Energy use, CO₂ emissions and economic growth – causality on a sample of SEE countries

Saša Obradović and Nemanja Lojanica

Macroeconomics, Faculty of Economics, University of Kragujevac, Kragujevac, Serbia

ABSTRACT
The primary aim of this study is to examine the causal relations between energy use, CO₂ emissions and economic growth, using the examples of Greece and Bulgaria. The empirical evidence on South Eastern Europe (SEE) considering this research is quite sparse, so there is merit in the analysis of the paper. Vector Error Correction model with annual data from 1980 to 2010 has been used in order to determine potential causality between the variables. The empirical findings indicate that, in the long run there is causality from energy and CO₂ emissions to economic growth in both countries. In the short run, there is no causality between energy and economic growth neither on Greece nor on Bulgaria. Based on the results of the analysis certain recommendations can be presented considering energy policy in the long run, through the orientation to saving energy could have negative impact on economic growth.

1. Introduction
In recent years, the issues of energy consumption and greenhouse gas emissions have become determinants of a particular interest in sustainable economic growth. The international circles advocate the thesis of ‘low carbon emissions and green growth’. This idea was also the basis of the Kyoto Protocol in 1997. This Protocol was signed, at the time, in order to reduce carbon-dioxide (CO₂) and other greenhouse gases. The two countries subjected to the analysis in this study, are Greece and Belgium. Greece has an area of 131,960 km² and a population of 11,090,000 people, while the Bulgaria has an area of 111,000 km² and 7,306,000 people. These countries are members of the European Union, so they are facing the task known as the ‘climate and energy package’, which, amongst other things, refers to a reduction of greenhouse gases and the fact that at least a fifth of the gross final energy consumption will come from renewable sources. In this lies the motivation for researching the relationship between these phenomena. According to Eurostat data (2014), the gross final energy consumption in Bulgaria that came from renewable sources was 16.3%, whereas in Greece it was 13.8%. Both Greece and Bulgaria signed the Kyoto Protocol in 1998. The
World Bank report on economic growth, energy consumption and greenhouse gas emissions suggests that these two countries are facing major challenges in meeting the objectives of energy efficiency, economic growth and gas emissions reduction.

The purpose of this study is to examine the causal relations among economic growth, energy consumption and carbon-dioxide emissions in Greece and Bulgaria by multivariate analysis. In addition, two more variables have been taken into consideration – gross fixed capital formation, and export as an indicator of trade openness – since both countries are included into integration flows and represent open economies. The following basic hypothesis of this paper is proposed.

Hypothesis 1: Higher energy use and lower CO₂ emissions lead to economic growth in these sample countries.

The VECM model has been used in order to determine long and short run causal relations among the variables. The time span of the monitoring is from 1980 to 2010. The structure of the paper is as follows: Section 2 gives a layout of the previous research on the subject of the economic growth and energy use relations. Due to the significance of the relations between these two variables, it has been pointed out four basic types of causal relations between these variables and their policy implications. This section also stresses the advantages of a multivariate approach over a bivariate one. In addition, previous studies preferred VAR model to the EKC one. Section 3 proceeds from the Cobb-Douglas production function, which is expanded by including energy, as the additional production factor. Furthermore, VECM model will be presented, because this model is essential in the determination of short and long-run causality among variables. Before the research results analysis in Section 4, it is important to mention that the Appendix shows descriptive statistics, the movements of the variables after converting to natural logarithms, model specification and impulse response function. Finally, the Conclusions provide a short discussion of the results and their policy implications.

2. Literature review

The idea of causal relations between energy use and economic growth has been interesting for a number of researchers. There are three important events that need to be considered. The first one is the Oil Shock that took place in the 1970s. During this period, Kraft and Kraft (1978) carried out pioneering research that dealt with energy and economic growth relations. They used data for the USA for the period of 1947–1974 and, observing GNP and energy consumption, established a unidirectional causal relation from GNP to energy consumption. Akarca and Long (1980) used the same method as Kraft, but obtained different results. The second important event was the Kyoto Protocol adoption in 1997, which bound developed countries to stabilise greenhouse gas emissions, and third one is the energy price increase due to the crude oil price increase. Since then, more studies on the subject have been carried out.

Payne (2010) points out that the problem of bias in omitting the variables present in bivariate approach (Dipendra, 2009; Narayan & Prasad, 2008) could be overcome by using a multivariate approach, which not only includes energy-economic growth relations but also the relations between the environment and economic growth in the model. Two types
of multivariate approaches were used in the previous studies, and they are the EKC (environmental Kuznets curve) hypothesis and the multivariate VAR model.

The EKC approach is based on the relation of the inverted U shape between various forms of pollution and income per capita. To be more precise, various forms of the environmental degradation are needed for the economic growth in the initial stages of economic development. Dinda (2004), in his review of EKC literature, points out that previous studies’ results are not consistent with the negative relation between environmental degradation and economic growth in the initial stages of development. In addition, the literature does not confirm the consensus about the level of income needed for a turning point, after which the ‘cleanness’ of the environment is very significant. The other type of multivariate approach is VAR methodology.

The empirical findings on the relationship between energy and economic growth are ambiguous. The reason for that can be found in the application of different econometric approaches: correlation analysis, regression analysis, bivariate causality, unit root tests, multivariate cointegration, panel cointegration, VECM model and the innovative accounting approach for detecting the direction of causality among variables (Chontanawat, Hunt, & Pierse, 2008). Payne (2010) and Ozturk (2010) presented a review of research studies that addressed the problems of causal relations between energy and economic growth. Their research shows that the literature does not provide a consensus about the direction of causality between the variables. Payne, in the end, emphasises that possible reasons for the lack of the consensus lie in the heterogeneous climate conditions, different consumption patterns, structure and level of the economic growth of the sample country, as well as in various econometric approaches.

In order to properly understand relations between energy consumption and economic growth, they can be categorised into four types of causal relations. Various forms of these relations can have significant policy implications. To date, based on the previous studies, these are the following.

1. **Unidirectional causality from energy consumption to economic growth, ‘so-called’ growth hypothesis.** According to this hypothesis, energy consumption plays a significant role (positive or negative) in economic growth, directly or indirectly through a production process as a complement to labour and capital. These findings appeared in the researches of Asafu-Adjaye (2000), Lee (2005), Akinlo (2008), Apergis and Payne (2009a, 2009b), Ismail and Mawar (2012), Jalil and Feridun (2014), Ucan, Aricioglu, and Yucel (2014), and Joo, Kim, and Yoo (2015). The policy implication of this hypothesis suggests that the orientation to saving energy could have a negative impact on economic growth.

2. **Bidirectional causality between energy consumption and economic growth; that is, the feedback hypothesis.** Energy consumption and economic growth affect each other at the same time, they are determined together in the positive direction. Ghali and El-Sakka (2004), Akinlo (2008), Jakovac (2013), Lin and Moubarak (2014), Mudarissov and Lee (2014), and Yuan, Xu, and Zhang (2014) corroborated this hypothesis in their researches. The implication of energy policy oriented toward efficient energy consumption can’t negatively affect economic growth.

3. **Unidirectional causality from economic growth to energy or conservation hypothesis.** It implies that the energy reduction policy will not negatively affect economic
growth, since economic growth of a country does not depend on energy. Therefore, it implies that the increase in GDP leads to the increase in energy consumption. Asafu-Adjaye (2000), Akinlo (2008), Yuan, Kang, Zhao, and Hu (2008), Zhang and Cheng (2009), and Magazzino (2015) corroborated this hypothesis. Nonetheless, it is possible for the growing economy to be burdened with political, infrastructural and poor resource management factors, which provokes less demand for goods and services and thus reduces energy consumption.

4. No causality between two variables, or the neutrality hypothesis. This views energy consumption as a small share of GDP, so it does not have a significant effect on economic growth. Furthermore, saving energy policy does not have a negative effect on GDP. Akinlo (2008) and Menegaki (2011) corroborated this hypothesis.

Let us now turn to some studies that have been carried out in the countries that are the subject of this analysis. The previous empirical studies in Greece examined the causality among energy demand and overall output and prices. Nonetheless, the studies that were carried out by Samouilidis and Mitropoulos (1984) and Donatos and Mergos (1989), did not consider problems with possible independence of the output and energy consumptions and their policy implications. Table 1 presents the results of some recent studies conducted in Greece and Bulgaria.

The analysis conducted by Hondroyiannis, Lolos, and Papapetrou (2002) ascertained long-run and short-run causality between energy consumption and economic growth. It also has significant policy implications since it has established that certain structural policies in the improvement of economic efficiency lead to energy conservation with no impact on economic growth. Tsani (2010) also pointed out the unidirectional causality from energy consumption to economic growth. The policy implications of this study are similar to those of the previous study. Ozturk and Acaravci (2010) examined the relation between economic growth and energy consumption in several countries, among which was Bulgaria. It was ascertained that in Bulgaria there is no long-run relationship between energy consumption and economic growth, indicating the importance of economic development of a country as a major determinant in implementation of certain energy policies. In order to make a step forward in relation to the cited papers in Table 1, it is very important to include CO₂ emission as an additional variable, because the analysis of the energy-CO₂-economic growth nexus is a very important topic in the field of energy economics, and therefore deserves further research. This will be new and original in our study. Wang and Feng (2015a) showed that redundancy in energy inputs and excessive emissions are the main sources of production inefficiency. In addition, Wang and Feng (2015b) showed that the energy, environmental and economic efficiency has begun to follow an ascending path (productivity has increased). Wang, Feng, and Zhang (2014) showed that technical progress is the key factor for energy efficiency.

### Table 1. Record of the empirical research for Greece and Bulgaria.

| Authors               | Period    | Methodology       | Empirical findings       |
|-----------------------|-----------|-------------------|--------------------------|
| Greece as a separate study |           |                   |                          |
| Hondroyiannis et al. (2002) | 1960–1996 | VECM, Granger causality | Hypothesis of growth     |
| Tsani (2010)          | 1960–1996 | Toda-Yamamoto     | Hypothesis of growth     |
| Bulgaria within the study of several countries |           |                   |                          |
| Ozturk (2010)         | 1980–2006 | ARDL, VECM        | Neutral hypothesis       |

Source: Own concept.
Zhang and Cheng (2009), and Soytas and Sari (2009) examined causality and its direction among economic growth, energy consumption and carbon dioxide. The empirical results of both studies are the same. Neither carbon dioxide emissions nor energy consumption lead to economic growth, which implies a carbon dioxide reduction policy as well as an energy saving policy without affecting growth. On the other hand, Ismail and Mawar (2012), Shahbaz (2012) and Shahbaz, Muhammad, and Tiwari (2012) examined the relations among energy, emissions and economic growth and their results corroborated the premise of long-run causality among variables. These studies raised some new questions considering environmental control by using energy efficient technologies.

3. Data and methodology

To derive an estimated model, a production function \( Y \) is presented as a function of capital stock \( K \) and labour \( N \), as follows:

\[
Y = f(K, N) \tag{1}
\]

Previous studies (Ismail & Mawar, 2012) include energy, \( E \), as the third factor of production function, thus equation (1) is augmented to be:

\[
Y = f(K, E, N) \tag{2}
\]

For modelling purposes, in this paper a Cobb-Douglas production function has been used:

\[
Y = K^a E^b N^c \tag{3}
\]

where \( a, b \) and \( c \) represent output elasticity to changes in capital, energy and labour and where, \( a + b + c = 1 \). We convert equation (3) into logarithms and scaling it with labour to produce per labour variables. The empirical equation is modelled as follows:

\[
LYP = c + aLKP + bLEP + dLCP + eLXP + \epsilon_i \tag{4}
\]

where \( LYP \) represents gross domestic product per capita, \( LKP \) represent gross fixed capital formation per capita, and \( LEP \) represents energy use per capita. The equation includes two new variables \( LCP \) and \( LXP \). \( LCP \) denotes per capita greenhouse gas (GHG) emissions. \( LCP \) is included into the model to measure the effects of the environment on economic growth. Greece and Bulgaria are very open economies and the openness indicator is also considered. To measure the trade effect, we use a proxy of export variable scaled by labour, \( LXP \), to be inserted in the model. Finally, \( \epsilon_i \) is the error term assumed to be normally distributed with zero mean and constant variance. A very similar methodological frame and theoretical analysis were used by Shahbaz (2012) and Shahbaz et al. (2012). Data on gross domestic product, capital, energy, emissions and exports are annual and they are taken from World Development Indicators (2014) for the period of 1980–2010. For the ease of comparability of data, output, capital and exports are expressed in constant 2005 US$. Ozturk and Acaravci (2010) used data in constant US$ in their research of causality between energy and GDP. Energy has been measured as kilos of oil equivalent. Emissions are expressed as \( \text{CO}_2 \) emissions in metric tonnes (\( \text{CO}_2 \) emissions figures are available, unlike the other six types of GHG emissions). Earlier researchers, Ang (2008), Soytas and Sari (2009), Zhang and Cheng (2009), Hamit-Haggar (2012) and Ismail and Mawar (2012) used \( \text{CO}_2 \) as an emission factor. According to European Environmental Agency data, in the total of GHG emissions, \( \text{CO}_2 \)
emission is 77.6% in Bulgaria and 86.5% in Greece (Eurostat, 2014). For statistical reasons, such as avoiding heteroscedasticity, all the variables are expressed in logarithmic form.

This paper used VECM methodology. The following part gives details of the performed operations. First, the stationarity of the variables has been examined, followed by error correction terms. In addition, we have examined the effects of transitory and permanent shocks to the movement of the endogenous variables through the impulse response function (IRF).

The main prerequisite for using Johansen’s (1991, 1995) approach is examining the stationarity of the variables. Johansen’s approach allows determination of causal relations among variables, but it has two preconditions. The first is for variables to be non-stationary in levels and the other is to be integrated of the same order. Purposefully, unit root tests have been used: the ADF test (Dickey & Fuller, 1979) and the KPSS test (Kwiatkowski, Philips, Schmidt, & Schin, 1992), without structural breaks, and Zivot and Andrews (1992) test with one structural break.

The ADF test starts from \( H_0: \) a variable has a unit root (non-stationary). On the other hand, KPSS tests \( H_0: \) a variable is stationary. The Zivot-Andrews test starts from \( H_0: \) variable has a unit root with a structural break. The next step is determination of the cointegration equations or ranks. Trace and maximum eigenvalue statistics are used to determine ranks. If variables are cointegrated, that is if they share stochastic trend, then the VECM model can be used since, in the long-run, variables move together (long-run relationship). When the VECM model is applied, variables convert into first difference. The following equation provides the vector formula:

\[
\Delta y_t = \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + \varepsilon_i
\]  

The number of endogenous variables in this case equals 5, therefore \( y_t \) is a 5×1 vector for endogenous variables (\( LYP, LKP, LEP, LCP \) and \( LXP \)) respectively. \( \Delta \) is a symbol of the first difference operator, the exponent \( \Pi y_{t-1} \) denotes the error correction term and it can be calculated with the product of parameters \( \alpha \) and \( \beta \), where \( \alpha \) is vector of the error-correction coefficient and estimates the long-run equilibrium, whereas \( \beta \) is a vector of cointegration parameters, while \( r \) is the number of cointegration equations. These are, therefore, 5×\( r \) parameters matrices. \( \Gamma_i \) for \( i=1, 2, ..., p-1 \) is a matrix of parameter 5×5, and \( \varepsilon_i \) is 5×1 vector of the residual. This equation can be represented as follows:

\[
\Delta y_t = \alpha (\beta y_{t-1} + \mu) + \sum_{i=1}^{p-1} \gamma_i \Delta y_{t-i} + \gamma + \varepsilon_i
\]  

Since the VECM model provides information for both, short and long-run causality, it is important to point out the importance of determining the parameters. The first addend in the equation refers to the error correction term and it indicates the existence of long-run causality between variables. The second addend refers to short-run causality. The paper examines short-run causality by using the Wald test. Finally, using the generalised impulse response function we have done a short-run and a long-run causality verification.
4. Empirical results

The Appendix (Table A1) provides descriptive statistics for all variables before converting to the natural logarithm for both countries. In addition, the Appendix shows a graphic presentation of the movement of the variables after converting to the natural logarithm (Figures A1 and A2) and, on the basis of these charts in both countries, it is clear that there are a trend and co-movement in variables, and the series follow certain trend patterns. The results from Table 2 of the unit root tests indicate that $LYP$, $LKP$, $LEP$, $LCP$ and $LXP$ are not stationary in levels for Bulgaria and Greece for the ADF test. For Greece, it is also the case for the KPSS test. However, the results for Bulgaria show the null hypothesis in KPSS is accepted for $LKP$ and $LXP$ in levels for constant. This problem has been overcome by using structural breaks. Structural breaks are given in brackets in Table 2. Accordingly, they enable variables to move from the stationary trend. Since all of the variables have been integrated of the same order, that is they are not stationary in levels, all conditions are met to implement the VECM model.

Since optimal lag selection is of a great importance for cointegration tests, three diagnostic test have been performed, in order to determine whether 2 is the optimal lag in Greece and Bulgaria. These tests are the VAR test of serial correlation LM, the VAR test of residual normality and the heteroscedasticity test (Tables A2 and A3). For VAR (2) null hypothesis of no series correlation of the residuals is accepted, then so is homoscedasticity, along with the hypothesis of the existence of multivariate normality of residuals for skewness, kurtosis

Table 2. Unit root test results – Greece and Bulgaria.

| Variable | Country: Greece |  | Constant | Constant with trend | Constant | Constant with trend | Constant | Constant with trend |
|----------|-----------------|---|-----------|---------------------|----------|---------------------|----------|---------------------|
| $LYP$    |                 |   | $-1.31(1)$ | $-1.98 (1)$         | $0.64**$ | $0.16**$            | $-2.95(2000)$ | $-2.35(1992)$      |
| $LKP$    |                 |   | $-0.79 (1)$ | $-2.18 (1)$         | $0.55**$ | $0.15**$            | $-2.97(1999)$ | $-2.11(1988)$      |
| $LEP$    |                 |   | $-1.78 (1)$ | $0.12 (1)$          | $0.68**$ | $0.16**$            | $-1.13(1987)$ | $-2.25(2005)$      |
| $LCP$    |                 |   | $-1.96 (1)$ | $-0.14 (1)$         | $0.66**$ | $0.17**$            | $-1.30(1987)$ | $-2.70(2005)$      |
| $LXP$    |                 |   | $-0.53 (1)$ | $-2.41 (1)$         | $0.67**$ | $0.13**$            | $-3.80(1997)$ | $-3.04(1999)$      |
| $D(LYP)$ |                 |   | $-3.39 ***(1)$ | $-3.81**(1)$         | $0.20$   | $0.13$              | $-5.23(1995)*$ | $-5.51(2003)*$    |
| $D(LKP)$ |                 |   | $-3.91 ***(1)$ | $-3.71**(1)$         | $0.18$   | $0.18$              | $-4.75(1995)*$ | $-5.15(2003)*$    |
| $D(LEP)$ |                 |   | $-4.13 *(1)$ | $-4.92**(1)$         | $0.37$   | $0.11$              | $-5.35(1996)*$ | $-5.65(2004)*$    |
| $D(LCP)$ |                 |   | $-4.80 *(1)$ | $-5.75**(1)$         | $0.42$   | $0.16$              | $-4.95(1997)*$ | $-5.22(2005)*$    |
| $D(LXP)$ |                 |   | $-4.88**(1)$ | $-4.81**(1)$         | $0.11$   | $0.10$              | $-5.45(2001)*$ | $-5.78(1997)*$    |

| Variable | Country: Bulgaria |  | Constant | Constant with trend | Constant | Constant with trend | Constant | Constant with trend |
|----------|-------------------|---|-----------|---------------------|----------|---------------------|----------|---------------------|
| $LYP$    |                   |   | $-0.66(1)$ | $-1.68(1)$          | $0.50**$ | $0.15**$            | $-3.46(1990)$ | $-3.96(1996)$      |
| $LKP$    |                   |   | $-1.45(1)$ | $-1.70(1)$          | $0.25$   | $0.16**$            | $-3.81(1990)$ | $-3.76(1990)$      |
| $LEP$    |                   |   | $-1.18(1)$ | $-1.87(1)$          | $0.55**$ | $0.13**$            | $-4.18(1991)$ | $-4.54(1991)$      |
| $LCP$    |                   |   | $-1.14(1)$ | $-2.11(1)$          | $0.57**$ | $0.13**$            | $-4.31(1991)$ | $-3.85(1991)$      |
| $LXP$    |                   |   | $-1.88(1)$ | $-1.61(1)$          | $0.27$   | $0.15**$            | $-1.78(2006)$ | $-3.91(2006)$      |
| $D(LYP)$ |                   |   | $-2.87***(1)$ | $-3.92**(1)$         | $0.17$   | $0.11$              | $-4.91(1989)*$ | $-5.16(1989)*$    |
| $D(LKP)$ |                   |   | $-3.10**(1)$ | $-3.65**(1)$         | $0.18$   | $0.10$              | $-5.01(1998)*$ | $-5.10(1998)*$    |
| $D(LEP)$ |                   |   | $-4.48**(1)$ | $-4.39**(1)$         | $0.08$   | $0.07$              | $-4.97(2000)*$ | $-5.78(1993)*$    |
| $D(LCP)$ |                   |   | $-5.92**(1)$ | $-5.80**(1)$         | $0.09$   | $0.09$              | $-5.48(2001)*$ | $-6.14(1993)*$    |
| $D(LXP)$ |                   |   | $-3.54**(1)$ | $-3.63**(1)$         | $0.16$   | $0.08$              | $-5.14(1992)*$ | $-5.76(1992)*$    |

Notes: *1% of significance level; **5% of significance level. ***10% of significance level, length of lag for ADF test is shown in brackets based on Schwarz information criterion (SIC). The KPSS test is based on the Newey-West method, and the method of spectral estimation is based on the Bartlett method. Structural breaks for the Zivot-Andrews test are given in brackets; lag length is based on Akaike information criterion (AIC).

Source: Author’s calculations.
and the Jarque-Bera test. For that reason, the optimal lag selection is set to 2. The following step presents the results of Johansen’s cointegration test. For the determination of maximum cointegration rank \(r\), trace and maximum eigenvalue statistics have been used.

The results from Table 3 show that for Bulgaria, \(r=2\) and for Greece, \(r=1\). Therefore, two cointegration equations appear in Bulgaria and one in Greece. With the first, the restriction is \(LYP=0\) and \(LKP=1\), whereas with the second equation the restriction is \(LYP=0\) and \(LKP=1\), in Bulgaria. These restrictions imply a long-run linkage between \(LYP\) and \(LCP\), \(LXP\) and \(LEP\), as well as \(LKP\) and \(LEP\), \(LCP\) and \(LXP\), while in Greece long-run linkage is between \(LYP\) and \(LKP\), \(LEP\), \(LCP\) and \(LXP\). Before performing long and short-run causality it is necessary to specify the model (Table A4). Therefore, the values of \(R^2\) and \(F\) statistics show the model fit the data well. In the case of LM serial correlation and homoscedasticity of the residual, null hypotheses are accepted, just as in the normal distribution. The Wald test has been used to determine the existence and direction of short-run causality between the variables. Short run Granger causalities are determined by Wald statistics for the significance of the coefficients of the series. Table 4 presents the short-run effect of the variables to each other.

### Table 3. Johansen’s cointegration test: Greece and Bulgaria VAR(2).

| Maximum rank | Trace statistics | 5% critical value | Maximum eigenvalue statistics | 5% critical value |
|--------------|------------------|-------------------|-------------------------------|-------------------|
| 0            | 109.7058         | 69.8188           | 62.60378                      | 33.87687          |
| 1            | 47.10204         | 47.85613          | 25.72596                      | 27.58434          |
| 2            | 21.37608         | 29.79707          | 10.68077                      | 21.13162          |
| 3            | 10.69531         | 15.49471          | 7.211995                      | 14.26460          |

Greece

Bulgaria

| Maximum rank | Trace statistics | 5% critical value | Maximum eigenvalue statistics | 5% critical value |
|--------------|------------------|-------------------|-------------------------------|-------------------|
| 0            | 115.2703         | 69.81889          | 53.52767                      | 33.87687          |
| 1            | 61.74263         | 47.85613          | 31.97290                      | 27.58434          |
| 2            | 29.76973         | 29.79707          | 16.12280                      | 21.13162          |
| 3            | 13.64693         | 15.49471          | 7.168591                      | 14.26460          |

Note: Linear trend and unlimited constant included in the model.
Source: Author’s calculations.

### Table 4. Wald test results of short-run causality.

| Dependent variable | Independent variable | Country: Greece | | | Country: Bulgaria | | |
|--------------------|----------------------|-----------------|---|---|-----------------|---|---|
| LYP                | LYP                  | 0.20            | 2.92 | 3.37 | 2.44 |  |
| LKP                | 5.98*+               | 0.22            | 0.93 | 1.37 |  |  |
| LEP                | 4.28                 | 8.17**+         | –    | 3.33 | 0.25 |  |
| LCP                | 5.82*+               | 13.28**+        | 5.89 | –    | 2.38 |  |
| LXP                | 2.45                 | 13.06**+        | 2.08 | 4.93*− | – |  |

Country: Bulgaria

| Dependent variable | Independent variable |  |  |  |  |
|--------------------|----------------------|---|---|---|---|
| LYP                | –                    | 2.78 | 3.01 | 2.22 | 3.57 |
| LKP                | 38.15*+              | –   | 12.05*− | 2.83 | 4.75*+ |
| LEP                | 3.19                 | 1.92 | –    | 6.61*− | 6.60*+ |
| LCP                | 4.82*+               | 5.85*− | 2.03 | –    | 19.73*+ |
| LXP                | 9.45*+               | 1.90 | 0.94 | 0.26 | – |

Notes: The values in the columns refer to the Chi-squares statistics, while *Denote the existing causality, + and − the sign of causality.
Source: Author’s calculations.
The results show different causal relations between the variables in these two countries. First, in Greece, unidirectional short-run causality is present from \( \Delta \text{LYP} \) to \( \Delta \text{LKP} \) and \( \Delta \text{LCP} \), from \( \Delta \text{LKP} \) to \( \Delta \text{LEP}, \Delta \text{LCP} \) and \( \Delta \text{LXP} \), as well as from \( \Delta \text{LCP} \) to \( \Delta \text{LXP} \). It is interesting to point out that in the short run higher carbon dioxide emissions decrease exports. That is in accord with the foreign countries’ intention of reducing import of the products whose production degrades the environment. In Bulgaria, it is found that \( \Delta \text{LYP} \) positively affects \( \Delta \text{LKP}, \Delta \text{LCP} \) and \( \Delta \text{LXP} \), \( \Delta \text{LKP} \) negatively affects \( \Delta \text{LCP} \), \( \Delta \text{LEP} \) negatively affects \( \Delta \text{LKP} \), \( \Delta \text{LCP} \) negatively affects \( \Delta \text{LEP} \), \( \Delta \text{LXP} \) positively affects \( \Delta \text{LKP}, \Delta \text{LEP} \) and \( \Delta \text{LCP} \). Those short run signs contradict the long-run relationships presented by the error-correction equations. As a result of the VECM model applied in the first differencing series, Table 5 represents long-run equations and the value of adjustment parameter (error correction term). In the case of Greece, for the \( \Delta \text{LYP} \) equation, the adjustment parameter is statistically significant, suggesting that, in the long-run, \( \Delta \text{LKP}, \Delta \text{LEP}, \Delta \text{LCP} \) and \( \Delta \text{LXP} \) cause \( \Delta \text{LYP} \). The adjustment coefficient indicates a slow adjustment to the long run with an estimated value of \(-0.17\). From the co-integration equation it is clear that \( \Delta \text{LKP}, \Delta \text{LEP} \) and \( \Delta \text{LXP} \) positively affect \( \Delta \text{LYP} \), while \( \Delta \text{LCP} \) negatively affects \( \Delta \text{LYP} \). In the case of Bulgaria, there are two cointegration equations. First, for the \( \Delta \text{LYP} \) equation, the adjustment parameter is statistically significant, suggesting that, in the long-run, \( \Delta \text{LEP}, \Delta \text{LCP} \) and \( \Delta \text{LXP} \) cause \( \Delta \text{LYP} \). The adjustment coefficient indicates adjustment to the long run with an estimated value of \(-0.21\). Secondly, for the \( \Delta \text{LKP} \) equation, the adjustment parameter is also statistically significant, suggesting that, in the long-run, \( \Delta \text{LEP}, \Delta \text{LCP} \) and \( \Delta \text{LXP} \) cause \( \Delta \text{LKP} \), and the adjustment coefficient indicates adjustment to the long run with an estimated value of \(-0.26\). From the cointegration equation, it is clear that, as in case of Greece, \( \Delta \text{LEP} \) and \( \Delta \text{LXP} \) positively affect \( \Delta \text{LYP} \), while \( \Delta \text{LCP} \) has a negative impact. Cointegration equation (2) suggests the same impact of the mentioned variables, but now on \( \Delta \text{LKP} \). Therefore, from the long-run perspective in both countries, \( \Delta \text{LEP} \) plays a significant role in economic growth, so the energy is a very important input of economic growth. Additionally, \( \Delta \text{LCP} \) negatively affects \( \Delta \text{LYP} \), which means that \( \text{CO}_2 \) emissions are not a significant factor in economic growth.

The impulse response function (IRF) examines shock effects on macroeconomic series. Since a shock in a variable does not only affect the variable, but the other endogenous variables as well through the dynamic structure of the VAR model, the IRF presents the effects of a simultaneous positive innovative shock in one variable on present and future values of endogenous indicators. In some way, IRF represents the result of a conceptual experiment. Koop, Pesaran, and Potter (1996) and Pesaran and Shin (1998) suggested using a generalised impulse response function for a cointegrated VAR model. In the case of Greece, the impulse response function indicated the positive response in economic growth due to standard shocks stemming from energy use and \( \text{CO}_2 \) emissions. This means that energy use and \( \text{CO}_2 \)

### Table 5. Long-run causality by VECM (from all other variables to a particular respective variable).

| Dependent variable | ECT(−1) | Cointegration equation |
|-------------------|---------|-----------------------|
| \( \Delta \text{LYP} \) | \(-0.17 \ (0.06)^*\) | \( \Delta \text{LYP} = 1.28 \Delta \text{LKP} + 2.77 \Delta \text{LEP} - 4.26 \Delta \text{LCP} + 0.74 \Delta \text{LXP} - 18.095\) |
| \( \Delta \text{LKP} \) | \(-0.21 \ (0.08)^*\) | \( \Delta \text{LKP} = 0.86 \Delta \text{LEP} - 0.38 \Delta \text{LCP} + 0.31 \Delta \text{LXP} - 16.37\) |
| \( \Delta \text{LCP} \) | \(-0.26 \ (0.09)^*\) | \( \Delta \text{LCP} = 1.58 \Delta \text{LEP} - 1.18 \Delta \text{LKP} + 0.51 \Delta \text{LXP} - 20.4\) |

Notes: * indicates the test statistics are significant at the 5% level; Numbers in brackets refer to appropriate std. error. Source: Author’s calculations.
emissions contribute to economic growth. The contribution of economic growth and CO\textsubscript{2} emissions is positive with respect to energy use. The response of CO\textsubscript{2} emissions is positive due to innovative shocks stemming from economic growth and energy use (Figure A3). On the other hand, in the case of Bulgaria, the Figure A4 indicates the negative response in economic growth due to standard shocks stemming from energy use and CO\textsubscript{2} emissions. The contribution of economic growth is positive with respect to energy use. The response of CO\textsubscript{2} emissions is positive due to innovative shocks stemming from economic growth. The impulse response function indicated that there is no effect between CO\textsubscript{2} and energy use.

5. Conclusions

In this paper we have examined causal relations among economic growth, energy and emissions on the example of Greece and Bulgaria, for the period of 1980–2010 with the VECM model. Our results indicated that the variables are cointegrated for long-run relationships. The long-run results suggest that energy is one of the engines of growth, along with capital, CO\textsubscript{2} emissions and trade openness. In the cases of both countries there is no short-run causality from energy to economic growth. The empirical evidence showed that there is no impact of energy use on CO\textsubscript{2} emissions and economic growth is a contributor to CO\textsubscript{2} emissions. Our results imply that, in the short-run, CO\textsubscript{2} emissions can be reduced at the cost of economic growth. On the other hand, in the long run, higher economic growth can be achieved by condensing CO\textsubscript{2} emissions. The rising trend of CO\textsubscript{2} emissions, which is more striking in Greece is a debatable issue, and has to be overcome by applying energy policy reforms in both countries.

The recommendation for both countries is to minimise the role of the government in the energy sector in order to increase efficiency and develop a more dynamic economy. This, of course, implies a reduction of the market share of the currently leading companies. Therefore, it is necessary to utilise energy-saving potentials, prioritising the implementation of energy efficiency, for both companies and the general population. In accordance with European Commission instructions, it is necessary to use renewable energy sources as a significant input for further industrial development. Greece should utilise its potentials of solar and wind energy. Finally, it should be noted, that the objectives of energy policy are only a part of the overall objectives of the national economy and should not be considered in isolation, but in conjunction with other social objectives and effects on an economy.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the Ministry of Science and Education of the Republic of Serbia under grant number 179015.

ORCID

Saša Obradović http://orcid.org/0000-0001-9918-7271
Nemanja Lojanica http://orcid.org/0000-0003-1460-8466
References

Akarca, A. T., & Long, T. V. (1980). On the relationship between energy and GNP: A reexamination. *Journal of Energy and Development, 5*, 326–331.

Akinlo, A. E. (2008). Energy consumption and economic growth: Evidence from 11 Sub-Saharan African countries. *Energy Economics, 30*, 2391–2400.

Ang, B. J. (2008). Economic development, pollutant, emissions and energy consumption in Malaysia. *Journal of Policy Modeling, 30*, 271–278.

Apergis, N., & Payne, E. J. (2009a). Energy consumption and economic growth in Central America: Evidence from a panel cointegration and error correction model. *Energy Economics, 31*, 211–216.

Apergis, N., & Payne, E. J. (2009b). Energy consumption and economic growth: Evidence from the Commonwealth of Independent States. *Energy Economics, 31*, 641–647.

Asafu-Adjaye, J. (2000). The relationship between energy consumption, energy prices and economic growth: Time series evidence from Asian developing countries. *Energy Economics, 22*, 615–625.

Chontanawat, J., Hunt, C. L., & Pierse, R. (2008). Does energy consumption cause economic growth? Evidence from a systematic study of over 100 countries. *Journal of Policy Modeling, 30*, 209–220.

Dickey, D. A., & Fuller, W. A. (1979). Distribution of the estimators for the autoregressive time series with a unit root. *Journal of the American Statistical Association, 74*, 427–431.

Dinda, S. (2004). Environmental Kuznets curve hypothesis: A survey. *Ecological Economics, 49*, 431–455.

Dipendra, S. (2009). The energy consumption –GDP nexus: Panel data evidence from 88 countries, Working Paper No. 18446. Munich Personal RePec Archive.

Donatos, George S., & Mergos, George J. (1989). Energy demand in Greece: The impact of the two energy crises. *Energy Economics, 11*, 147–152.

Eurostat. (2014). European Commission, EU. Retrieved April 22, 2014, from http://ec.europa.eu/eurostat/statistics-explained/index.php/Renewable_energy_statistics

Ghali, H. K., & El-Sakka, M. I. T. (2004). Energy use and output growth in Canada: A multivariate cointegration analysis. *Energy Economics, 26*, 225–238.

Hamit-Haggar, M. (2012). Greenhouse gas emissions, energy consumption and economic growth: A panel cointegration analysis from Canadian industrial sector perspective. *Energy Economics, 34*, 358–364.

Hondroyiannis, G., Loios, S., & Papapetrou, E. (2002). Energy consumption and economic growth: Assessing the evidence from Greece. *Energy Economics, 24*, 319–336.

Ismail, M. A., & Mawar, M. Y. (2012). Energy use, emissions, economic growth and trade: A Granger non-causality evidence for Malaysia, Working Paper No. 38473. Munich Personal RePec Archive.

Jakovac, P. (2013). Empirical analysis on economic growth and energy consumption relationship in Croatia. *Economic Research-Ekonomskia Istraživanja, 26*, 21–42.

Jalil, A., & Feridun, M. (2014). Energy-Driven economic growth: Energy consumption- economic growth nexus revisited for China. *Emerging Markets Finance and Trade, 50*, 159–168.

Johansen, S. (1991). Estimation and hypothesis testing of Cointegration vectors in Gaussian vector autoregressive models. *Econometrica, 59*, 1551–1580.

Johansen, S. (1995). *Likelihood-Based inference in cointegrated vector autoregressive models*. Oxford: Oxford University Press.

Joo, Y. J., Kim, C. S., & Yoo, S. H. (2015). Energy consumption, CO₂ emission, and economic growth: Evidence from Chile. *International Journal of Green Energy, 12*, 543–550.

Koop, G., Pesaran, H. M., & Potter, M. S. (1996). Impulse response analysis in nonlinear multivariate models. *Journal of Econometrics, 74*, 119–147.

Kraft, J., & Kraft, A. (1978). On the relationship between energy and GNP. *Journal of Energy and Development, 3*, 401–403.

Kwiatkowski, D., Phillips, P., Schmidt, P., & Shin, Y. (1992). Testing the null hypothesis of stationarity against the alternative of a unit root: How sure are we that economic time series have a unit root? *Journal of Econometrics, 54*, 159–178.

Lee, C. C. (2005). Energy consumption and GDP in developing countries: A cointegrated panel analysis. *Energy Economics, 27*, 415–427.
Lin, B., & Moubarak, M. (2014). Renewable energy consumption-Economic growth nexus for China. *Renewable and Sustainable Energy Reviews, 40*, 111–117.

Magazzino, C. (2015). Economic growth, CO₂ emissions and energy use in Israel. *International Journal of Sustainable Development & World Ecology, 22*, 89–97.

Menegaki, Angeliki N. (2011). Growth and renewable energy in Europe: A random effect model with evidence for neutrality hypothesis. *Energy Economics, 33*, 257–263.

Mudarissov, B. A., & Lee, Y. (2014). The relationship between energy consumption and economic growth in Kazakhstan. *Geosystem Engineering, 17*, 63–68.

Narayan, P., & Prasad, A. (2008). Electricity consumption-real GDP causality nexus-Evidence from a bootstrapped causality test for 30 OECD countries. *Energy Policy, 36*, 910–918.

Ozturk, I. (2010). A literature survey on energy-growth nexus. *Energy Policy, 38*, 340–349.

Ozturk, I., & Acaravci, A. (2010). The causal relationship between energy consumption and GDP in Albania, Bulgaria, Hungary and Romania: Evidence from ARDL bound testing approach. *Applied Energy, 87*, 1938–1943.

Payne, J. (2010). Survey of the international evidence on the causal relationship between energy consumption and growth. *Journal of Economic Studies, 37*, 53–95.

Pesaran, H. H., & Shin, Y. (1998). Generalized impulse response analysis in linear multivariate models. *Economics Letters, 58*, 17–29.

Samouilidis, J., & Mitropoulos, C. S. (1984). Energy and economic growth in industrializing countries. *Energy Economics, 6*, 191–201.

Shahbaz, M. (2012). Multivariate granger causality between CO₂ emissions, energy intensity, financial development and economic growth: Evidence from Portugal. Working Paper No. 37774. Munich Personal RePec Archive.

Shahbaz, M., Muhammad, H. Q. A., & Tiwari A. K. (2012). Economic growth, energy consumption, financial development, international trade and CO₂ emissions in Indonesia. Working Paper No. 43294. Munich Personal RePec Archive.

Soytas, U., & Sari, R. (2009). Energy consumption, economic growth and carbon emissions: Challenged faced by an EU candidate member. *Ecological Economics, 68*, 1667–1675.

Tsani, Stela Z. (2010). Energy consumption and economic growth: A causality analysis for Greece. *Energy Economics, 32*, 582–590.

Ucan, O., Aricioglu, E., & Yucel, F. (2014). Energy consumption and economic growth Nexus: Evidence from developed countries in Europe. *International Journal of Energy Economics and Policy, 4*, 411–419.

Wang, Z., & Feng, C. (2015a). Sources of production inefficiency and productivity growth in China: A global data envelopment analysis. *Energy Economics, 49*, 380–389.

Wang, Z., & Feng, C. (2015b). A performance evaluation of the energy, environmental, and economic efficiency and productivity in China: An application of global data envelopment analysis. *Applied Energy, 147*, 617–626.

Wang, Z., Feng, C., & Zhang, B. (2014). An empirical analysis of China's energy efficiency from both static and dynamic perspectives. *Energy, 74*, 322–330.

World Development Indicators. (2014). Washington, D.C: World Bank. Retrieved April 10, 2014, from [http://data.worldbank.org/sites/default/files/wdi-2014-book.pdf](http://data.worldbank.org/sites/default/files/wdi-2014-book.pdf)

Yuan, J. H., Kang, J. G., Zhao, C. H., & Hu, Z. G. (2008). Energy consumption and economic growth: Evidence from China at both aggregated and disaggregated levels. *Energy Economics, 30*, 3077–3094.

Yuan, J. H., Xu, J., & Zhang, X. (2014). Income growth, energy consumption, and carbon emissions: The case of China. *Emerging Markets Finance and Trade, 50*, 169–181.

Zhang, X. P., & Cheng, X. M. (2009). Energy consumption, carbon emissions, and economic growth in China. *Ecological Economics, 68*, 2706–2712.

Zivot, E., & Andrews, D. (1992). Further evidence on the Great Crash, the oil price shock, and the unit-root hypothesis. *Journal of Business and Economic Statistics, 10*, 251–270.
### Appendix

**Table A1. Summary of descriptive statistics.**

|          | Greece                     | Bulgaria                   |
|----------|----------------------------|----------------------------|
|          | GDP per capita             | GDP per capita             |
| Mean     | 17,409.45                  | 2,986.09                  |
| Maximum  | 23,430.76                  | 4,640.98                  |
| Minimum  | 14,268.68                  | 2,217.62                  |
| Jarque-Bera | 4.36                     | 5.83                      |
| Observations | 31                      | 31                        |
| Capital per capita | 3,416.03     | 625.74                   |
| Maximum  | 6,274                      | 1,530.57                  |
| Minimum  | 2,371.66                   | 225.82                    |
| Jarque-Bera | 5.31                      | 5.56                      |
| Observations | 31                      | 31                        |
| Energy use per capita | 2,186.86      | 2,803.24                  |
| Maximum  | 2,724.029                  | 3,488.29                  |
| Minimum  | 1,505.28                   | 2,225.87                  |
| Jarque-Bera | 2.15                      | 3.81                      |
| Observations | 31                      | 31                        |
| CO₂ emissions per capita | 7.37           | 7.49                      |
| Maximum  | 8.89                       | 10.21                     |
| Minimum  | 5.21                       | 5.33                      |
| Jarque-Bera | 2.42                      | 3.78                      |
| Observations | 31                      | 31                        |
| Export per capita | 3,273.16      | 2,554.94                  |
| Maximum  | 5,632.87                   | 5,900.93                  |
| Minimum  | 1,703.79                   | 717.88                    |
| Jarque-Bera | 3.34                      | 3.60                      |
| Observations | 31                      | 31                        |

Source: Own calculations and results based on WDI data.

![Figure A1. Chart of variables movement in natural logarithms – Greece. Source: Own calculations and results based on WDI data.](chart-url)
Figure A2. Chart of variables movement in natural logarithms – Bulgaria. Source: Own calculations and results based on WDI data.

Table A2. Optimal lag value, residual tests, Greece.

| Lag | LM-stat   | Probability |
|-----|-----------|-------------|
| 2   | 28.64201  | 0.2792      |

Component normality tests-Cholesky of covariance Lutkepohl

| Component | Skewness (Chi-sq) | Probability |
|-----------|-------------------|-------------|
| 2         | 0.068548          | 0.7935      |

| Component | Kurtosis (Chi-sq) | Probability |
|-----------|-------------------|-------------|
| 2         | 0.026837          | 0.8699      |

| Component | Jarque-Bera       | Probability |
|-----------|-------------------|-------------|
| 2         | 0.095385          | 0.9534      |

White heteroscedasticity (no cross terms)

| Dependent | Chi-sq  | Probability |
|-----------|---------|-------------|
| res2*res2 | 24.39374| 0.1386      |

Source: Author's calculations.
**Table A3.** Optimal lag value, residual tests, Bulgaria.

| Lag | LM-stat | Probability |
|-----|---------|-------------|
| 2   | 26.84336| 0.3638      |

**Component**

- Multivariate normality tests-Cholesky of covariance Lutkepohl
  - Skewness (Chi-sq) | Probability |
  - 2 | 0.274978 | 0.6 |

- Kurtosis (Chi-sq) | Probability |
  - 2 | 0.043990 | 0.8339 |

- Jarque-Bera | Probability |
  - 2 | 0.318968 | 0.8526 |

**White heteroscedasticity (no cross terms)**

- Observing $R^2$ for $res^2 * res^2$: 24.53080 | 0.1274 |

Source: Author’s calculations.

**Table A4.** Model specification- residual diagnostic

| Dependent variable | Country: Greece |
|--------------------|-----------------|
|                    | $R^2$ | F statistics | Serial correlation LM | Heteroscedasticity | Normality |
| LYP                | 52.49% | 1.61 | 7.43 | 0.31 | 0.24 |
| LKP                | 52.61% | 1.62 | 12.82 | 0.07 | 1.63 |
| LEP                | 61.53% | 2.33 | 10.84 | 1.18 | 0.34 |
| LCP                | 73.67% | 4.07 | 11.17 | 0.11 | 0.94 |
| LXP                | 60.50% | 2.28 | 12.10 | 0.80 | 2.54 |

| Country: Bulgaria |
|-------------------|
| LYP                | 65.06% | 2.33 | 11.21 | 0.39 | 0.62 |
| LKP                | 82.28% | 5.81 | 14.19 | 0.3 | 0.75 |
| LEP                | 69.68% | 2.87 | 2.73 | 0.66 | 5.39 |
| LCP                | 74.86% | 3.72 | 7.83 | 0.19 | 2.58 |
| LXP                | 65.63% | 2.37 | 4.90 | 0.22 | 0.10 |

Notes: $R^2$ denotes the coefficient of determinations, $p$-value of statistics F is less than 5%. For the series LM residual correlation lag was extended to 7 in both cases. The Breusch-Godfrey test was used. The value in the column refers to Observed $R^2$. The heteroscedasticity analysis done by the ARCH test and the values in the column refer to Observed $R^2$. The residual distribution is examined with Jarque-Bera values.

Source: Author’s calculations.
Figure A3. Response to generalized one S.D. innovations ± 2 S.E., Greece. Source: Author’s calculations.

Figure A4. Response to generalized one S.D. innovations ± 2 S.E., Bulgaria. Source: Author’s calculations.