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Does Electricity Supply Matter for Economic Growth in Russia: A Vector Error Correction Approach

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ABSTRACT

In this article we investigate the relationship between electricity consumption and economic growth in Russia. According to the production function of economic growth models, energy supply must be a catalyst of great importance for the economic growth. We investigate this nexus on the example of the Russian data for the period 1990-2017. Using vector error correction approach and granger causality test we aim to detect presence or absence of cointegration in the long run between electricity supply, economic growth and employment rate. Results show that the sampled variables are cointegrated and there exists a long-run relationship between them. Short-run effects analysis show that electricity supply does not significantly affects economic growth. Granger causality test shows that there exist a unidirectional causality running from electricity supply to economic growth and from economic growth to employment. The results show that electricity supply is essential for boosting economic growth in Russia in the long run.

Keywords: Economic Growth, Employment, Electricity Supply, Cointegration, Granger Causality
JEL Classifications: C22, O13, Q14

1. INTRODUCTION

Electricity is one of the main sources of energy today. Ensuring the safety and uninterrupted supply of electricity is an essential condition for ensuring the continuity of the production process and the industrial needs of the national economy. For good reason, electricity is one of the important factors of production. The importance of electricity supply was realized in the early 20th century, namely between 1902 and 1912. It was during this period that data on the supply and demand for electricity became publicly available. As national economies developed and as industrialization intensified, electricity consumption increased at a fast rate. For example, electricity consumption increased significantly between 1920 and 1929. During this period, electricity consumption has doubled. A slight reduction in civil electricity consumption was recorded during the post-war recovery period. Observation and empirical comparison of economic growth trends in the United States of America and electricity consumption showed similar trends. It was this observation that drew attention of researchers to the analysis of the relationship between electricity consumption and economic growth in order to determine the causal relationship of its nature.

In modern conditions, the importance of electricity as a factor of production is quite difficult to overestimate. The relationship between electricity consumption and economic growth, even in an environment where national economies are industrializing, remains an important and relevant issue. Important factors affecting the relationship between electricity supply and economic growth are fluctuations in energy prices, energy security, climate changes, national economies' dependence on energy resources, as well as environmental problems. It is also important what energy sources are used for electricity production. If non-renewable resources, such as coal, are actively used, the consequences could be high levels of carbon emissions in the atmosphere on the one hand. On the other hand, in case of insufficient supply of energy raw materials, there may be problems with ensuring the continuity of reproduction process, hence maintaining the pace of economic growth. This situation is quite relevant for developing economies. A striking example is South Africa, that accounts for 42% of emissions across the Continent (Kohler, 2013). In case of South Africa, 92% of the electricity produced is produced using coal (Inglezi-Lotz, and Blignaut, 2011). The use of coal as the main source of electricity in resource-limited conditions has led to the fact that the demand for electricity significantly exceeds its supply, causing the effect of electricity rationing. The disappointing consequence of this imbalance is the periodic disruption of the industrial sector, and hence of economic growth (Khobai et al., 2016).

In this paper we set a task to investigate the casual relationship between energy supply, economic growth and employment in Russia for the period 1990-2016. It's consistent with previous studies, investigating energy consumption-economic growth nexus, despite the fact that we use energy supply as a control variable (Wolde-Rufael, 2009, Kohler, 2013, Menyah and Wolde-Rufael, 2010). For analysis purposes we use vector error correction approach using quarterly data.

The remainder of the paper is organized as follows: Section 2 provides an overview of relevant literature; section 3 describes econometric modeling techniques and data used; section 4 presents an analysis of empirical results; section 5 presents the conclusion of the study.

2. LITERATURE REVIEW

To test the stated hypothesis, we refer to the relevant literature on the issue. The "electricity/energy consumption – economic growth" is studied well enough. Some findings state that electricity may be viewed as one of the main catalysts for economic growth, especially industrial one (Muhammad and Mete, 2012; Atif and Siddiqi, 2010; Bekhet and Othman, 2011; Michieka, 2015; Khobai et al., 2016; Sharmin and Khan 2016). Some papers seek to establish causal relationship between electricity consumption and electricity consumption, albeit the results are ambiguous. These include: Muhammad and Mete (2012) for Kazakhstan, Atif and Siddiqi (2010) for Pakistan, Bekhet and Othman (2011) for Malaysia established that electricity consumption granger-causes economic growth. Similar findings were established for Botswana (Adebola, 2011) and Nigeria (Ankilo, 2009) for African economies. Similarly, the one-way causality from economic growth to electricity consumption was established in other studies; Yoo and Kim (2006) for Indonesia; Jamil and Ahmad (2010) for Pakistan; Smyth and Lean (2010) for Malaysia; Masuduzzaman (2013) for Bangladesh; Akinwale et al. (2013) for Nigeria and Inglesi-Lotz et al. (2013) for South Africa; Sharmin and Khan (2016) for Angola. On the other hand, some papers find no significant causal relationship between electricity consumption and economic growth (Akpan and Akpan, 2012) for Nigeria and Ghosh (2009) for India). Some papers present results, consistent with the feedback hypothesis (Ouedrago, 2010; Tang, 2008; Ahmad and Islam, 2011; Odhiambo, 2009; Shahbaz and Lean, 2012; Solarin and Shahbaz, 2013; Ahmad, et al., 2013; Sharmin and Khan 2016).

Cross-country studies, based on panel regression analysis, also show ambiguous results. Wolde-Rufael (2006) conducted a study for 17 African countries to determine the causal relationship between electricity consumption and economic growth. His results indicate that economic growth granger causes electricity consumption in 12 countries, while in the rest causality is statistically insignificant. Squalli (2007) tested the hypothesis on the relationship between economic growth and electricity consumption for the OPEC. A unidirectional causality running from electricity consumption to economic growth is present in Indonesia, Iran, Nigeria, Qatar and Venezuela. The results show no causal relationship between electricity consumption and economic growth for Kuwait, Saudi Arabia and the UAE. Apergis and Payne (2011) tested 88 countries, pooled into high, upper middle, low middle and low income countries groups. The results show that for high income and upper-middle income countries, there exist a statistically significant bidirectional causality between electricity consumption and economic growth, while the lower income countries' results suggest a unidirectional causality running from electricity consumption to economic growth.

Studies, devoted to investigating Granger causality between electricity supply and economic growth are rare. e.g., Ghosh (2002) found a unidirectional causality running from electricity supply to economic growth in India. Similar results were found by Gupta (2009) for India, Sarker (2010) for Bangladesh and Nanaji et al. (2013) for Nigeria, Khobai et al. (2016) for South Africa. Smyth and Lean's (2010) suggest a unidirectional causality running from economic growth to electricity supply in Malaysia. Bidirectional causality flowing between electricity supply and economic growth was established in Portugal (Cerdeira, 2012).

Given the above we use a VEC approach on the data for the period 1990-2016 for detecting Granger causality between electricity supply and economic growth in Russia.

3. MATERIALS AND METHODS

3.1. Research Methods

To test the hypothesis about relationship between electricity supply and Russian economic growth, we use econometric techniques to analyze time series. The algorithm of the ongoing study is determined by several key stages. First and foremost, one should test sampled variables on stationarity or order of cointegration, since the time series must have the same order, as can be seen from equation (1). Secondly, it is necessary to determine presence/absence of correlation in long term between the variables in the equation. To check this assumption, we use a Johansen cointegration test. In a case of a long-term relationship on the one hand and condition of stationarity of sampled time series in the first order I(1) on the other, it is possible to use VEC model. In case of confirmation of presence of cointegration between the variables of the sample, residuals of the equilibrium regression can be used to estimate error correction model. The final stage of constructing a model is to conduct diagnostic tests to determine validity of the model. These include testing for heteroscedasticity and serial correlation, normality and stability of the model. Another tool for detecting presence or absence of the studies nexus in Russian economy is Granger causality test.

The study uses the extended neoclassical production function where technology is endogenously determined by employment.

The general form of this production function may be written as follows:

$$GDP_t=\beta_1+\beta_2 ES_t+\beta_3 EM_t+\varepsilon_t \quad (1)$$

Where gross domestic product (*GDP*) represent the real gross domestic product (in constant prices), *ES* is the electricity supply measured in Gigawatt-hours and *EM* is the total labor force. The variables are all expressed in logarithmic form to stimulate stationarity of the mean, variance and covariance as a result reducing heteroscedasticity (Acaravci and Ozturk, 2010).

3.1.1. Unit root test

For the analysis of long-term relationships between the variables, Johansen and Juselieus (1990) admit that this form of testing is only possible after fulfilling the requirements of stationarity of the time series. In other words, if two series are co-integrated in order d (i.e., $I(d)$) then each series has to be differenced d times to restore stationarity. For d=0, each series would be stationary in levels, while for d=1, first differencing is needed to obtain stationarity. A series is said to be non-stationary if it has non-constant mean, variance, and auto-covariance over time (Johansen and Juselius, 1990). It is important to cover non-stationary variables into stationary process. Otherwise, they do not drift toward a long-term equilibium. There are two approaches to test the stationarity: Augmented Dickey and Fuller (ADF) test (1979) and the Phillips-Perron (P-P) test (1988). Here, test is referred to as unit-root tests as they test for the presence of unit roots in the series. The use of these tests allows to eliminate serial correlation between the variables by adding the lagged changes in the residuals of regression. The equation for ADF test is presented below:

$$\Delta Y_t=\beta_1+\beta_2 t+aY_{t-1}+\delta_3 \sum\Delta Y_{t-1}+\varepsilon_t \quad (2)$$

Where ε_t is an error term, β_1 is a drift term and $\beta_1 t$ is the time trend and Δ is the differencing operator. In ADF test, it tests whether a=0, therefore the null and alternative hypothesis of unit root tests can be written as follows:
H_0: a = 0 (Yt is non-stationary or there is a unit root).
H_1: a < 0 (Yt is stationary or there is no unit root).

The null hypothesis can be rejected if the calculated t value (ADF statistics) lies to the left of the relevant critical value. The alternate hypothesis is that a < 0. This means that the variable to be estimated is stationary. Conversely, we cannot reject the null hypothesis if null hypothesis is that a = 0, and this means that the variables are non-stationary time series and have unit roots in level. However, normally after taking first differences, the variable will be stationary (Johansen and Juselius, 1990). On the other hand, the specification of P-P test is the same as ADF test, except that the P-P test uses nonparametric statistical method to take care of the serial correlation in the error terms without adding lagged differences (Gujarati, 2003). In this research, we use both ADF and P-P test to examine the stationarity of the sampled time series.

3.1.2. Johansen co-integration test

To test for presence of cointegration we apply the Johansen test using non-stationary time series (values in levels). If between variables does exist a cointegration, the first-best solution would be using VECM model. An optimal number of lags according to Akaike information criterion for providing Johansen test is determined in VAR space. To conduct Johansen test, we estimate a VAR model of the following type:

$$y_t = A_1 y_{t-1}+\ldots+A_p y_{t-p}+B_{xt}+\epsilon_t \quad (3)$$

in which each component of y_t is non-reposeful series and it is integrated of order 1. x_t is a fixed exogenous vector, indicating the constant term, trend term and other certain terms. ε_t is a disturbance vector of k dimension.

We can rewrite this model as:

$$\Delta y_t = \prod y_{t-1} + \sum_{i=1}^{p-1} V_i \Delta y_{t-1} + Bx_t + \in_t \quad (4)$$

Where

$$\prod = \sum_{i=1}^{p} A_i - I, \qquad V_i = -\sum_{j=i+1}^{p} A_j \quad (5)$$

If the coefficient matrix $\prod$ has reduced rank $r < k$, then there exist k x r matrices α and β each with rank r such that $\prod=\alpha\beta'$ and $\beta' y_t$ is I(0). r is the number of cointegrating relations (the cointegrating rank) and each column of β is the cointegrating vector. The elements of α are known as the adjustment parameters in the VEC model. Johansen's method is to estimate $\prod$ matrix from an unrestricted VAR and to test whether we can reject the restrictions implied by the reduced rank of $\prod$ (Johansen, 1991).

3.1.3. Vector error correction model

Granger (1988) suggested the application of vector error correction methodology (VECM) in case if the variables are cointegrated in order to find short-run causal relationships. VECM, therefore, enables to discriminate between long-run equilibrium and short-run dynamics. In this sense, we employ following VECMs to estimate causal linkages among the variables:

$$\Delta ln l = a_0 + \sum_{i=1}^{k} a_1 \Delta lnl_{t-i} + \sum_{i=1}^{n} a_2 \Delta lnm_{t-i} + \sum_{i=1}^{m} a_3 \Delta lnr_{t-i} + \lambda ECT_{t-1} + v_1$$

$$\Delta ln m = \beta_0 + \sum_{i=1}^{k} \beta_1 \Delta lnm_{t-i} + \sum_{i=1}^{n} \beta_2 \Delta lnl_{t-i} + \sum_{i=1}^{m} \beta_3 \Delta lnr_{t-i} + \phi ECT_{t-1} + v_2$$

$$\Delta ln r = \eta_0 + \sum_{i=1}^{k} \eta_1 \Delta lnr_{t-i} + \sum_{i=1}^{n} \eta_2 \Delta lnl_{t-i} + \sum_{i=1}^{m} \eta_3 \Delta lnm_{t-i} + \chi ECT_{t-1} + v_3$$

Where l – electricity supply, m – employment level in Russia, r – economic growth (real GDP). (Granger, 1988)

Providing regression analysis of the sampled variables by modeling VECM allows to determine the existence of substantial and statistically significant dependence not only on the values of other variables in the sample, but also dependence on previous values of the variable.

However, VEC model must meet the requirements of serial correlation's absence, homoscedasticity of the residuals and to meet the requirement of stability and normality. Only in this case the results can be considered valid. Madhavan et al. (2010) indicates that Granger-causality in VAR domain is applied in the first differenced form if the variables are not co-integrated. If the variables are co-integrated, Granger-causality which entails the lagged error correction term (ECT) should be used in the equation as an additional variable. The information pertaining to long run relationship between the variables is contained in the ECT, while the short run information is determined by the lagged terms of individual coefficients (Adebola, 2011). Adebola (2011) further shows that the long run relationship is depicted by a negative sign on the coefficient of the ECT. Then, the direction of causality can be differentiated between long run and short run Granger-causality effects. The *t*-statistics is used to test the significance of the lagged ECT. The significance of ECT will prove the existence of long run Granger-causality (Ghosh, 2009). The short run Granger-causality is tested by the *F*-statistics and testing the significance of the lagged independent variables (Odhiambo, 2009).

3.2. Materials and Data Processing

We test a hypothesis about the relationship between electricity consumption and economic growth on example of Russian data for the period 1990 to 2016. The base period is one quarter. Data on electricity supply and economic growth is obtained from Federal Service of State Statistics (www.gks.ru). Following the studies by Narayan and Smyth (2005) and Odhiambo (2009) labor is calculated as the total number of people who are employed in the manufacturing industry. We also include workers, employed in the mining and manufacturing sectors.

To conduct time-series analysis, all variables are transformed into logarithms. To study sensitivity and causal linkages between the variables in the sample in short-and long-run, we turn to regression analysis, which involves the construction of VEC model of certain type based on stationary time series, testing the model for heteroscedasticity of the residuals, autocorrelation. To test casual linkages between the sampled variables we use Granger causality test in VEC domain.

4. RESULTS AND DISCUSSION

The first step in testing hypotheses is to test variables for the presence of unit root. For this purpose, we use standard tests - ADF and P-P test. Results of unit root testing are presented in Table 1.

As can be seen from the test results of the variables for the presence of unit root in their differentiation to the first order, we can reject the null hypothesis of unit root in each of the variables. Thus, the condition of stationarity at I(1) is performed, which gives us reason to test variables for cointegration. However, it is necessary to determine the optimal time lag.

The results of the model, showing the relationship between the sampled variables are presented in Table 2.

As can be seen from the Table 2, the value of ECT C(1) is negative in sign and statistically significant. This suggests the existence of long-run relationship between the variables of the sample. In other words, we obtained evidence that electricity supply, real GDP and employment in manufacturing sector are cointegrated, so that they have similar trends of movement in the long term.

The C (1) shows speed of long run adjustment. In other words, this coefficient shows how fast the system of interrelated variables would be restored back to equilibrium in the long run or the disequilibrium would be corrected. Given statistical significance at 5% level (P-value being <5%) and negative meaning, the system of variables corrects its previous period disequilibrium at a speed of 33.48% in four quarters (given optimal lag meaning of four quarters for ECM). It implies that the model identifies the sizeable speed of adjustment by 33.48% of disequilibrium correction in four quarters for reaching long run equilibrium steady state position.

Yet, we find no evidence of existence of the short-run effects coming from GDP or employment level to electricity supply. On the one hand, long-run trends of GDP, electricity supply and employment are cointegrated. And dependency in the long-run exist between them, given the fact that Russian economy is heavily dependent on electricity in industrial sector. Yet, short-run effects for sampled variables are absent. This means that there's no causality in the short-term running from economic growth and employment to electricity supply.

Another test to check the hypothesis is Granger causality test. The results of the test are presented in Table 3.

As can be seen from Table 3, results of Granger causality test confirm that electricity supply affects economic growth in Russia, as well as economic growth causes employment.

Table 1: Results of individual unit root test

Variables in	ADF		PP	
	Statistic	Prob.**	Statistic	Prob.**
Levels				
Intercept	8.123	0.698	10.846	0.7874
Intercept and trend	10.964	0.417	23.608	0.1152
First-difference				
Intercept	49.198	0.0000**	58.382	0.0000**
Intercept and trend	38.265	0.0000**	67.104	0.0000**

**denotes statistical significance at the 5% level of significance

Table 2: Results of vector error correction model

Granger causality (long run)		
Dependent variable	ECT	P-value
Cointegrating Equation error term C (1)	−0.3348	0.0067*
Real GDP	0.0748	0.6357
Employment level	0.0291	0.4892

*denotes statistical significance at 5% level

Table 3: Results of pairwise Granger causality test

Null hypothesis	Chi-square	p-value
ES does not Granger cause RGDP	0.42153	0.0401*
RGDP does not Granger cause ES	2.14166	0.6020
EM does not Granger cause ES	0.47790	0.8139
ES does not Granger cause EM	0.56583	0.4206
EM does not Granger cause RGDP	1.06645	0.3606
RGDP does not Granger cause ES	0.51841	0.0259*

*denotes rejection of the null hypothesis

5. CONCLUSION

In this article we investigate the relationship between electricity consumption and economic growth in Russia. According to the production function of economic growth models, energy supply must be a catalyst of great importance for the economic growth. We investigate this nexus on the example of the Russian data for the period 1990-2017. Using vector error correction approach and granger causality test we aim to detect presence or absence of cointegration in the long run between electricity supply, economic growth and employment rate.

To test the hypothesis about relationship between electricity supply and Russian economic growth, we use econometric techniques to analyze time series. The algorithm of the ongoing study is determined by several key stages. First and foremost, one should test sampled variables on stationarity or order of cointegration, since the time series must have the same order. Secondly, it is necessary to determine presence/absence of correlation in long term between the variables in the equation. To check this assumption, we use a Johansen cointegration test. In a case of a long-term relationship on the one hand and condition of stationarity of sampled time series in the first order I(1) on the other, it is possible to use VEC model. In case of confirmation of presence of cointegration between the variables of the sample, residuals of the equilibrium regression can be used to estimate error correction model. The final stage of constructing a model is to conduct diagnostic tests to determine validity of the model. These include testing for heteroscedasticity and serial correlation, normality and stability of the model. Another tool for detecting presence or absence of the studies nexus in Russian economy is Granger causality test.

Results suggest the existence of long-run relationship between the variables of the sample. In other words, we obtained evidence that electricity supply, real GDP and employment in manufacturing sector are cointegrated, so that they have similar trends of movement in the long term. Given statistical significance at 5% level (P-value being <5%) and negative meaning, the system of variables corrects its previous period disequilibrium at a speed of 33.48% in four quarters (given optimal lag meaning of four quarters for ECM). It implies that the model identifies the sizeable speed of adjustment by 33.48% of disequilibrium correction in four quarters for reaching long run equilibrium steady state position. Yet, we find no evidence of existence of the short-run effects running from GDP or employment level to electricity supply. Results of Granger causality test also confirm that electricity supply affects economic growth in Russia, as well as economic growth causes employment.

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