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THE GRANGER CAUSALITY ANALYSIS OF ENERGY CONSUMPTION AND ECONOMIC GROWTH

After the first oil crisis the world's countries had to face recession caused by the high oil prices, and the role of energy consumption became a core element of economics. Many studies examined (and examine today) connection between energy consumption, economic growth and energy efficiency. The purpose of the paper is to contribute to this topic with an analysis of Granger causality between energy consumption and economic growth in East-Central Europe.

Keywords: energy economics, econometric, Granger causality, energy consumption, economic growth.

Formulation of the problem generally. Recognition of causality directions between energy consumption and economic growth is critically important not only for academia, since it has many empirical consequences. If it is proved that energy consumption Granger causes the Gross Domestic Product (GDP), every measure has to be rethought because negative effect can occur, decreasing the economic growth. So the purpose of this paper is to analize Granger causality between energy consumption and economic growth in East-Central Europe.

Analysis of recent researches and publications. The analysis of connection between economic growth and energy consumption has been a central topic for several decades but the methodology has changed greatly over time. The Hungarian literature has been enriched by many significant results (e.g., Jánossy F. [29; 30]; Bauer T. [4], Erdősi P. [22], Vajda Gy. [64], Kovács F. [34]). Jánossy F. analyzing the economic development, concluded that "the economic development … cannot be measured with value of the domestic product", so a new methodology should be formed [29, p. 59]. He argued "the economic development is reflected in each areas of the production and consumption" so he chose natural indices to compare the economies. The starting point of the comparison of countries based on their economic development was inter alia the electricity consumption per capita (kWh per capita) and the energy consumption (in coal equivalent, tonne). It can be stated that Jánossy's main objective was not the examination of the connection between economic development and the physical indicators mentioned above but to determine economic development using natural indices.

Erdősi P. [22] offers mathematical-statistical methods (such as trend analysis, correlation and elasticity analysis) to analyze the connection between the energy use and the gross value of production, the gross value of industrial production or the national income. These are suitable for determining the nature of the connection and the strength of linear dependence between two variables, or for forecasting, but are not sufficient to demonstrate the presence of a causal relationship. Does economic development cause the increasing energy consumption or is this latter variable the explanatory one?

In this sphere of economic research Kraft's analysis was the pioneering work, analyzing the relationship between energy consumption and the Gross National Product (GNP) in the

USA between 1947 and 1974 (Kraft J. and Kraft A. [36]). In the more than three decades since then many publications have been issued but their results are really contradictory. According to the literature, these differences stem from factors such as the different econometric methods, time periods, the national heterogeneity, the different consumption samples, climate, economic development (Belke A. et al. [6]; Stern D.I. [58-60]) and every other indicator which affects energy consumption and economic growth, such as structural change. The reviewed literature also confirms this: the results are inconsistent and differ by author. In the author's view, main causes are different examined time horizons, specific characteristics of the nations and different methodology. Main publications of the 21st century are summarized in Table 1.

Zikovic S. [68] analyzed causality between crude oil consumption and the GDP in 22 European countries and concluded that in the countries where the economic growth is the independent variable (so the causal factor) that are developed post-industrial societies with strong service sector or transition economies where the industrial production greatly decreased because of the deindustrialization process. In the other group of the countries where the crude oil consumption is Granger causes the economic growth, the crude oil represents a significant part in the total energy consumption (Zikovic S. et al. [68, p. 7]).

Feng T. et al. [24] carried out causality analysis of energy intensity, economic structure and the structure of the energy consumption (energy sources). What is new in this model is that they used the final consumption of coke (which is dominant in Chinese energy consumption) instead of the conservative final energy consumption and the contribution of the service sector to the GDP. They concluded: "to reduce energy intensity in the future, China should reduce the proportion of coal in energy consumption and improve the development of tertiary industry" (Feng T. et al. [24, p. 5479]).

Narayan P.K. et al. [49] examined the causality connection between the electricity consumption and the GDP for 30 OECD members. In Iceland and Korea there is bidirectional causality, in 6 other countries (including Hungary) the electricity consumption is the effect and in 8 countries the GDP is the dependant. In 16 cases no connection was found.

Chontanawat J. et al. [15] analyzed the Granger causality between the energy consumption and the GDP per capita in 30 OECD members and 78 non-OECD members. They concluded that in most of the developed countries the energy consumption Granger causes the GDP, while in the developing countries it is less common, justified in just 46% of the cases that were investigated.

Unsolved issues as part of the problem. In the reviewed literature there were some inaccuracies, which make reproduction of calculations and the controllability difficult. In many cases the exact definitions, unit and the source of data are lacking. Another problem is the logical contradictions between data; in many cases researchers use aggregate and disaggregate data at the same time. Table 1 shows the results of summarizing of granger causality analysis in the field of energy economics.

Chary S.R. et al. [11] analyzed the causality among the energy consumption of three countries. Using bivariate and univariate models (with three variables) he concluded that the energy consumption of Bangladesh does not Granger cause the energy consumption of Pakistan, while in every other case the causality can be verified. But in author's view their results are questionable, because models include only energy consumption of three countries, which is too limited.

Table 1 – **Summary of the results of Granger causality analysis in the sphere of energy economics,** (developed by the author)

Publication	Economic variable	Country and time period	Methodology	Results
1	2	3	4	5
Kraft J. and Kraft A. [36]	GNP (constant 1958 US$) Energy consumption (EN)	USA (1947-1974)	Sims causality test	GNP→EN
Aqeel A. and Butt M. S [3]	GDP* Energy consumption * (EN) Crude oil consumption* (O) Natural gas consumption* (G) Electricity consumption* (EL) Employment*(EM)	Pakistan (1955-1996)	ADF test Cointegration test (OLS method) Granger test (Hsiao)	GDP→EN GDP→O EL→GDP EN →EM
Soytas U. et al. [56]	Energy consumption (million mtoe) (EN) GDP*	Turkey (1960-1995)	ADF, PP test Johansen-Juselius cointegration test VECM model	EN→GDP
Soytas U. et al. [57]	Energy consumption (million metric tons of coal equivalent) (EN) GDP per capita* (GDP)	17 countries, after doing the required tests; the analysis of Turkey, West Germany, France, Japan, Italy, South Korea, Argentina (1950/1953/1960/1965-1990/1991/1992/1994)	ADF, PP test Johansen cointegration test VECM model	Turkey, West-Germany, France, Japan: EN→GDP Italy, Korea: GDP→EN Argentina: GDP↔EN
Mehrara M. [45]	Real GDP per capita (constant 2000 in local currencies), (GDP) Energy consumption per capita (koe), (EN)	Iraq, Kuwait, Saudi Arabia (1971-2002)	ADF test Johansen and Engle-Granger cointegration test VECM model	Saud-Arabia: EN→GDP Iran, Kuwait: GDP→EN
Chiou-Wei S. Z. et al. [14]	Energy consumption (ktoe) (EN) GDP (constant 2000)	Taiwan, South Korea, Singapore, Hong Kong, Indonesia, Malaysia, Philippines, Thailand, USA (1954/1960/1971-2003/2006)	ADF test Johansen-Juselius cointegration test VECM model (by the USA and Taiwan) VAR model (with exception USA and Taiwan)	Taiwan, GDP→EN USA, South-Korea, Thailand: no connection found Hong-Kong, Indonesia: EN→GDP Malaysia, Philippines, Singapore: GDP↔EN
Chontanawat J. et al. [15]	Real GDP per capita (US$, PPP), (GDP) Energy consumption per capita (ktoe), (EN)	30 OECD members (1960-2000) 78 non-OECD members (1971-2000)	ADF test Johansen cointegration test Hsiao causality test ECM-modell	EN→GDP (OECD – such as **Hungary, Czech Republic, Poland, Slovakia**: in 21 cases) EN→GDP (non-OECD members: in 36 cases)

Table 1 (continued)

1	2	3	4	5
Narayan P. K. et al. [49]	Electricity consumption* (EL) GDP (in constant 1995 US$) (GDP)	Ausztralia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, South Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland, Turkey, UK, USA (1960/1965/1970/1971-2002)	ADF test Monte Carlo simulation Granger-test (bootstrap method)	UK, Korea, Finnland, Iceland, Netherlands, **Hungary**: GDP→EL Australia, Iceland, Italy, **Slovakia, Czech Republic,** Korea, Portugal, UK: EL→GDP Others: no connection found
Feng T. et al. [24]	Energy intensity (energy consumption per national output, tons of standard coal/10 thousand RMB), (EI); The rate of coal consumption to the total energy consumption (%), (ECS); Services value added (% of GDP), (ES)	China (1980-2006)	ADF test Johansen cointegration test VECM model VAR model	EI→ES
Mallick H. [44]	economic growth rate (%) (GDP) Natural gas (G), electricity (EL), coke (C), crude oil (O) and energy consumption (EN) (of real GDP %)	India (1970-2005)	ADF, PP test VAR model	GDP →G GDP →EL C→GDP GDP→EN
Žiković S. et al. [68]	GDP (US$) Crude oil consumption (1000 barrel/day) (O)	22 European countries (1980/1993-2007)	ADF, PP test Johansen cointegration test ECM model VAR model	O→GDP (in 4 cases) GDP→O (in 5 cases) O ↔GDP (in 3 cases)
Chary S.R. et al. [11]	Primary energy consumption per capita*	Bangladesh, India, Pakistan (1965-2005)	ADF test Johansen cointegration test ECM model VAR model	India →Bangladesh India + Pakistan →Bangladesh Bangladesh→ Pakistan India →Pakistan India + Bangladesh →Pakistan Bangladesh→India Pakistan→ India Bangladesh + Pakistan→ India

Table 1 (continued)

1	2	3	4	5
Kumar S. et al. [36]	Coke use* (C) Economic growth rate* (GDP)	Pakistan (1971-2009)	LM unit root test ARDL-model to the cointegration analysis VECM-model	C→GDP
Mutascu M. et al. [47]	Electricity consumption per capita (EL)* Capital use per capita (K)* GDP per capita (GDP)*	Romania (1980-2008)	ADF, PP, DF-GLS test ARDL technic cointegration test, Toda-Yamamoto Granger test, VAR-model	EL↔GDP K↔GDP K↔EL
Vlahinic-Dizdarevic N. and Zikovic S. [68]	GDP (million US$) Energy consumption by the household sector (toe) (ECH) Energy consumption of industry (toe) (ECI) Primary energy production (PEP) Net energy import (toe) (IMP) Crude oil consumption (1000 barrel/day) (O)	Croatia (1993-2006)	ADF test Johansen cointegration test ECM model VAR model	GDP→ECH GDP→ECI GDP→PEP GDP→IMP GDP→O
Chang C. et al.[10]	Energy consumption (ktoe) (EN) GDP (million constant 2000 US$) (GDP) Carbon-dioxide emission (kt) (C)	Argentina, Bolivia, Brazil, Trinidad &Tobago, Ecuador, Chile, Costa Rica,Dominican Republic El Salvador, Guatemala, Honduras, Jamaica, Columbia, Mexico, Nicaragua, Panama, Paraguay, Peru, Uruguay, Venezuela (1971-2005)	PP-test Johansen cointegration test VECM model VAR model	GDP→EN (in 3 cases) GDP→C (4 cases) C→EN (1 cases) EN→GDP (3 cases) EN→C (5 cases) (the causality analysis was made for 8 countries)
Tianli H. et al. [61]	Economic structure (the value added of the service sector to the GDP, %) (IS) Energy intensity (t/10.000US$) (EI)	China (1999-2009)	ADF test Engle-Granger cointegration test VECM model	IS→ EI

* – missing unit

Abbreviations: VECM (vector error correction model); ADF-test (augmented Dickey-Fuller test); PP-test (Phillips-Perron test); VAR model (vector autoregressive model), DF-GLS-test (Dickey-Fuller Generalized Linear Square Unit Root-test), ARDL-test (Autoregressive Distributed Lag model)

Aims of the article. The main steps of the research are:

– stationarity test;

– if the levels values of the series are stationary we should use the vector autoregressive model (VAR model) and if the differences of the variable are stationary we test cointegration;

– with regard to the results we use the vector autoregressive model (VAR model) or vector error correction model (VECM model);

– determine the Granger causality connections.

Figure 1 presents detail steps and main definitions.

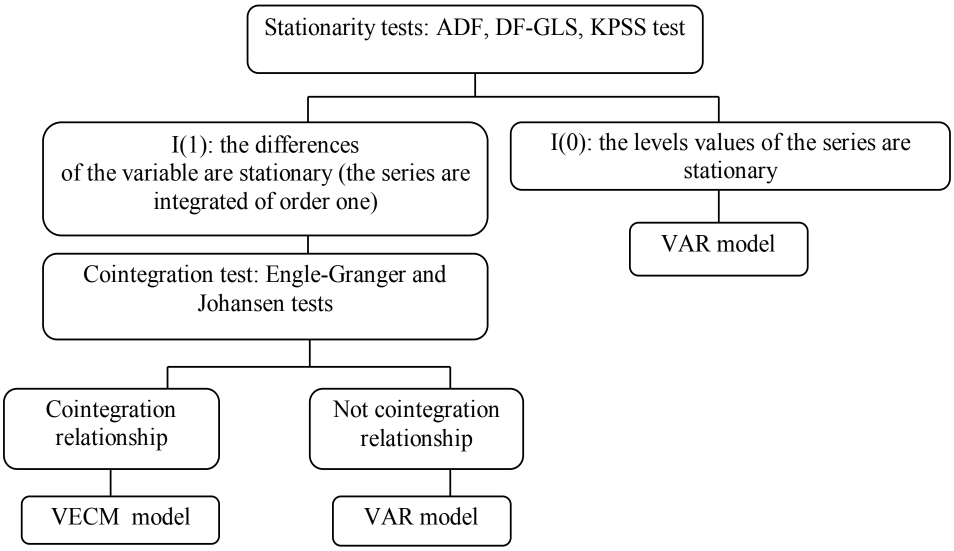

Figure 1 – **The Granger causality analysis,** (developed by the author)

The starting point of the method is that *X* variable Granger causes *Y* variable but *Y* does not Granger cause *X* [26]:

$$Y_t = \sum_{i=1}^{p} \alpha_i Y_{t-i} + \sum_{j=1}^{q} \beta_j X_{t-j} + u_{t,} \tag{1}$$

where u_t is the white noise, *p* is the lag order of *Y* variable and *q* is the lag order of *X* variable. The white noise is normally, independently, and identically distributed with zero mean [55]. Mostly effects of the economic decisions do not appear immediately, but later. The economic actors need time to react. Practically we integrate not only the independent variables at period *t*, but the period *t-1* as well. To determine the optimum lags in the models we used the AIC (Akaike criterion), the BIC (Schwarz Bayesian criterion) and the HQC (Hannan-Quinn criterion).

Basic principle of the Granger causality analysis "the two variables are *X* and *Y* evaluate whether the past values of *X* are useful to predict *Y*, and *Y* is said to be Granger caused by X if *X* helps to predict *Y* and vica versa" [13, p. 6571]. The null hypothesis is that *X* does not Granger cause *Y* so β_j=0 [41; 55]. We assume that there is a linear relationship between the variables [14].

The Granger causality analysis requires that the variables should be stationary. Time series is said to be stationary if both its mean and its variance (amplitude) remain constant through time [41; 65]. Most time series (the levels of the time series) are not stationary, but the first differences will be. "If the first differences of the series are stationarity we say that series are integrated of order 1 or I (1)" [55, p. 492]. One of the most popular stationarity tests was developed by D.A. Dickey and W.A. Fuller and it is called the augmented Dickey-Fuller test:

$$\Delta Y_t=\alpha+\lambda Y_{t-1}+\sum_{j=1}^{p}\theta_i\Delta Y_{t-j}+u_t, \tag{2}$$

where Y_t is the economic variable in time period t, $\Delta Y_{t-1}=Y_{t-1}-Y_{t-2}$ and u_t is the residual term. The null hypothesis is that $\lambda=0$ (or $\rho=1$); if we reject it, we can state that the series is stationary. We utilized the DF-GLS and the KPSS test worked out by Kwiatkowski to confirm the stationarity. According to Adkins [3] these tests have significantly greater power than the previous version of the ADF test. "Consequently, it is not unusual for this test to reject the null hypothesis of nonstationarity when the usual augmented Dickey-Fuller test does not" [3, p. 288]. After the stationarity tests we need to check cointegration. Two series are cointegrated if they tend to move together through time. To test this we applied both the Engle-Granger and the Johansen cointegration test as well. If the series are cointegrated we estimate a VECM model, if not, the solution is the VAR model [10, p. 4217]. Mallick H. confirms this: "Granger causality test and variance decomposition analysis of VAR are most suitable techniques when all the variables are stationary at their levels" [43, p. 258]. In addition to determining the direction of causality, the VECM approach allows us to distinguish between long run and short run causality" [56, p. 841].

The VECM belongs to the family of VAR models and is a special form that can take into account cointegration relationships between variables. The general form of the VECM model is:

$$\Delta y_t=\beta_0+\beta_1\Delta x_t+\gamma_1 x_{t-1}+\gamma_2 y_{t-1}+u_t \tag{3}$$

where x_t and y_t are economic variables, $\Delta y_t = y_t-y_{t-1}$ and $\Delta x_t = x_t-x_{t-1}$ is the first lag of the x variable, y_{t-1} is the first lag of the y variable, and u_t is the residual term.

The VAR models include a number of equations and can be written as (using two variables and the lag lengths of the time series is two):

$$\begin{aligned} X_t&=\alpha_0+\alpha_1 X_{t-1}+\alpha_2 X_{t-2}+\alpha_3 Y_{t-1}+\alpha_4 Y_{t-2} \\ Y_t&=\beta_0+\beta_1 Y_{t-1}+\beta_2 Y_{t-2}+\beta_3 X_{t-1}+\beta_4 X_{t-2} \end{aligned} \tag{4}$$

where X_t and Y_t are economic variable, X_{t-i} is the lag order of X variable, and Y_{t-i} is the lag order of Y variable. The VAR model enables to present the short time effects of the variables, so it forecasts the results of the Granger causality analysis and confirms them [11; 44; 47]. The model includes the causality results.

Basic material. In the calculations it was used the Worldbank database. We chose energy consumption (ktoe) and GDP (constant 2000 US$). According to the definition of Worldbank energy consumption refers to use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport. The GDP is more effective for our analysis than the GNP. This is confirmed by Soytas U. et al. [56]: "it is better to use GDP instead of GNP since energy consumption should be related to domestically produced goods and services" [56, p. 839].

We used the natural logarithm of the variables. In our view selecting data it is extremely important to appoint the right scale: for a bivariate model we should integrate only aggregate or only disaggregate data at the same time [67]. We assumed that the GDP includes trends but the energy consumption does not.

The examined territories (and time period) are the countries of Central-East Europe: Hungary (1990-2009), Poland (1990-2009), the Czech Republic (1990-2009), Slovakia (1990-2009), and Slovenia (1990-2008). In the figures we use the following abbreviations: HU – Hungary; PL – Poland; CZ – Czech Republic; SK – Slovakia; SLO – Slovenia.

Using the methodology presented above, I started the analysis with tests of stationarity. The results are presented in Table 2. If the augmented Dickey-Fuller and the ADF-GLS tests could not prove the stationarity we accepted the results of the KPSS test.

Table 2 – **Analysis of the stationarity with augmented Dickey-Fuller, DF-GLS, and KPSS tests, (**developed by the author)

	Variable	**ADF test** H_0: the series is integrated H_1: the series is (trend) stactonary	**ADF-GLS test** H_0: the series is integrated H_1: the series is (trend) stationary	**KPSS test** H_0: the series is (trend) stationary H_1: the series is integrated	Stationarity
HU	ENC	-3,19277 (0.0365) I(0)	-3,33368 (0,0008397) I(1)	0,1059 (>10%) I(0)	Stationary I(0)
	GDP	–	–	0,122599 (>10%) I(0)	Trend stationary I(0)
PL	ENC	-3,62997 (0.01582) I(1)	-3,61424 (0.0001) I(1)	0,108973 (>10%) I(1)	Stationary I(1)
	GDP	-5,29081 (0.002647) I(1)	3,83462 (1%) I(1)	0,0640316 (>10%) I(0)	Trend stationary I(1)
CZ	ENC	-3,74894 (0.01245) I(1)	-2,834 (0.004471) I(1)	0,203234 (>10%) I(0)	Stationary I(1)
	GDP	–	–	0,105295 (>10%) I(1)	Trend stationary I(1)
SK	ENC	-4,66428 (0.001763) I(0)	-2,45504 (0.01364) I(0)	0,155862 (>10%) I(0)	Stationary I(0)
	GDP	-3,69457 (0.02263) I(0)	–	0,141597 (>10%) I(0)	Trend stationary I(0)
SLO	ENC	-4,43824 (0.0001) I(1)	–	0,100663 (>10%) I(1)	Stationary I(1)
	GDP	-4,99303 (0.0001) I(0)	-3,08139 (5%) I(1)	0,132072 (>10%) I(1)	Trend stationary I(1)

Where: I(0) – zero order integrated time series; I(1) – first order integrated time series; the value in ( ) is level of significance

From the KPSS test results we could not reject the null hypothesis (H_0: the series are stationarity) even at the 10% significance level. In the case of Hungary and Slovakia the series are zero-order integrated, while in the other countries the series are first-order integrated. Then we calculated the cointegration test for Poland, the Czech Republic and Slovenia (Table 3).

Table 3 – **Cointegration test for Poland, Czech Republic and Slovenia,**
(developed by the author)

Country	Engle-Granger cointegration test	Johansen cointegration test	Cointegration
PL	-1,92416 (0,577) -0,533151 (0,9618)	4,7347 (0,8626)	No cointegration
CZ	-1,217 (0.8542) -3,39344 (0,08198)	11,537 (0,2401)	No cointegration
SLO	-1,79483 (0,6388) 3,64983 (0,02125)	10,791 (0,2957)	No cointegration

The series are not cointegrated. In the next step we determine causality directions with the VAR-model. The direction between the energy use and the GDP can be of four kinds:

– no connection (neutrality theory; the researcher explains it by the small costs of energy compared to the total costs);

– the energy consumption causes the economic growth (it can happen that restraints in the energy use may retard the economic growth and the income and decrease the employment rate),

– the economic growth causes the energy consumption;

– a bidirectional connection.

This context is really important from the perspective of energy policies because if it is found that the energy consumption Granger causes the economic growth, energy conservation policies can retard the growth rate of GDP.

According to the results of the VAR model, in the case of Hungary, Czech Republic and Slovakia the energy use Granger causes the GDP. For Poland and Slovenia we could not accept one direction of causality even at the 10% significance level (Table 4).

Table 4 – **Causality tests,** (developed by the author)

Country	Granger causality	Lags	ENC→GDP	GDP→ENC	Test
HU	*ENC→GDP*	1	13,547 (0.0020)***	1.4743 (0,2423)	VAR model
PL	no connection found	1	1,4649 (0,2449)	0,0061589 (0,9385)	VAR model
CZ	*ENC→GDP*	4	3,8164 (0,0708)*	2,5799 (0,1440)	VAR model
SK	*ENC→GDP*	1	10,444 (0,0052)***	0,010551 (0,9195)	VAR model
SLO	no connection found	1	0,59281 (0,4541)	2,6155 (0,1281)	VAR model

Comment: by VAR models we present the F-tests of zero restrictions, in parentheses the p-value; *– 10% significance level, ** – 5% significance level; *** – 1% significance level

The decomposition of variance is suitable to test the variables and confirm the results of the Granger causality analysis.

It shows how a shock happening in a series affects the variance of the forecast error of the other series. It divides the time series into equal periods.

In the case of Hungary in the 10^{th} period the shock in the energy use affected 40,4 percent of the variance of the forecast error of the GDP (Table 5). This supports our earlier findings that energy consumption affects the economic growth.

Table 5 – **Results of decomposition of variance for Hungary,**
(developed by the author)

Decomposition of variance for l_ENC				Decomposition of variance for l_GDP			
period	std. error	d_l_ENC	d_l_GDP	period	std. error	d_l_ENC	d_l_GDP
1	0.0253584	100.0000	0.0000	1	0.0330673	2.6915	97.3085
2	0.0270126	99.6838	0.3162	2	0.0505729	12.6240	87.3760
3	0.0272056	99.0762	0.9238	3	0.0666157	22.7827	77.2173
4	0.0273099	98.3382	1.6618	4	0.0806016	29.1478	70.8522
5	0.0274592	97.5747	2.4253	5	0.0927019	33.0995	66.9005
6	0.0276369	96.8318	3.1682	6	0.103269	35.6745	64.3255
7	0.0278237	96.1250	3.8750	7	0.112618	37.4431	62.5569
8	0.0280101	95.4578	4.5422	8	0.120991	38.7160	61.2840
9	0.0281918	94.8296	5.1704	9	0.12857	39.6692	60.3308
10	0.0283673	94.2380	5.7620	10	0.135489	40.4066	59.5934

Interestingly, in the case of Poland the results contradict our earlier findings: a really weak causality direction is shown by Table 6.

Table 6 – **Results of decomposition of variance for Poland,** (developed by the author)

Decomposition of variance for d_l_ENC				Decomposition of variance for d_l_GDP			
period	std. error	d_l_ENC	d_l_GDP	period	std. error	d_l_ENC	d_l_GDP
1	0.0321998	100.0000	0.0000	1	0.014835	8.6096	91.3904
2	0.0322504	99.9913	0.0087	2	0.0162715	20.2804	79.7196
3	0.0322512	99.9907	0.0093	3	0.0163653	20.9838	79.0162
4	0.0322512	99.9906	0.0094	4	0.0163708	21.0250	78.9750
5	0.0322512	99.9906	0.0094	5	0.0163711	21.0274	78.9726
6	0.0322512	99.9906	0.0094	6	0.0163712	21.0275	78.9725
7	0.0322512	99.9906	0.0094	7	0.0163712	21.0275	78.9725
8	0.0322512	99.9906	0.0094	8	0.0163712	21.0275	78.9725
9	0.0322512	99.9906	0.0094	9	0.0163712	21.0275	78.9725
10	0.0322512	99.9906	0.0094	10	0.0163712	21.0275	78.9725

The results here support the earlier results in the case of the Czech Republic: in the 10th period the shock in the energy use affected 76.87 percent of the variance of the forecast error of the GDP. There is a weak connection in the contrary direction (from the GDP to the energy consumption), but the value is low (just 31.7 percent) (Table 7).

Table 7 – **Results of decomposition of variance for Czech Republic,**
(developed by the author)

Decomposition of variance for d_l_ENC				Decomposition of variance for d_l_GDP			
period	std. error	d_l_ENC	d_l_GDP	period	std. error	d_l_ENC	d_l_GDP
1	0.0176689	100.0000	0.0000	1	0.00895799	13.2692	86.7308
2	0.0180991	98.4066	1.5934	2	0.0121959	12.3721	87.6279
3	0.0199159	81.8317	18.1683	3	0.0137158	30.6859	69.3141
4	0.0231545	71.0663	28.9337	4	0.017842	48.6353	51.3647
5	0.0268294	54.4924	45.5076	5	0.0209992	54.5900	45.4100
6	0.0270147	55.1117	44.8883	6	0.0217434	53.0035	46.9965
7	0.0275939	55.9619	44.0381	7	0.023113	55.0922	44.9078
8	0.0334141	69.7999	30.2001	8	0.0270721	65.2547	34.7453
9	0.0368096	68.5369	31.4631	9	0.0311693	73.2851	26.7149
10	0.03688	68.3153	31.6847	10	0.034095	76.8736	23.1264

In the case of Slovakia the results are similar to the earlier results: in the 10th period the shock in the energy consumption (the variance of the energy consumption) affected 36,31 percent of the variance of the forecast error of the GDP. Similarly to the case of the Czech Republic, there is a weak causality in the contrary direction, which value is only 24,6 percent (Table 8).

Table 8 – **Results of decomposition of variance for Slovakia,** (developed by the author)

Decomposition of variance for l_GDP				Decomposition of variance for l_ENC			
period	std. error	d_l_ENC	d_l_GDP	period	std. error	d_l_ENC	d_l_GDP
1	0.0482543	100.0000	0.0000	1	0.0242401	24.2800	75.7200
2	0.0657102	91.7603	8.2397	2	0.0259076	24.4200	75.5800
3	0.0809001	83.3952	16.6048	3	0.0261348	24.4932	75.5068
4	0.0952125	77.2556	22.7444	4	0.0261665	24.5270	75.4730
5	0.109058	72.9607	27.0393	5	0.0261713	24.5425	75.4575
6	0.122687	69.9124	30.0876	6	0.0261727	24.5505	75.4495
7	0.136282	67.6849	32.3151	7	0.0261738	24.5556	75.4444
8	0.149982	66.0075	33.9925	8	0.0261751	24.5598	75.4402
9	0.163897	64.7102	35.2898	9	0.0261765	24.5638	75.4362
10	0.178117	63.6840	36.3160	10	0.0261781	24.5681	75.4319

In Slovenia the relationship is quite weak (just 6,54% and 4,89%), so we cannot prove the presence of the connection or causality (Table 9).

Table 9 – **Results of decomposition of variance for Slovenia,** (developed by the author)

Decomposition of variance for d_l_ENC				Decomposition of variance for d_l_GDP			
period	std. error	d_l_ENC	d_l_GDP	period	std. error	d_l_ENC	d_l_GDP
1	0.0302134	00.0000	0.0000	1	0.0154797	8.3736	91.6264
2	0.0307954	96.3123	3.6877	2	0.0175327	6.8030	93.1970
3	0.0309494	95.3725	4.6275	3	0.0179606	6.5906	93.4094
4	0.0309832	95.1694	4.8306	4	0.0180512	6.5491	93.4509
5	0.0309904	95.1261	4.8739	5	0.0180704	6.5403	93.4597
6	0.030992	95.1168	4.8832	6	0.0180745	6.5385	93.4615
7	0.0309923	95.1149	4.8851	7	0.0180754	6.5381	93.4619
8	0.0309924	95.1144	4.8856	8	0.0180756	6.5380	93.4620
9	0.0309924	95.1144	4.8856	9	0.0180756	6.5380	93.4620
10	0.0309924	95.1143	4.8857	10	0.0180757	6.5380	93.4620

Conclusions and directions of further researches. It is broadly accepted that there is a strong connection between energy consumption and the economy of nation, but the direction is debated. The results are in many cases quite contradictory, and not adequately supported by empirical data. However, the causality direction is extremely important, because in countries where the GDP is the effect (the dependant variable) of energy consumption, restrictions on energy consumption can limit or mitigate economic growth.

In the analysis we used bivariate models to examine the Granger causality directions between energy consumption and economic growth in Hungary, Poland, Czech Republic, Slovakia and Slovenia. To test the stationarity we used the augmented Dickey-Fuller, the ADF-GLS and the KPSS tests. The time series were in every cases zero order or first order cointegrated. After that the analysis continues in two ways: in the case of Poland, the Czech Republic and Slovenia we applied the Engle-Granger and the Johansen cointegration tests. For the other countries (Hungary, Slovakia) we used the VAR model. In the first group the cointegration relationship could not be proved so in the next step I used the VAR model. Based on the results in Hungary, the Czech Republic and Slovakia the energy consumption Granger causes the economic growth. In Poland this causality is present but is weak. In case of Slovenia we could not verify causality. The results partly confirm Chontanawat J. et al. [15]: he concluded (in spite of using per capita data) that in Hungary, the Czech Republic, Poland and Slovakia energy consumption causes economic growth. The difference for Poland is explained by the fact that Chontanawat J. et al. made their calculations for the time period of 1960-2000.

It can be stated that in East-Central Europe (the Czech Republic, Hungary, Poland, Slovakia, and Slovenia) there is a significant relationship between energy consumption and economic growth, with the exception of Poland and Slovenia. In Hungary, Slovakia, and the Czech Republic the energy consumption Granger causes the GDP in the long run, so the energy consumption can induce economic growth. In these nations the energy conservation policies have to be carefully considered, because such policies may retard economic growth.

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Аналіз причинно-наслідкового зв'язку енергоспоживання та економічного зростання на основі теореми Граджера

Після першої нафтової кризи країнам світу довелося зіткнутися зі спадом, викликаним високими цінами на нафту. Роль споживання енергії стала одним з основних елементів економіки. Багато досліджень присвячені зв'язку між споживанням енергії, економічним зростанням та ефективністю використання енергії. У цій статті автор має за мету проаналізувати причинність цього зв'язку.

Ключові слова: економіка енергетики, економетрія, причинно-наслідковий зв'язок Гранджера, споживання енергії, економічне зростання.

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Анализ причинно-следственной связи между энергопотреблением и экономическим ростом на основе теоремы Гранджера

После первого нефтяного кризиса странам мира пришлось столкнуться со спадом, вызванным высокими ценами на нефть. Роль потребления энергии стала одним из основных элементов экономики. Многие исследователи изучали связь между потреблением энергии, экономическим ростом и эффективностью использования энергии. Цель данной работы в анализе причинности этой связи.

Ключевые слова: экономика энергетики, эконометрия, причинно-следственная связь Гранджера, потребление энергии, экономический рост.

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