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Electricity Consumption and Economic Growth: Analysis and Forecasts using VAR/VEC Approach for Greece with Capital Formation

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ABSTRACT: This paper tests for the existence and direction of causality between electricity consumption and real gross domestic product for Greece. The study examines a trivariate system with capital formation for the period 1980-2010. Robust empirical results indicate that all variables are integrated of order one and cointegration analysis reports that cointegrating relationship exists between the variables. VAR/VEC approach suggests that all variables return to the long-run equilibrium whenever there is a deviation from the cointegrating relationship and that unidirectional causal links exists running from capital formation and electricity consumption to RGDP in the short-run implying that the economy of Greece is strongly energy dependent. Forecasts for the period 2011-2020 indicate increasing consumption of electricity and positive growth rates from 2013. Policy makers will need to liberalise the electricity sector and to turn the economy towards renewable and natural gas sources in order to reduce imports of oil and coal dependency.

Keywords: Electricity consumption; Economic Growth; Capital Formation; Cointegration; Greece
JEL Classifications: Q43; C32; O55

1. Introduction

It is widely accepted by the academic community that electrical energy plays a vital role in modern economies, not only because it affects various aspects of the economic activity but also because it has a massive influence on a country's efforts towards long-term economic growth and promotes the quality of life. The energy crisis of the 1970s and persistently high energy prices, particularly oil prices, have had a significant impact on the economic activity especially of developing economies. This crisis attracted the interest of academics, scholars and practitioners on investigating the relationship between energy consumption and economic growth using modern advances in the time series econometrics.

The crucial role of energy and its impact on economic growth is documented by numerous academic studies; for example Jumbe (2004) underlines that consumption of energy, particularly commercial energy like electricity signifies high economic status of a country. Although, the existence of a relationship between electrical energy consumption and economic prosperity is now well-established in the relevant literature, it is important to investigate whether there is a causal link between electricity consumption and economic growth and to clarify the direction of this possible causality, issues that still remain an unsettled and controversial issue. Moreover, the causality in either direction between energy consumption and economic growth may have a significant impact upon energy conservation policies, since energy conservation measures depend on the direction of causality (Rufael, 2006).

In the literature between energy consumption (or its components) and economic growth four possible relationships have been emphasized; growth, conservation, neutrality and feedback hypothesis (Ozturk, 2010). Jumbe (2004), reports that if causality exists from energy consumption to economic growth and the relationship is positive (i.e. the growth hypothesis) this suggests that an economy is energy-dependent and hence energy consumption leads to growth. On the other hand, a shortage of energy may negatively affect economic performance, leading to a fall in income and employment. If, instead, causality runs from economic growth to energy consumption and the relationship is positive, this implies that an economy is not energy-dependent and hence energy conservation policies may be implemented with no adverse effect on growth and employment (Masih and Masih, 1997). However, it is possible that a growing economy constrained by politics, weak infrastructure, or mismanagement of resources could generate inefficiencies and the reduction in the demand for goods and services, including energy consumption (Squalli, 2007).

In addition, the feedback hypothesis suggests that energy consumption and real Gross Domestic Product (RGDP) are interrelated and may very well serve as complements to each other. Should this result hold, then shocks, positive or negative, to either one of these variables would have effects, possibly permanent, on the other. Finally, if there is no causality in either direction (i.e. the neutrality hypothesis) this implies that changes in the level of energy consumption is not associated with changes in GDP, so that energy conservation policies may be pursued without adversely affecting the country's economy.

Thereupon, the central objective of this study is to empirically investigate the causal links between electrical energy consumption and economic growth, as measured by RGDP for a European Union (EU) and European Monetary Union (EMU) member country, Greece, for the period 1980-2010. This study's empirical work is largely derived from the seminal contribution to the energy literature by Stern (1993). Stern's approach examined the relationship between energy and growth by considering the possibility that the relationship may include more complex interactions with capital and labour. Within this context, we employ the techniques of multivariate cointegration, vector auto-regression (VAR) with an error-correction mechanism, causality testing and innovation accounting. Finally, we forecast energy consumption within the framework of the VAR/VEC approach.

Although it would be ideal to investigate the interrelation of energy consumption (and its components) with RGDP unfortunately there is a lack of relevant data for Greece. Moreover, Greece is a country which depends mostly on electricity as an energy source. Mahadevan and Asafu-Adjaye (2007) suggest that the use of electricity consumption (see studies such as Jumbe, 2004; Shiu and Lam, 2004; Yoo, 2006, Enflo et al, 2009) may be appropriate for economies which are heavily reliant on electricity for their energy (Greece is such a case). Moreover, Ferguson et al. (2000) find that there is a stronger correlation between electricity use and wealth creation for the global economy as a whole than there is for total energy use and wealth creation.

This study is motivated by a number of factors; First, there is lack of studies investigating the interdependence of RGDP and electrical energy consumption for the case of Greece. Georgantopoulos and Tsamis (2011) is the only relevant empirical source to the best of our knowledge for Greece. This study investigates the causal relationships between total energy consumption and nominal GDP for the case of four emerging Balkan countries, including Greece. Second, it enriches the existing literature on energy economics by exploring the relationship between these two variables and by analyzing the various aspects of energy conservation implications that empirical results imply. Third, it covers a period which includes some of the most important economic, political and social transformations leading to more development oriented and therefore more energy-depended economy of Greece. Moreover, considering the severe sovereign debt crisis of 2008 which emerged in Greece, it is crucial to further investigate whether policy makers in this country should control efficiently the electricity consumption in an effort to promote growth under the deep recession that threatens Greece's 20 years efforts towards European economic integration. Forth, it is important to add that the EU Commission published on July 2, 2010 a document called "Towards a new Energy Strategy for Europe 2011-2020".

The new Energy 2020 strategy will have a significant impact on the economy of Greece and the Balkan countries in general. It has defined five priorities for the energy sector: (i) achieving an energy efficient Europe, (ii) building a pan-European integrated energy market, (iii) empowering consumers and achieving the highest level of safety and security, (iv) extending Europe's leadership in energy technology and innovation, and (v) strengthening the external dimension of the EU energy market. Once approved, both the EU members in the region (i.e. Bulgaria, Greece and Romania) and the other non-EU countries, through their membership at the Energy Community, will have to implement the strategic guidelines and action plans in their national legislation. This will probably translate into revisions of the national energy strategy and action plan documents that most of the Southeast Europe countries have already developed and started implementing, as well as new national energy strategy documents for the countries that still do not have them. Thus, it is interesting to investigate the interdependence between economic growth and energy consumption (as measured by electrical energy use) in order to understand at some point the effect that these structural energy reformations will have on the economic development of Greece, which is the leading economy in the Balkan region.

The rest of the paper is organized as follows. Section 2 provides a brief profile of energy consumption in Greece, focusing on electrical energy consumption. Section 3 presents a brief review of the pertinent empirical literature on electricity consumption and economic growth. Section 4 introduces the empirical model, econometric methodology and data sources used in this research paper. Section 5 presents the results and analysis. Section 6 discusses the policy implications, summarises the main findings and provides some concluding remarks.

2. A Brief Overview of Greece's Energy Profile

There is no doubt that, over the last years, energy has been the centre of global attention. Achieving energy security and diversification combined with fighting climate change, has become the number one issue on the agenda of all developed countries in the world. In this respect, Greece, situated at the southeast part of Europe, can play a significant role as an energy gateway between the East and the West.

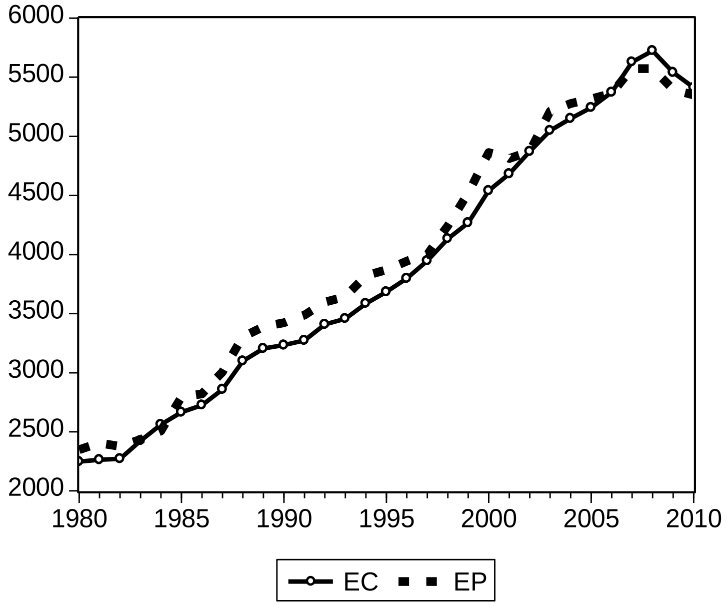
On a more practical level, the Energy 2020 strategy, as briefly analysed above, will create the framework that will allow a number of energy projects in the Balkan region to move forward. Also, the creation of a new Energy Infrastructure Package will provide financial support for these projects of about 1 trillion euros in order to integrate all the EU countries in pan-European energy networks. Some of these projects will involve Greece as well. The EU will also focus on increasing the energy efficiency in the two main sectors of transport and building, which will create business opportunities in Greece as well. Finally, the countries in the region will have the opportunity to be proactive participants in the definition and implementation of a potential future common European energy policy.

Greece imports practically all the oil and gas it needs, and security of supply is one of the key objectives of the Greek energy policy. The supply sources for natural gas are diversified, as Russian gas is imported through the Greek-Bulgarian entry point, while the Greek-Turkish entry point allows Greece to import gas from the Middle East and the Caspian region. The liquid natural gas (LNG) terminal adds flexibility to the gas import system. During January 2009 the Russia-Ukraine gas supply crisis, helped Greece cope better than other countries in the region. Gas use is projected to grow to 2020 and Greece seems to have sufficient capacity to accommodate this growth. However, the growing peak demand may pose challenges. Greece is therefore right in trying to further diversify import routes and sources, while expanding LNG import capacity. Also crude oil and oil products sources are well diversified and Greece is taking measures to increase its indigenous oil production. Greece has also been compliant with the IEA 90-day stockholding obligation since the end of 2004.

Figure 1, illustrates the sharp upward trend of electricity consumption (EC) and production (EP) in Greece during the tested period 1980-2010. It is evident that electricity intensity has evolved rapidly mostly due to the general economic growth that Greece presented during the period under investigation. Moreover, it should be noted that Greece was capable to produce all the electricity needed until 2006. Since then, in order for the country to continue to support its rapid growth pace, Greece was forced to import electricity from abroad burdening the country's budget deficits, due to the fact that the Public Power Corporation (PPC) remains by far the largest provider of electrical energy and enjoys monopolistic privileges.

Figure 2, shows the sources of electricity for the case of Greece. From this graph it is evident that Greece's energy depends mainly in coal, which is without doubt the primary provider of electrical energy on average during the tested period although declining especially the last decade. Lignite is Greece's only significant fossil fuel resource, with reserves totaling 4,299 million short tons (Mmst). With lignite output of 80 million short tons (Mmst) in 2004, Greece is second only to Germany in European lignite production. The largest deposits are at Ptolemais and Amintaio regions, which are located in northern Greece. Since Greece has no hard coal reserves, it is imported from South Africa, Russia, Venezuela, and Colombia. Domestic production has been partly opened to private companies, but the Public Power Corporation (PPC) remains the largest producer with the right to exploit 63 percent of known reserves.

Figure 1. Trends in Electricity Consumption (EC) and Electricity Production (EP) (in kWh per capita)



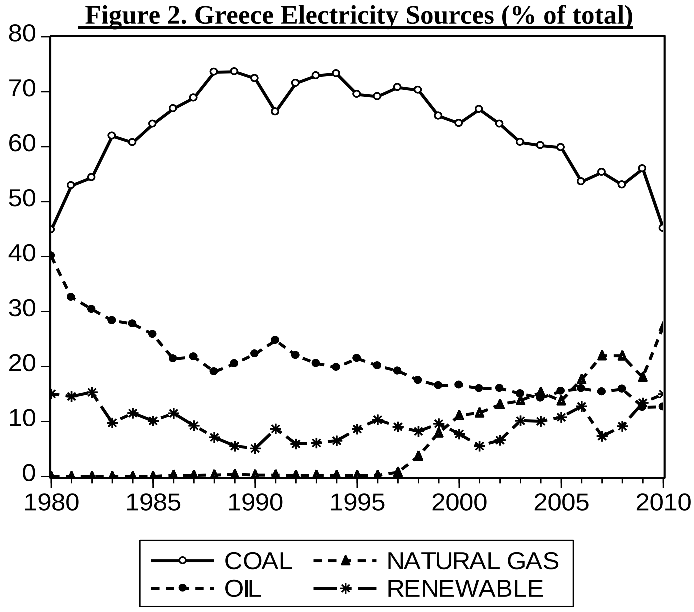
Source: World Development Indicators (WDI)

Oil could be regarded as the second most important energy source during the period 1980-2010. Greece has oil reserves of just 7 million barrels. With domestic production of only 6,400 barrels per day (bbl/d) in 2005, Greece relies heavily on imports, primarily from Iran, Saudi Arabia, Russia, Libya and Egypt – to meet its 439,000 bbl/d of oil consumption. Oil's market share of total energy consumption is gradually declining as the country increases its reliance on natural gas. Although the Middle East is expected to remain Greece's major oil supplier, oil from Russia and the Caspian Sea region will become more important as Greece constructs new pipelines.

Greece produces negligible amounts of natural gas. Consumption, however, has increased significantly especially since 1998 and is expected to continue to increase, possibly tripling over the next decade. Despite the recent strong demand growth, the share of natural gas in total energy consumption is still limited mainly due to limited liberalization. Public gas corporation, DEPA, dominates the market and is involved in import, distribution, and storage. Greece relies on Russia for 80 percent of its natural gas imports. DEPA began importing natural gas from Russia via Bulgaria in July 1997. Greece has a 20-year contract with Russia's Gazexport (a subsidiary of Gazprom) to purchase approximately 99 billion cubic feet per year (Bcf/y) of natural gas. It currently expires in 2016, but the Greek government is considering extending the agreement until 2026. "Prometheus Gas", which is jointly owned by "Gazexport" and Greece's "Copelouzos Group", was formed to import gas by pipeline from Russia and develop the energy sector in Greece. The company's ability to import gas will be activated when Greek demand exceeds the annual amount contracted by DEPA with Gazprom, and will increase competition in the natural gas market.

Electricity production from renewable sources in Greece remains at 15% on average during the tested period, showing promising signs of a sharper upward trend especially since 2007 in order for Greece to meet relevant EU mandates. The Centre for Renewable Energy Sources (CRES), supervised by the Greek Development Ministry, was created in 1987 to promote renewable energy. The CRES estimates that 15 percent of the country's electricity needs can be produced by wind farms. Wind farms are already located on the Greek islands of Crete, Evia, Andros, and Samos. Moreover, the use of solar technology in Greece has almost tripled since 2000. Although Greece has massive potential for wind and solar energy most ambitious projects delay due to bureaucratic conditions such as complicated licensing procedures and weak incentives for local acceptance.

Figure 2. Greece Electricity Sources (% of total)

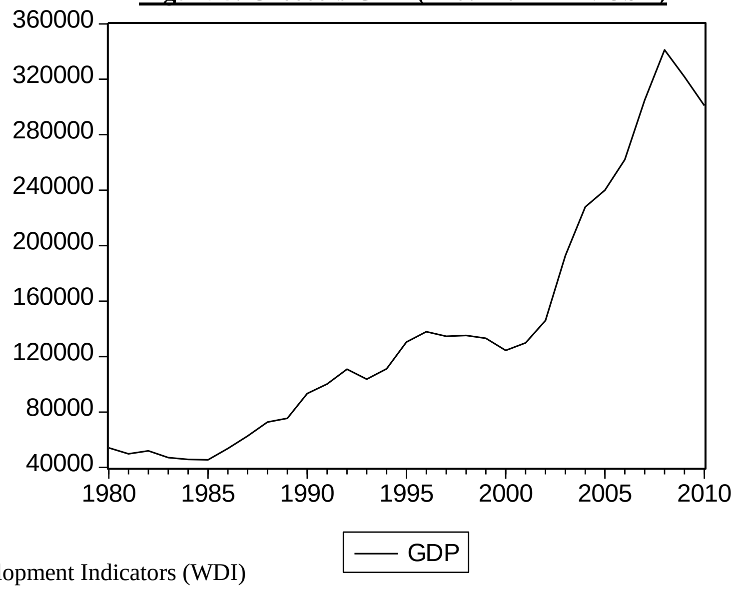


Source: World Development Indicators (WDI)

Overall, increasing competition and reducing the role of the state in the energy sector of Greece should add efficiency and dynamism to the Greek economy. This, in turn, should help generate self-sustained employment and prosperity for the country, issues which are top priorities of the Greek Government. Energy policy in Greece could make a significant contribution to the country's efforts towards rapid economic recovery considering the recent sovereign debt crisis of 2008, which threatens to ruin the so called "Greek economic miracle" constructed the last three decades, as Figure 3 illustrates.

Moreover, considering Figures 1 and 3 it is evident that there is a relationship between the growing electricity consumption and economic growth of Greece during the period 1980-2010. Therefore, econometric methods are required to examine not only the significance of this nexus, but also to define the causal links and direction of causality. Otherwise, any application of energy policy is likely to have unpredictable impact on the efforts of Greece to return to positive growth rates and long-term economic prosperity. However, before testing the nature, direction and significance of this relationship, the next section provides a review of related studies on the research field under investigation.

Figure 3. Greece's GDP (in current mill. USD)



Source: World Development Indicators (WDI)

3. Literature Review

The relationship between energy consumption and economic growth has been the subject of investigation for numerous studies in bivariate and multivariate models for different countries and periods and by employing a variety of econometric methodologies. Since the seminal work of Kraft and Kraft (1978), an increasing body of literature has assessed empirical findings on the energy-growth nexus for both developed and developing countries. Their study finds evidence of a unidirectional causal relationship running from Gross National Product (GNP) to energy consumption for the case of USA during the period 1947-1974. However, Akarca and Long (1980) although their research focuses on the same data but for the period 1947-1972, they find no relationship on the energy-growth nexus for the USA.

The relationship between energy consumption and economic development has puzzled academics, scholars and practitioners for more than three decades (Lise and Van Montfort, 2007; Mehrara, 2007; Narayan and Singh, 2007; Zamani, 2007; Lau et al., 2011; Ozturk et al., 2010; Kaplan et al., 2011; Abid and Sebri, 2012). The common characteristic of these studies is the use of a bivariate approach. This technique has been criticised by several authors (Stern, 1993, 1997; Glasure, 2002). The latter argue on the importance of omitted variables and suggest that multivariate models can offer multiple causality links which, under a bivariate approach, may remain hidden or can lead to spurious correlations and biased conclusions. Employing a four-variable VAR (capital, labour, energy consumption, and GDP), Stern (1993) finds that energy Granger causes GDP in the USA. Moreover, Stern (2000) in a further investigation of the USA finds a long-run relationship between energy use and GDP. Glasure and Lee (1998) in their study on South Korea and Singapore observed bidirectional causality between energy and GDP growth. In the same spirit, Francis et al. (2007) analyse the relationship for several Caribbean countries, Haiti, Jamaica, and Trinidad and Tobago, from 1971 to 2002, concluding that bidirectional Granger causality exist for all three countries in the short run. However, in the long run, no evidence of a relationship was found for Haiti and Jamaica; in contrast, a feedback relationship was discovered for Tobago and Trinidad.

The energy-capital-labour-GDP approach originated by Stern (1993). Although several studies focus their research subject on multivariate causality analysis, most of them lack of adequate theoretical background. In this study, Stern finds no causal links between gross energy consumption and GDP. However, more recent studies (e.g. Ghali and El-Sakka, 2004; Soytas and Sari, 2007; Yuan et al., 2008) adopted the theoretical background of Sterns' pioneering work. Ghali and El-Sakka assume a neo-classical one-sector production function with three inputs for Canada and find bilateral causality between energy use and GDP growth. Employing a four-variable model (i.e. output, capital, labour and energy) Soytas and Sari find one-way causal links from electricity consumption to output for the case of the manufacturing industry in Turkey. Yuan et al. (2008) in their study, employ aggregated and disaggregated levels for the case of China. They find a long-run causal relationship among output, capital, labour and energy at both aggregated and disaggregated levels. Moreover, for the short run the authors find significant causal links running from electricity and oil consumption to GDP and from output to gross energy consumption, coal and oil consumption.

Other studies focus specifically on the causal relationships between electricity consumption and output growth. Kouakou (2011) for Cote d'Ivoire, Sami (2011) for Japan, Altinay and Karagol (2005) for Turkey, Lee and Chang (2005) for Taiwan and Soytas and Sari (2003) for Turkey, France, Germany and Japan found unidirectional causal links running from electricity consumption to GDP. According to the relevant theory, the results of these studies imply that these countries are strongly energy dependent and that any changes in the energy policy could have direct implications (positive or negative) in the output growth. On the other hand, Narayan and Singh (2007) in their study for the case of Fiji islands, Odhiambo (2009) for South Africa, Ghosh (2002) for India and Hatemi and Irandoust (2005) for Sweden found unidirectional Granger causality relationships from real output to electricity consumption, implying that electric power conservation policies can be undertaken with insignificant or no adverse effects on the economic growth of these countries. In addition, other studies conducted by Soytas and Sari (2003) for Argentina and Yoo (2005) for Korea find strong interdependence between output and electrical energy consumption suggesting that policy makers of these countries should be extremely cautious in changing the environment in the energy sector due to the strong energy-growth nexus. Finally, Cheng (1995) for China and Stern (1993) for USA conclude that there are no causal linkages between GDP growth and electricity consumption. Therefore, changes in the electrical energy sector will have no direct effects in the growth of these countries.

To summarize, the studies analysed above provide contradictory evidence on the existence and direction of causality between energy consumption (and its components) and economic growth. As Apergis and Payne (2009) note, this can be attributed in part to the heterogeneity in climatic conditions, varying consumption patterns, the structure and stages of development within countries, alternative statistical techniques employed, omitted variables bias, and the different spans of the data sets used in the studies conducted.

4. Data Analysis and Methodology

The present study employs data that consist of annual observations during the period 1980 - 2010. Electricity consumption (EC), capital formation (CF) and labour (L) data are obtained from the World Bank Indicators[1] (WDI). All data sets are transformed into logarithmic returns in order to achieve mean-reverting relationships, and to make econometric testing procedures valid. Moreover, this study employs data of real GDP (RGDP), which is calculated by dividing nominal GDP by the GDP deflator both derived from WDI also.

On the empirical framework of this study, in order to investigate the relationship between electricity consumption and output growth, the study follows a neo-classical one-sector aggregate production model, originally proposed by Stern (1993) and furthered by Ghali and El-Sakka (2004), Soytas and Sari (2007) and Yuan et al. (2008) that treats capital, labour and energy (in this study electricity) as separate inputs. Therefore, the following equation is formed:

$$RGDP_t = (Capital_t, Labour_t, Electricity_t) \quad (1)$$

Where RGDP is the aggregate output of real GDP; Capital is the capital stock; Labour is the level of employment; Electricity is the total electricity consumption and the subscript (t) denotes the time period. As proposed by Adebola (2011), the study employs per capita form of the variables by dividing each variable by Labour and then taking their logs. Hence, equation (1) is transformed as follows:

$$RGDP_t = a(\dot{Capital})_t + \beta(\dot{Electricity})_t \quad (2)$$

Where the dot above each variable indicates that each variable is in per capita form. The constant parameter (α) and (β) measures the marginal effect of capital and electricity respectively on real output. The production function (1) suggests that long-run movements of the variables may be related (Ghali and El-Sakka, 2004). Furthermore, for short-run dynamics in factor-input behaviour, the specification in (2) would suggest that past changes in variables such as capital and electricity could contain useful information for predicting the future changes of output, ceteris paribus (Lorde, Waithe and Francis, 2010). In other words, causality tests can be employed to examine the relationship among the variables.

This study's econometric methodology firstly examines the stationarity properties of the univariate time series. Augmented Dickey-Fuller (ADF) test is employed to test the unit roots of the concerned time series variables (Dickey and Fuller, 1979). It consists of running a regression of the first difference of the series against the series lagged once, lagged difference terms, and optionally, by employing a constant and a time trend. This can be expressed as:

$$\Delta y_t = \alpha_1 y_{it-1} + \sum_{j=1}^{p_i} \beta_{ij} \Delta y_{it-j} + x_{it}^{'} \delta + \varepsilon_t \quad (3)$$

The test for a unit root is conducted on the coefficient of (y_{t-1}) in the regression. If the coefficient is significantly different from zero then the hypothesis that (y) contains a unit root is rejected. Rejection of the null hypothesis implies stationarity. Moreover, Phillips-Perron (PP) test is used (Phillips and Perron, 1988) in order to formally discern the unit root properties of the series.

Furthermore, the time series has to be examined for cointegration. Cointegration analysis helps to identify long-run economic relationships between two or several variables and to avoid the

[1] Online available at: http: //www.worldbank.org

risk of spurious regression. Cointegration analysis is important because if two non-stationary variables are cointegrated, a Vector Autoregression (VAR) model in the first difference is misspecified due to the effect of a common tend. If a cointegration relationship is identified, the model should include residuals from the vectors (lagged one period) in a dynamic Vector Error Correcting Mechanism (VECM) system. In this stage, the Johansen (1988, 1991) cointegration test is utilized to identify a cointegrating relationship among the variables. Within the Johansen multivariate cointegration framework, the following system is estimated:

$$\Delta z_t = \Gamma_1 \Delta z_{t-1} + \ldots + \Gamma_{k-1} \Delta z_{t-k-1} \Pi z_{t-1} + \mu + \varepsilon_t : \quad t = 1, \ldots, T \tag{4}$$

where, Δ is the first difference operator, z′ denotes a vector of variables, $\varepsilon_t \sim$ n iid $(0,\sigma^2)$, μ is a drift parameter, and Π is a (p x p) matrix of the form Π = αβ′, where α and β are both (p x r) matrices of full rank, with β containing the r cointegrating relationships and α carrying the corresponding adjustment coefficients in each of the r vectors. The Johansen approach can be used to carry out Granger causality tests as well. In the Johansen framework, the first step is the estimation of an unrestricted, closed p-th order VAR in k variables. Johansen (1988) suggested two tests statistics to determine the cointegration rank. The first of these is known as the trace statistic:

$$N\{trace(r_0 / k) = -T \sum_{i=r_0+1}^{k} \ln(1 - \hat{\lambda}_i) \tag{5}$$

where, $\hat{\lambda}_i$ are the estimated eigenvalues $\lambda_1 > \lambda_2 > \lambda_3 > \ldots > \lambda_\kappa$ and r_0 ranges from zero to k-1 depending upon the stage in the sequence. This is the relevant test statistics for the null hypothesis $r \le r_0$ against the alternative $r \ge r_{o+1}$. The second test statistic is the maximum eigenvalue test known as λ_{max}; we denote it as λ_{max} (r_0). This is closely related to the trace statistic, but arises from changing the alternative hypothesis from $r \ge r_{o+1}$ to $r = r_{o+1}$ The idea is trying to improve the power of the test by limiting the alternative to a cointegration rank which is just by one more than the null hypothesis. The λ_{max} test statistic is:

$$\lambda_{max}(r_0) = - T \text{ in } (1 - \lambda_i) \text{ for } i = r_0 + 1 \tag{6}$$

The null hypothesis is that there are r cointegrating vectors, against the alternative of r + 1 cointegrating vectors. Johansen and Juselius (1990) indicated that the trace test might lack power relative to the maximum eigenvalue test. Based on the power of the test, the maximum eigenvalue test statistic is often preferred. According to Granger (1969), Y is said to "Granger-cause" X if and only if X is better predicted by using the past values of Y than by not doing so with the past values of X being used in either case. In short, if a scalar Y can help to forecast another scalar X, then we say that Y Granger-causes X. If Y causes X and X does not cause Y, it is said that unidirectional causality exists from Y to X. If Y does not cause X and X does not cause Y, then X and Y are statistically independent. If Y causes X and X causes Y, it is said that feedback exists between X and Y. Essentially, Granger's definition of causality is framed in terms of predictability. To implement the Granger test, a particular autoregressive lag length k (or p) is assumed and Models (7) and (8) are estimated:

$$X_t = \lambda_1 + \sum_{i=1}^{k} a_{1i} X_{t-i} + \sum_{j=1}^{k} b_{1j} Y_{t-j} + \mu_{1t} \tag{7}$$

$$Y_t = \lambda_2 + \sum_{i=1} a_{2i} X_{t-i} + \sum_{j=1} b_{2j} Y_{t-j} + \mu_{2t} \tag{8}$$

Moreover, a time series with a stable mean value and standard deviation is called a stationary series. If d differences have to be made to produce a stationary process, then it can be defined as integrated of order d. Engle and Granger (1987) state that if several variables are all $I_{(d)}$ series, their linear combination may be cointegrated, that is, their linear combination may be stationary. Although the variables may drift away from equilibrium for a while, economic forces are expected to restore equilibrium. Thus, they tend to move together in the long run irrespective of short run dynamics. The definition of Granger causality is based on the hypothesis that X and Y are stationary or $I_{(0)}$ time series. Therefore, the fundamental Granger method for variables of $I_{(1)}$ cannot be applied. In the absence of a cointegration vector, with $I_{(1)}$ series, valid results in Granger causality testing are obtained by simply first differentiating the VAR model. With cointegration variables, Granger causality will require further inclusion of a VEC term in the stationary model in order to capture the short term deviations of series from their long-term equilibrium path. The VAR in the first difference can be written as:

$$N\left\{\Delta X_t = \lambda_1 + \sum_{i=1}^{k} a_{1i}\Delta X_{t-i} + \sum_{j=1}^{k} b_{1j}\Delta Y_{t-j} + \mu_{1t}\right. \quad (9)$$

$$N\left\{\Delta Y_t = \lambda_2 + \sum_{i=1}^{p} a_{2i}\Delta X_{t-i} + \sum_{j=1}^{p} b_{2j}\Delta Y_{t-j} + \mu_{2t}\right. \quad (10)$$

In addition, innovation accounting analysis is used to trace the dynamic responses of the variables. The impulse response function is based on a moving average representation of the VAR model, and the dynamic responses of one variable to another are evaluated over various horizons. This method ascertains the effects of a shock of an innovation of an endogenous variable on the variables in the VAR. Variance decompositions provides information concerning the relative importance of each innovation towards explaining the behavior of endogenous variables. This study employs the generalized forecast error variance decomposition technique attributed to Koop et al. (1996) and Pesaran and Shin (1998), as results of this method are not sensitive to the ordering of the variables in the VAR model.

5. Empirical Results

Tables 1 and 2 display the estimates from the unit root tests. The results from the application of the Augmented Dickey – Fuller (ADF) and Phillips-Perron (PP) tests in levels and in first differences of the data with an intercept, with an intercept and trend and with no intercept or trend. The lag selection of the ADF test is based on Schwartz Information Criterion (Schwartz, 1978) with a lag length of 1. The tests have been performed on the basis of 5 percent significance level using the MacKinnon (1996) critical values (C.V) and the null hypothesis is that of no stationarity. The PP test is estimated based on Bartlett Kernel with Newey-West bandwidth. Collectively, test results from both ADF and PP unit root approaches imply that the logarithmic forms of the variables under study (i.e. LGDP, LCF and LEC) are not stationary at conventional levels at any accepted level of significance (i.e. 5 percent significance level or above) and at any form of unit root test (i.e. intercept, intercept and trend or no intercept or trend). These are stationary variables at 1st differences. So, robust results indicate that all three variables are integrated of order one i.e. I (1) for the case of Greece. Therefore, we are allowed to proceed with the cointegration test, since the selected variables appear to have stationarity properties.

Table 1. Augmented Dickey – Fuller Unit Root Test Results

Variables	Test with Intercept		Test with Intercept and Trend		Test with no Intercept or Trend	
	Levels	1st Differences	Levels	1st Differences	Levels	1st Differences
LRGDP	-0.009	-3.637**	-2.830	-3.650**	1.694	-3.075***
LCF	-0.867	-5.447***	-3.043	-5.319***	0.975	-5.164***
LEC	-2.351	-3.550**	-1.356	-4.729***	1.961	-3.844**

Note: *, **, *** denote significance at 10%, 5% and 1% respectively. This note also applies to the subsequent tables.

Table 2. Phillips – Perron Unit Root Test Results

Variables	Test with Intercept		Test with Intercept and Trend		Test with no Intercept or Trend	
	Levels	1st Differences	Levels	1st Differences	Levels	1st Differences
LRGDP	-0.009	-3.907***	-2.329	-3.520**	2.233	-3.158***
LCF	-0.851	-5.944***	-2.991	-5.637***	1.069	-5.171***
LEC	-1.839	-3.849**	-0.217	-3.549**	4.688	-3.728**

Table 3 provides the results from the application of the Johansen cointegration test, in order to verify if the variables under investigation are cointegrated. The testing hypothesis is the null of non-cointegration against the alternative that there is a cointegrating relationship. The results for the model (LGDP, LCF and LEC) indicate that there is a long-run relationship between the variables, since both the trace and the maximum eigenvalue tests reject the hypothesis of no cointegration at the 5 percent significance level according to critical value (C.V.) estimates.

Table 3. Johansen Cointegration Test Results for (LRGDP, LCF and LEC)

Null Hypothesis	Trace Statistic	5% C.V.	Maximum Eigenvalue Statistic	5% C. V.
r* = 0	28.924**	24.276	18.111**	17.797
r ≤ 1	10.813	12.321	9.214	11.225
r ≤ 2	1.600	4.130	1.599	4.129

Note: * r is the number of cointegrating vectors under the null hypothesis.

The results that appear in table 3 suggest that the number of statistically significant cointegrating vectors is equal to 1 and is of the following form:

$$LRGDP = -0.5262 LCF^{***} - 0.6450 LEC^{***} \quad (11)$$
$$[-3.761] \qquad [-4.736]$$

The coefficients' estimates in equilibrium relationships, which are essentially the long-run estimated elasticities relative to the logarithmic form of real GDP suggest that both variables are statistically significant (figures in brackets are t-statistics) and inelastic to the economic growth of Greece.

Therefore, after determining that the logarithms of the variables are cointegrated, estimation of a VAR model arises that includes a mechanism of an error-correction. In such a case, the long-run cointegration relationship has the following form:

$$\Delta LRGDP = lagged(\Delta LCF_t, \Delta LEC_t) + \lambda u_{t-1} + V_t \quad (12)$$

Where, (Δ) is reported to first differences of the variables, (u_{t-1}) are the estimated residuals from the cointegrating equation (i.e. long-run relationship), (λ) is the short-run parameter and (V_t) is the white noise disturbance term.

Table 4 reports the results from the application of the VAR model. According to these estimations the error-correction term (ECT) for the case of the electricity consumption equation is strongly significant implying that all variables return to the long-run equilibrium whenever there is a deviation from their cointegrating relationship. However, these results reject the possibility of bidirectional relationship in the long-run among the data set. On the other hand, the short-run dynamics indicate that electricity consumption granger-causes real output. Nevertheless, these estimations suggest no short-run causality running from real GDP to EC, evidence that are in line with the studies of Kouakou (2011) for Cote d'Ivoire, Altinay and Karagol (2005) for Turkey, Lee and Chang (2005) for Taiwan and Soytas and Sari (2003) for Turkey, France, Germany and Japan implying that Greece is strongly energy dependent and therefore any structural reformations in the energy sector will have direct effects in the growth trend of the economy of Greece.

Table 4. A VAR Model with an Error Correction Mechanism for (RGDP, CF, EC)

Dependent Variable	ΔLRGDP	ΔLCF	ΔLEC	ECT
ΔLRGDP	-	-0.062 (-2.412)**	-0.103 (-2.121)**	-0.140 (-1.297)
ΔLCF	0.167 (0.433)	-	1.468 (0.893)	-0.040 (-0.218)
ΔLEC	-0.031 (-0.603)	0.029 (0.817)	-	-0.076 (-3.142)***

Note: Figures in parentheses are t-statistics.

After determining the directions of causality from the application of the VAR/VEC model, Figure 4 shows how a shock to one variable affects another variable and how long the effect lasts. For this purpose, this study employs the generalised impulse responses following Koop et al. (1996) and Pesaran and Shin (1998) innovative studies. Impulse responses of the variables are illustrated for a ten year period. These graphs indicate for the case of Greece that an unexpected shock to electricity consumption leads to a jump in real output which continues to grow during the 10 year period. These interactions are consistent with the findings from the VAR model, implying that the economic growth of Greece is strongly energy (electricity in our case) dependent. Furthermore, an unanticipated shock to real output leads to a downward trend in EC.

Figure 4. Impulse Responses between (LRGDP, LCF, LEC)

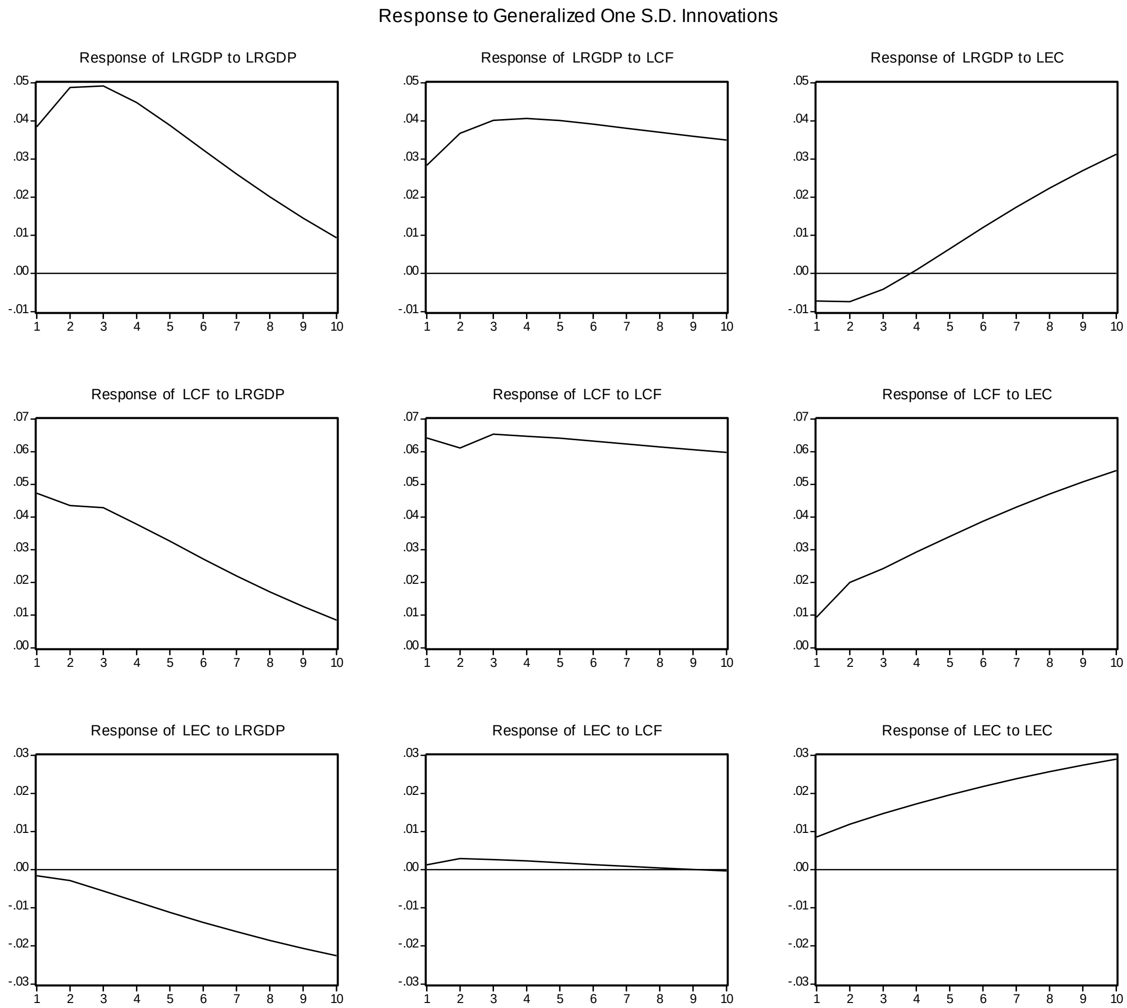


Table 5.1 presents the estimations of the variance decomposition for real output. These results indicate that the logarithmic form of electricity consumption initially explains relatively little of the future variation in real output. However, as the forecast horizon widens the explanatory power of EC increases, however with a slow pace presenting a relatively small percentage at the end of the 10 year period.

In addition, the variance decomposition of GDP as tabulated in Table 5.2 reports that real output accounts only for the 3.547% of the future variation of total electricity consumption. However, RGDP explains a continuously growing portion of EC's future variability and climbs to 17.746% after 5 years into the future and 10 years into the future real output explains more of electricity's consumption that EC alone (i.e. 30.875%).

Table 5.1. Variance Decomposition for LRGDP

Period	Standard Error	LRGDP	LCF	LEC
1	**0.038**	**100.000**	**0.000**	**0.000**
2	0.062	99.906	0.037	0.056
3	0.079	99.271	0.551	0.176
4	0.092	97.652	1.902	0.445
5	**0.101**	**94.739**	**4.358**	**0.901**
6	0.109	90.419	8.018	1.562
7	0.116	84.786	12.801	2.412
8	0.123	78.138	18.453	3.408
9	0.130	70.905	24.609	4.484
10	**0.138**	**63.553**	**30.873**	**5.573**

Table 5.2. Variance Decomposition for LEC

Period	Standard Error	LRGDP	LCF	LEC
1	**0.008**	**3.547**	**17.786**	**78.666**
2	0.014	4.805	30.415	64.778
3	0.021	8.982	35.832	55.185
4	0.028	13.51	39.027	47.460
5	**0.036**	**17.746**	**40.775**	**41.478**
6	0.044	21.395	41.734	36.869
7	0.053	24.453	42.242	33.303
8	0.061	26.993	42.497	30.509
9	0.070	29.106	42.606	28.286
10	**0.079**	**30.875**	**42.632**	**26.492**

Finally, this study attempts to forecast total electricity consumption and real output using the VAR model constructed in the earlier stages of this paper. The forecast horizon is 10 years (i.e. 2011-2020) and results are presented in Table 6.

Table 6. Forecasts of RGDP (in mill. USD) and EC (in mill. kWh) 2011 – 2020.

Year	VAR (LRGDP, LEC and LCF)			
	Units		Growth (%)	
	RGDP	EC	RGDP	EC
2011	291310,415	61349,756	-3,240	-0,194
2012	279105,469	61588,327	-4,190	-0,389
2013	288494,323	61979,582	3,364	0,635
2014	290745,016	62432,043	0,780	0,730
2015	293886,549	62900,428	1,081	0,750
2016	297386,036	63361,614	1,191	0,733
2017	300956,528	63804,095	1,201	0,698
2018	304447,869	64222,571	1,160	0,656
2019	307785,119	64615,119	1,096	0,611
2020	310934,676	64981,533	1,023	0,567

The forecast results for real output suggest that RGDP shows negative growth rates during the first two forecasted years (i.e. 2011 and 2012). These results could be explained from the fact that the economy of Greece experiences deep recession due to the severe sovereign debt crisis emerged since 2008 and affects almost every sector of the domestic economy. However, the tabulated forecast calculations show that positive growth rates return in Greece from 2013 and remain positive during the remainder forecast period (i.e. 2013-2020), although presenting a slow pace of economic development

(1.362% on average). On the other hand, total electricity consumption seems to follow the negative signs of real output for the forecast years 2011 and 2012, and presents positive rates from 2013 until 2020. These findings support the result from the long-run cointegrating vector for this model (see equation 11) which indicated the inelastic behaviour of total electricity consumption for the case of Greece.

6. Concluding Remarks and Policy Implications

This study investigated the relationship between electricity consumption and economic growth for the case of Greece and for the period 1980-2010 utilizing a neo-classical one sector production model. To assess the relationship between the selected variables (i.e. total electricity consumption, real output, labour and capital formation) a trivariate model was formed by dividing EC, RGDP and CF with labour and taking their logarithmic form. Within this framework, multivariate cointegration techniques and innovation accounting were employed. Therefore the study provided exhaustive empirical evidence from the application of unit root tests (ADF and PP), Johansen cointegration test, VAR model with an error-correction mechanism, impulse responses, variance decomposition and finally forecasts for real output and total electricity consumption on the basis of the VAR/VEC model.

The empirical results indicated that all variables are integrated of order one and that a long-run relationship exists between total electricity consumption and real GDP. Moreover, it was noted that all variables return to the long-run equilibrium whenever there is a deviation from their cointegrating relationship and that unidirectional granger causality exists from EC to RGDP implying that the economy of Greece is strongly energy-depended. These findings were further supported from the application of impulse responses, since relevant graphs indicated that an unexpected shock to electricity consumption leads to a jump in real output which continues to grow during a 10 year period. Finally, the tabulated forecasts for EC and RGDP indicated that Greece will return in positive (however slow) growth rates from 2013. Similar calculations were generated for total electricity consumption. Furthermore, these calculations verified the inelastic behaviour of EC supporting the form of the vector cointegrating equation.

Achieving energy security and diversification considering the rapid deterioration of climate conditions, has become a top priority of all developed countries in the world. Therefore, it is evident that energy policy in Greece could become a central driver towards the economic recovery considering the severe recession which the country experiences and threatens to demolish the economic structure that yielded impressive growth rates particularly in the past three decades which had as a foundation the European Union entry and the benefits of the following European Monetary Union. Increasing competition and reducing the role of the state in the energy sector should add efficiency and dynamism to the Greek economy. Reforming the electricity and gas markets is an economic and political necessity. In particular, regulatory authorities must be given the necessary power and independence to reduce the market power of dominant firms.

Greece recently transposed the provisions of the so-called 3rd EU Energy Package into Greek law by statute 4001/2011 in August 2011. This new legal framework also reflects obligations undertaken by the Greek government pursuant to the Memoranda of Understanding signed between Greece, International Monetary Fund (IMF), European Central Bank (ECB) and the European Commission. This new framework is bound to replace statute 2773/1999 which, as amended to transpose the provisions of the 2nd Electricity Directive 54/2003/EC, had failed to bring about liberalization and to challenge the monopolistic hold of the market by the Public Power Corporation (PPC). The old legal framework of 1999 was a first step towards a more liberalized energy sector (modelled after legislations which were introduced in the United Kingdom during the 90's) which allowed, yet to a very modest degree, independent power producers, traders and suppliers to enter the Greek market, however with significant restrictions. Of late, Greece has been requested persistently by various EU authorities to further open-up the energy market and make radical reforms that will promote in a more efficient way competition through the sale of lignite-fired and hydroelectric power units which are now exclusively owned by PPC.

In this spirit, there is no doubt that Greece has large potential to utilize its rich energy sources in order to promote growth and long-term sustainability and modernization via the introduction of the green economy. Especially the renewable energy sector provides opportunities for new industrial development, in particular if linked with R&D activities. However, in order for the country to enjoy the benefits of the so called "green-growth", given the significant energy-growth link as analysed in this study, requires several implications. First, the radical liberalization of the energy sector through the immediate application of the statute 4001/2011, which although passed by the Greek parliament still remains on paper. Furthermore, it is the thesis of this study that the privatization of the PPC is a prerequisite not only because it will accelerate the opening-up of the energy sector in Greece, but also it will relieve the Greek State from the payment of wages and to cover deficits. Furthermore, liberalization will have a significant and positive effect in the country's efforts to reduce unemployment which demonstrates a sharp upward trend during the last five years[2]. Second, it is crucial to accelerate the reduction of the country's dependence from oil and coal as energy sources. At the same time it is necessary to further exploit the significant potential of the country in energy production from renewable sources which still remains even below the country's commitments as signed under the Kyoto protocol. This policy implementation not only significantly contributes to exploit the country's comparative advantages but also robustly promotes competitiveness in which Greece suffers greatly and carries significant benefits for the environment. In addition it will result in reducing oil and coal imports and will gradually lead Greece to decarbonize its coal-dominated power sector and to use coal as an almost exclusive exporting product, since Greece still has considerable coal resources which are currently used to cover domestic electricity consumption. Third, in order for the country to attract foreign investments it is necessary to further simplify and accelerate licencing procedures and to fight structural problems of the Greek public sector, such as exhaustive bureaucratic conditions and corruption of public officials. Moreover, this study suggests that Greece could benefit from providing tax and other incentives for FDI and more generous subsidies supported by European Union funds intended to finance loans in order to swift domestic entrepreneurship towards the exploit of renewable energy sources.

To summarize, this study supports that given that energy consumption (electricity consumption in our case) significantly influences economic growth, any decisive plans to liberalize the electricity market in Greece, should promote; (i) efficiency and innovation in electricity production and distribution, which could result in lower prices for domestic and business use, (ii) competitiveness, (iii) new job opportunities, (iv) further globalization and modernization of the Greek economy, (v) significant environmental benefits, (vi) significant import of technology, (vii) privatizations, and (viii) radical changes in social and business culture towards more "green-friendly" solutions and entrepreneurship.

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