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Energy Consumption, electricity, and GDP Causality; The Case of Russia, 1990-2011

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Abstract

This article examines the causal relationship between the energy consumption, electricity consumption and GDP in Russia by using time series data from 1990-2011 implying the Toda and Yamamoto approach, which is revised form of the Granger (1969) causality test (Econ. 66 (1995) 225). The maximum order of integration was determined by using PP and ADF unit root tests. The Toda and Yamamoto test is applied regardless of whether the series are $I(0)$, $I(1)$, or $I(2)$, mutually cointegrated or non-cointegrated. The variables were estimated at level in the unrestricted lag-augmented VAR. The AIC, SC and LR lag criteria were used to determine the optimal lag length. The diagnostics tests were performed at the optimum lag selected by estimating the variables at level and confirmed the stability of the unrestricted VAR model. The empirical evidence showed that there exists a the bi-directional causality from electricity consumption to GDP that implies the validity of feedback hypothesis but no causality was found for GDP and energy consumption supporting the neutrality hypothesis. The estimated results confirmed that both the economic growth and electricity consumption empirically support each other and have a mutual and complementary relationship. But on another hand the energy sector of Russia has no impact on the economic growth for a period 1990-2011. Furthermore, if the Government of Russia devises policies to promote the access of energy and higher level of consumption, economic growth will not be affected.

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Keywords: Lag-augmented VAR, Electricity, GDP, Energy, Russia.

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1. Introduction

Energy consumption has been the burning issue around the world especially in the industrialized advanced nations. A huge literature can be found about the debate, on both energy consumption and GDP and the empirical results has been different for countries. The studies were conducted with the aim to know about the causality direction of energy consumption and GDP. Two views have inferred from the empirical studies conducted. One view is that as the economy expands that causes increase in demand for energy consumption. The second view that is an alternative view to the first argument claims that it is because of the energy consumption that the economy expands. While the third view is both the economic growth and energy consumption cause each other. i.e. bidirectional causality. Not only the causal relationship was studied, but also the long term relationship was analyzed between GDP and energy consumption. This is evident from the study conducted by Bowden and Payen, (2010), Lee (2006), Ozturk (2010); Apergis and Pyne, (2009a, 2011b;), Ewing et al.,2007, Soytas and Sari (2003), and Payne (2010) by setting four different hypothesis. The *growth hypothesis* in which the use of energy stimulates economic growth characterizes by causality direction from energy consumption to GDP. This causal relationship indicates that if the energy supplied to an economy is limited that may result in poor economic performance. In growth hypothesis the government should encourage the investment in more innovative approaches that should be aimed at improving the access to the energy at affordable rates for all productive sectors (Squalli, 2007).

The *conservation hypothesis means* that it is because of the economic growth which stimulates the increase consumption of energy supported by uni-directional causality from GDP to energy consumption. This supports the fact that economic growth stimulates the development of energy sector in an economy that is characterized by less dependence on energy. The policies which are based on energy conservation, if implemented properly, will have no adverse impact on economic growth. The *feedback hypothesis* is reinforced by the mutual relationship of economic growth and the energy consumption reinforced by bi-directional causality. The *neutrality hypothesis* means that both the energy consumption and GDP does not affect each other. The absence of causality of neutrality hypothesis implies that the policies reinforced by promotion of energy access and increase level of consumption will not have any impact on economic growth (Ouedraogo 2013). The rest of the article is organized as follows. Section 2 highlights brief literature review. Section 3 elucidates the data and model specification. Section 4 explains econometric methodology. Section 5 outlines the empirical results. Finally section 6 concludes.

2. Literature Review

Table 1. Literature Review

Authors	Estimation Sample	Country	Econometric Methodology	Causality direction	Hypothesis
Odhiambo (2009a)	1971-2006	South Africa	ARDL Bounds test	EC → GDP	Growth hypothesis
Odhiambo (2009b)	1971-2006	South Africa	ARDL Bounds test	GDP → EC	Conservation Hypothesis
Soyatas and Sari (2003)	1950-1992	Italy, Japan, South Korea	Vector error correction model, Granger Causality test	GDP — EC	Neutrality hypothesis
Akinlo (2008)	1980-2003	Ghana, Ghambia and Senegal	Fully modified OLS	GDP ↔ EC	Feedback hypothesis
Wolde-Rufael (2006)	1971-2001	Algeria, Cango, Egypt, Ghana, Ivory coast	Toda and Yamamoto granger causality test	GDP → EC	Conservation Hypothesis
Lee (2005)	1975-2001	Ghana	VEC model, granger causality	EC → GDP	Growth hypothesis
Twerefo et al (2008)	1975-2006	Ghana	VEC model, granger causality	GDP → EC	Conservation Hypothesis
Fatai et al(2004)	1960-1999	Philippines	Toda and Yamamoto	GDP ↔ EC	Feedback

					hypothesis
Stern (2000)	1948-1994	U.S.A	Cointegration, granger causality	EC $\rightarrow$ GDP	Growth hypothesis

Another important study was conducted by Adhikari and Chen (2012) to find the impact of energy consumption and economic growth for 80 developing countries using data from 1990-2009.These countries were categorized on the basis of income in three main categories. Dynamic ordinary least square (DOLS) and panel co-integration and panel unit root test were applied. The estimated results indicated the presence of a long run relationship between the variables and the causality direction is from energy consumption to GDP in case of upper and lower middle countries and opposite direction was confirmed for the low income countries. Another study was conducted by Adeniran (2009), okonkwo and Gbadebo (2009) conducted study on the causal relationship between energy consumption and GDP growth for Nigeria. The estimated results confirmed the causality direction moves from energy consumption to GDP growth. The growth hypothesis was also confirmed in a causal study conducted by Sarkar (2010) on Bangladesh. A feedback hypothesis was confirmed by Ebohon *et al.*(1996) and Kahsaia (2012) Wolde-Rufael (2005) conducted a study on energy consumption and GDP growth on a number of African countries and found that some of the African countries were not having any evidence of co-integration.

The huge literature is available on energy consumption and growth nexus, but no general consensus has been derived regarding the estimation results developed and developing countries. This may be because of different estimation samples and different econometric methods for various countries. Electricity has become one of the most important energy supply tool that has improved the life standards by making significant changes and contribution to technology as well as scientific progress. Thus from the literature both the electricity and energy consumption played a vital role in improving economic growth for many countries and many researchers has considered electricity consumption as an important economic indicator modern energy sources Ouedraogo (2013).

3. Methodology

3.1. Data description

The estimated sample in this study has been taken for a period 1990-2010. The period was chosen as a result of availability of the data. The data was collected from the World Bank (2015). The estimated variables in this article have been consistent with the literature energy growth nexus. The bivariate includes energy consumption and economic growth on one hand while electricity consumption and GDP on the other hand. The proxy utilized for economic growth is constant GDP 2005 U.S dollars. The proxy used for energy consumption is energy used measured in (Kt of oil equivalent) while the proxy used for electricity consumption KWH (Kilo watt hour). As the data has been taken for 22 years, which is based on availability of data from world development and is sufficient enough to apply toda-Yamamoto approach for causal analysis.

3.2. Unit Root

The Toda-Yamamoto approach can be applied regardless of the order of the integration whether the underline regressors are mutually $I(0)$,$I(1)$, $I(2)$ co-integrated or non-co-integrated of any arbitrary order. The unit root is applied to test the maximum order of integration $I(0)$, $I(1)$, $I(2)$. The augmented Dickey Fuller test (1981) and Phillips-Perron (PP) (1988) is utilized to determine the order of integration for the estimated variables.

3.3. The Toda-Yamamoto approach to Granger causality test

In order to determine the causality relationship among the estimated variables at level, a modified Wald test (MWALD) is utilized as suggested by Toda and Yamamoto (1995) that shows flexibility and choosing the variables different order of integration as normally followed. Conversely, in Granger causality test can only be conducted to that series which are having the same order of integration thereby by using cointegration and then tested for causality. The Toda and Yamamoto (1995) approach for causality is applied on the variables at levels but not rather than the first difference which is normally performed in Granger causality test (Mavrotas & Kelly, 2001). The approach can be utilized in such a way to add the correct lag order under the VAR system, by the d_{max} that represents the maximum order of integration. Once order of maximum integration has been determined then VAR is estimated with ($k+d_{max}$) th order, and the co-efficient of the last lag d_{max} vector are ignored (Rambaldi & Doran; Caporale & Pittis,1999). The Toda and Yamamoto (1995), can be applied to the following equations under the VAR system at levels as below.

$$LEC_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i} LEC_{t-1} + \sum_{j=K+1}^{d_{max}} \alpha_{2j} LEC_{t-j} + \sum_{i=1}^{k} \varphi_{1i} LGDP_{t-1} + \sum_{j=K+1}^{d_{max}} \varphi_{2j} LGDP_{t-j} + e_{1t} \quad (1)$$

$$LGDP_t = \beta_0 + \sum_{i=1}^{k} \beta_{1i} LGDP_{t-1} + \sum_{j=K+1}^{d_{max}} \beta_{2j} LGDP_{t-j} + \sum_{i=1}^{k} \phi_{1i} LEC_{t-1} + \sum_{j=K+1}^{d_{max}} \phi_{2j} LEC_{t-j} + e_{2t} \quad (2)$$

Similarly for electricity the modified version of Granger causality test can be

$$LEL_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i} LEL_{t-1} + \sum_{j=K+1}^{d_{max}} \alpha_{2j} LEL_{t-j} + \sum_{i=1}^{k} \varphi_{1i} LGDP_{t-1} + \sum_{j=K+1}^{d_{max}} \varphi_{2j} LGDP_{t-j} + e_{1t} \quad (3)$$

$$LGDP_t = \beta_0 + \sum_{i=1}^{k} \beta_{1i} LGDP_{t-1} + \sum_{j=K+1}^{d_{max}} \beta_{2j} LGDP_{t-j} + \sum_{i=1}^{k} \phi_{1i} LEL_{t-1} + \sum_{j=K+1}^{d_{max}} \phi_{2j} LEL_{t-j} + e_{2t} \quad (4)$$

4. Results and Discussions

4.1. Empirical Evidence

The first step in estimation is to determine the maximum order of integration. Table 1 gives the result of unit root test.

Table 2. Augmented Dickey Fuller Unit Root test results for Stationarity of variables

Country(Sample Period)	ADF		ADF		ADF	
Russia (1990-2011)	Level		First Difference		Second Difference	
	Intercept	Intercept and Trend	Intercept	Intercept and Trend	Intercept	Intercept & trend
LGDP	-2.9543*	-3.0591	-2.0579	-2.6048	-7.1300***	-5.5210***
LEL	-2.1495	-2.4217	-2.3228	-3.2681	-6.8667***	-6.3972***
LEC	-2.3392	-1.7255	-2.8960*	-4.7244***	-8.4967***	-8.1715***

Note: (i) The EVeiws 9 has been used for performing the unit root tests. (ii) The Augmented Dickey Fuller unit root test was performed both at level and first differenced (intercept, and both the trend and intercept) (iii) The automatic lag selection has set 04 maximum lags by using the Schwarz info criteria (SIC). (iv)*, **, *** represents significant at 10%, 5%, and 1%.

Table 3. Philips Perron (PP) Unit Root test results for Stationarity of variables

Country(Sample Period)	PP	PP	PP
Russia (1990-2011)	Level	First Difference	Second Difference

	Intercept	Intercept and Trend	Intercept	Intercept and Trend	Intercept	Intercept & trend
LGDP	-0.8763	-2.8509	-2.0579	-2.6581	-7.6626***	-18.9767***
LEL	-1.5342	-2.4217	-2.2109	-3.3595*	-9.9107***	-16.3257***
LEC	-2.2839	-1.7669	-2.9059*	-4.7124***	-21.5590***	-19.8409***

Note: (i) The EVeiws 9 has been used for performing the unit root tests with Newey-West using Bartlett Kernel.. (ii) The Phillips-Perron unit root test was performed both at level and first differenced (intercept, and both the trend and intercept) (iii)*, **, *** represents significant at 10%, 5%, and 1%.

As table shows that both the augmented Dickey Fuller test, Phillips-Perron (PP) (1988) concludes that the maximum order of integration for the series is I(2).

The second step in Toda Yamamoto approach is to determine the optimal lag in the estimated model. Several approaches have been used in literature to determine the optimal lag. For example, Lutkepohl (1993,p. 306) in his study suggested the maximum lag length to be (m_{lag}) according to the sample size represented by (T) and the endogenous variable in the system then lag can be estimated as $m = m_{lag} = T^{1/3}$ as we have number of observation 22 the lag length (k) was chosen 3 and SBIC, SIC,FPE and adjusted LR criterion was used to determine the order of VAR (Enders, 1995).

Table 4. Results of the Lag criteria for GDP and electricity consumption

lag	Log L	LR	FPE	AIC	SC	HQ
0	47.6848	NA	2.80e-05	-4.8089	-4.7095	-4.7921
1	89.9391	71.1650	5.01e-07	-8.8356	-8.5374	-8.7852
2	100.7776*	15.9725*	2.49e-07*	-9.5554*	-9.0584*	-9.4714*
3	103.3580	3.2594	3.03e-07	-9.4061	-8.7102	-9.2883

Note: * represents the optimal lag selected on the basis of lag criteria in case of GDP and electricity under the unrestricted VAR. The LM test was performed at lag 2 and found the absence of serial correlation at lag 2.

Table 5. Roots of Characteristics Polynomial.(GDP and Electricity consumption)

Roots of Characteristics polynomial	
Endogenous Variable : LGDP LEL	
Root	**Modules**
0.889088 – 0.159385i	0.903262
0.889088 + 0.159385i	0.903262
-0.060311 – 0.478213i	0.482002
-0.060311 + 0.478213i	0.482002

Source: Authors computation

Note: The results of AR Characteristics Polynomial were confirmed by the Roots of characteristics polynomial at optimum lag 2 in case of GDP and electricity consumption, implies that estimated VAR model is stable.

Table 6. Results of the Lag criteria for GDP and Energy consumption

lag	Log L	LR	FPE	AIC	SC	HQ
0	32.9106	NA	0.000132	-3.2537	-3.1543	-3.2369
1	75.3477	71.4730	2.33e-06	-7.2997	-7.0015	-7.2492
2	82.8866*	11.1098*	1.64e-06*	-7.6722*	-7.1752*	-7.5881*
3	85.3881	3.1598	2.01e-06	-7.5145	-6.8186	-7.3967

Note: * represents the optimal lag selected on the basis of lag criteria in case of GDP and energy consumption under the unrestricted VAR. The LM test was performed at lag 2 and found the absence of serial correlation at lag 2.

Table 7. Roots of Characteristics Polynomial.(GDP and Energy consumption)

Roots of Characteristics polynomial	
Endogenous Variable : LGDP LEC	
Root	**Modules**
0.881589 – 0.154836i	0.895083
0.881589 + 0.154836i	0.895083

0.036499 – 0.390685i	0.392386
0.036499 + 0.390685i	0.392386

Source: Authors computation

Note: The results of AR Characteristics Polynomial were confirmed by the Roots of characteristics polynomial at optimum lag 2 in case of GDP and energy consumption.

The lag 2 was determined on the basis of AIC, SIC, FPE and LR criteria. It can be observed that both the Schwartz criteria and Akaike criteria provides the same results in both the cases. Furthermore the auto correlation LM test was performed for both the cases and found the absence of auto correlation at optimal lag k=2. The residuals for both the variables were analysed for white noise by checking the box-Pierce Q- statistics and AR unit root characteristics and miss-specification tests. The residuals were found white noise at all lags and the results of the AR unit characteristic indicated the stability of the unrestricted VAR model in both the cases.

After the identification of the optimal lag length and integration properties has been establish for the series, the Toda Yamamoto approach can be applied. The results of the causality test have been shown in table 6.

Table 8. Long run non-causality test due to Toda-Yamamoto (1995) for dmax=2

From (Dependent Variable)	To (Independent Variable)	F- Statistics M. Wald Statistics	P-Value	Causality Direction
GDP	EC	1.1026[a]	0.3320	GDP ≠> EC
EC	GDP	0.1820[a]	0.8335	EC≠> GDP
GDP	EK	2.9882[a]	0.0504*	GDP => EK
EK	GDP	3.8115[a]	0.0221**	EK => GDP

Note:GDP, EC, and EK represents GDP, Energy consumption and Electricity consumption. ** and * denotes the significance at 5 and 10% level respectively. [a] represents the optimum lag selected on the basis of lag criteria that includes the length of the VAR ($k + d_{max}$).

As it can be observed from the table 6 that no causality has been found from energy consumption and GDP as the P value is greater, that has made the F-values of the modified Wald statistics small, but conversely there exist a bi-directional causality case of electricity consumption and GDP (both P values are smaller at α=10% in turns the significance of F-values of the modified Wald statistics for a period 1990-2010 that has been consistent with the results of Ebohon et al.(1996) and Kahsaia (2012) Wolde-Rufael (2005). It has been confirmed from the estimations, that a neutrality hypothesis is valid in case of energy consumption and GDP but feedback hypothesis has been proved for electricity consumption and GDP.

5. Conclusion

In this article Toda-Yamamoto Approach (1995) that is a revised form of Granger causality was used to analyse the causal relationship between energy consumption and GDP on one hand and electricity consumption and GDP on other hand for a period 1990-2010. It was found the bi-directional causality was observed from electricity consumption to GDP implying the validity of feedback hypothesis but no causality was observed for GDP and energy consumption supporting the neutrality hypothesis. The estimated results confirmed that both the electricity consumption and economic growth empirically support each other and have a mutual and complementary relationship. But on another hand the energy sector of Russia has no impact on the economic growth. Furthermore if the Government of Russia devises policies to promote the access of energy and higher level of consumption, economic growth will not be affected.

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