Relationship between GDP Growth and Oil and Natural Gas Consumption in EU Countries[1]

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Abstract

Crude oil and natural gas, as energy carriers forming the basis of European Union countries energy mix, are nowadays at the heart of policy measurements aiming at lowering their consumption with respect to environmental and security threats associated with them. In this article we used Granger causality test in order to examine whether there exists the possibility of negative consequence related to the implementation of such policy for economic development of the EU countries. Based on results we conclude the persistence of continuing existence of environmental risks in relation to restarting economic growth. The absence of more significant influence of oil and gas consumption on economic growth can be perceived positively.

Keywords: *Granger causality, oil, natural gas, energy policy*

JEL Classification: Q43

1. Introduction

Crude oil and natural gas has dominated to energy mix of almost every developed country in the world during last six decades. During this period the pace of economic development gained unprecedented speed and therefore the legitimate question of relationship between fossil fuels consumption and economic growth have aroused. The research aimed at this issue has become the important part of energy economics discipline. However the economic theory itself still does not provide the definite answer to this particular question of mutual relationship between the economic growth and oil and natural gas consumption.

The current mainstream neoclassical school of thoughts sees energy as one of many inputs that are subject to process of substitution, its availability is determined by price signals which basically eliminate any constraints that could scarce

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resources put on production in broader view (Sollow, 1974; Hotelling, 1931). This approach to energy is found flawed by so called ecological economists (Barleet and Gounder, 2010). We need to emphasize that this school of thoughts has been for a long time an integral part of economic studies as confirms work of S. Podolinsky (1883), F. Soddy (1925), F. Cottrell (1955) or later by N. Georgescu-Roegen (1975). The growing interest for further research was caused by *oil crisis* during 1970's and 1980's and previous economists were joined by R. Kümmel (1981), R. Ayres and B. Warr (2009), who enriched the previous thoughts for deeper mathematical analysis supporting their stand. Apart from this, oil crisis has clearly shown the importance of energy for economy as shortage of oil in western economies deepened the negative effect of economic system transformation of that time.

Multiple studies examining relationship between economic growth and energy consumption have led to contradictory conclusions. Correlation, causality and even results itself differ with respect to country, examined period or used methodology and variables. The controversy of empirical causality testing, respectively the intense of its importance therefore remains, although the need to understand mutual relationship between these two indicators is of a high importance because implications to economic policy are substantial.

Eddrief-Cherfi and Kourbali (2012) declared existence of 4 options, that can exist between variables describing energy consumption (EC) and economic growth (EG). These are: unidirectional causality running from EC to EG; unidirectional causality running from EG to EC; no causality; bidirectional causality.

According to Sa'ad (2010) the conclusion of unidirectional causality running from EC to EG implies that the country is energy dependent. Therefore in case of disruption of energy supplies or due to policy preventing further growth of energy consumption via higher taxes or any other forced limitation of energy consumption can negatively affect economic growth. On the other hand, unidirectional causality running from EG to EC indicates lower energy dependence. This implies that lack of energy or political steps aimed at savings in energy consumption should not negatively influence economic growth. Bidirectional causality between energy consumption and economic growth is known as *Feedback hypothesis* (Eddrief-Chefri and Kourbali, 2012) and indicates mutual interdependence of indicators development. To conclude, confirmation of causality non-existence is known as neutral hypothesis. In such case EC and EG are mutually independent and economic policy aimed at constraining the energy consumption can be implemented without impacts on economic growth.

Barleet and R. Gounder (2010) stated that from the creation of economic policy point of view, the most important causal relationship is that running from EC to EG, since energy supplies disruption or implementation of policy aimed at reduction of energy consumption can negatively influence the whole economy.

The goal of this paper is to identify mutual relationship between natural gas and oil consumption and economic growth between individual countries of EU. As EU long-run declared energy goal is to limit energy dependence of its economy and limit the fossil fuels usage *per se*, this is an important issue that needs to be addressed with respect to identification of even not so obvious challenges possibly resulting from this intention if successfully realized. To our best knowledge, testing for Granger causality on this set of EU countries and variables was not realized so far.

2. Literature Review on Causality Relationship between Energy Consumption and Economic Growth

The research of relationship between energy consumption and economic growth was firstly examined in seminal paper by Kraft and Kraft (1978), who used standard Granger causality test (Granger, 1969) to analyze the variables in case of United States for 1947 – 1974. They came to conclusion of existence of unidirectional causality heading from Gross National Product (GNP) to energy consumption indicating that growth of national income would lead to higher consumption of energy and policy aimed at reduction of energy consumption would not negatively affect economic growth of the country. The conclusions of this study were consequently contradicted by study of Akarca and Long (1979), who (by using different methodology) realized the research for USA for the period 1950 – 1968 and found the non-existence of causality between variables. Yu, Chow and Choi (1988) confirmed the non-existence of causal relationship between examined variables however discovered that energy consumption negatively affects the rate of employment. The research was obviously not limited to U.S. example only.

Yu and Choi (1985) used standard test of Granger causality to analyze causality between GNP and various sources of energy on the sample of multiple countries during 1954 – 1976. Their empirical study indicates unidirectional causality leading from economic development to energy consumption in case of Korea, from energy consumption to income for Philippines, no relationship was discovered in case of U.S., Poland and United Kingdom. Erol and Yu (1987) discovered unidirectional causality leading from economic growth to income for Western Germany, bidirectional for Italy and no evidence of this relationship was discovered in Great Britain, Canada and France. Apart from that, they came to conclusion of causality leading from energy consumption to economic growth for Japan during period of 1950 – 1982.

By using the method of cointegration and ECM (Error Correction Model) modification of Granger causality (Engle and Granger, 1987), Cheng (1995) discovered the presence of unidirectional causality running from economic growth to energy consumption in India. What more, Masih and Masih (1996) discovered the existence of cointegration between GDP and energy for India, Pakistan and Indonesia, although the cointegration was not confirmed in case of Malaysia, Singapore and Philippines. By applying Vector Error Correction Model (VECM) they discovered unidirectional causality going from energy consumption for Indonesia, unidirectional causality of opposite direction for India and bidirectional in case of Pakistan. They also applied standard Granger test for Malaysia, Singapore and Philippines with conclusion of non-existence of Granger causality. Pirlogea and Cicea (2012) examined the long term relationship between GDP/p.c. and energy consumption of various energy sources on aggregated level of EU-27 countries with conclusion of existence of causality between renewable energy sources, oil and GDP/p.c. The overview of results of some further studies in this field is summarized in Table 1.

T a b l e 1

Results of Studies Examining the Relationship between Energy Consumption (EC) and Economic Growth (EG)

Authors	**Year**	**Findings**	**Subject of research**
Kraft and Kraft	1978	EG → EC	USA
Yu and Choi	1985	EG → EC	South Korea
		EG ← EC	Philippines
Erol and Yu	1987	EG ~ EC	USA
Masih and Masih	1996	EG ~ EC	Malaysia
		EG → EC	India
		EG ← EC	Indonesia
		EG ↔ EC	Pakistan
Glasure and Lee	1998	EG ↔ EC	South Korea
		EG ↔ EC	Singapor
Asafu-Adjaye	2000	EG ← EC	India and Indonesia
		EG ↔ EC	Thainland & Philippines
Hondroyiannis et al.	2002	EG ↔ EC	Greece
Soytas and Sari	2003	EG → EC	Italy & Korea
		EG ← EC	Turkey, France, Germany & Japan
Paul and Bhattacharya	2004	EG ← EC	India
Lee	2005	EG ← EC	18 developing countries
Francis, Moseley and Iyare	2007	EG ← EC	Caribean countries
Bowden and Panye	2009	EG ← EC	USA
Sharma	2010	EG ← EC	Europe and Central Asia
Noor and Siddiqi	2010	EG → EC	South Africa
Magazzino	2011	EG ↔ EC	Portugal & Italy
Dergaides et al.	2011	EG ← EC	Greece
Žiković and Vlahinić-Dizdarević	2011	EG ← EC	Slovakia, Czech Republic, Austria
		EG → EC	Sweden, Denmark, Norway, Ireland
Fuinhas and Marques	2012	EG ↔ EC	Greece, Spain, Turkey
Záhradník	2012	EG → EC	Finland, France, Japan, Germany, Portugal
		EG ← EC	Iceland, Austria, Canada
		EG ↔ EC	Greece, Ireland, Iceland, India, Egypt
		EG ~ EC	Australia, Korea, USA, UK, Iran, Indonesia

Source: Pirlogea and Cicea (2012); Záhradník (2012); Žiković and Vlahinić-Dizdarević (2011).

3. Methodology

Our goal was aimed at finding the relationship between oil and natural gas consumption and economic growth of individual EU countries. We decided to realize the statistical testing on disaggregated group of countries long expressing common goal of creation the single energy market due to two pragmatic reasons. Firstly, the aggregated data for our testing in required quality were simply not available. Secondly and more importantly, this approach allowed us to compare the importance of oil and natural gas for economic growth of individual countries and therefore it could help us to answer the question whether the common energy policy aimed at ensuring the energy security via fossil fuels consumption reduction have same importance for all EU member states. Hypothetically, if in case of country „A“ we discover the causality running from oil and natural gas consumption to GDP and in case of country „B“ the neutrality hypothesis is valid, the energy policy aimed at improving of energy security situation will be more valued in county „A“ than in country „B“.

For our statistical testing in case of oil and natural gas consumption we used aggregated value of O&G in individual countries converted to units enabling aggregation of these two fuels. GDP growth (differenced and logarithm GDP values) is expressed in constant prices of 2005. As different sources provide time series of different length we decided to use various sources in order to make each individual time series long enough to obtain as robust results as possible.

The times series we used in our statistical testing were obtained (in case of O&G) from U.S. Energy Information Administration (EIA), BP Statistical Review 2012 and EU statistical portal Eurostat. The sources of time series on GDP were the database of World Bank – World Development Indicators (WDI), online statistical database of UN and Eurostat. In order to keep data coherent, we did not combine data from different sources for individual variables. The main criterion for selection the source of the data was the length of time series. In final step we did the statistical testing on 26 countries of EU as we did not manage to obtain the data for Cyprus in required quality. Before testing itself we transferred the data to their natural logarithm values. Using log transformation of GDP and energy consumption indicators as a proxy values when examining relationship between energy consumption and economic growth can be considered to be a standard procedure and was previously used for instance by Sa’ad (2010), Eddrief-Chefri and Kourbali (2012), Gelo (2009), Altunbas and Kapusuzoglu (2011) or Bekhet and Yusop (2009). To test the model we used EViews software package.

3.1. Causality

Granger causality is based on simple assumption that past could not have been affected by future. In other words, if we have two events („A“ and „B“) and event „A“ took place before event „B“, then event „A“ might had caused the occurrence of event „B“ but in no case *vice versa*. This causality then basically means that historical values of one variable can provide us information that could help to explain the development of some other variables (Granger, 1969). For our purposes this idea can be expressed in simple model consisting of two equations:

$$\Delta \ln GDP = \alpha_1 + \sum_{i=1}^{m} \beta_i \Delta \ln GDP_{t-i} + \sum_{j=1}^{n} \lambda_j \Delta \ln O\&G_{t-j} + \nu_t \quad (1)$$

$$\Delta \ln O\&G = \alpha_2 + \sum_{i=1}^{m} \gamma_i \Delta \ln O\&G_{t-i} + \sum_{j=1}^{n} \delta_j \Delta \ln GDP_{t-j} + \varepsilon_t \quad (2)$$

where

α_1, α_2 – constants;
ν_t, ε_t – white noise;
i, j – lag length;
t – time period.

The null hypothesis supposes the non-existence of causality. In case the estimators λ and δ are statistically significant, we reject the null hypothesis and accept the alternative hypothesis of the existence of Granger causality. In equation (1) O&G affects GDP in such case when current values of GDP can be predicted more precisely by including past values of O&G compared to alternative of not including them into equation. The equation (2) can be explained analogically. If present values of GDP can be predicted more precisely when past values O&G are included then O&G affects GDP.

3.2. Vector Error Correction Model

Engle and Granger (1987) proved that Granger causality (uni or both directional) between two variables exists in such case that two time series are cointegrated (variables have common stochastic trend). Testing for Granger causality on time series of the same integration ordered (except for that stationary I(0)) must therefore be done only after execution of cointegration analysis.[2] In case that cointegration assumption proved valid, VECM needs to be employed to do the testing for Granger causality. The advantage of such procedure lays in ability of VECM to capture, at the same time, both short term dynamics and via the estimator of Error Correction Term (ECT) also the state of long-run equilibrium between the time series of variables (Bekhet and Yusop, 2009). The ECT is basically one lag length value of residues obtained from cointegration regression equation and represents the long-run relationship between variables. The estimator of ECT has negative sign and it is also known as coefficient of short term adaptation. When its value is closing to 1 it means fast convergence to state of equilibrium and values close to 0 mean slow convergence. The model with ECT includes in it specification the variables in its original level value as well as its differentials, therefore after its correct specification it is considered to be a model delivering better prognosis results compared to others econometric models (Lukáčik and Pekár, 2006).

In our case the VECM can be defined as follows:

$$\Delta \ln GDP = \alpha_1 + \sum_{i=1}^{m} \beta_i \Delta \ln GDP_{t-i} + \sum_{j=1}^{n} \lambda_j \Delta \ln O\,\&\,G_{t-j} + \sigma_1 ECT_{t-1} + \nu_t \quad (3)$$

$$\Delta \ln O\,\&\,G = \alpha_2 + \sum_{i=1}^{m} \gamma_i \Delta \ln O\,\&\,G_{t-i} + \sum_{j=1}^{n} \delta_j \Delta \ln GDP_{t-j} + \sigma_2 ECT_{t-1} + \varepsilon_t \quad (4)$$

where

α_1, α_2 – constants;
λ, δ, β, γ – coefficients of short-run causality;
σ_1, σ_2 – coefficients of long-run causality;
ν_t, ε_t – residuals.

As we already noted, in such specified model 2 sources of Granger causality can be observed – long-run and short-run. Short-run unilateral causality running from O&G → GDP will be confirmed in equation (7), if value of $\lambda_j \neq 0$ and long-run causality is determined by condition $\sigma_1 \neq 0$. Unilateral causality in direction from GDP → O&G can be observed in equation (8). Short-run causality will depend on condition $\delta_j \neq 0$ and long-run on $\sigma_2 \neq 0$. To confirm the presence of causality, the estimators σ_1, resp. σ_2 must reach negative values and be statistically significant. In case both variables (O&G and GDP) mutually Granger causes each other we can say there exists bidirectional causal relationship.

To conclude, in case of cointegration existence the ECT must be incorporated into system of equations, otherwise the model specification might be incorrect or

[2] Generally, a variable is said to be integrated of order *d*, written by I*(d)*, if it turns out to be stationary after differencing *d* times. The variable is integrated of order greater than or equal to 1 is non-stationary.

might omit some sources of causality. In such case the Granger causality testing will be realized in accordance with VECM procedure. Otherwise in case of absence of cointegration the standard method of Granger causality testing needs to be applied (Altunbas and Kapusuzoglu, 2011).

4. Empirical Results

Testing for Granger causality requires data to be stationary. Stationarity in strict sense means that the joint statistical distribution of the time series variables never depends on time (Lukáčiková and Lukáčik, 2008). For practical research the time series can be considered stationary when their mean, variance and covariance do not depend on time. Economic time series often includes trend and are therefore often non-stationary with respect to mean. If this trend is linear simple first differencing data will restore stationarity. In order to establish the order of integration of the variables, we employed the conventionally used Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests. In case of ADF test we used Schwarz information criteria to select the lag length and in case of PP unit root test the Newey and West method (1987) was applied to choose the optimal lag lengths. When considering whether to confirm or reject the null hypothesis of unit root existence we used 5% level of significance. In order to conclude the variables are integrated I(1) we required both tests to yield results supporting such outcome. In case times series are integrated of the same order we continued along the VECM[3] methodology. Otherwise we applied the standard test of Granger causality.

4.1. Lag Length Selection

When testing for Granger causality, estimation of lag length is a crucial aspect. So far multiple studies have clearly shown that cointegration test, VECM and causality test are very sensitive to the selection of lag length. If chosen lag length is less or more than the true lag length the results are likely to be biased (Gelo, 2009). Eviews software tool, that evaluates optimal lag length on the basis of lowest values offers optimal lag lengths estimates under consideration according to the following criteria: LR – test statistic; FPE – final prediction error; AIC – Akaike information criterion; SC – Schwarz information criterion; HQ – Hannan-Quinn information criterion. In each individual case we considered Akaike information criterion and Schwarz information criterion to determine appropriate lag length.

[3] VECM could also used in case, when one time serie is integrated of order I(I) and second of order I(2). This can be considered as a statstical anomaly (Záhradník, 2012).

Table 2

Results of Unit Root Tests

Unit Root Tests:			ADF				Phillips-Perron			
			Level		1. difference		Level		1. difference	
Country	Period	Variable	t-stat.	p-value	t-stat.	p-value	t-stat.	p-value	t-stat.	p-value
Austria	1965 –	LGDP	–2.446	0.352	–5.992	0.000	–2.439	0.356	–5.973	0.000
	2012	LO&G	–3.168	0.103	–5.497	0.000	–3.086	0.121	–5.602	0.000
Belgium	1980 –	LGDP	–1.341	0.859	–4.640	0.001	–1.874	0.644	–4.628	0.001
	2012	LO&G	–3.053	0.135	–6.195	0.000	–3.440	0.064	–6.175	0.000
Bulgaria	1980 –	LGDP	0.743	0.870	–2.922	0.005	1.273	0.945	–2.931	0.005
	2012	LO&G	–2.486	0.332	–3.631	0.001	–1.950	0.606	–3.631	0.001
Czech	1990 –	LGDP	–1.693	0.718	–5.100	0.001	–3.982	0.025	–4.963	0.001
Republic	2012	LO&G	–1.254	0.632	–3.449	0.002	–1.306	0.608	–3.439	0.002
Denmark	1983 –	LGDP	–2.354	0.163	–4.034	0.019	–2.182	0.217	–3.910	0.025
	2012	LO&G	–0.538	0.475	–4.474	0.007	0.117	0.712	–4.597	0.005
Estonia	1992 –	LGDP	–2.360	0.386	–2.303	0.024	–1.952	0.591	–2.327	0.023
	2012	LO&G	–2.218	0.206	–4.993	0.000	–2.384	0.158	–4.996	0.000
Finland	1965 –	LGDP	–2.639	0.266	–4.298	0.001	–1.581	0.786	–4.261	0.002
	2012	LO&G	1.307	0.950	–5.604	0.000	0.802	0.882	–5.635	0.000
France	1965 –	LGDP	–2.401	0.374	–5.058	0.001	–2.327	0.412	–5.081	0.001
	2012	LO&G	1.654	0.975	–3.475	0.001	0.890	0.897	–3.352	0.001
Germany	1970 –	LGDP	–1.584	0.783	–5.219	0.000	–1.526	0.805	–5.105	0.000
	2012	LO&G	0.556	0.832	–5.401	0.000	0.556	0.832	–5.373	0.000
Greece	1965 –	LGDP	–2.608	0.279	–3.777	0.027	–1.865	0.657	–3.900	0.020
	2012	LO&G	–2.211	0.206	–5.488	0.000	–1.224	0.894	–5.519	0.000
Hungary	1965 –	LGDP	–2.284	0.434	–2.955	0.004	–2.333	0.409	–2.955	0.004
	2012	LO&G	–0.266	0.585	–4.881	0.001	0.887	0.897	–5.031	0.001
Ireland	1970 –	LGDP	–2.284	0.434	–2.955	0.004	–2.333	0.409	–2.955	0.004
	2012	LO&G	–0.266	0.585	–2.130	0.033	0.887	0.897	–3.252	0.002
Italy	1965 –	LGDP	–1.175	0.904	–6.632	0.000	–1.151	0.909	–6.684	0.000
	2012	LO&G	–3.033	0.134	–2.381	0.018	–2.809	0.201	–3.366	0.001
Latvia	1990 –	LGDP	–1.478	0.521	–2.653	0.011	–1.046	0.717	–2.496	0.016
	2011	LO&G	–2.752	0.228	–2.600	0.012	–2.898	0.183	–2.600	0.012
Lithunia	1990 –	LGDP	–0.395	0.894	–2.205	0.030	–0.866	0.780	–2.182	0.031
	2012	LO&G	–3.721	0.011	–4.237	0.016	–6.722	0.000	–4.237	0.016
Luxembourg	1980 –	LGDP	0.088	0.996	–3.811	0.007	–0.436	0.982	–3.865	0.006
	2012	LO&G	–1.647	0.751	–3.676	0.039	–1.338	0.860	–3.678	0.039
Malta	1980 –	LGDP	–0.027	0.994	–3.406	0.019	–0.729	0.962	–3.526	0.014
	2011	LO&G	–2.482	0.334	–7.248	0.000	–2.343	0.400	–7.248	0.000
Netherlands	1965 –	LGDP	–2.679	0.250	–3.929	0.019	–1.900	0.639	–3.942	0.018
	2012	LO&G	2.294	0.994	–3.425	0.001	1.259	0.945	–3.341	0.001
Poland	1970 –	LGDP	–1.649	0.755	–2.287	0.023	–1.657	0.753	–2.573	0.011
	2012	LO&G	1.229	0.942	–3.182	0.002	2.130	0.991	–3.131	0.003
Portugal	1965 –	LGDP	0.625	0.847	–2.631	0.010	3.517	1.000	–2.769	0.007
	2012	LO&G	–1.168	0.906	–3.471	0.056	–1.189	0.901	–6.897	0.000
Romania	1970 –	LGDP	0.755	0.873	–2.663	0.009	1.728	0.978	–2.515	0.013
	2012	LO&G	–0.962	0.295	–4.198	0.000	–0.739	0.390	–4.191	0.000
Slovakia	1984 –	LGDP	0.960	0.906	–2.433	0.017	1.681	0.975	–2.472	0.016
	2012	LO&G	–0.412	0.526	–6.453	0.000	–0.453	0.510	–6.435	0.000
Slovenia	1990 –	LGDP	2.236	0.991	–2.743	0.009	1.903	0.983	–2.748	0.009
	2011	LO&G	0.677	0.854	–4.412	0.000	0.639	0.846	–4.431	0.000
Spain	1965 –	LGDP	–2.115	0.524	–2.229	0.026	–2.272	0.441	–2.107	0.035
	2012	LO&G	–0.151	0.626	–1.999	0.045	1.982	0.988	–3.600	0.001
Sweden	1965 –	LGDP	–0.888	0.784	–5.275	0.000	–0.865	0.791	–5.158	0.000
	2012	LO&G	–0.556	0.870	–6.531	0.000	–0.763	0.820	–6.531	0.000
United	1965 –	LGDP	–0.880	0.786	–4.515	0.001	–0.818	0.805	–4.474	0.001
Kingdom	2012	LO&G	1.544	0.968	–5.265	0.000	1.209	0.940	–5.279	0.000

Source: Authors, based on EViews outputs.

4.2. Cointegration and Granger Causality Testing

Cointegration can be defined as the existence of long-run equilibrium between time series. In other words, it means that two or more variables have common trend. The idea of cointegration came from Engle and Granger (1987) who obtained a Nobel Prize for that (Bekhet and Yusop, 2009). They have proved that if two or more time series are individually integrated of the same order, but their liner combination can bring a lower order of integration, such time series are called cointegrated. We followed the Engle and Granger (1987) recommendation of a two-step procedure for cointegration analysis. In first step we estimated the long-run (equilibrium) equations:

$$\ln GDP = \alpha_0 + \alpha_1 \ln O\&\text{G} + v_t$$

and

$$\ln O\&\text{G} = \alpha_0 + \alpha_1 \ln GDP + u_t$$

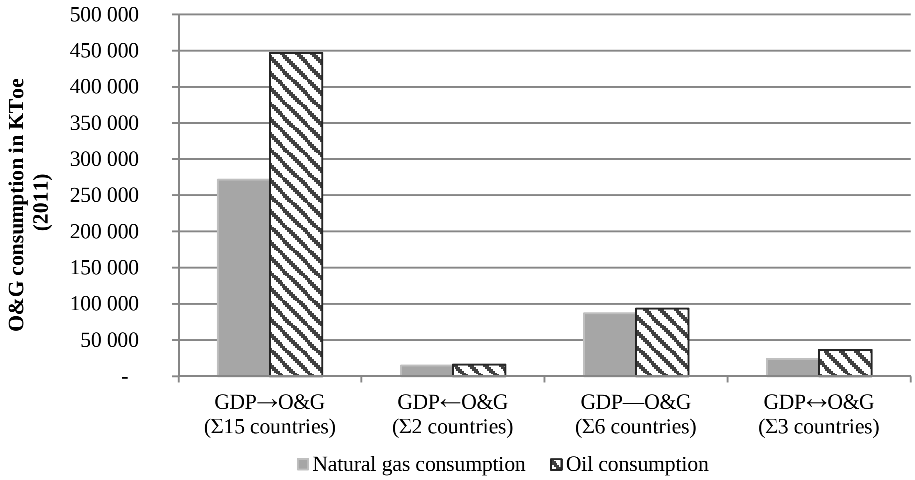
Afterwards in second step we tested the OLS (ordinary least squares) residuals from these equations (which can be considered as measure of disequilibrium) using ADF test, with the MacKinnon (1991) critical values adjusted for the number of variables, in order to determine whether they are stationary. In case Engle-Granger test confirmed cointegration between GDP and O&G, the examined variables have common stochastic trend and long-run relationship between them exists. In order to determine the direction of causality between variables we consequently used VECM. Wald test was used in order to determine the short-run causality.

5. Results

Statistical testing proved that consumption of oil and natural gas expressed as their aggregated combination can affect the GDP growth and *vice versa* GDP growth affects O&G consumption. Even though simple and expected, however important conclusion is that relationship between variables is not the same in all EU countries. Granger causality running in direction GDP → O&G was identified in case of 15 countries which were in 2011 responsible for 68% of EU's natural gas consumption and 75% of EU's oil consumption. Countries belonging to this group are Bulgaria, Estonia, Finland, France, Germany, Greece, Luxembourg, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden and United Kingdom. In almost all of these countries (except for Bulgaria and Greece) we observed long-run relationship. This means that so far the linkage between fossil fuels consumption and economic growth has not been interrupted and remains challenge for EU policies aimed both at boosting the economic growth and protecting environment. According to Žiković and Vlahinić-Dizdarević (2011) the explanation of this differs among countries on different level of economic development. In case of developed countries belonging into this group, it can be explained by *Jevons paradox* or so *called Rebound effect* (Gross, 2012). The growth of GDP affects the growth of oil and natural gas consumption as a result of cycle in which technology progress enabled decrease in energy consumption due to higher energy efficiency, but on the other hand the raising living standard – side effect of more efficient technologies – led to overall growth of energy consumption. In case of former Eastern bloc countries this causality can be explained by other process. The reason of this dependence is consequences of former orientation of economies towards large industries requiring extensive amount of energy during Soviet Union era. The collapse of this economic bloc caused that former soviet *satellite countries* lost both access to their markets and subsidized prices of energy – enablers of previous period of large industry boom. Decline in GDP and deindustrialization that followed led to lowering oil and natural gas consumption which was largely imported from Russia.

G r a p h 1

Summary of Granger Causality Testing



Source: Authors, based on tested model.

Causality running from O&G towards GDP was identified only in two countries – Denmark and Romania. These were responsible for approximately 3% of oil and 4% of natural gas consumption in EU in 2011. The obvious implication of such causality would be that forced interruption of oil and natural gas supplies or policies intended on reduction of oil and natural gas consumption could have negative impact on GDP growth. Further analysis though suggests that consequences might be only limited in these cases.

Table 3

Individual Results of Granger Causality Testing

Country	Cointegration	Tested Hypothesis		t-test(Long-run rel.)				Wald test (Short-run rel.)		Direction of GC
		H0	H1	Coef.	Std. Error	t-stat	P-value	χ^2-stat.	P-value	
Austria	Yes	GDP does not GC O&G	GDP GC O&G	–0.341	0.084	–4.050	0.000	2.582	0.461	GDP↔O&G
	Yes	O&G does not GC GDP	O&G GC GDP	0.020	0.017	1.170	0.246	18.107	0.000	
Belgium	Yes	GDP does not GC O&G	GDP GC O&G	–0.458	0.127	–3.600	0.001	0.015	0.901	GDP↔O&G
	Yes	O&G does not GC GDP	O&G GC GDP	–0.055	0.048	–1.163	0.250	7.888	0.005	
Bulgaria	No	GDP does not GC O&G	GDP GC O&G					3.259	0.055	GDP→O&G
	No	O&G does not GC GDP	O&G GC GDP					0.455	0.640	
Czech Republic	No	GDP does not GC O&G	GDP GC O&G					0.008	0.931	GDP−O&G
	No	O&G does not GC GDP	O&G GC GDP					0.220	0.644	
Denmark	No	GDP does not GC O&G	GDP GC O&G					0.085	0.774	GDP←O&G
	No	O&G does not GC GDP	O&G GC GDP					5.072	0.033	
Estonia	Yes	GDP does not GC O&G	GDP GC O&G	–0.510	0.151	–3.370	0.002	0.890	0.042	GDP→O&G
	No	O&G does not GC GDP	O&G GC GDP					0.485	0.496	
Finland	Yes	GDP does not GC O&G	GDP GC O&G	–0.188	0.045	–4.155	0.000	0.033	0.855	GDP→O&G
	No	O&G does not GC GDP	O&G GC GDP					0.431	0.515	
France	Yes	GDP does not GC O&G	GDP GC O&G	–0.238	0.054	–4.416	0.000	2.657	0.448	GDP→O&G
	No	O&G does not GC GDP	O&G GC GDP					1.415	0.254	
Germany	Yes	GDP does not GC O&G	GDP GC O&G	–0.263	0.084	–3.130	0.003	1.397	0.237	GDP→O&G
	No	O&G does not GC GDP	O&G GC GDP					0.686	0.413	
Greece	No	GDP does not GC O&G	GDP GC O&G					4.126	0.024	GDP→O&G
	No	O&G does not GC GDP	O&G GC GDP					1.256	0.296	
Hungary	No	GDP does not GC O&G	GDP GC O&G					1.869	0.168	GDP−O&G
	No	O&G does not GC GDP	O&G GC GDP					1.248	0.298	
Ireland	No	GDP does not GC O&G	GDP GC O&G					1.869	0.168	GDP−O&G
	No	O&G does not GC GDP	O&G GC GDP					1.248	0.298	
Italy	No	GDP does not GC O&G	GDP GC O&G					1.416	0.254	GDP−O&G
	No	O&G does not GC GDP	O&G GC GDP					0.886	0.457	
Latvia	Yes	GDP does not GC O&G	GDP GC O&G	–0.346	0.086	–4.026	0.000	0.081	0.776	GDP↔O&G
	Yes	O&G does not GC GDP	O&G GC GDP	–0.017	0.005	–3.773	0.001	0.281	0.596	
Lithunia	No	GDP does not GC O&G	GDP GC O&G					1.762	0.201	GDP−O&G
	No	O&G does not GC GDP	O&G GC GDP					0.007	0.9327	
Luxembourg	Yes	GDP does not GC O&G	GDP GC O&G	–0.602	0.184	–3.279	0.002	0.357	0.836	GDP→O&G
	Yes	O&G does not GC GDP	O&G GC GDP	0.151	0.101	1.492	0.142	4.136	0.126	
Malta	No	GDP does not GC O&G	GDP GC O&G					0.016	0.901	GDP−O&G
	No	O&G does not GC GDP	O&G GC GDP					1.130	0.297	
Netherlands	Yes	GDP does not GC O&G	GDP GC O&G	–0.277	0.063	–4.390	0.000	6.388	0.094	GDP→O&G
	Yes	O&G does not GC GDP	O&G GC GDP	0.012	0.010	1.195	0.236	4.548	0.208	
Poland	Yes	GDP does not GC O&G	GDP GC O&G	–0.367	0.120	–3.055	0.003	6.864	0.076	GDP→O&G
	Yes	O&G does not GC GDP	O&G GC GDP	0.132	0.078	1.703	0.094	4.875	0.181	
Portugal	Yes	GDP does not GC O&G	GDP GC O&G	–0.210	0.068	–3.108	0.003	1.989	0.159	GDP→O&G
	No	O&G does not GC GDP	O&G GC GDP					0.502	0.482	
Romania	No	GDP does not GC O&G	GDP GC O&G					2.387	0.107	GDP←O&G
	Yes	O&G does not GC GDP	O&G GC GDP	–0.074	0.026	–2.877	0.005	0.877	0.645	
Slovakia	Yes	GDP does not GC O&G	GDP GC O&G	–0.352	0.143	–2.461	0.018	7.997	0.018	GDP→O&G
	No	O&G does not GC GDP	O&G GC GDP					2.342	0.121	
Slovenia	Yes	GDP does not GC O&G	GDP GC O&G	–0.479	0.134	–3.564	0.001	7.767	0.005	GDP→O&G
	No	O&G does not GC GDP	O&G GC GDP					1.105	0.308	
Spain	Yes	GDP does not GC O&G	GDP GC O&G	–0.203	0.080	–2.530	0.014	0.686	0.953	GDP→O&G
	No	O&G does not GC GDP	O&G GC GDP					0.464	0.762	
Sweden	Yes	GDP does not GC O&G	GDP GC O&G	–0.185	0.066	–2.794	0.007	0.127	0.721	GDP→O&G
	No	O&G does not GC GDP	O&G GC GDP					0.075	0.785	
United Kingdom	Yes	GDP does not GC O&G	GDP GC O&G	–0.235	0.063	–3.719	0.000	1.941	0.164	GDP→O&G
	No	O&G does not GC GDP	O&G GC GDP					0.432	0.515	

Source: Authors, based on tested model.

While for Denmark the relationship was observed only in short-run and therefore having only limited implications for long term policies planning, the relationship in case of Romania seems to be of long-run nature. Such long-run relationship seems to prove valid as long similar result was identified also in paper by Georgantopoulos and Tsamis (2011). On the other hand a simple look at the O&G and GDP time series suggests that common trajectory of this development has disappeared in recent decades, however a detailed analysis (which is not intention of this paper) of this relationship would be needed in order to clarify it.

Neutral hypothesis of non-existence of causality was accepted in case of Czech Republic, Hungary, Ireland, Italy, Lithuania and Malta. The oil and natural gas consumption of these countries in 2011 accounted for 16%, resp. 22% of overall EU consumption. Since these countries have not shown any relationship between fossil fuels consumption and economic growth, the energy security strategy aimed at lowering consumption of these carbon fuels and their replacement by renewable energy sources could be adopted without any risks of negative consequences for economy. Moreover, such strategy would not only lower dependence on politically unstable exporters of hydrocarbons, but also have positive effect on their trade balances.

The hypothesis of bidirectional causality proved valid in 3 countries, namely Austria, Belgium and Latvia. While statistically significant long-run relationship GDP → O&G was identified in all cases, the long-run relationship in opposite direction was either not statistically significant or value of ECT does not suggested any strong relationship. However in case of Austria and Belgium short-run Granger causality O&G → GDP seems to affect mutual relationship. Such results seem acceptable as negative impacts of oil and natural gas supply interruption for economic growth in short-runs are one of the primary concerns for energy security policies to address.

Conclusion

As was already stated, the direction of causality between oil and natural gas consumption and economic growth has significant implications for creation of economic and energy policies. As CO_2 emissions reduction and increase in renewable energy usage are primary objectives of European Union energy policy, the activities aimed at restrictions of fossil fuel usage are likely to become more pressing in near future. Findings of our paper only confirms that impulses for growth of economy that EU seeks will likely negatively affect its environmental commitments since long-run linkage between economic growth and oil and natural gas consumption still seems to prove valid. Realization of this is and decision on what is currently more important for EU is basically seen also in EU environmental targets for period till 2030, when (planned) 40% reduction of greenhouse gases emissions is basically only 8 percentage points above so called business as usually scenario and binding renewable targets of 27% are as J. M. Barosso claimed the function of previous goal and only slightly above the 24% of business as usual trajectory.

On the other hand, the positive findings are non-existence of Granger causality for 6 countries and limited existence of Granger causality in direction O&G → GDP, suggesting that artificially set cap on consumption of oil and natural gas (as significant energy sources and CO_2 emitting energy carries) should not have major implications for economic growth of most of EU countries, at least in long term as signal countries where feedback hypothesis proved valid.

We are aware that due to the high level of aggregation our results are not are not absolutely conclusive but they clearly suggest that before creation of actual energy policy itself a more detailed study on causality on level of individual energy consuming segments and individual energy sources should be considered. Such approach would ensure that policy aimed at energy consumption reduction would only be focused on segments where this was safe from economic point of view.

At the same time we also note the main bias of (not only) our research which is variables selection. Variable describing total energy consumption is hence omitting one important fact – how much of consumed energy was actually effectively used (so called *exergy*). However in reality this exactly is the prime determinant defining the energy demand and can significantly alter the relationship between variables (Stafford, 2012) – explicitly written, if current energy efficient machinery was used in past the energy demand of that time would be much lower and *vice versa*, *ceteris paribus* nowadays oil and natural gas consumption would be significantly higher if older and less efficient technologies were used. This would certainly influence the relationship between energy consumption and economic growth. Such ideas were empirically elaborated by Ayres and Warr (2009), Kummel (1981) and even though they are not the prime subject of research they have significant influence on this discourse and must be taken into account at all times.

References

AKARCA, A. T. – LONG, T. V. (1979): Energy and Employment: A Time Series Analysis of the Causal Relationship. Resources and Energy, *2*, No. 2 – 3, pp. 151 – 162.

ALTUNBAS, Y. – KAPUSUZOGLU, A. (2011): The Causality between Energy Consumption and Economic Growth in United Kingdom. Ekonomska istraživanja, *24*, No. 2, pp. 60 – 67.

AYRES, U. R. – AYRES, H. E. (2010): Crossing the Energy Divide: Moving from Fossil Fuel Dependence to a Clean-Energy Future. New Jersey: Pearson Education, Inc., 256 p. ISBN 10 0-13-701544-5.

AYRES, U. R. – WARR, B. (2009): The Economic Growth Engine. Cheltenham, UK: Edward Elgar Publishing Ltd., 448 p. ISBN 978 1 84844 182 8.

BALÁŽ, P. a kol. (2011): Energetická bezpečnosť v období globalizácie a jej vyplyv na konkurencieschopnosť EÚ. Bratislava: Sprint dva, 278 p. ISBN 978-80-89393-71-1.

BARLEET, M. – GOUNDER, R. (2010): Energy Consumption and Economic Growth in New Zealand: Results of Trivariate and Multivariate Models. Energy Policy, *38*, No. 7, pp. 3508 – 3517.

BEKHET, A. H. – YUSOP, M. Y. N. (2009): Assessing the Relationship between Oil Prices, Energy Consumption and Macroeconomic Performance in Malaysia: Co-integration and Vector Error Correction Model. International Business Research, *2*, No. 3, pp. 152 – 175.

BP (2001 – 2012): BP STATISTICAL REVIEW OF WORLD ENERGY 2001 – 2012. Available at: <www.bp.com>.

BURKETT, P. – FOSTER, J. B. (2008): The Podolinsky Myth: An Obituary Introduction to 'Human Labour and Unity of Force', by Sergei Podolinsky. Historical Materialism, *16*, No. 1, pp. 115 – 161.

CHENG, B. (1995): An Investigation of Co-integration and Causality between Energy Consumption and Economic Growth. Journal of Energy Development, *21*, No. 1, pp. 73 – 84.

CLEVELAND, C. J. (1999): Biophysical Economics: From Physiocracy to Ecological Economics and Industrial Ecology. In: GOWDY, J. and MAYUMI, K. (eds): Bioeconomics and Sustainability: Essays in Honor of Nicholas Gerogescu-Roegen. Cheltenham, UK: Edward Elgar Publishing Ltd., pp. 125 – 154.

CLEVELAND, C. J. et al. (2000): Agregation and the Role of Energy in the Economy. Ecological Economics, *32*, No. 2, pp. 301 – 317.

COTTRELL, F. (1955): Energy&Society: The Relation between Energy, Social Change, and Economic Development. New York: McGraw Book Company. ISBN O-8371-3679-2.

EDDRIEF-CHERFI, S. – KOURBALI, B. (2012): Energy Consumption and Economic Growth in Algeria: Co-integration and Causality Analysis. International Journal of Energy Economics and Policy, *2*, No. 4, pp. 238 – 249.

EIA, INTERNATIONAL ENERGY STATISTICS: <www.eia.gov>.

ENGLE, R. F. – GRANGER, C. W. J. (1987): Co-integration and Error-correction: Representation, Estimation and Testing. Econometrica, *55*, No. 2, pp. 251 – 276.

EROL, U. – YU, E. (1987): Time Series Analysis of the Causal Relationships between U.S. Energy and Employment. Resources and Energy, *9*, No. 1, pp. 75 – 89.

EUROSTAT: <ec.europa.eu/eurostat/>.

GELO, T. (2009): Causality between Economic Growth and Energy Consumption in Croatia. In: Proceedings of Rijeka Faculty of Economics, Journal of Economics and Business, *27*, No. 2, pp. 327 – 348.

GEORGESCU-ROEGEN, N. (1975): Energy and Economic Myths. Southern Economic Journal, *41*, No. 3, pp. 347 – 381.

GEORGANTOPOULOS, G. A. – TSAMIS, D. A. (2011): The Relationship between Energy Consumption and GDP: A Causality Analysis on Balkan Countries. European Journal of Scientific Research, *61*, No. 3, pp. 372 – 380.

GONDA, V. (2013): Energetické záujmy Európskej únie a Ruska. Ekonomický časopis/Journal of Economics, *61*, No. 3, pp. 297 – 326.

GRANGER, C. W. J. (1969): Investigating Causal Relations by Econometric Models and Cross Spectral Methods. Econometrica, *37*, No. 3, pp. 424 – 438.

GROSS, CH. (2012): Explaining the (non-) causality between Energy and Economic Growth in the U.S. – A Multivariate Sectoral Analysis. Energy Economics, *34*, No. 2, pp. 489 – 499.

HATTERSLEY, M. (1988): The Doctrine of "Virtual Wealth". [Online.] Boston: National Economy. Available at: <http://nesara.org/articles/soddy88.htm>.

HOTELLING, H. (1931): The Economics of Exhaustible Resources. The Journal of Political Economy, *39*, No. 2, pp. 137 – 175.

KRAFT, J. – KRAFT, A. (1978): On the Relationship between Energy and GNP. Journal of Energy and Development, *3*, No. 2, pp. 401 – 403.

KÜMMEL, R. (1981): The Impact of Energy on Industrial Growth. Würzburg: Physikalisches Institut der Universität Würzburg.

LUKÁČIKOVÁ, A – LUKÁČIK, M. (2008): Ekonometrické modelovanie s aplikáciami. Bratislava: Vydavateľstvo Ekonóm. ISBN 978-80-225-2614-2.

LUKÁČIK, M. – PEKÁR, J. (2006): Kointegračná analýza v ekonometrii. [Online.] Available at: <http://www.fhi.sk/files/katedry/kove/veda-vyskum/prace/2006/Lukacik-Pekar2006.pdf>.

MacKINNON, J. G. (1991): Critical Values for Co-integration Tests. In: ENGLE, R. F. and GRANGER, C. W. J. (eds): Long-run Economic Relationships, Readings in Co-integration: New York: Oxford University Press, pp. 266 – 276.

MASIH, A. – MASIH, R. (1996): Energy Consumption and Real Income Temporal Causality, Results for a Multi-country Study Based on Cointegration and Error Correction Techniques. Energy Economics, *18*, No. 3, pp. 165 – 183.

OBADI, S. M. (2006): Do Oil Prices Depend on the Value of US Dollar? Ekonomický časopis/Journal of Economics, *54*, No. 3, pp. 253 – 265.

OBADI, S. M. – OTHMANOVÁ.S. (2012): Oil Prices and the Value of US Dollar: Theoretical Investigation and Empirical Evidence. Ekonomický časopis/Journal of Economics, *60*, No. 8, pp. 771 – 790.

PIRLOGEA, C. – CICEA, C. (2012): Econometric Perspective of the Energy Consumption and Economic Growth Relation in European Union. Renewable and Sustainable Energy Reviews, *16*, No. 8, pp. 5718 – 5726.

PODOLINSKY, S. (1883): Menschliche Arbeit und Einheit der Kraft. Die Neue Zeit, *1*, No. 9, pp. 413 – 24.

SA'AD, S. (2010): Energy Consumption and Economic Growth: Causality Relationship for Nigeria. Journal Compilation © 2010 Organization of the Petroleum Exporting Countries, *34*, No. 1, pp. 15 – 24.

SODDY, F. (1926): Wealth, Virtual Wealth And Debt. New York: George Allen&Unwin, 320 p.

SOLLOW, M. R. (1974): The Economics of Resources or the Resources of Economics. The American Economic Review, *64*, No. 2, pp. 1 – 14.

STAFFORD, J. (2012): Don't Fall for the Shale Boom Hype – Chris Martenson Interview. [Online.] [Cit. 2013-1-5.] Available at: <http://oilprice.com/Interviews/Dont-Fall-for-the-Shale-Boom-Hype-Chris-Martenson-Interview.html>.

UNSTAT: NATIONAL ACCOUNTS MAIN AGGREGATES DATABASE. Available at: <http://unstats.un.org/unsd/snaama/introduction.asp>.

WARR, B. – AYRES, R. (2012): Useful Work and Information as Drivers of Economic Growth. Ecological Economics, *73*, No. 15, pp. 93 – 102.

WB – WORLD DEVELOPMENT INDICATORS. Available at: <http://data.worldbank.org/data-catalog/world-development-indicators>.

YU, E. – CHOI, J. (1985): The Causal Relationship between Energy and GNP: An International Comparison. Journal of Energy and Development, *10*, No. 2, pp. 249 – 272.

YU, E. – CHOW, P. – CHOI, J. (1988): The Relationship between Energy and Employment: A Re-examination. Energy Systems and Policy, *11*, pp. 287 – 295.

ZÁHRADNÍK, M. (2012): Manažment a ekonomické súvislosti výroby a spotreby energie. [Diplomová práca.] Bratislava: Univerzita Komenského.

ŽIKOVIĆ, S. – VLAHINIĆ-DIZDAREVIĆ, N. (2011): Oil Consumption and Economic Growth Interdependence in Small European Countries. Ekonomska istraživanja, *24*, No. 3, pp. 15 – 32.