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Financial Development, Economic Growth and Renewable Energy Consumption in Russia: A Vector Error Correction Approach

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ABSTRACT

This article aims to explore the causal relationship between financial development, economic growth and renewable energy consumption on the example of Russia. Using data from 1990 to 2014, we build the vector error correction model to determine the nature of short-term and long-term relationships between the variables. To determine causality and its direction, we use the Granger causality test VEC in domain. The results of the VEC model show that the system of variables corrects its previous period disequilibrium at a speed 22,98% in one year. Based on the results of the Wald test, we find no statistically significant causality running from renewable energy consumption to either economic growth or financial development. The results of Granger causality test show that there is bi-directional causality between economic growth and financial development in Russia, while renewable energy consumption does not Granger cause economic growth or financial development. Although economic growth does Granger cause changes in renewable energy consumption.

Keywords: Renewable Energy, Economic Growth, Financial Development, Vector Error Correction Model
JEL Classifications: D53, O40, Q42, Q43

1. INTRODUCTION

Energy is one of the main sources of economic growth of the national economy. Energy consumption is an integral part of the production process of most modern consumer goods. However, the current industrial structure of most countries is based on the use of non-renewable energy sources. In condition of a growing demand for energy and their limitations, the question of their effective utilization, on the one hand, and the shift to wider use of renewable energy sources on the other side, takes its place. For example, according to the EIA, the modern supply is unstable from an economic point of view, not to mention the social side and the environmental one. According to forecasts (Apergis and Danuletiu, 2014), primary energy demand will continue to grow until 2030 at a rate of 1.5% per year. While fossil fuels will be the main source of energy, the active use of fossil fuels with the increasing growth of consumption will lead to an increase in CO2 emissions in several times that will only exacerbate problems of environmental and energy security. This, in turn, will lead to a revision of the strategy of energy development and could lead to a paradigm shift from the use of non-renewable energy to renewable energy for not polluting the environment. Renewable energy sources are those sources that generate energy, such as wind, geothermal, solar activity, biomass, etc. Unlike the modern energy sources, generating environmental pollution, clean energy sources are secure and inexhaustible. In this lies the reason for the steadily growing demand for them. For example, the growing demand for clean sources of energy in the world is sustained around 8% per year. Especially, this trend is observed in developed and rapidly developing countries, such as USA, EU and China (IEA, 2009).

As noted above, energy resources are one of the main factors of economic growth. To date, economic growth in most countries of the world is unstable because of dependence on fossil sources of energy (oil, gas, coal). The instability is called to life by the fact that in the case of the imported energy sources, significant dependence appears on changes of prices on world markets, a negative shock in which may lead to a significant deterioration in the export position and the position on domestic markets and households' welfare. Thus, increased active use of renewable energy contributes not only to ensuring environmental, but to energy security and independence from the world market. This proves the importance of learning about clean energy sources as one of the key areas to strengthen and ensure stable economic growth of the national economy.

A logical continuation of the previous theses, then, is the assumption about the existence of the relationship between energy consumption, financial development and economic growth of the national economy. This issue attracts quite a lot of attention from researchers. The rationale behind this connection stems from the fact that energy consumption is one of the key determinants of economic performance in terms of impact on the volume and cost of production. The growth of the national economies of developing countries, accompanied by population growth leads to increased energy consumption. An example is the rapidly growing countries of Asia (India, China). Thus, the increase in economic growth leads to financial development and ceteris paribus can lead to reduction in energy consumption on the one hand and the shift to safer renewable sources of energy, on the other. The Reason for this is global competition and the sensitivity of world markets to price shocks in the medium term. The decrease in capital intensity of production, the production of environmentally friendly products leads to an increase in demand for national products.

Considering the need to ensure stable and accelerated development of the national economy of Russia, the desire to "get off the oil needle" and increase the share of national product of Russia on the world market, the active development of alternative, clean energy sources, their use in the national economy should be a priority to ensure not only energy security, but also a key element of a growth strategy. For these purposes, the existing economic growth, contributing to the development of the financial sector should lead to the active use of financial resources for the implementation of clean, renewable energy sources, or through the lending and investment in this sector, either through government programs support or venture funding. Therefore, being aware of the importance of energy security, we set ourselves a task to analyze the relationship between the use of clean energy sources, economic growth and financial development for the presence of causal relationships, and testing the hypothesis of active support by the financial sector of "green" energy projects.

This study aims to determine the presence of a causal relationship between the share of renewable energy in the production of the national economy, economic growth and financial development in the long term, as well as to determine the presence and the vector of the causal relationships between the above variables in the short term. The study is conducted on the example of Russia. The paper is organized as follows. Section 2 presents an overview of the major and most influential studies on the relationship between renewable energy, economic growth and financial development, as well as the formulation of the hypothesis and its novelty. Section 3 presents an overview and description of used research methods. Section 4 presents the description and explanation of the obtained results of the study. Section 5 presents the final provisions and suggestions for application of findings.

2. LITERATURE REVIEW

The literature on the issue of the relationship between energy consumption, economic growth and financial development is a diverse array of research, both of national and international scale. In the famous article on "economic growth-energy" nexus,, Ozturk (2010) describes the current state of the directions of studies on the relationship between renewable energy consumption and economic growth, in terms of causal relationships as a set of different hypotheses. According to the "growth hypothesis" there is a direct causal relationship running from renewable energy to economic growth. Then, conservative policy on the use of renewable resources can lead to negative effect on economic growth. According to the "conservation hypothesis", the causal relationship is reversed: Allows for the existence of unidirectional causality running from economic growth to renewable energy consumption. In this case, the policy of prohibition of renewable energy consumption has no significant effect on economic growth. According to the "feedback effect" hypothesis there exists a bi-directional causality between energy consumption and economic growth. This allows for the possibility of the influence of each variable on the other through various channels. According to the "neutrality hypothesis" causality between economic growth and renewable energy consumption does not exist, which makes the protection policy of renewable energy is insignificant (Ozturk, 2010).

Conventionally, all the existing studies can be divided between the above stated hypotheses. Depending on the empirical sample, different studies present different results. For example, some researchers using cross-country and within-country (regional) samples, find bi-directional causality between economic growth and renewable energy consumption, which confirms the hypothesis of a "feedback effect" (Apergis and Payne, 2010; Fang, 2011; Rafindadi and Ozturk, 2017; Tugcu, 2013). Other studies show that there is a unidirectional causality from energy consumption to economic growth, allowing the authors to conclude that the impact of energy consumption on economic growth exist, supporting the growth hypothesis (Fotourehchi, 2017, Bhattacharya et al., 2016; Esso, 2010; Fang, 2011; Leitão, 2014; Payne, 2010). The study by Ocal and Aslan (2013) on the example of Turkey gives the arguments in favor of the conservation hypothesis, describing the dependence of renewable energy from economic growth. Also worthy of noting is the number of studies in which were received ambivalent, mixed results in determining the direction of causality between the different proxies to measure economic growth and energy consumption. These include the papers by Bowden and Payne (2010), Jebli et al. (2016), Pao and Fu (2013b), Tugcu et al. (2012) Yildirim et al. (2012). Among the works that speak in favor of the hypothesis of absence of causality between the studied variables one should highlight the papers by Menegaki (2011) and Payne (2010), giver different proxies used to measure renewable energy consumption.

Speaking on the relationship between renewable energy consumption and consumption in general and financial development, we conditionally can distinguish several directions of research results. Some studies confirm the existence of causality running from energy consumption to financial market development. For example, Al-Mulali and Sab (2012) investigated the effect of energy consumption on economic growth and financial markets development on the example of the 19 countries for the period 1980 to 2008. The results showed that energy consumption is statistically significant and affects the development of the financial sector and economic performance. Islam et al. (2013), based on the use of VEC models, tested the relationship between the growth of financial market, economic growth, population and energy consumption on the example of Malaysia. As a result of the study, the authors came to the conclusion about the existence of a causal relationship in the long run. Energy consumption affects financial development and economic growth also in the short term. Shahbaz et al. (2013a) studied the relationship between energy consumption and economic growth, including such variables as financial development and trade on the example of China during 1971-2011 using ARDL model. The results of the study showed that the consumption, financial market development and trade are positively related to economic growth. The study on the example of Indonesia by Shahbaz et al. (2013b) concluded that the growth of national GDP and consumption leads to higher CO2 emissions, while financial development and liberalization suppress them. In other words, they found evidence that financial development facilitates the spread of renewable clean energy. Çoban and Topcu (2013) investigated the issue of causality on the example of the Eurozone countries for the period 1990-2011. The results of the study showed that financial development has significant impact on energy consumption among the old EU members. Chang (2015) on the sample of 53 countries for the period 1999-2008 investigated the nonlinear impact of financial markets on consumption and income. Income growth leads to increased energy consumption in the case of developing countries. In developed countries, the increase is of short-term nature. In low-income countries, the energy consumption grows with the development of financial markets (in the case of bank loans). If as a proxy are used data on indices of the securities market, enrgy consumption decreases with the development of financial markets in developed countries, but growing in developed countries. Ozturk and Acaravci (2013) investigated long-term relation between energy, economic growth, openness and financial sector development on the example of Turkey for the 1960-2007. The results showed the presence of a long-term relationship between the variables. The development of the financial sector has no statistically significant influence on the emission of carbon in the long term. Ali et al. (2015) investigated the relationship between financial development and energy consumption on the example of Nigeria, using ARDL approach. The results showed that the variables sampled are in cointegration, and therefore have a long-term relationship. In the short term, financial development and economic growth have a negative impact on energy consumption. In the long run, financial development has a little negative impact on energy consumption.

Yazdi and Shakouri (2017) investigate the relationship between economic growth, renewable energy consumption, energy consumption, financial development, and trade openness over the period 1979-2014 in case of Iran, using ARDL approach and Granger causality test. Results of the study show that renewable energy consumption has a negative impact on economic growth in the short run and the long run. Also the authors find unidirectional causality from renewable energy consumption to economic growth. Zeren and Koc (2014) study the relationship between energy consumption and financial development on example of 7 developing countries for period 1971-2010. Results show that financial development and energy consumption may affect each other in positive and negative way.

Tugcu et al. (2012) investigate the long-run and causal relationships between renewable and non-renewable energy consumption and economic growth using ARDL approach for G7 countries for 1980-2009. Results show bidirectional causality for all countries in case of classical production function, mixed results are found for each country when the production function is augmented.

Given the above, we can note the absence of detail studies on the relationship between renewable energy consumption, financial development and economic growth on the example of Russia, which determines the novelty of the research. Among the studies on the relationship between the energy sector and the financial sector in Russia can be mentioned the study by Burakov (2015), where relationship between energy efficiency of the Russian economy and bank lending of green projects is studied.

3. MATERIALS AND METHODS

3.1. Research Methods

To test the hypothesis about relationship between renewable energy consumption, economic growth and financial development, 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. Also based on VEC model it is possible to identify short-term relationships between sampled variables. For this purpose, we use the Wald test. To determine causal linkages between variables we use Granger Causality Test. The final stage of constructing a model is to conduct diagnostic tests to determine validity of the model. These include testing for heteroscedasticity, serial correlation, normality and stability of the model.

3.1.1. Unit root test

For the analysis of long-term relationships between the variables, Johansen and Juselius (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 equilibrium. 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:

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

Where ε_t is an error term, β_1 is a drift term and β_2 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:

H0: a = 0 (Y_t is non-stationary or there is a unit root).

H1: a < 0 (Y_t 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:

$$y_t = A_1 y_{t-1} + \ldots + A_p y_{t-p} + Bx_t + \varepsilon_t \quad (2)$$

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:

$$\Delta y_t = \prod y_{t-1} + \sum_{i=1}^{p-1} V_i \Delta y_{t-1} + Bx_t + \varepsilon_t \quad (3)$$

Where,

$$\prod = \sum_{i=1}^{p} A_i - I, \qquad \Delta_i = -\sum_{j=i+1}^{p} A_j \quad (4)$$

If the coefficient matrix Π has reduced rank $r < k$, then there exist $k \times r$ matrices α and β each with rank r such that $\Pi = \alpha\beta'$ 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 Π matrix from an unrestricted VAR and to test whether we can reject the restrictions implied by the reduced rank of Π (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:

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

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

$$\Delta ln\, y = \eta_0 + \sum_{i=1}^{k} \eta_1 \Delta lny_{t-i} + \sum_{i=1}^{n} \eta_2 \Delta lnl_{t-i} + \sum_{i=1}^{m} \eta_3 \Delta lns_{t-i} + \chi ECT_{t-1} + v_3$$

Where, l – Renewable energy consumption, s – Economic growth, y – Einancial development (Granger, 1988).

Providing regression analysis of the sampled variables by modeling VECM allows us 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.

3.1.4. Granger causality test

The last stage to determine the relationship and its direction is the use of Granger causality test. So, rejection of the null hypothesis of Granger test (H0), according to which:

$$b_1 = b_2 = \ldots.. = b_p = 0 \quad (5)$$

In favor of the alternative hypothesis (H1) suggests that changes in renewable energy consumption Granger cause changes in Russian economic growth and financial development (Granger, 1969).

3.2. Materials and Data Processing

We test the hypothesis on example of Russian data for the period 1990 to 2014. The base period is one year. Unfortunately, use of monthly and quarterly values of variables for the analysis is hindered due to availability of only yearly data for renewable energy consumption in Russia. Using VECM, we set ourselves a task to determine sensitivity of economic growth and financial development to shocks in renewable energy consumption as a share of total final energy consumption.

Data on financial development is obtained from the statistical database of the Central Bank of Russia (www.cbr.ru). Financial development is measured as a share of bank loans (broad money) to national GDP in constant 2000 US dollars. Data on economic growth is obtained from the statistical database of Federal Service of State Statistics (www.gks.ru). Data on renewable energy consumption is derived from World Bank database (www.data.worldbank.org).

To conduct time-series analysis, all variables were 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 as well as stability and normality. Based on the model, we study causal linkages between variables in the short run by applying 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.

Building a VAR model involves determining the optimal number of lags. In our case, the Akaike information criterion equals 1.

Table 1: Results of individual unit root test

Variables	ADF		PP	
	Statistic	P**	Statistic	P**
Levels				
Intercept	5.39865	0.4521	6.70331	0.5138
Intercept and trend	1.74693	0.8160	1.33419	0.8021
First-difference				
Intercept	32.7125	0.0000**	39.2509	0.0000**
Intercept and trend	22.6734	0.0012**	34.1103	0.0000**

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

Consequently, we built a model based on the use of time lag of 1 year to determine the relationship in the short run. The results of the diagnostic testing of VAR model for heteroscedasticity of residuals, autocorrelation, serial cross-correlation, and stability are presented in Table 2. As can be seen from Table 2, the model is stable, heteroscedasticity and serial correlation of residuals in the model are absent.

The model is used to determine the level of sensitivity of control variables to shocks in renewable energy consumption in the short run and we use it to test for stable long-run relationship, applying Johansen cointegration test. Results of Johansen co-integration test are presented in Table 3.

Johansen test results show the presence of cointegration between a number of equations, which allows presuming the existence of a long-term relationship between them. Starting from the results of the cointegration test, we can proceed to the construction of VECM model to reveal presence or absence of long-term and short-term relations between variables.

The results of the model, showing the relationship between the variables are presented in Table 4. As can be seen from the Table, the value of error correction term 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 can assume that renewable energy consumption, economic growth and financial development 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 less than 5%) and negative meaning, the system of variables corrects its previous period disequilibrium at a speed of 22,98% in one year (given optimal lag meaning of one year for ECM). It implies that the model identifies the sizeable speed of adjustment by 22,98% of disequilibrium correction in 1 year for reaching long run equilibrium steady state position.

High speed of adjustment of relations between variables towards equilibrium is understandable. The reason for the existence of the relationship between the variables of the sample, and, namely, renewable energy consumption, economic growth and financial development is the internal processes of the relationship. In particular, economic growth leads to increased demand for credit resources, which leads to increased financial development of the national economy. In this case, we can assume that a causal relationship is bi-directional. On the other hand, economic growth leads to increased energy consumption overall, however, this in no way suggests that economic growth leads to increased use of renewable energy sources. A possible reason for long-term relationship between economic growth in the case of Russia and renewable energy may be tougher competition on world markets and the need to reduce the cost of production of finished goods. In case of financial development, the question of a causal relationship with renewable energy can be of different nature.

Table 2: Results of unrestricted VAR model diagnostic testing

Type of test	Results		
	Lags	LM-statistics	P-value
VAR residual serial correlation LM test	1	11.09531	0.0832**
	2	32.25085	0.0031
	3	47.19086	0.0002
Stability condition test	All roots lie within the circle VAR satisfies stability condition		
Heteroscedasticity (White test)	0.1905*		
VAR residual cross correlation test	No autocorrelation in the residuals		

**Denotes acceptance of null hypothesis (Ho: there is no serial correlation). *Denotes acceptance of null hypothesis of homoscedasticity

Table 3: Results of Johansen co-integration test

Hypothesized No. of CE (s)	Eigenvalue	Trace statistics	0.05 critical value	P*
None *	0.786213	41.09763	31.70702	0.0146*
At most 1	0.279981	12.10985	17.80567	0.1933
At most 2	0.096307	1.607931	4.220348	0.0979

Trace statistics indicate 1 cointegrating equation at the 0.05 level. *denotes statistical significance at the 5% level of significance

Table 4: Results of vector error correction model

Coefficient number	Coefficient meaning	Standard error	t-statistic	P
C(1)	–0.229864*	0.071376	–2.630810	0.0476*
C(2)	0.024309	0.176172	0.210988	0.6234
C(3)	0.132439	0.209985	0.197604	0.5671
C(4)	0.158962	0.189317	0.180934	0.5295
C(5)	0.080645	0.136129	0.103931	0.5032

*Denotes statistical significance

Table 5: Wald test results for short run relationship

Test statistic	Value	df	Probability	Test statistic	Value	df	Probability
t-statistic	0.0246	23	0.6198	t-statistic	0.485723	23	0.3419
F-statistic	1.0241	(1, 23)	0.6198	F-statistic	0.9825	(1, 23)	0.3419
Chi-square	1.0241	1	0.2546	Chi-square	0.9825	1	0.5136
Null hypothesis: C (3)=0 (economic growth)				Null hypothesis: C (4)=0 (financial development)			

*Denotes statistical significance and rejection of Ho: no short-run relationship

On the one hand, financial sector development can promote the implementation of green technologies in the energy sector. On the other hand, the development of alternative sources of energy can contribute to economic growth and, thereby, contribute to financial development.

To identify short-term relationship between the variables we refer to the Wald test results. This test allows to determine the interrelationship between variables in the short term. In other words, under the null hypothesis of this test, the response of error correction term to explanatory variables equals zero, i.e. the sensitivity of resulting variable to changes (shocks) in explaining are not observed. Results of Wald Test for the model are presented in Table 5.

As can be seen from the results of the Wald test in the short term there is no statistically significant relationship between changes in renewable energy consumption and economic growth in Russia. Based on the results of the Wald test, we detect no statistically significant causality. A possible reason for absence of causality in the short term is a significant dependence of the Russian economy from fossil energy sources, the dependency of Russian economy on oil and gas resources, their relative prevalence in historically formed technological structure of the economy. It is important to note that the share of renewable energy in total final energy consumption in Russia is not more than 4%, which allows to speak of insignificance of renewable energy sources as a factor of influence on economic growth. Feedback from economic growth is also unlikely due to presence of the falling trend of renewable energy consumption in Russia over the investigated 25 years.

The second result also shows absence of causality running from financial development to renewable energy consumption. The absence of causality between financial development and renewable energy allows us to speak about the absence of significant incentives in the financial market of Russia to massive investment in green energy. This fact probably can be explained by the fact that Russia is an exporter of energy and most of the exports are energy resources. In this context, the lower costs of production through the transition to environmentally friendly sources of energy do not seem to be a pressing need.

The last stage of analysis are the test results for causality in the Granger causality in the VEC environment. The results of Granger causality test are presented in Table 6.

The Granger test results confirmed our assumptions. Renewable energy sources do not have a statistically significant impact neither on economic growth nor on financial development. The same is true for feedback. Economic growth does not Granger cause of economic growth and financial development. The only identified bi-directional causality between economic growth and financial development. As we can note, the only uni-directional causality runs from economic growth to renewable energy consumption.

Table 6: Results of Granger causality test

Excluded	Chi-square	df	P
Dependent variable: Renewable energy consumption			
Economic growth	3.193318	1	0.0218*
Financial development	0.249123	1	0.6177
All	0.210331	2	0.4438
Dependent variable: Economic growth			
Renewable energy consumption	0.006066	1	0.8160
Financial development	8.967673	1	0.0253*
All	0.699304	2	0.1336
Dependent variable: Financial development			
Renewable energy consumption	0.011233	1	0.9156
Economic growth	9.768316	1	0.0107
All	4.851795	2	0.1370

*Denotes statistical significance and rejection of Ho: No Granger causality

The final stage of the analysis of the model is to determine the extent of its validity. For this, it is necessary to conduct some diagnostic tests, including tests for heteroscedasticity of the residuals, serial correlation, stability and normality of the model. The results of these tests are presented in Table 6.

As can be seen from Table 7, the model is characterized by the fulfillment of all requirements - homoscedasticity and absence of serial, auto and partial correlation. In Figures 1-3 we present test results for normality and stability (CUSUM and CUSUM square test).

As can be seen from the data of Figures 1-3, the model meets the requirement of normality.

5. CONCLUSION

This article aims to explore the causal relationship between financial development, economic growth and renewable energy consumption on the example of Russia. Using data from 1990 to 2014, we build the vector error correcting model to determine the nature of short-term and long-term relationships between the variables. To determine causality and its direction, we use the Granger causality test VEC in domain. We test the hypothesis on example of Russian data for the period 1990 to 2014. The base

Table 7: Results of diagnostic testing

Test type	Value	Probability characteristic		P-value
Heteroscedasticity test: Breusch-Pagan-Godfrey				
F-statistic	8.697	Prob. F (6,17)		0.4421
Obs*R^2	6.421	Prob. Chi-square (6)		0.3217
Scaled explained SS	4.378	Prob. Chi-square (6)		0.8798
Heteroskedasticity test: ARCH				
F-statistic	2.483	Prob. F (1,21)		0.9109
Obs*R^2	0.013	Prob. Chi-square (1)		0.8875
Breusch-Godfrey serial correlation LM test				
F-statistic	2.198	Prob. F (1,18)		0.7812
Obs*R^2	0.167	Prob. Chi-square (1)		0.8067
Autocorrelation/partial correlation				
Lag	**AC**	**PAC**	**Q-statistics**	**P**
1	–0.012	–0.012	0.0045	0.917
2	0.157	0.157	0.2538	0.784

Figure 1: Results of normality test

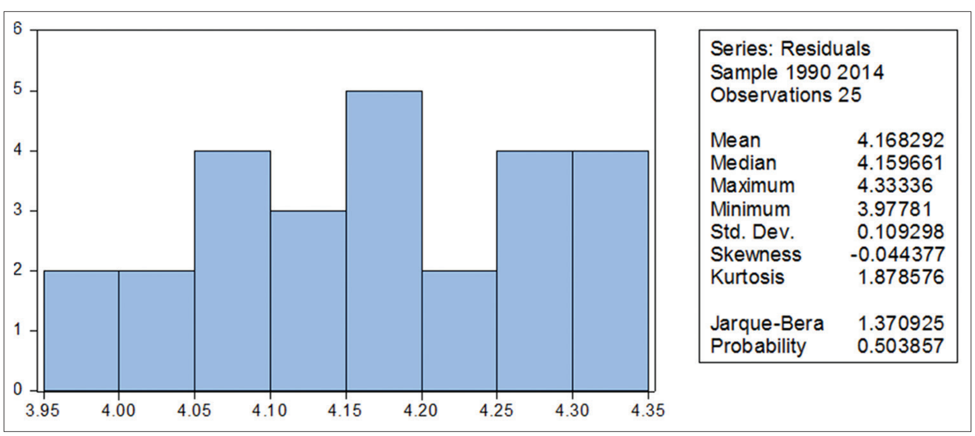


Figure 2: Results of CUSUM test

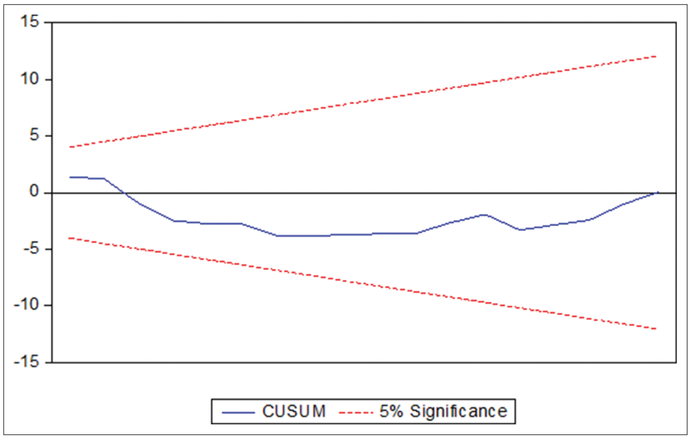
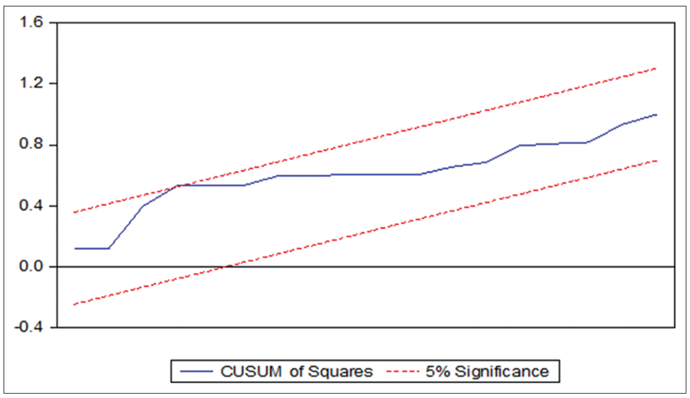


Figure 3: Results of CUSUM square test



period is one year. To conduct time-series analysis, all variables were 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 as well as stability and normality. Based on the model, we study causal linkages between variables in the short run by applying Granger causality test in VEC domain.

The results of the VEC model show that the system of variables corrects its previous period disequilibrium at a speed 22,98% in one year. Based on the results of the Wald test, we find no statistically significant causality running from renewable energy consumption to either economic growth or financial development. The results of Granger causality test show that there is bi-directional causality between economic growth and financial development in Russia, while renewable power does not Granger cause the economic growth or financial development. Although economic growth does Granger causes changes in renewable energy consumption.

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