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Energy Consumption and Economic Growth in the European Union: A Causality Analysis

Introduction

The discussion about the relation of energy consumption and economic growth has been extensively researched, especially over the last years. When debating on the issue of energy consumption, it is vital to first indicate energy sources. Oil is still the most dominant fuel in the world as it accounted for over a third of all energy consumed in 2017. Coal is the second one with a market share of 27.6%, then there is natural gas with 23.4% share of world's total primary energy consumption. The last one is renewable power which had 3.6 % share of energy consumption and it has been constantly growing over the last years (BP 2018).

Since oil plays a crucial role in the energy production, it should be mentioned that oil prices have been subject to fluctuations due to some political and natural disasters, such as Iraq war or hurricanes (Mahadevan and Asafu-Adjaye 2007). Therefore, such phenomena raise questions about their negative impact on economic growth, especially for those countries that import oil. Fluctuations in oil price, and especially its increases, raise the issue of energy efficiency in the policy agenda. Mehrara (2007) shows that there is a one-way strong causal relationship from economic growth to energy consumption in oil-exporting countries. In the majority of oil-exporting countries, government maintains a policy of keeping domestic prices below the free market level. This results in a high level of domestic energy consumption. Thus, energy conservation through reforming energy price policy does not have a detrimental effect on economic growth for such countries.

It then poses a question whether the introduction of an energy saving policy is a factor inhibiting or stimulating economic growth. This issue was widely discussed in the literature on energy economics and the answer is often based on the

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direction of causality between energy consumption and economic growth (Mahadevan and Asafu-Adjaye 2007). It is assumed that GDP growth may have an impact on energy consumption. This comes from the fact that private households could increase expenses for energy-intensive activities, as well as from the fact that economic growth may increase energy production (Hunt and Evans 2011).

Energy expenditure is particularly important for countries that export energy, as they also use energy to extract and produce energy. Net energy exporters in the developing countries often use relatively cheap energy for home use, which is artificially maintained at low prices through tariffs and consumer subsidies, and this causes energy wastage. Thus, energy consumption does not transform into GDP growth, as it is in more efficient countries – the developed economies (Mahadevan and Asafu-Adjaye 2007).

This paper is an attempt to examine the causality between energy consumption and economic growth in the European Union (EU). The EU countries consist of both developing and developed economies, so analyzing the EU as a whole allows us to draw some general implications at the EU level, what then might be a starting point for further research in this field. This paper starts from a brief literature review on energy consumption and economic growth. Then, it continues with providing some notes on the methods applied in the research. The next section presents empirical results and their discussion. The last section is designed for a conclusion.

1. Literature review

Energy economics has always been a matter of many debates not only in academia, but also at the governmental level. Energy consumption, economic growth and very often carbon emission have been a matter of many studies (e.g. Lapinskienė et al. 2017, Soytas and Sari 2009, Wang et al. 2016). This is due to the fact that it concerns natural environment which is a vital part of life.

In 1865, William Stanley Jevons proposed the following scheme of thinking of energy-efficiency and energy consumption: he argued that economically justified improvements in energy efficiency will increase, not reduce, energy consumption. In short, this is the so-called Jevons paradox. The problem with using energy-efficiency as good environmental performance indicator was raised by York and McGee (2016). They argue that highly efficient nations, power plants, households and other entities use more absolute resources rather than a smaller amount. Sorrell (2009) argues that Jevons's paradox is very difficult to test empirically, however it could have a profound impact on energy and climate policy.

From the theoretical standpoint, there are four possible types of causal relations between energy consumption and economic growth, which are implied by the following: growth hypothesis, conservation hypothesis, feedback hypothesis and neutrality hypothesis (Apergis and Payne 2011, Ozturk 2010)upper middle, lower middle, and low income. All these types of causal relations are summarized by Chen et al. (2018). The first hypothesis assumes that energy consumption can stimulate economic growth both directly and indirectly as a complementary factor in relation to labor and capital in the production process. In addition, it implies that energy conservation policies might result in a decline in economic growth. Based on the Granger definition, from empirical standpoint, there is a causal relation running unidirectional from energy consumption to economic growth. Then, the conservation hypothesis implies a reverse relation that runs from economic growth to energy consumption. In this case, economic growth does have an influence on energy consumption, however energy consumption does not affect economic growth. The third one is the feedback hypothesis that points at a mutual relation between energy consumption and economic growth. In this scenario, energy conservation policies which decrease energy consumption can have an impact on economic growth. Similarly, any changes in economic growth may impact energy consumption. The last one, the neutrality hypothesis suggests no causality between energy consumption and economic growth. The rationale behind this hypothesis is that the cost of energy is relatively small as a GDP proportion, and therefore it is not perceived to significantly affect economic growth. Thus, energy conservation policies, likewise in the conservation hypothesis, do not have an impact on economic growth. However, Stern (2000) argues that the declining amount of energy consumption may cause a decrease in economic growth and an increase in the unemployment rate due to the fact that energy is perceived as an essential production factor. Other researchers note that energy consumption and economic growth are usually highly correlated, and energy is perceived as a basic production input that stimulates economic growth (Murad et al. 2019).

Bozoklu and Yilanci (2013)we employ a Granger causality test in the frequency domain which allows us to distinguish short (temporary examined 20 OECD countries, which are mostly perceived as developed economies, and brought interesting insights about the causality relationship in these countries. Based on a Granger causality test, they distinguished countries in which causality run from economic growth to energy consumption from countries with causality running from energy consumption to economic growth.

Hitherto, as Hondroyiannis et al. (2002) noted, most literature had contradictory and inconsistent results regarding the causal link between energy consumption and economic growth. This happened mainly due to the various institutional, structural and policy frameworks applied by the concerned countries, as well as methodological differences. Ghoshray et al. (2018) took one step further by identifying different approaches and methods used for the analysis of energy consumption and economic growth. Among different methods and models, Granger causality still remains popular in this type of research; however, considering its limitations (e.g. structural breaks of chosen variables), there is a growing trend to apply nonlinear techniques.

2. Methodology

The first step in our study is to investigate the stationarity of the processes. In this case, two unit root tests are used: the augmented Dickey–Fuller test (ADF) and

Kwiatkowski–Phillips–Schmidt–Shin test (KPSS). The ADF test is based on the autoregressive model (Dickey and Fuller 1979):

$$Y_t = \rho Y_{t-1} + \varepsilon_t, \quad t = 1, 2, \ldots \tag{1}$$

where: $Y_0 = 0$, $\rho \in R$, $\{\varepsilon_t\}$ – sequence of independent normal random variables with mean zero and variance σ^2. The process Y_t is stationarity when $|\rho| < 1$.

The KPSS test is based on the following model (Kwiatkowski et al. 1992):

$$y_t = \xi t + r_t + \varepsilon_t, \tag{2}$$

$$r_t = r_{t-1} + u_t, \tag{3}$$

where: t – deterministic trend, r_t – random walk process, ε_t – stationarity error, $u_t \sim iid(0, \sigma_u^2)$. The time series y_t is stationarity when $\sigma_u^2 = 0$.

For stationary time series the vector autoregression (VAR) model is estimated and verified. The model takes the following form:

$$\begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} = \begin{bmatrix} \alpha_{10} & \beta_1 \\ \alpha_{20} & \beta_2 \end{bmatrix} \cdot \begin{bmatrix} 1 \\ t \end{bmatrix} + \begin{bmatrix} \alpha_{11,1} & \alpha_{12,1} \\ \alpha_{21,1} & \alpha_{22,1} \end{bmatrix} \cdot \begin{bmatrix} Y_{1,t-1} \\ Y_{2,t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix}, \tag{4}$$

where: Y_1 – gross domestic product per capita growth in the European Union, Y_2 – final energy use growth in the European Union, t – deterministic trend.

Then, the Granger causality for the considered processes is tested. Finally, the impulse response analysis is conducted.

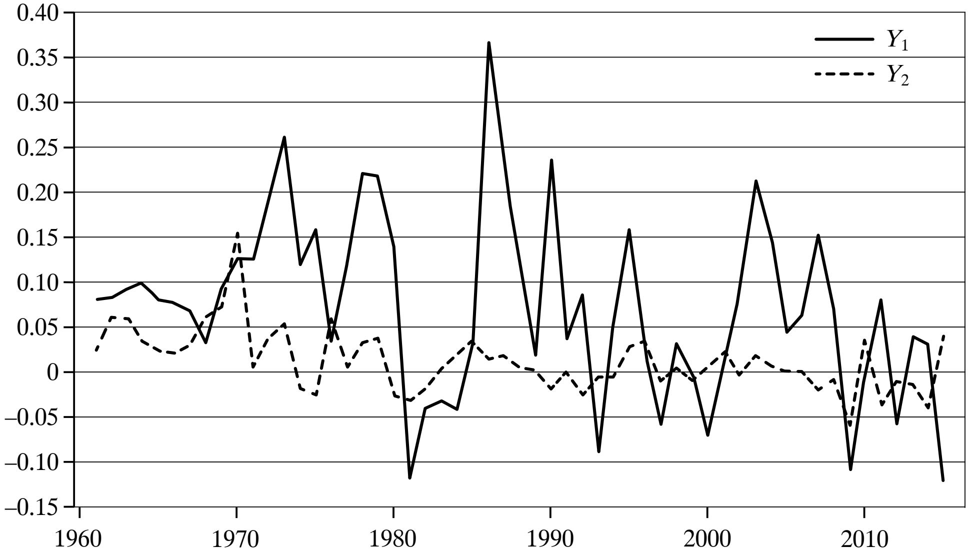
3. Empirical results

In the analysis, we use data from the period of 1960–2015, taken from the World Bank statistical database. The values of GDP per capita growth (Y_1) and energy use growth (Y_2) are derived from our own calculations. Figure 1 presents the picture of the considered time series. The revival of the European economy after World War II resulted in an increase in GDP per capita until the early 1980s. The last period of economic recovery in the EU countries was in 1980. Systemic changes in the early 1980s slowed down economic growth, as evidenced by the decline in the value of GDP per capita in the next several periods. After 1990, economic development of the EU countries was constantly fluctuating. After 2000, economic development was stopped by the financial crisis and the European economy has still been recovering from it.

Energy consumption is undoubtedly influenced by the GDP per capita growth. Higher energy consumption influences an increase in GDP, but this effect is only visible in the future, what is related to the production process. The Pearson correlation coefficient between Y_1 and Y_2 is 0.2176 (with p-value higher than 5%). It means that there is no simultaneous dependence between the considered processes. Similarly, the correlation between Y_2 and first lag of Y_1 is not statistically significant. However, the correlation between Y_1 at the time t and Y_2 at the time $t-1$ is statistically significant: the Pearson correlation coefficient takes the value

Figure 1

Time series Y_1 and Y_2 in the years 1960–2015



Source: authors' own elaboration with the use of Gretl software.

0.4044 (p-value for its significance test is equal to 0.0022). Based on these results, we formulate a presumption that the energy use growth can have an impact on the GDP per capita growth in the EU.

The first step of investigation is to check occurrence of the unit root in the time series characterizing the GDP per capita growth and the final energy use growth. We adopt the ADF test based on the models in three versions. The first version is without constant variable and without deterministic (ADF_1) trend, the second is with constant variable and without deterministic trend (ADF_2), and the third one is with both constant variable and deterministic trend (ADF_3). Moreover, we adopt the KPSS test.

Table 1 presents the results of unit root tests for the considered time series. For Y1, the constant variable is different than zero and statistically significant (at a 5% level of significance) and deterministic trend is not identified, so the ADF test in the second version and the KPSS test without deterministic trend are the best tools to conclude about the unit root presence (bolded results in Table 1 for Y_1). For Y_2, we identify the deterministic trend with the statistically significant constant variable. Therefore, we use the ADF test in the third version and the KPSS test with deterministic trend in order to conclude about the presence of the unit root in the Y_2 process (bolded results in Table 1 for Y_2).

For both time series, we reject the null hypothesis in the ADF test of non-stationarity at the 5% level of significance. For the KPSS test, the null hypothesis of stationarity cannot be rejected in levels. We conclude that the series are integrated of order zero (stationary).

Table 1

The results of unit root tests for variables Y_1 and Y_2

Test	Y_1		Y_2	
	Statistics value	*p*-value	Statistics value	*p*-value
ADF_1	–3.7596	0.0003	–3.1954	0.0014
ADF_2	**–4.8464**	**0.0001**	–3.3748	0.0119
ADF_3	–5.2336	0.0004	**–6.5387**	**0.0000**
KPSS	**0.4167**	**0.0700**	**0.1024**	**> 0.1000**

Source: authors' own calculations with the use of Gretl software.

Table 2

The results of estimation and verification of the vector autoregressive model

GDP per capita				
Parameter	Estimate	Standard error	*t*-statistics	*p*-value
α_{10}	0.0543	0.0361	1.5060	0.1384
$\alpha_{11,1}$	0.2933	0.1321	2.2210	0.0309
$\alpha_{12,1}$	0.8935	0.4304	2.0760	0.0430
β_1	–0.0005	0.0010	–0.5126	0.6105
Durbin–Watson statistics: 1.9342				
Energy use				
Parameter	Estimate	Standard error	*t*-statistics	*p*-value
α_{20}	0.0455	0.0124	3.6810	0.0006
$\alpha_{21,1}$	–0.0253	0.0453	–0.5599	0.5780
$\alpha_{22,1}$	0.0631	0.1474	0.4277	0.6707
β_2	–0.0011	0.0003	–3.3490	0.0015
Durbin–Watson statistics: 1.9594				
Autocorrelation test				
Rao *F* statistics: 0.9960 (0.4137)				

Source: authors' own calculations with the use of Gretl software.

In the literature, the direction of dependence between GDP growth and energy use growth is not clearly defined, thus we estimate and verify the vector autoregressive model for stationary time series. We choose the maximum lag for the VAR model based on the Bayesian Information Criterion (BIC) and it is the first lag chosen in our analysis.

Table 2 presents the results of the estimation and verification of the VAR model. In the first and second equation, the dependent variable is the growth of GDP per capita and energy use growth respectively. In the VAR model, we add the deterministic trend because of the observed tendency in energy use growth. Based on the model estimation, we conclude that the GDP per capita growth depends on the energy use growth and GDP per capita growth from the previous period (p-values for parameters $\alpha_{11,1}$ and $\alpha_{12,1}$ are less than 5% – parameters are statistically significant). Positive signs of these parameters show that the considered processes have a positive influence on GDP per capita growth. Moreover, the energy use growth depends on the tendency in time and falls – the sign of parameter β_2 is negative. Both equations do not show autocorrelation in residuals – Durbin–Watson statistics is close to 2.

Table 3

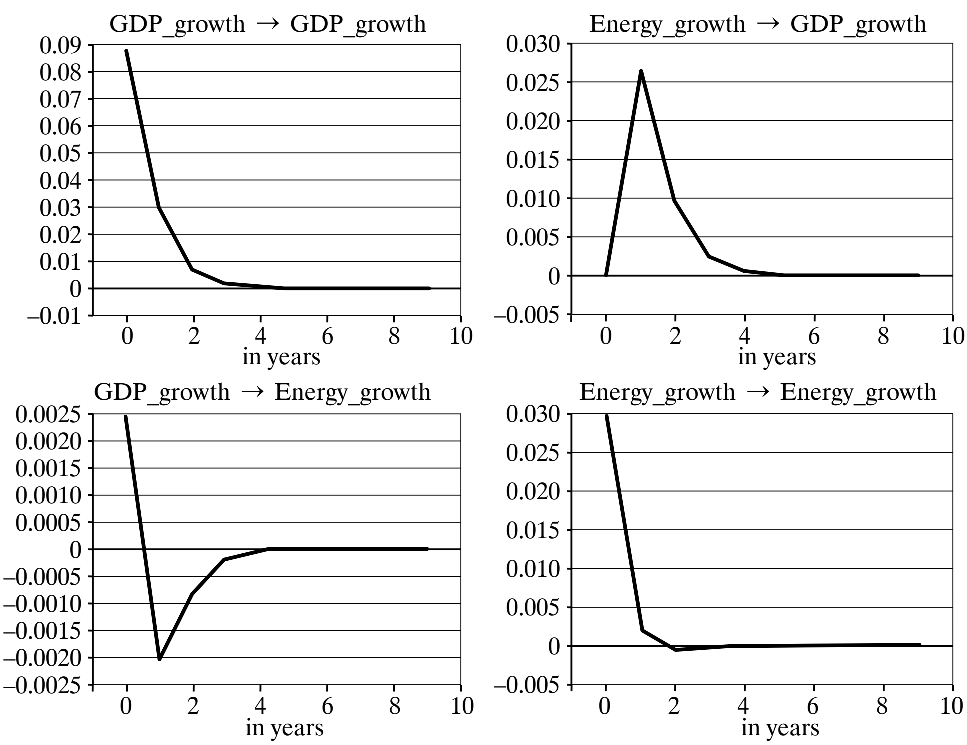
The results of Granger causality tests for series Y_1 and Y_2

Granger causality test			
$Y_2 \rightarrow Y_1$		$Y_1 \rightarrow Y_2$	
F statistics	p-value	F statistics	p-value
4.3102	0.0430	0.3135	0.5780

Source: authors' own calculations with the use of Gretl software.

Figure 2

The results of the impulse response analysis



Source: authors' own elaboration with the use of Gretl software.

In the next step of our investigation, we check the causality between the considered processes. Table 3 shows the results of the Granger causality test for series Y_1 and Y_2. In the first case, we check if the Y_2 process is the cause of the Y_1 process. The probability (p-value) in the Granger causality test is less than 5%, so we reject the null hypothesis and conclude that the process Y_2 is the cause for Y_1 process. It means that the energy use growth influences the GDP per capita growth. In the second case (Y_1 process is the cause for Y_2 process), we conclude that the GDP per capita growth does not influence the energy use growth. For the European Union, the relation between the considered processes has an unidirectional character.

Finally, we conduct the impulse response analysis. Figure 2 presents the results of this analysis. We focus only on the statistically significant relation in our previous analysis – influence of the energy use growth on the GDP per capita growth. Individual rise in the energy use growth (Y_2) at the time t causes a rise in the GDP per capita growth (Y_2), which in the subsequent periods falls to the initial level. In addition, the impulse related to economic growth has a positive effect on economic development in the next several periods, after which it slowly diminishes. The impact of an increase in energy consumption is associated with an increase in energy consumption in two consecutive years, after which it rapidly returns to the baseline.

4. Discussion

The problem of energy use and economic growth implies one more vital issue related to the ecological aspect of it in the form of the so-called sustainable development. We need to address a principle question: should economic growth be driven by energy consumption (or vice versa) and if yes, to what extent? No matter if it is a growth-, conservation- or feedback- hypothesis, there is a need to discuss the potential implication of their implications for the quality of life and sustainable development. In the up-dated version of the book *Limits to Growth*, there was the first scientific attempt at a computer simulation that forecasted a possible collapse of the global ecosystem (Meadows et al. 2004). About fifteen years later, first definition of sustainable development was formulated by the United Nations. Vezzoli et al. (2018) underline that energy is the largest industrial sector in the world. That is why it is important to speak about sustainable energy when discussing the issue of sustainable development. They emphasize the importance of energy in the daily life as it has a key impact on productivity, communication, health, education, etc. On the one hand, having an access to energy is a blessing and it leads to inequality and poverty reduction. However, currently energy system is mainly based on a fossil fuel scheme which is a limited resource, not available in every country. Therefore, it very often implies political and economic tensions among nations. Having an access to this resource simply means better possibilities for economic growth. Thus, energy access is vital for people's quality of life and any limitation to that access is seen as barrier to sustainable development.

On the top of that we have a global initiative by the United Nations called "Sustainable Development Goals". One of these goals is to ensure sustainable consumption and production patterns. The goal is about "promoting resource and energy efficiency, sustainable infrastructure, and providing access to basic services, green and decent jobs and a better quality of life for all", and its aim is to: "reduce future economic, environmental and social costs, strengthen economic competitiveness and reduce poverty" (United Nations 2019).

Considering all these issues and the result of our analysis, which indicates that in the EU countries in the considered period an increase in the energy consumption led to a rise in economic growth, there is a need to put more attention to sustainable development practices. In line with the sustainable development goals and the concept of sustainable consumption there should be a way to further develop without any loss for the environment and the quality of life. That must be a significant question for the policy makers, which is in line with the idea of sustainable consumption and production: how to do more and better with less.

This study confirms the general dependence of the EU's economic development on the volume of energy consumption. We believe that the quite simple methodology used in this research is its advantage. In addition, this model is very often used in the research on the relationship between energy consumption and GDP growth. The main drawback of this model is the fact that it only tests linear dependence. Therefore, in further analysis, the research will be enriched with an analysis of non-linear relationship between the processes examined. In addition, the study will be expanded to include an analysis of the relationship between GDP and energy consumption in individual EU countries.

Conclusion

In this paper, we analyzed the causal relationship between energy consumption and economic growth in the European Union in the period 1960–2015. The following variables were employed: GDP per capita growth and final energy use growth. The research showed that energy consumption in the EU had a significance influence on its economic growth. On a theoretical plane, such a relationship between energy consumption and economic growth is called growth hypothesis. An increase in the energy use leads to the increase in the GDP per capita in the next period. Hence, it means that changes in the energy use do not affect economic growth immediately. Further research on this topic may include a comparative analysis between more developed western economies and eastern ones; it may also take into consideration short-run and long-run causality. It can also apply different methodology, e.g. by treating such a relationship as nonlinear.

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ENERGY CONSUMPTION AND ECONOMIC GROWTH IN THE EUROPEAN UNION: A CAUSALITY ANALYSIS

Summary

Energy sector is one of the most important matters in the economic policies of the European Union since it has a significant impact on the quality of life and economic growth. The aim of this paper is to examine the causal relationship between energy consumption and economic growth in the European Union, based on the data from the period of 1960–2015. Using a Granger causality test, empirical results clearly indicate that energy consumption contributed to economic growth in the European Union. More precisely, an increase in energy consumption led to an increase in GDP per capita growth in the next period. This relationship is often called a growth hypothesis, which implies that energy consumption can stimulate economic growth. This research also analyzed the opposite relationship: the impact of economic growth on the change in energy consumption, which is called conservation hypothesis. However, this analysis has not proved such an impact in the considered period. The vector autoregression model (VAR) was used in the dependency analysis. In addition, an analysis of the impulse response shows the behavior of both processes as a result of a unitary, unexpected change in one of them.

Keywords: energy consumption, economic growth, Granger causality, European Union
JEL: C32, Q43

ZUŻYCIE ENERGII I WZROST GOSPODARCZY W UNII EUROPEJSKIEJ – ANALIZA PRZYCZYNOWOŚCI

Streszczenie

Sektor energetyczny jest jedną z najważniejszych kwestii w polityce gospodarczej Unii Europejskiej, ponieważ ma duży wpływ na jakość życia i wzrost gospodarczy. Celem tego artykułu jest zbadanie związku przyczynowego między zużyciem energii a wzrostem gospodarczym w Unii Europejskiej na podstawie danych z lat 1960–2015. Wyniki empiryczne uzyskane przy pomocy testu przyczynowości w sensie Grangera wyraźnie wskazują, że zużycie energii przyczyniło się do wzrostu gospodarczego w Unii Europejskiej. Mówiąc ściślej, wzrost zużycia energii prowadził do wzrostu PKB *per capita* w następnym okresie. Związek ten jest często nazywany hipotezą wzrostu, co oznacza, że zużycie energii może stymulować wzrost gospodarczy. Badanie to analizuje również odwrotną zależność: wpływ wzrostu gospodarczego na zmianę zużycia energii, co nazywa się hipotezą konserwacyjną. Analiza ta nie wykazała jednak, że wzrost gospodarczy nie wpływa na zużycie energii w UE w badanym okresie. W analizie badanej zależności wykorzystano wektorowy model autoregresji (VAR). Ponadto analiza odpowiedzi na impuls pokazuje zachowanie obydwu procesów wskutek jednostkowej, nieoczekiwanej zmiany jednego z nich.

Słowa kluczowe: zużycie energii, wzrost gospodarczy, przyczynowość w sensie Grangera, Unia Europejska

JEL: C32, Q43

ПОТРЕБЛЕНИЕ ЭНЕРГИИ И ЭКОНОМИЧЕСКИЙ РОСТ В ЕВРОСОЮЗЕ – АНАЛИЗ ПРИЧИННОЙ СВЯЗИ

Резюме

Энергетический сектор является одним из самых важных в экономической политике Евросоюза, так как имеет большое влияние на качество жизни и экономический рост. Целью настоящей статьи является изучение причинной связи между потреблением энергии и экономическим ростом в Евросоюзе на основе данных за период 1960 – 2015 гг. Эмпирические результаты, полученные с помощью теста причинности по Грэнджеру, отчетливо указывают, что потребление энергии способствовало экономическому росту в Евросоюзе. Точнее говоря, рост потребления энергии приводил к росту ВВП на душу населения в последующий период. Эта взаимосвязь часто называется гипотезой роста, что означает, что потребление энергии может стимулировать экономический рост. Это исследование анализирует также обратную связь: влияние экономического роста на изменение потребления энергии, что называется гипотезой сохранения. В свою очередь, не было доказано, что экономический рост не влияет на потребление энергии в ЕС в исследуемый период. Для анализа исследуемой взаимозависимости была использована векторная модель авторегрессии (VAR). Кроме того, анализ ответов на импульс позволяет описать поведение обоих процессов в условиях единичного, неожиданного изменения одного из них.

Ключевые слова: потребление энергии, экономический рост, причинность по Грэнджеру, Евросоюз

JEL: C32, Q43