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Energy use, CO_2 emissions and economic growth – causality on a sample of SEE countries

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ABSTRACT

The primary aim of this study is to examine the causal relations between energy use, CO_2 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 CO_2 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.

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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 (CO_2) 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 km^2 and a population of 11,090,000 people, while the Bulgaria has an area of 111,000 km^2 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

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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 CO_2 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 CO_2 emission as an additional variable, because the analysis of the energy-CO_2-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:

$$LYP = c + aLKP + bLEP + dLCP + eLXP + \varepsilon_i \tag{4}$$

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, ε_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 CO_2 emissions in metric tonnes (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 CO_2 as an emission factor. According to European Environmental Agency data, in the total of GHG emissions, 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. Two conventional 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:

$$\Delta y_t = \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + \varepsilon_i \tag{5}$$

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. Δ is a symbol of the first difference operator, the exponent Πy_{t-1} denotes the error correction term and it can be calculated with the product of parameters α and β, where α is vector of the error-correction coefficient and estimates the long-run equilibrium, whereas β is a vector of cointegration parameters, while r is the number of cointegration equations. These are, therefore, 5×r parameters matrices. Γ_i for i=1, 2, ..., p−1 is a matrix of parameter 5×5, and ε_i is 5×1 vector of the residual. This equation can be represented as follows:

$$\Delta y_t = \alpha\left(\beta' y_{t-1} + \mu\right) + \sum_{i=1}^{p-1} \gamma_i \Delta y_{t-i} + \gamma + \varepsilon_i \tag{6}$$

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.

	ADF		KPSS		Zivot-Andrews	
			Country: Greece			
Variable	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)*
			Country: Bulgaria			
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).

Greece				
Maximum rang	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
Bulgaria				
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				
	LYP	*LKP*	*LEP*	*LCP*	*LXP*
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				
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 *LYP* to *LKP* and *LCP*, from *LKP* to *LEP*, *LCP* and *LXP*, as well as from *LCP* to *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 *LYP* positively affects *LKP*, *LCP* and *LXP*, *LKP* negatively affects *LCP*, *LEP* negatively affects *LKP*, *LCP* negatively affects *LEP*, *LXP* positively affects *LKP*, *LEP* and *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 *LYP* equation, the adjustment parameter is statistically significant, suggesting that, in the long-run, *LKP*, *LEP*, *LCP* and *LXP* cause *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 *LKP*, *LEP* and *LXP* positively affect *LYP*, while *LCP* negatively affects *LYP*. In the case of Bulgaria, there are two cointegration equations. First, for the *LYP* equation, the adjustment parameter is statistically significant, suggesting that, in the long-run, *LEP*, *LCP* and *LXP* cause *LYP*. The adjustment coefficient indicates adjustment to the long run with an estimated value of −0.21. Secondly, for the *LKP* equation, the adjustment parameter is also statistically significant, suggesting that, in the long-run, *LEP*, *LCP* and *LXP* cause *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, *LEP* and *LXP* positively affect *LYP*, while *LCP* has a negative impact. Cointegration equation (2) suggests the same impact of the mentioned variables, but now on *LKP*. Therefore, from the long-run perspective in both countries, *LEP* plays a significant role in economic growth, so the energy is a very important input of economic growth. Additionally, *LCP* negatively affects *LYP*, which means that 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 CO_2 emissions. This means that energy use and CO_2

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

Dependent variable	ECT(−1)	Cointegration equation
	Country: Greece	
Δ*LYP*	−0.17 (0.06)*	Δ*LYp*= 1.28*LKP*+2.77*LEP*−4.26*LCP*+0.74*LXP*−18.095
	Country: Bulgaria	
Δ*LYP*	−0.21 (0.08)*	Δ*LYp*= 0.86*LEP*−0.38*LCP*+0.31*LXP*−16.37
Δ*LKP*	−0.26 (0.09)*	Δ*LKp*= 1.58*LEP*−1.18*LCP*+0.51*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_2 emissions is positive with respect to energy use. The response of CO_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_2 emissions. The contribution of economic growth is positive with respect to energy use. The response of CO_2 emissions is positive due to innovative shocks stemming from economic growth. The impulse response function indicated that there is no effect between CO_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_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_2 emissions and economic growth is a contributor to CO_2 emissions. Our results imply that, in the short-run, CO_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_2 emissions. The rising trend of CO_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.

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Appendix

Table A1. Summary of descriptive statistics.

Greece	GDP per capita	Capital per capita	Energy use per capita	CO_2 emissions per capita	Export per capita
Mean	17409.45	3,416.03	2,186.86	7.37	3,273.16
Maximum	23,430.76	6,274	2,724.029	8.89	5,632.87
Minimum	14,268.68	2,371.66	1,505.28	5.21	1,703.79
Jarque-Bera	4.36	5.31	2.15	2.42	3.34
Observations	31	31	31	31	31
Bulgaria	GDP per capita	Capital per capita	Energy use per capita	CO_2 emissions per capita	Export per capita
Mean	2,986.09	625.74	2,803.24	7.49	2,554.94
Maximum	4,640.98	1,530.57	3,488.29	10.21	5,900.93
Minimum	2,217.62	225.82	2,225.87	5.33	717.88
Jarque-Bera	5.83	5.56	3.81	3.78	3.60
Observations	31	31	31	31	31

Source: Own calculations and results based on WDI data.

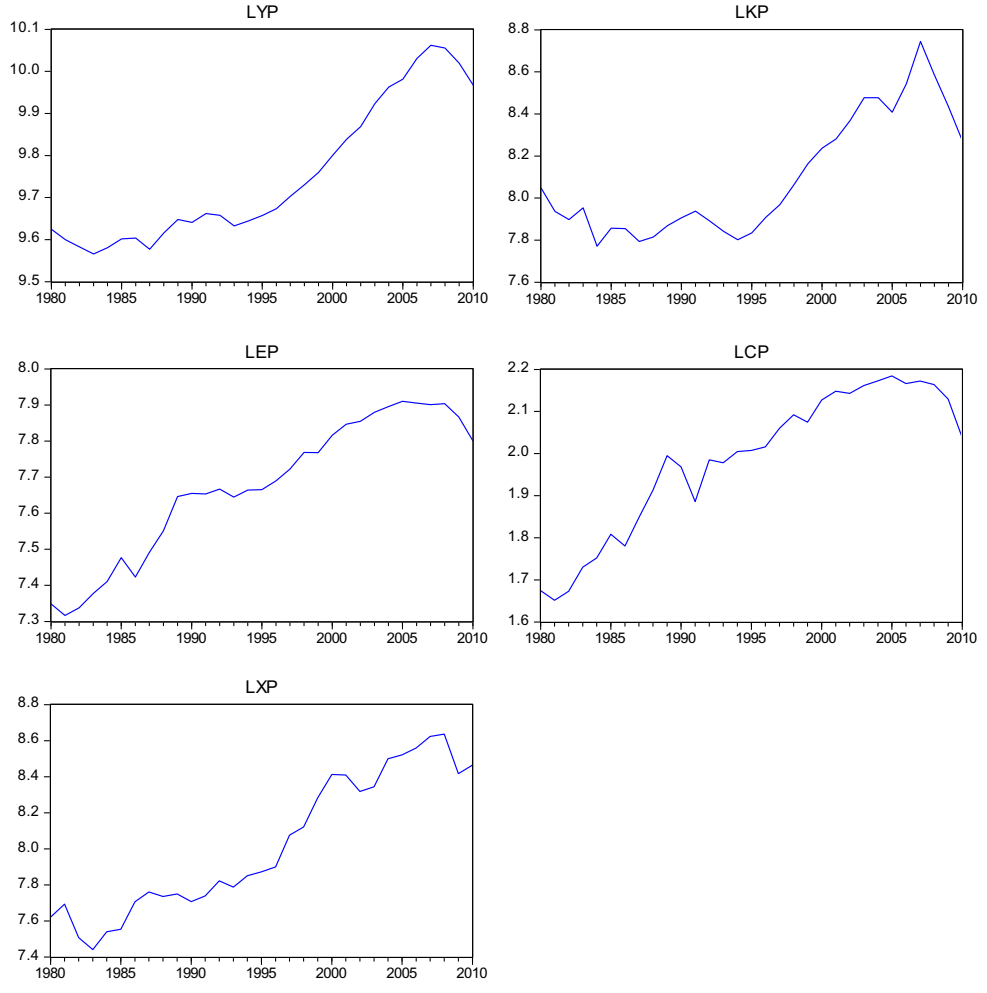

Figure A1. Chart of variables movement in natural logarithms – Greece. Source: Own calculations and results based on WDI data.

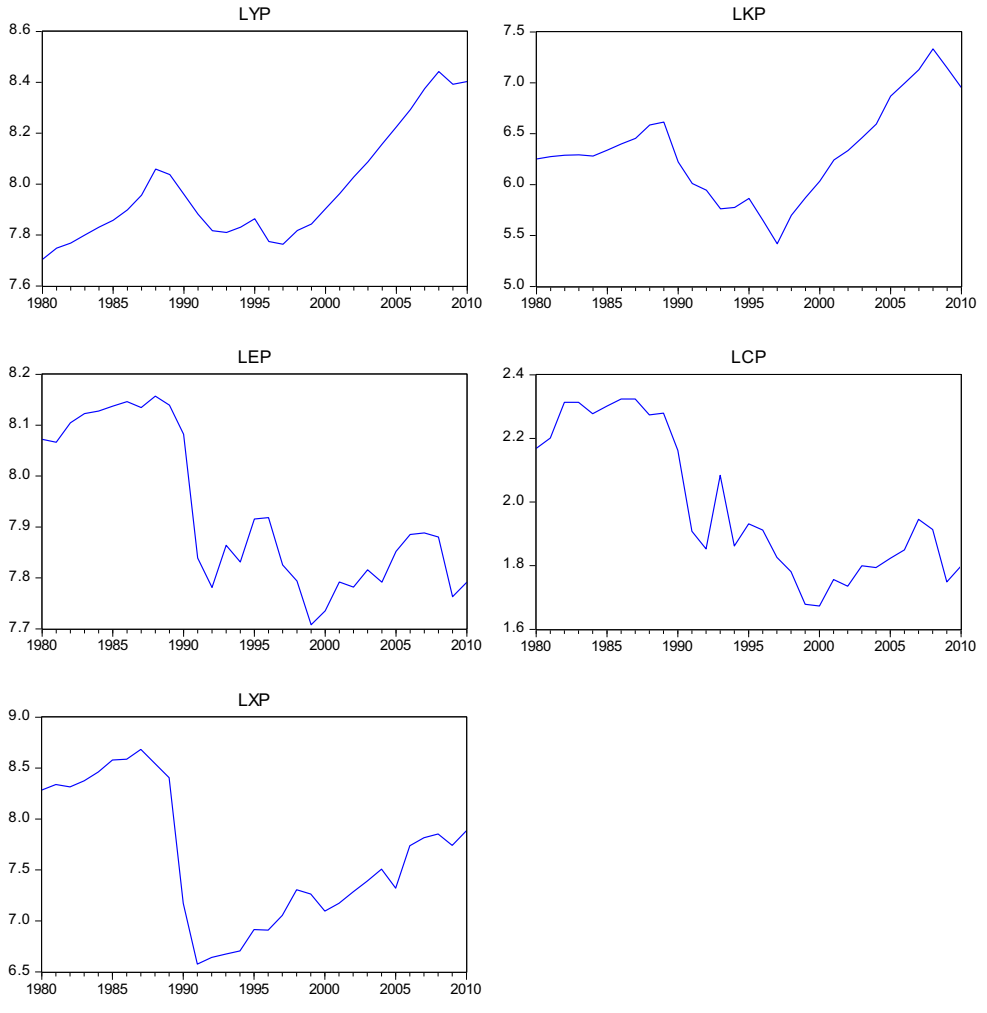

Figure A2. Chart of variables movement in natural logarithms - BulgariaChart of variables movement in natural logarithms – Bulgaria. Source: Own calculations and results based on WDI data.

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

Autocorrelation LM test		
Lag	LM-stat	Probability
2	28.64201	0.2792
Multivariate 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.

Autocorrelation LM test		
Lag	LM-stat	Probability
2	26.84336	0.3638
	Multivariate normality tests-Cholesky of covariance Lutkepohl	
Component	Skewness (Chi-sq)	Probability
2	0.274978	0.6
Component	Kurtosis (Chi-sq)	Probability
2	0.043990	0.8339
Component	Jarque-Bera	Probability
2	0.318968	0.8526
	White heteroscedasticity (no cross terms)	
Dependent	Chi-sq	Probability
res2*res2	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* square. The heteroscedasticity analysis done by the ARCH test and the values in the column refer to Observed *R* square. The residual distribution is examined with Jarque-Bera values.

Source: Author's calculations.

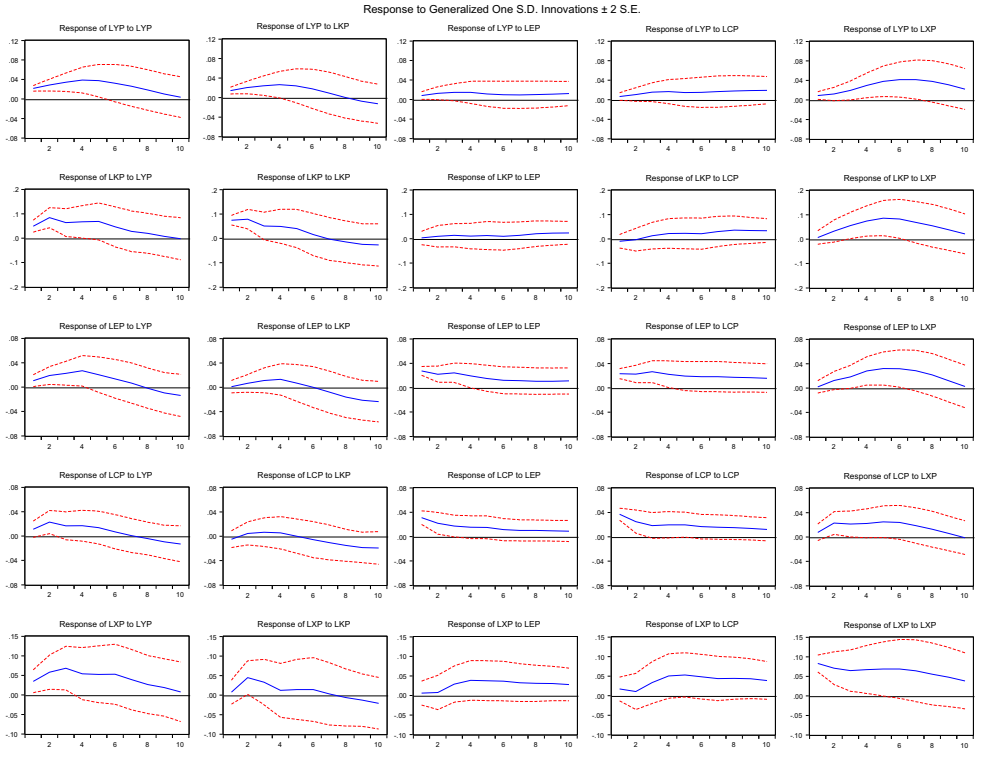

Figure A3. Response to generalized one S. D. innovations ± 2 S.E., Greece. Source: Author's calculations.

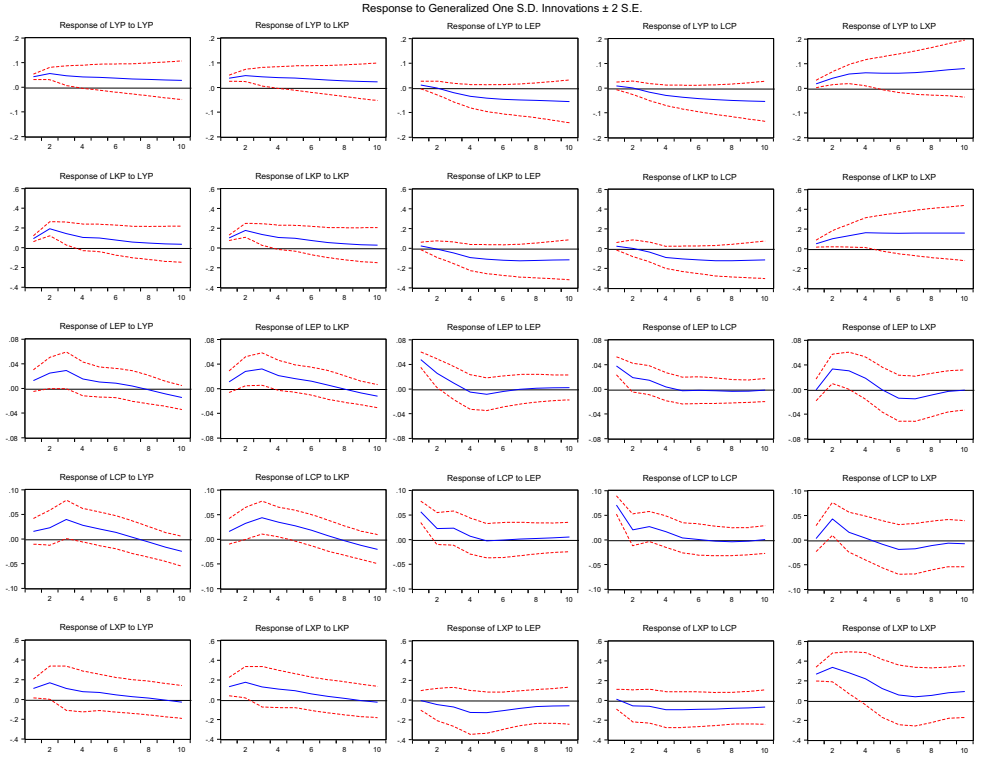

Figure A4. Response to generalized one S. D. innovations ± 2 S.E., Bulgaria. Source: Author's calculations.