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ASSESSMENT OF RELATIONS BETWEEN RENEWABLE ENERGY AND ECONOMIC GROWTH IN BULGARIA - VAR ANALYSIS

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Abstract: The role of existing interconnections between renewable energy on the one hand and economic growth on the other is an emphasis on many studies, but within the scope of Bulgaria, the specificity of these relations requires an in-depth review of the growing importance of renewable energies. The main factors to be surveyed are: consumption of renewable energy, production of renewable energy and per capita GDP. The interaction of these variables is analyzed to show the direction and importance of the relationship. The analyzes include the vector autoregression model and a number of cointegration and causality tests. The period covers the years after the collapse of the socialist system and the integration of modern energy use, as well as the specific crisis moments that changed and reduced the prospects for sustainable growth, part of which are also the alternatives for the extraction of natural energy resources.

Keywords: Renewable energy, Economic growth, Johansen Cointegration, Granger causality, Macroeconomic influence

ОЦЕНКА НА ОТНОШЕНИЯТА МЕЖДУ ВЪЗОбНОВЯЕМАТА ЕНЕРГИЯ И ИКОНОМИЧЕСКИЯ РАСТЕЖ В БЪЛГАРИЯ – VAR АНАЛИЗ

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Резюме: Ролята на съществуващите взаимни връзки между енергията от възобновяеми източници, от една страна, и икономическия растеж, от друга, са акцент на много проучвания, но в обхвата на България спецификата на тези отношения изисква задълбочен обзор на нарастващото значение на възобновяемите енергийни източници. Основните фактори, подлежащи на изследване, са: потреблението на възобновяема енергия, производството на възобновяема енергия и БВП на глава от населението. Взаимодействието на тези променливи е анализирано, за да покаже посоката и важността на връзката. Анализите включват модела на векторната авторегресия и редица тестове за коинтеграция и причинност. Периодът обхваща годините след разпада на социалистическата система и интегрирането на модерното използване на енергия, както и специфичните кризисни моменти, изменили и редуцирали перспективите за устойчив растеж, част от който са и алтернативите за добив на енергийни ресурси с природен характер.

Ключови думи: възобновяема енергия, икономически растеж, Johansen коинтеграция, Granger causality, макроикономическо влияние.

INTRODUCTION

At the forefront of the most important needs of countries with a high level of development, consumption continues to increase, and this increase continues into the future. Today the nations have to consume energy directly and indirectly in order to continue the technological developments and gather all offered possibilities. The vast majority of the energy that is consumed today is from fossil fuels and the rest is from nuclear and renewable energy sources. It will be inevitable that the cause of fossil fuel use to the environment and human health all over the world will be very large if measures are not taken into account. The fact that the use of fossil resources can not continue in energy production is a fact to be accepted. In this case, the trend of implementing renewable energy resources (which are their natural products) is increasing instead of the traditional and the positive effects are getting better and better every day.

Existing oil, natural gas, coal, also known as fossil resources, are expected to decline rapidly due to future population growth and increased use of devices in everyday life. For this reason, the use of renewable energy resources, both local and renewable natural resources, is of great importance for meeting the energy needs of both Bulgaria and the rest of the world. The emergence of insecurity about access to fossil fuels following the Oil Crisis, the energy agenda has been engaged in the issue of energy diversity and it has been desired to avoid dependence on energetic fossil resources. For this reason, it has begun to turn to energy sources that can renew itself more quickly in nature.

In this paper, the effects of renewable energy consumption and output on the economic growth in Bulgaria is investigated. According to literature research, there are not many studies on this subject in the literature. The *main hypothesis* of this study is that "the increase in

renewable energy production and consumption in Bulgaria could cause a sustainable growth in the economy of the country." The strategic agreement to be made in this direction and the unity of the foundations predicted that economic growth could occur in reductions of energy prices.

The distinguishing *characteristics* and *contribution* of this work from other studies related to the subject can be summarized as follows:

➤ We have seen that there is not such empirical works for the case of Bulgaria to study the relationship between renewable energy and economic growth, and we aimed at this important point in our work;

➤ Along with reducing the negative impacts and dependence on fossil fuels, we predicted how the influence upon the country economy would be equal to the transition in renewable energy use;

➤ We have foreseen the direction of Bulgaria's renewable energy development;

➤ Reducing oil and natural gas dependency has to define the extent to which the renewable energy strategies of the country should be in order of affection to a minimum extent from possible crises. We sought to determine that the investments needed to be realized together with the forecast that the renewable energies will have an important place in the realization of the economic growth of the country.

LITERATURE REVIEW

In the recent years, there have been important studies on the relationship between renewable energy and economic growth. For example, Stern (2000) studied the period 1948-1994 using the Cointegration analysis for the United States. The result is a cointegration between energy use and economic growth. Aqeel and Butt (2001) reviewed the period 1955-1996 with the version of Granger causality Hsiao for Pakistan. The result of the study is that economic growth has caused energy consumption. Oh and Lee (2004) studied the period 1970-1999 using the granger causality test for Korea, resulting in a bilateral causality relationship between energy and economic growth. At the same time, in the short run, energy has reached a unilateral causality relation to economic growth. Hondroyannis, Lolos and Papapetrou (2002) examined the period 1960-1996 using the Error Correction Model for Greece. According to empirical results, a long-run relationship between three variables supporting the intrinsic value of real output and energy consumption has been expressed. According to findings, adaptation of appropriate structural policies aimed at improving economic efficiency has important policy implications because it will increase energy protection without obstructing economic growth.

Narayan and Smyth (2008) reviewed the period 1972-2002 using the Unit Root test, Cointegration Analysis, Granger Causality Analysis and Long Term Structural Estimation Method for G7 countries. There is a cointegration between capital accumulation, energy consumption and real gross domestic product; Long-term capital accumulation and the real gross domestic product of consumption of energy is Granger's reason. Odhiambo (2009) reviewed the period 1971-2006 using the Stability test for South Africa, Cointegration Analysis and Granger causality tests. There is a clear bi-directional causality between energy consumption and economic growth in South Africa, as well as the fact that employment is Granger's cause of economic growth.

Apergis et al. (2010) examined this relationship using the panel cointegration, panel causality, panel error correction model for the 19 developed and developing countries, taking the 1984-2007 period. The result is that there is a bi-directional causality relationship between economic growth and renewable energy consumption. Menyah and Wolde - Rufael (2010) used the Granger Causality Test for the United States between 1960 and 2007 to examine this relationship using methods of variance decomposition causality. As a result of the study, he

stated that there is a one-way causality relation at the level of 5% significance towards the renewable energy consumption without economic growth. Pao and Fu (2013) reviewed the 1980-2013 period using the Johansen Cointegration Test for Brazil, Granger Causality tests. The result of the study is that there is a one-way causality relation to economic growth in non-hydropower renewable energy consumption, which is a two-way causality relationship between economic growth and total renewable energy consumption. Seabri and Ben-Salha (2014) reviewed the 1971-2010 period for BRICS countries using the ARDL test and the granger causality test. He pointed out that there is a bi-directional causality relationship between economic growth and renewable energy consumption. Bloch et al. (2015) examined the period 1977-2013 using the Structural Fracture Test for China, ARDL Cointegration, VECM Granger Nedensech tests. In the long run, there is a two-way causality between renewable energy consumption and economic growth. Ibrahim (2015) examined the 1980-2011 period using the ARDL boundary test for Egypt using the Granger causality test. Renewable electricity consumption has a positive effect on economic growth in the long run, and it is the result of two-way causality relationship between two variables. Bhattacharya et al. (2016) reviewed the 1991-2012 period using Panel Cointegration, Panel Predictive, Hausman tests for 38 countries in the Renewable Energy Country Attractiveness Index (RECAI). In 57% of the selected countries, the long-term increase in renewable energy consumption resulted in a significant and positive impact on economic output. Inglesi Lotz (2016) reviewed the cointegration panel-based estimate for 34 countries with 1990-2010 OECD membership using Hausman's Tests. It is concluded that renewable energy consumption has a positive and significant effect on economic growth.

METHODOLOGY AND DATA

This study analyze the interdependent relations between renewable energy and economic growth of Bulgaria. The observation encompasses twenty year (1995-2015) period and the data is on annual base. This period is characterized by the democratization of the Balkans and several crisis cycles in Bulgaria.

The data soruce is Worldbank database and the chosen variables are:

- ✓ Renewable energy consumption (% of total final energy consumption) - (REC);
- ✓ Renewable electricity output (% of total electricity output) - (REO);
- ✓ GDP per capita (current US\$) - (GDP)

The software, used for empirics, are MS Excel 2016 and Eviews 8 Corporate Edition. All data series should be checked whether they are stationary. The factors are transformed into natural logs to avoid spurious regressions. An unit root test is taken to define the order of stationarity (levels or I(1), I (2)). There are different tests for observation the steadiness of time series and have the following hypotheses:

- null hypothesis –there is a unit root;
- alternative hypothesis - stationarity (contant steadiness, trend steadiness,both constand and trend assumptions).

Here it is preffered ADF Unit root test, cause some factors have high order dynamics.. It is modified by Dickey and Said (Dickey & Said, Testing for Unit Roots in Autoregressive-Moving Average Models of Unknown Order, 1984), and it originates from DF test (Dickey & Fuller, Distribution of the Estimators for Autoregressive Time Series with a Unit Root, 1979). For the dependable factors it is the following explanation:

$$(\nabla)GDP_t = \mu + \beta t + \rho GDP_{t-1} + i \sum_{i=1}^k \beta_i \nabla GDP_{t-i} + \epsilon_t$$

$$(\nabla)REC_t = \mu + \beta t + \rho REC_{t-1} + i \sum_{i=1}^k \beta_i \nabla REC_{t-i} + \epsilon_t$$

$$(\nabla)REO_t = \mu + \beta t + \rho REO_{t-1} + i \sum_{i=1}^k \beta_i \nabla REO_{t-i} + \epsilon_t$$

The ADF test handles with τ – statistics, defined by critical values (here they are considered by Eviews). The more negative are the coefficients, the steadiness grows. The τ – statistics is defined as:

$$\tau_{DF(ADF)} = \frac{\hat{\gamma}}{SE(\hat{\gamma})}; (\gamma = \rho - 1)$$

If all the series are stationary on first difference, a cointegration test should be included. Although its performance depends on the selection of lag length with the support of several criteria (Ozciçek, 1999). The problems of appropriate criteria is discussed by several econometricists (Braun & Mitnik, 1993); (Lutkepohl, 1993), that pointed if the analysis is done by choice of higher order lag choice, it can result in errors in wrong relations, autocorrelations and stochastic deviations. This criteria use the following criteria: Final Prediction Error (FPE), Akaike's information criterion (AIC), Schwarz's information criterion and the Hannan and Quinn information criterion (HQIC).

After defining the optimal lag length, the Johansen test is applicable. Granger cointegration is not used, because there are three time series. The implementation of Johansen method is derived from a VAR system and it is developed by Johansen (Johansen, 1991). The time series relations depends on the matrix Π in the equation. Eviews has five types of Johansen test (inclusions of trends and intercepts). In this report Johansen cointegration is done by the application of linear trend in the variables and intercept in equations. The test uses two types of statistics: trace and maximum eigenvalue, and sometimes their results are not equivalent. The zero hypothesis is common and the alternative is individual for every statistic method:

$$Trace: H_0(r): rk(\Pi) = r_0; H_1(r): rk(\Pi) > r_0$$

$$MaxEigen: H_0(r): rk(\Pi) = r_0; H_1(r): rk(\Pi) > r_0 + 1$$

After the cointegration is clear, VECM model is runned. The ordinary VAR model looks like:

$$Y_t = A_1 y_{t-1} + \dots + A_p y_{t-p} + B x_t + \epsilon_t$$

Where Y_t is k vector of the variables at I(1); x_t – d vector of the variables; A_p – k × k vector matrix; B - k×d matrix of estimated coefficients of the variables; ϵ_t – vector of deviations

The dependent variables can be cointegrated in I(1) and have inner individual behavior of different order. The interdependent relations can exist both in long and short terms and to differ in time. The specifics of cointegration relationship determines the use of VECM. In the equation Π and Γ are vectors of the factors.

$$Y_t = \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i y_{t-i} + B x_t + \epsilon_t$$

$$\Pi = \sum_{i=1}^p A_i \quad I; \quad \Gamma_i = \sum_{j=i+1}^p A_j$$

VECM model defines the interdependent relations and influence between renewable energy and economic growth in the present and the future. The vectors Π and Γ_i supports the meaning of the oncoming impact.

It`s important to test the timeseries for casuality. The Granger casuality is used for forecasting the influence upon time series, generated by historical data of other dependent factor (Granger, 1969). The model is defined by VAR methodology and every dependant variable has its own individual test. In this case there is the following meaning:

$$GDP_t = a_1(U)GDP_t + b_1(U)REC_t + c_1(U)REO_t + \epsilon_{1,t}$$

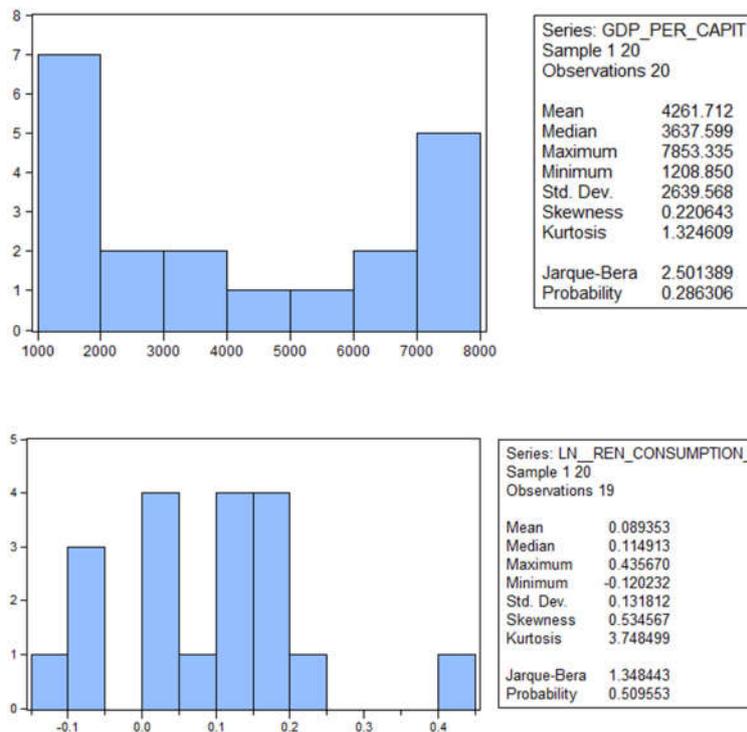
$$REC_t = a_2(U)GDP_t + b_2(U)REC_t + c_2(U)REO_t + \epsilon_{2,t}$$

$$REO_t = a_3(U)GDP_t + b_3(U)REC_t + c_3(U)REO_t + \epsilon_{3,t}$$

Where GDP, REC, REO are the time series, a, b,c – polynomials of a matrix system and ϵ shows the variation. VEC Granger Causality/Block Exogeneity Wald Tests is performed for the analysis` needs.

EMPIRICAL RESULTS

The descriptive statistics and histogram review of the chosen variables show lack of stationarity and although the skewness/ kurtosis are not at very high position, the use of natural logarithm is preffered (see figure 1). This stage have to convert the variables into a compatible base for the needs of the subsiquent actions. After conversion, the Unit root test is following in the analitical procedure.



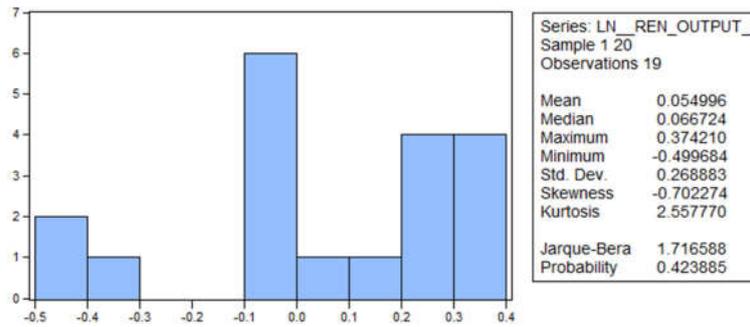


Figure 1. Histograms of GDP, Renewably energy consumption and output (1995-2015)

The ADF test is used both without presence of additional element and with implementation of intercept on levels and first difference (Table 1.) Two of the variables are characterized by high dynamics at level (GDP P-Value is 28.94% and renewable energy consumption – 6.45%), but at first difference, the time series show steady state and are subject to cointegration testing. A basic conclusion can be made as regards the renewable energy consumption and output: their residuals have a slightly dynamic excitement and that prove the majority of the following testing.

Table 1. ADF Unit root tests

Variables	Level				First difference			
	None		Intercept		None		Intercept	
	T-statistics	P-value	T-statistics	P-value	T-statistics	P-value	T-statistics	P-value
GDP	-0.952957	0.2894	-7.184839	0.0000	-1.073776	0.6989	-6.951420	0.0000
REC	-1.836654	0.0645	-4.247711	0.0003	-4.411349	0.0033	-4.262093	0.0057
REO	-3.900840	0.0006	-3.885121	0.0008	-4.071584	0.0069	-3.719520	0.0156

Before the cointegration analysis` performance, it is imperative to define the optimal lag delay for the needs of the VAR system. Observation of the information in Table 2 shows that the optimal lag is of third order (approved by four of the five tests). LR test adds individual meaning of second order. The prime values are connected to the two crisis cycles in the economy of Bulgaria (1997 and 2008) and the authors consider that the suitable lag length is obvious.

Table 2. Lag order selection

Lag	LogL	LR	FPE	AIC	SC	HQ
0	31.94910	NA	5.39e-06	-3.618637	-3.473777	-3.611219
1	39.62405	11.51243	6.56e-06	-3.453007	-2.873565	-3.423334
2	55.15735	17.47496*	3.39e-06	-4.269668	-3.255646	-4.217742
3	69.71036	10.91476	2.68e-06*	-4.963795*	-3.515191*	-4.889615*

The long–run relationship is examined by Johansen cointegration test (Table 3). Both Trace and Max Eigen statistics at 5% critical value show presence of expected dependencies. This relations exist in I (0) and I (1), but not in I (2). The Trace statistics has greater efficiency than Max Eigen, but the coincidence of levels is not unusual and there is significant interdependence between the macroeconomic variables.

Table 3. Johansen cointegration test

Variables	Eigenvalue	Trace statistic			Max Eigen test		
		Statistic	Critical Value 5%	Prob.	Statistic	Critical Value 5%	Prob.
None *	0.851485	51.71831	29.79707	0.0000	30.51309	21.13162	0.0018
At most 1 *	0.723063	21.20522	15.49471	0.0062	20.54342	14.26460	0.0045
At most 2	0.040519	0.661809	3.841466	0.4159	0.661809	3.841466	0.4159

* denotes rejection of the hypothesis at the 0.05 level; **MacKinnon-Haug-Michelis (1999) p-values

The next procedure includes running VECM system to evaluate the dependencies in time. The error correction estimates result in contradictory long-term relationships. The t-statistics is significant and the slightly positive development in GDP is followed by sharp decline in consumption and output of renewable energy. (table 4.A.). A structural conclusion here it is: if there is no consumption and client search for green energy, its manufacturing collapses in the long run and the effect on economic growth is minor, due to slow market tracing and traditional energy sources, that are widespread in general national use. If the economic growth slows down, all perspectives of low cost ecological energy and energy independence will not grow sustainable due to recession moments and redirection of the investments to more important structural problems.

Table 4A. Error correction terms of long term relationship

Error Correction:	D(LN_REN_CONSUMPTION_)	D(LN_REN_OUTPUT_)	D(LN_GDP_PER_CAPIT_)
CointEq1	-1.266989	-2.543143	0.181615
	(0.25395)	(1.05081)	(0.37235)
	[-4.98912]	[-2.42016]	[0.48775]

*Standart error in parenthesis

The short term relationship is defined again by VAR matrix with error correction elements. Due to short observation period, this matrix is of second order (see table 4.B.) Observation of the final results prove the general conclusions above. Renewable energy consumption growth of 21 % generates huge breaking bound in output (99%), but has an extremely negative effect on economic growth (-90%). The lag term changes the situation a little bit. The values of usage grows to 37,2 %, which indicates deduction of the negative impact on economic progress (-42%) and reducing the output levels with an enormous decline. According to the movements of renewable energy output, it is obvious that this variable has inversely proportional relations both with GDP, and consumption. The negative production stimulates the GDP improvement and usage gravitates minimally (+/-7%), which means that the output meets the needs of the national market, but an overproduction would catalyze the redeployment of energy markets and problems in existing stability. The surplus of this type of energy may not find use and coverage of infrastructure costs.

Similarly, the GDP turn down provokes extreme development of renewable energy output. It is important to note that an increase in production and consumption of renewable energy is available in short terms with the delay of economic growth. This fact can be explained with the essence of economic cycles. In this case, a recession leads to increased interest in more cost-effective sources of energy both for private use by individuals and for the purposes of infrastructure and industrial service.

Table 4B. Short term relationship (VECM)

	D(LN_REN_CONSUMPTION_)	D(LN_REN_OUTPUT_)	D(LN_GDP_PER_CAPIT_)
D(LN_REN_CONSUMPTION_(-1))	0.210258	0.997745	-0.902170
	(0.29917)	(1.23794)	(0.43866)
	[0.70280]	[0.80597]	[-2.05665]
D(LN_REN_CONSUMPTION_(-2))	0.372040	0.011277	-0.421004
	(0.24566)	(1.01652)	(0.36020)
	[1.51443]	[0.01109]	[-1.16880]
D(LN_REN_OUTPUT_(-1))	0.072543	-0.196232	0.312231
	(0.08502)	(0.35178)	(0.12465)
	[0.85330]	[-0.55782]	[2.50481]
D(LN_REN_OUTPUT_(-2))	-0.076058	0.038152	0.051467
	(0.10471)	(0.43326)	(0.15352)
	[-0.72640]	[0.08806]	[0.33524]
D(LN_GDP_PER_CAPIT_(-1))	-0.019206	0.034605	-0.125952
	(0.16005)	(0.66228)	(0.23468)
	[-0.12000]	[0.05225]	[-0.53670]
D(LN_GDP_PER_CAPIT_(-2))	0.358035	1.410974	-0.418128
	(0.14239)	(0.58920)	(0.20878)
	[2.51445]	[2.39474]	[-2.00272]
C	-0.038727	-0.027237	-0.014461
	(0.01763)	(0.07294)	(0.02585)
	[-2.19688]	[-0.37339]	[-0.55947]

The Granger causality test is performed for investigation if some of the current values of one macroeconomic indicator can define the future changes in other variable. There are four obvious causal relationships: three individual and one common. The dependent renewable energy consumption is granger by GPD and there is a more complicated connection, described by the collective influence of the independent values.

Table 5. VEC Granger Causality/Block Exogeneity Wald Tests

Dependent Variable	Excluded	df	Chi-sq	Prob.
D(LN_REN_CONSUMPTION_)	D(LN_REN_OUTPUT_)	2	1.573194	0.4554
	D(LN_GDP_PER_CAPIT_)	2	6.536644	0.0381
	All	4	19.75229	0.0006
D(LN_REN_OUTPUT_)	D(LN_REN_CONSUMPTION_)	2	0.898597	0.6381
	D(LN_GDP_PER_CAPIT_)	2	6.109083	0.0471
	All	4	8.910902	0.0634
D(LN_GDP_PER_CAPIT_)	D(LN_REN_CONSUMPTION_)	2	4.235892	0.1203
	D(LN_REN_OUTPUT_)	2	6.305829	0.0427
	All	4	7.597400	0.1075

**Standart error in parenthesis*

The dual relationship between GDP and renewable energy output made the most striking impression. It focuses on the important role of eco-friendly production capacities and their prospects for export and sales on international energy market. The rejection of the null hypothesis primarily failed in the relations between renewable energy consumption and output.

CONCLUSION

In the case of Bulgaria the effect of renewable energy use on economic growth exhibits certain trends within VAR system. GDP, renewable energy consumption and output are partly cointegrated, and their interdependent relations tend to keep this movement for both short and long period. Bulgaria is energy dependent mainly on fuels and gas, but the alternative provided by renewable sources would contribute to economic progress in the future only if the cost of establishing this energy as well as its accessibility and cost is competitive with traditional energy directions.

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