant data for energy consumption have been obtained from the World Bank database. Explanatory variables that are expected to measure the changes in the dependent variable are shown in Table 4. In order to get the real oil prices series, nominal world oil prices are divided by the consumer price index of each country.

Table 4.

VARIABLES, DATA SETS AND DATA SOURCES

No	Data	Description	Abbreviation	Period	Source
1	Energy Consumption	Total Oil Consumption (million tons)	ECON	1992-2018	BP Statistics, 2019
2	Gross Domestic Product	Total Gross Domestic Product (million dollars)	GDP	1992-2018	World Bank, 2019
3	Foreign Direct Investments	Total Foreign Direct Investment (million dollars)	FDI	1992-2018	UNCTAD, 2019
4	Energy Prices	World Oil Prices (dollar barrel price) / Consumer Prices Index	PRICE	1992-2018	BP Statistics, 2019

Table 5 shows the minimum and maximum values, averages and standard deviation values of the dependent variable and explanatory variables. Note that the standard deviation values in the economic growth (lnGDP) and foreign direct investments (lnFDI) series are higher than that of the other variables. In addition, it is worth noting that the average and minimum values in the energy prices (lnPRICE) series are negative.

Table 5.

DESCRIPTIVE STATISTICS

	LnECON	LnFDI	LnGDP	LnPRICE
Average	4.464	3.190	4.765	-1.160
Maximum	6.442	6.889	28.633	1.772
Minimum	2.849	0.078	0.032	-1.678
Standard Average	0.933	1.766	4.567	0.571

5. THE MODEL, ECONOMETRIC METHOD AND EMPIRICAL RESULTS

While analyzing the determinants of energy consumption in the study, in parallel to the literature, the energy consumption function was formulated as follows.

$$ECON = f\left(GDP, FDI, PRICE\right) \qquad \text{(eq. 1)}$$

In equation 1;

ECON denotes energy consumption, GDP is the total gross domestic product, FDI shows the total foreign direct investment flows, and PRICE variable shows the oil prices.

In an effort to obtain more efficient results from the empirical analysis, the logarithmic form of the model is taken to get the equation below.

$$lnECON_{it} = \propto_{0+} \propto_1 lnGDP_{it} + \propto_2 lnFDI_{it} + \propto_3 lnPRICE_{it} \qquad \text{(eq. 2)}$$

where i = 1, ………..N indicates the number of cross sections, and t = 1, …………..T shows the time dimension.

5.1. Cross section dependency test

It may be assumed that the effects of the variables not included in the model show an independent distribution along the cross section. But any shock that may arise as a result of a decision taken by economic decision-making units in order to avoid any risk may lead to an addiction that may affect the choices of other economic decision-making units (Hsiao, 2007: 16). For this reason, while performing an analysis with limited time dimension, ignoring any dependence that may occur in this way may lead to inconsistency in the estimation results of the analysis (Huang, 2008: 219). Therefore, testing the variables of the model against cross-sectional dependency in the first stage of the analysis will give better results.

In the literature various tests have been developed to check the presence of cross sectional dependency. In order to test cross-section dependence, "CD_{LM}" test developed by Breusch and Pegan (1980), "CD" and "CD_{LM2}" tests developed by Peseran (2004) are used as a common practice in this literature. In addition to these, "LM_{adj}" (deviation corrected LM test) proposed in Pesaran *et al*. (2008) is also used.

The first of these tests analyzing cross section dependence is Breusch and Pegan (1980) "CD_{LM}" test. This test is used when the size (N) of the cross section in the panel data is smaller than the time length (N < T) (Pesaran, 2004: 4-5). This method developed by Pesaran (2004) uses the following equational form:

$$CD_{LM} = T\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}^{2} \quad \text{(eq. 3)}$$

In the above equation, ρ_{ij} shows the sample estimate of the correlation coefficients of the residuals. The H_0 hypothesis means that "cross-sectional dependency is not in question." Besides, in this test, when T approaches ∞ and if N is constant, $\frac{N(N-1)}{2}$ degrees of freedom chi-square shows an asymptotic distribution (Pesaran, 2004: 4; Güloglu and Ivrendi, 2010: 384).

Compared to the CD_{LM} test, the CD test developed by Pesaran (2004) shows a test property with small sample properties not based on a specific spatial weight matrix, especially when N is large and T is small and (N>T), the following test is used (Pesaran, 2004: 5).

$$CD = \sqrt{\frac{2T}{N(N-1)}}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij} \quad \text{(eq. 4)}$$

CD_{LM2} test is another test that measures cross section dependency developed by Pesaran (2004). This test is a scaled version of the CD_{LM} test and the asymptotic standard shows a normal distribution. Just like the CD_{LM} test, this test is used when (N < T), it can also be used in larger N and T cases. The calculation of this test is done by the equation 5 below.

$$CD_{LM2} = \sqrt{\frac{1}{N(N-1)}}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\left(T\hat{\rho}_{ij}^{2}-1\right) \quad \text{(eq. 5)}$$

In order to eliminate the deviations that may occur in the CD_{LM} test regarding the panel and group averages, Pesaran *et al*. (2008) put forward the LM_{adj} test. It uses basically the mean and variance values of the CD_{LM} test. This technique, which does not have any limitation in terms of cross-section and time, can also be employed in small sample groups. In this test, just like others, the H_0 hypothesis means that there is no cross sectional dependency. LM_{adj} test is calculated by equation 6 given below. Table 6 gives the test results.

$$LM_{adj} = \left(\frac{2}{N(N-1)} \right)^{\frac{1}{2}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \frac{(T-K)\hat{\rho}_{ij}^{2} - \mu_{Tij}}{u_{Tij}} \qquad \text{(eq. 6)}$$

Table 6.

CROSS SECTION DEPENDENCY TEST RESULTS

Regression Model:		
$\ln ECON_{it} = \propto_{0\dagger} + \propto_1 \ln GDP_{it} + \propto_2 \ln FDI_{it} + \propto_3 \ln PRICE_{it}$	**Statistic**	**p-value**
Cross-section dependency tests:		
LM (BP,1980)	56.114	0.000***
CD_{lm} (Pesaran, 2004)	7.506	0.000***
CD (Pesaran, 2004)	1.143	0.127
LM_{adj} (PUY, 2008)	4.307	0.000***

Note: *** indicates the level of significance at 1%.

As can be seen from Table 6, H_0 hypothesis is rejected by all tests at 1% level of significance, hence we conclude that there is cross section dependence between the series.

5.2. Homogeneity test

Following the cross-section dependency test, it is important to determine the homogeneity of the slope coefficients of the panel data. The *Swamy Test* developed by Swamy (1970) to determine the homogeneity of the slope coefficients is based on individual slope estimates. It can be applied in panels when (N < T) and it allows for inter-section heterogeneity (Pesaran and Yamagata, 2007: 5). The Swamy test is calculated as shown in equation 7 below.

$$\hat{S} = \sum_{i=1}^{N} \left(\hat{\beta}_i - \hat{\beta}_{WFE}\right) \frac{X_i' M_T X_i}{\hat{\sigma}_i^2} \left(\hat{\beta}_i - \hat{\beta}_{WFE}\right) \quad \text{(eq. 7)}$$

The Delta (Δ) test developed by Pesaran and Yamagata (2007) can be used to test the slope homogeneity of the panel data (Pesaran and Yamagata, 2008: 54-55). Pesaran and Yamagata (2008) propose delta test statistic to check homogeneity in small samples, and Δ_{adj} test statistic to do the same in large samples. The formula used to calculate these test statistics are shown in equations 8 and 9 below, respectively. Table 7 shows homogeneity test results.

- *Suggested test statistics for large samples:*

$$\Delta = \sqrt{N}\left(\frac{N^{-1}\hat{S} - k}{\sqrt{2k}}\right) \quad \text{(eq. 8)}$$

- *Suggested test statistics for small samples:*

$$\Delta_{adj} = \sqrt{N}\left(\frac{N^{-1}\hat{S} - E\left(\tilde{Z}_{iT}\right)}{\sqrt{var\tilde{Z}_{iT}}}\right) \quad \text{(eq. 9)}$$

Table 7.

RESULTS OF THE HOMOGENEITY TEST

Homogeneity tests:	Statistics	P-value
Δ	15.505	0.000***
Δ_{adj}	17.107	0.000***

Note: *** indicates the level of significance at 1%.

Homogeneity tests are used in the panel data analysis to determine whether any difference in the country has the same effect on other countries. In this sense, the model coefficients of countries with different economic structures are expected to show heterogeneous characteristics, while countries with similar structures are expected to show homogeneity (Kar *et al*., 2018: 312). The homogeneity test results show heterogeneous characteristics as expected, since the sample countries reasonably differ in structure.

5.3. Unit root test

It is also important to determine whether there is *stationarity* between data sets. We used “Second generation unit root tests” in this study. These methods are used in the presence of cross-sectional dependency between series (Pesaran, 2007: 265). In this method, individual results can be found for each horizontal section of the CADF test, as well as CIPS statistics by obtaining cross-sectional averages and results for the overall panel. In addition, CADF test provides the opportunity to be applied for both T>N and T<N cases (Pesaran, 2007: 266-268).

A simple linear panel model with heterogeneous properties in the form of y_{it} is shown in equation 10 (t: time, *it*: cross section observation).

$$\boldsymbol{y_{it}} = (1-\varnothing_i)\boldsymbol{\mu_i} + \varnothing_i \boldsymbol{y}_{i,\,t-1} + \boldsymbol{u_{it}}\,(\boldsymbol{i}=1,\ldots\ldots \boldsymbol{N};\, \boldsymbol{t}=1,\ldots\ldots \boldsymbol{T}) \qquad \text{(eq. 10)}$$

where u_{it} refers to the error term with a single factor feature:

$$\boldsymbol{u_{it}} = \gamma_i \boldsymbol{f_t} + \boldsymbol{\varepsilon_{it}}$$

While f_t in the error term (equation 11) indicates unobservable common effects for each country, ε_{it} indicates individual error terms. The differential form of eq. 10 is given below:

$$\Delta \boldsymbol{y_{it}} = \boldsymbol{a_i} + \boldsymbol{\beta_i y}_{i,\,t-1} + \boldsymbol{\varepsilon_{it}} \qquad \text{(eq. 11)}$$

where $\propto_i = (1-\varnothing_i)\mu_i$, $\beta_i = -(1-\varnothing_i)$ and $\Delta y_{it} = y_{it} - y_{i,\,t-1}$. Hence, the hypotheses of the CADF test under the condition $\varnothing_i = 1$ can be formed as follows:

$H_0 : \beta_i = 0$: there is no stationarity between the series (for all i’s)

$H_1 : \beta_i = 1$: there is stationarity between series (in some of the individual results).

Ultimately, the regression model for the CADF test takes the following form:

$$\Delta \boldsymbol{y_{it}} = \boldsymbol{a_i} + \boldsymbol{b_i y}_{i,\,t-1} + \boldsymbol{c_i \bar{y}}_{t-1} + \boldsymbol{d_i}\Delta \boldsymbol{\bar{y}_t} + \boldsymbol{e_{it}} \qquad \text{(eq. 12)}$$

The CIPS statistic value consists of the arithmetic mean of the t statistic values calculated for each cross section. The CIPS statistical value that gives information about the panel in general is calculated by equation 13 (Pesaran, 2007: 276).

$$\boldsymbol{CIPS}(\boldsymbol{N},\boldsymbol{T}) = \boldsymbol{N}^{-1}\sum_{\boldsymbol{i}=1}^{N} \boldsymbol{t_i}(\boldsymbol{N},\boldsymbol{T}) \qquad \text{(eq. 13)}$$

The H_0 hypothesis is accepted if the probability values calculated for the CIPS statistics are smaller than the critical table values. In this case, there is no stationarity between the series, that is, the series do not contain unit roots. Table 8 contains the unit root test results of the series whose first differences were taken. The results confirm that the country series have stationarity.

Table 8.

UNIT ROOT TEST RESULTS

	Level		**Difference**	
	Constant	**Constant and Trend**	**Constant**	**Constant and Trend**
	CIPS / Panel Statistics	**CIPS / Panel Statistics**	**CIPS / Panel Statistics**	**CIPS / Panel Statistics**
lnECON	-2.26**	-2.697	-2.309**	-2.222
lnGDP	-1.240	-1.746	-2.744*	-2.669
lnFDI	-1.691	-2.929**	-4.585*	-4.657**
lnPRICE	-5.247***	-5.230***	-7.032***	-8.510***

Note: Maximum delay length (lags) was taken as 2 and optimal delay lengths were determined according to the Schwarz information criterion. Panel statistics critical values were -2.57 (1%), -2.33 (5%) and -2.21 (10%) in the constant model. Pesaran 2007, table II (b), p: 280); -3.10 (1%), -2.86 (5%) and -2.73 (10%) in the fixed and trend model (Pesaran 2007, table II (c), p: 281). Panel statistics is the average of CADF statistics.

5.4. Cointegration test

Using tests that take into account the cross-sectional dependency while conducting cointegration analysis would be better for the results. In this context, although there are many methods in the literature measuring cointegration, the Westerlund (2007) test is seen as a newer and relatively more advantageous test compared to the others.

In the Westerlund (2007) test, the test statistics that form the panel must be calculated first. For this purpose, the models given in equations 14 and 15 below should be estimated directly with the least squares method.

$$\Delta Y_{it} = \delta_i d_t + \lambda X_{it-1} + \sum_{j=1}^{\rho i} a_{ij} \Delta Y_{it-1} + \sum_{j=0}^{\rho i} \lambda X_{it-j} + e_t \quad \text{(eq. 14)}$$

$$\Delta Y_{it-1} = \delta_i d_t \lambda X_{it-1} + \sum_{j=1}^{\rho i} a_{ij} \Delta Y_{it-1} + \sum_{j=0}^{\rho i} \lambda X_{it-j} + \varepsilon_t \quad \text{(eq. 15)}$$

After calculating the test statistics, the error correction coefficient of the panel and the resulting standard deviation are calculated by using the following formuale.

$$a_i = \left[\sum_{i=1}^{N} \sum_{t=2}^{T} \left(\tilde{Y}_{it-1} \right)^2 \right]^{-1} \sum_{i=1}^{N} \sum_{t=2}^{T} \frac{1}{a_{i(1)}} \tilde{Y}_{it-1} \Delta \tilde{Y}_{it} \quad \text{(eq. 16)}$$

$$S.E\left(a_i\right) = \left[\left(\tilde{S}_N \right)^2 \sum_{i=1}^{N} \sum_{t=2}^{T} \tilde{Y}_{it-1}^2 \right]^{-\frac{1}{2}} \quad \text{(eq. 17)}$$

In Westerlund (2007) panel cointegration analysis, test statistics are found as the last step as a result of calculating the following equations.

$$P_t = \frac{a}{S.E(a)} \sim N(0,1) \quad \text{(eq. 18)}$$

$$P_a = T_a \sim N(0,1) \quad \text{(eq. 19)}$$

In Westerlund (2007) cointegration analysis technique, H_0 hypothesis ($a_i = 0$) means there is no cointegration between the series, while $H_1(a_i = a < 0)$ means otherwise.

When interpreting the results obtained by the ECM test offered by Westerland (2007), Bootsrap p-values are taken into consideration to see if there is a cross-sectional dependency between the series used in the study (Nazlıoglu, 2010: 96). Since there is heterogeneity between the series, the critical values of *group_tau* and *group_alpha* are taken into account when interpreting the results (Arslan, 2017: 203).

Table 9.

WESTERLAND (2007) ECM PANEL COINTEGRATION TEST RESULTS

BRICS-T Error Correction Method	**Unconstant**		**Constant**		**Constant and Trend**	
(Ho: no cointegration)	Statistic	Boostrap P-value	Statistic	Boostrap P-value	Statistic	Boostrap P-value
Group_tau	2.775	0.985	4.438	0.999	1.329	0.956
Group_alpha	0.913	0.768	2.735	0.991	-4.316	0.008
Panel_tau	0.456	0.807	2.064	0.958	1.129	0.895
Panel_alfa	0.456	0.556	2.064	0.964	1.129	0.061

ECM test results show that according to group_tau and group_alpha statistics with both constant and trend, H_1 hypothesis should be accepted. Therefore, we find that there is a long-term relationship between energy consumption and other variables.

5.5. Estimating long term cointegration coefficients

AMG (Extended Mean Group Estimator) is one of the second generation estimators recommended for estimating the cointegration coefficients in heterogeneous panel models and in case of cross-sectional dependence. With the AMG estimation method, different coefficients of the equations created by the sections can be calculated.

AMG estimation method can be applied in case of any problem arising from the error terms of the series, as well as for the estimations in case of unbalanced panels (Eberhardt and Bond, 2009: 1-3). It gives more reliable and consistent results than the CCE estimator suggested by Pesaran (2006) (Eberhardt and Bond, 2009; Eberhardt and Teal, 2010: 19). In the AMG method recommended for estimating long term coefficients; the following models are used to make estimations and calculations are done according to these results.

$$\Delta \boldsymbol{y}_{it} = \boldsymbol{b}'\Delta \boldsymbol{x}_{it} + \sum_{t=2}^{T} \boldsymbol{c}_t \Delta \boldsymbol{D}_t + \boldsymbol{\varepsilon}_{it} \quad \text{(eq. 20)}$$

$$\Rightarrow \hat{c}_t \equiv \boldsymbol{\mu}_t^{\bullet}$$

$$y_{it} = a_i b' x_{it} + c_i t + d_i \mu_t^{\bullet} + \varepsilon_{it} \quad \text{(eq. 21)}$$

$$\hat{b}AMG = N^{-1} \sum_i \hat{b}_i \quad \text{(eq. 22)}$$

Table 10 shows the long term coefficient estimation results of the AMG estimator for the panel as a whole.

Table 10.

AMG ESTIMATOR PANEL RESULTS

lnECON	**Coefficient**	**P-value**
lnFDI	0.0300	0.082*
lnGDP	-0.0568	0.141
lnPRICE	0.3329	0.014***

Note: *, **, *** indicate significance levels at 10%, 5% and 1%, respectively.

According to these findings, energy prices and foreign direct investment variables are found to be significant at 1% and 10% level respectively, while the economic growth variable is insignificant. Cointegration coefficient estimation results for each country by the AMG estimator are given in Table 11.

Table 11.

AMG ESTIMATOR INDIVIDUAL COUNTRY RESULTS

Brazil	**Coefficient**	**P-value**
lnFDI	0.0484	0.005***
lnGDP	-0.0019	0.145
lnPRICE	0.0221	0.250
Russia	**Coefficient**	**P-value**
lnFDI	0.0127	0.049**
lnGDP	0.0003	0.953
lnPRICE	0.3430	0.000***
India	**Coefficient**	**P-value**
lnFDI	-0.0091	0.029**
lnGDP	0.0012	0.231
lnPRICE	0.1050	0.413
China	**Coefficient**	**P-value**
lnFDI	0.1072	0.001***
lnGDP	-0.0057	0.088**
lnPRICE	0.8015	0.000***
S. Africa	**Coefficient**	**P-value**
lnFDI	0.0064	0.089**
lnGDP	-0.1044	0.103
lnPRICE	0.6602	0.020**
Turkey	**Coefficient**	**P-value**
lnFDI	0.0144	0.100*
lnGDP	-0.2302	0.000***
lnPRICE	0.0656	0.139

Note: *, **, *** indicate significance levels at 10%, 5% and 1% respectively.

As can be seen in the Table 11, the AMG estimator results show that foreign direct investments variable is meaningful for all countries in the sample. Moreover, economic growth is significant in China and Turkey. Energy price appears to be meaningful for Russia, China and S. Africa.

6. CONCLUSION

Energy is no doubt one of the most important elements not only in the process of economic growth and development, but also in our daily lives as well. It is no surprise, therefore, to see energy and controlling energy reserves as well as distribution channels is one of the major reasons today for the ongoing international disputes and conflicts all over the world, particulalrly in the Middle East and Eastern Mediterranean.

This paper investigates the determinants of energy consumption in BRICS-T countries which are also called *emerging economies* for a period of 27 years (1992-2018). Even though individual country results may differ, in general FDI, energy prices and economic growth are found to be the critical variables in determining the energy consumption.

Looking at the analysis results for Brazil, the FDI series is meaningful at 1%, while the economic growth and energy prices are not. A 1% increase in foreign direct investments increases the amount of energy consumption by 0.04% in Brazil. This finding is in conformity with the theoretical expectations.

Analysis for Russia shows that energy prices and FDI are meaningful at 1% and 5%, respectively. A 1% increase in foreign direct investments increases the energy consumption by 0.01%, while 1% increase in energy prices increases the energy consumption by 0.34% in Russia. In other words, while the effect of FDI on energy consumption in Russia is compatible with theoretical expectations, the effect of energy prices on energy consumption is not. A possible expalanation might be the fact that Russia is an energy exporter, increasing energy prices generates higher revenues, which in turn supports growth, hence energy consumption.

For India, it seems that only the FDI is significant at 5% level, while the other two variables are not. In China, on the other hand, all variables are meaningful: FDI, economic growth and energy prices are meaningful at 1%, 5% and 1% level, respectively. A 1% increase in energy prices in China increases energy consumption by 0.80%. This finding, contradicting with the theoretical expectations on the relationship between energy consumption and energy prices, may be related with the high growth performance of China in recent decades, i.e. use more energy to grow, no matter what. In parallel to theoretical expectations, a 1% increase in foreign direct investments in China increases energy consumption by 0.1%. While FDI and energy prices are meaningful in S. Africa at the 5% significance level, the economic growth series is meaningless. A 1% increase in foreign direct investments in S. Africa seems to increase energy consumption by 0.006%.

Finally, FDI and GDP growth are meaningful at 10% and 1% level of significance in Turkey, whereas energy prices seem to be not meaningful. Accordingly, a

1% increase in foreign direct investments increases energy consumption by 0.01%, and contrary to theoretical expectations, 1% increase in GDP reduces energy consumption by 0.23%. The relationship between GDP and energy consumption in Turkey is inconsistent with the theory. A possible explanation for this unexpected result may be related with efficient use of energy, i.e. energy-saving technologies as the economy grows.

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ODREDNICE ENERGETSKE POTROŠNJE U BRICS-T ZEMLJAMA: EKONOMETRIJSKA ANALIZA

Sažetak

S pojavom globalizacije granice nestaju, a gospodarstva postaju sve više međuovisna, s povećanjem obujma trgovine. Kako globalna populacija raste, potražnja za potrošnjom pojačava povećanje proizvodnje. U tom smislu, energija se može smatrati jednim od najkritičnijih faktora proizvodnje u procesu razvoja i rasta. Sukladno tome, proces rasta i industrijalizacije postupno povećava ovisnost svjetskih gospodarstava o energiji. Potrošnja energije je u stalnom porastu iz godine u godinu, što dodatno povećava ovisnost o energiji. Ovo istraživanje ispituje čimbenike koji određuju potrošnju energije. U tu svrhu, analizirani su čimbenici koji određuju potrošnju energije u zemljama BRICS-T (Brazil, Rusija, Indija, Kina, Južnoafrička Republika i Turska) za razdoblje 1992.-2018. Izravna strana ulaganja, cijene energije i gospodarski rast smatraju se potencijalnim faktorima koji određuju potrošnju energije. Model korekcije pogrešaka (ECM) kojeg je predložio Westerland i LM Boostrap kointegracijski testovi predloženi od strane Westerlanda i Edgertona, koriste se za testiranje postojanja dugotrajnog odnosa između serija. Dugoročni kointegracijski koeficijenti procijenjeni su korištenjem procjenitelja srednje skupine uobičajenih koreliranih učinaka (CCEMG) i procjenitelja proširene srednje skupine (AMG). Nalazi dobiveni analizom potvrđuju kako su, prvo, sve tri varijable (izravna strana ulaganja, cijene energije i gospodarski rast) kritične i dugoročno povezane s potrošnjom energije. Kao drugo, serije izravnih stranih ulaganja značajne su u svim zemljama koje su predmet naše analize panel podataka. Serije gospodarskog rasta značajne su samo za Tursku i Kinu. Pokazalo se i kako su serije cijena energije značajne u Rusiji, Južnoj Africi i Kini.

Ključne riječi: potrošnja energije, BDP, izravna strana ulaganja, cijene energije, BRICS-T zemlje