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On the Dynamic Linkages between CO_2 Emissions, Energy Consumption and Growth in Greece

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Abstract:

This paper attempts to analyze the short-and long-run causal dynamic interactions between energy consumption, CO_2 emissions and economic growth in Greece, using time-series techniques. To this end, annual data covering the period 1980-2012 are employed and tests for unit roots, the ARDL-bounds approach of cointegration, and Granger-causality based on error-correction models are applied. The results reveal strong feedback in the long-run between all the examined variables. For the short-run, there is evidence of two-way causality in all examined pairs with only exception the direction CO2 towards GDP.

Key Words: *CO2 Emissions, Energy Consumption, Growth, Causality, Greece*

JEL Classification : *L14, N54, N70, Q51, Q43*

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1. Introduction

In the past decade, numerous studies have been carried out to examine the gradual development of the relationship between environmental quality and the level of GDP for either a country or a group of countries. Such studies are known as environmental analyses of Kuznets curves, as a result of a hypothesis supported by Simon Kuznets in 1995. The causal relationship between environmental quality and the level of development is considered to have a specific direction and in particular from growth to emissions and therefore to environmental quality. However, it has also been argued that increased levels of emissions due to economic growth may have harmful effects on production (Pearson 1994, Stern et al. 1994) and consequently, the causal relationship between them might be bidirectional.

Therefore, causality analysis is not simply a prerequisite for further research on the relationship "environmental quality - GDP" but also a useful tool for policy decisions. For example, if there is lack of causal effects then policies aiming at reducing emissions may not have any impact on economic growth. In any case, if there exist causal linkages, then policy measures should be designed with a clear awareness of the significance and direction of the causal link between emissions and GDP.

The causality analysis has been applied in numerous empirical studies that investigate either the causal relationship between energy consumption and income levels (e.g. Yang, 2000, Shiu and Lam 2004, Yoo 2005) or the one between CO_2 emissions and income. The study of Coondoo and Dinda (2002), reports one-way causal relationship between CO_2 emissions and income for the groups of developed countries in North America, Eastern and Western Europe.

In parallel, a considerable number of studies on economic growth and environmental pollution has focused on the relationship between economic growth and energy consumption, since the pollution emissions are produced primarily by the consumption of solid fuels. Obviously, the understanding of the interaction and the direction of causality between energy consumption and economic growth is very important in the formulation of policies for energy and the environment.

For both the above mentioned bivariate relationships, the relevant literature considers the following cases:
(1) The "growth" hypothesis: The causal direction is from energy consumption / emissions to income.
(2) The "conservation" hypothesis: The causal direction is from income to energy consumption / emissions.

(3) The "neutrality" hypothesis: There is no causality between income and energy consumption / emissions and last
(4) The "feedback" hypothesis: There is bidirectional causality between income and energy consumption / emissions.

The literature has not yet come to a general acceptance for the nature and direction of the causal relationship between energy consumption, pollution and economic development and this is because the results depend on the level of development, the considered time period as well as the applied empirical methodology.

The combination of the two bibliographies for the CO_2-Growth nexus and the Energy Consumption-Growth nexus, so that the relationship between economic growth, energy consumption and pollution emissions could be tested within a multivariate causal framework, is a relatively new and very interesting area for the relative research. Besides, it seems much more promising for policies aiming at the gradual reduction of the national energy needs since policy makers have to consider the possible «causal linkages» between economic growth, energy consumption and environmental pollution.

Most existing studies refer to individual countries. There are studies for developed countries, such as France (Ang, 2007) and USA (Soytas et al., 2007), studies for developing countries, such as China (Zhang & Cheng, 2009), Malaysia (Ang, 2008) and Turkey (Halicioglu 2009, Soytas& Sari 2009) and for the rich oil countries of OPEC (Sari & Soytas, 2009). Apergis and Payne (2009), studied a panel of countries of Central America and Lean and Smyth (2010), a panel of 5 Asian countries. The survey results are still mixed. For the case of Greece, although several studies have already examined the relationship between energy usage and economic development, only a few have investigated this relationship based on advanced econometric approaches (e.g. cointegration) and, more importantly, in a broader framework that includes environmental feedbacks.

Hondroyiannis et al. (2002), examined the empirical relationship between energy consumption and economic growth in the period 1960-1996. Rapanos and Polemis (2005), analyzed the causal relationship between GDP and energy consumption for the period 1965-1998. Papadopoulos and Haralambopoulos (2006), investigated whether changes in carbon emissions are associated with changes in energy intensity, price, and energy consumption.

Undoubtedly, there is a need for multi-dimensional understanding of the energy situation in Greece on forming clear, new views for the relationship between economic growth, energy intensity and emissions of CO_2.

The aim of this research is to examine the relationship between economic growth, energy intensity and emissions of CO_2 using Greek data. First, we identify the integration properties and test for possible presence of cointegration between the CO_2 emissions and real GDP series. Depending on the results, we proceed with the estimation of error correction models (ECM) and test for the detection of Granger-type causality (Granger, 1969), in both the long and short run.

2. The Kyoto Protocol

The Kyoto Protocol emerged from the Framework Convention on Climate Change which was signed at the Rio conference, in June 1992, by almost all Member States (Greece ratified the Convention, making it a law of State, in April 1994). The aim of the Convention was "the stabilization of concentrations of greenhouse gases in the atmosphere at a level that prevents dangerous climate impacts of human activities."
In 1997, in Kyoto, a hundred countries, mainly these from the North agreed, within the next 15 years to reduce their greenhouse gas emissions to a 5.2 % below the levels existed in 1990 (or till 1995 for certain gases), defining the first "commitment period", which would cover the years 2008-2012.

However, China and India, which have had the fastest growth rates in terms of pollution, were not included in the agreement. As it was reported, they preferred to adopt a five-year commitment period instead of accepting a target year to smooth out annual fluctuations in emissions due to uncontrollable factors such as weather. This agreement was not sufficient to satisfy the first condition of the Rio Conference to stabilize the concentrations of gases in the atmosphere. Moreover, each country was given a quota based on the current levels of emissions (called grandfathering). This directly violated the second requirement for equality since, the greater the damage caused to the country in the past the more it would be allowed for the country to pollute in the future.

Finally, the Kyoto Protocol was signed by 178 countries, which represent the 95.7% of the population of the planet.
The gases discussed in the Kyoto Protocol are the following six:
• Carbon dioxide CO_2 (which is the most important greenhouse gas)
• Methane CH_4,
• Nitrous oxide N_2O,
• Hydro fluorocarbons HFC,
• Fully fluorinated hydrocarbons or per fluorocarbons and PFC
• Sulphur hexafluoride SF_6.

However, according to a research edited by the Joint research Centre of the European Union (JRC) and the Environmental Assessment of the Netherlands, entitled "Long-term trends in global emissions of CO_2", global carbon emissions rose between 1990 and 2010 by 45 %, reaching the record level of 33 billion tones. It should be noted that today's development of renewable energy, nuclear power and improving energy efficiency are insufficient to meet the demand for power and transport, especially in developing countries.

3. Empirical Analysis

3.1 Data

In the context of the empirical analysis we used data for Greece provided by the World Bank Database for the period 1980-2010. Specifically, we used annual data on real per capita GDP (YRPCE, in Euro, the per capita CO_2 emissions (COPC), in metric tons and the per capita energy use (EUPC), in kgs.

3.2 Methodology and Results of the Empirical Analysis

It is well known that in the context of time series analysis the order of integration of the involved series is of primary importance in order to avoid the spurious regression problem. Thus, to identify the integration properties (non-stationarity) of the variables we applied the Augmented Dickey-Fuller test (ADF) and that of Elliot, Rothenberg and Stock (1996), known as ADF-GLS which is considered of higher statistical power. The results from both tests for all our variables at their level and in first differences are shown in Table, 1 below.

Table 1: Unit Root Tests

VARIABLE	ADF	ADF-GLS	CONCLUSION
LCOPC	-1.1759 (-3.5023)	-0.2938 (-3.19)	NON-STATIONARY
LEUPC	-1. 6312 (-3.4986)	-0.5564 (-3.1868)	NON-STATIONARY
LYRPCE	-2.4153 (-3.5577)	-2.1157 (-3.1900)	NON-STATIONARY
DLCOPC	-8.0437 (-3.5043)	-7.507288 (-3.1900)	STATIONARY
DLEUPC	-5.5781 (-3.5004)	-5.6918 (-3.1868)	STATIONARY
DLYRPCE	-2.1392 (-3.5577)	-3.2931 (-3.2120) *	STATIONARY

Based on the reported results, all the series are found non-stationary of order one I(1). Therefore, the next step is to test for the existence of cointegration between them and detect the possible presence and direction of long-run causal effects.
For the purposes of our research, we adopted the methodology of ARDL cointegration suggested by Pesaran et al. (2001). This methodology saves degrees of freedom and leads to more reliable conclusions because technically it is a single equation cointegrating equation and does not require prior audit stagnation of test sequences to confirm that it is non-stationary same order of integration.
The ARDL method allows the assessment of long-term relationship with a simple OLS. In the first step, a model that comprises the series Y_t, X_t and Z_t, is estimated in the form of the following conditional error correction model using OLS:

$$\Delta Y_t = a_0 + \gamma_1 Y_{t-1} + \gamma_2 X_{t-1} + \gamma_3 Z_{t-1} + \sum_{i=1}^{n} \beta_{1,i} \Delta Y_{t-i} + \sum_{i=1}^{n} \beta_{2,i} \Delta X_{t-i} + \sum_{i=1}^{n} \beta_{3,i} \Delta Z_{t-i} + u_t \quad (1)$$

Where α_0 is the constant term, γ is the long-term multipliers and β is the short-term coefficients. Model (1), may include deterministic variables such as a time trend, dummy variables and other exogenous variables with fixed number of lags.
Then we test the following hypothesis:

$$H_0 : \gamma_1 = \gamma_2 = \gamma_3 = 0$$
$$H_1 : \gamma_1 \neq 0, \gamma_2 \neq 0, \gamma_3 \neq 0 \quad (2)$$

Rejection of the null hypothesis means implies existence of a long-run causal relationship among the variables. To test the null hypothesis, a modified F statistic (FPSS) is calculated with different asymptotic distribution from the usual F distribution.

Table 2: Cointegration Tests

Model	F-statistic	Conclusion
LYRPC\LCOPC,LEUPC	4.5493	Inconclusive
LCOPC\LYRPC,LEUPC	7.2801	Long-run causality
LEUPC\LCOPC,LYRPC	4.4265	Inconclusive
NOTE: 90% Lower Bound 95% Upper Bound 90% Lower Bound 90% Upper Bound 4.3867 5.6666 3.5115 4.6144		

In Table 2 above, we present the results of cointegration tests for all the examined relationships. We observe that the inference is inconclusive when the dependent variable is the income or the energy consumption. If one rejects the null hypothesis of the non-existence of a long-run relationship between the variables or even if the results fall into the inconclusive area, the next step is the selection of the optimal ARDL model which best fits the data based on the well known selection criteria such as Akaike-AIC or Schwarz-SBC. To this end, we use a general ARDL model as the one below:

$$Y_t = \beta_0 + \sum_{i=1}^{p} \beta'_{1,i} Y_{t-i} + \sum_{i=0}^{q} \beta'_{2,i} X_{t-i} + \sum_{i=0}^{r} \beta'_{3,i} Z_{t-i} + \varepsilon_t \tag{3}$$

Where p, q and r stand for the number of lags.
From the estimated model (3) we can calculate the long-term coefficients using non-linear functions of estimated coefficients as below:

$$a_0 = \frac{\beta'_0}{1-\sum_{i=1}^{p}\beta'_{1,i}}, \qquad a_1 = \frac{\sum_{i=0}^{q}\beta'_{2,i}}{1-\sum_{i=1}^{p}\beta'_{1,i}}, \qquad a_2 = \frac{\sum_{i=0}^{r}\beta'_{3,i}}{1-\sum_{i=1}^{p}\beta'_{1,i}} \tag{4}$$

where α_0 is the constant term and α_1 and α_2 are the long-term coefficients.
We present in Table 3 below, the estimates of the corresponding long-term equilibrium relations.

Table 3: Long Run Estimates

Independent Variables	DependentVariables		
	Estimatedcoefficients (prob-value)		
	LRYPC	LCOPC	LEUPC
LRYPC	-	-0.2139[.008]	0.3426[.001]
LCOPC	-2.0215 [0.028]	-	1.2089[.000]
LEUPC	1.9650 [0.011]	0.8766[.000]	-
constant	-1.5362 [0.680]	-2.7000[.006]	2.0054[.033]

Apart from the long-run equilibrium relationship linking the three variables Y_t, X_t and Z_t, it is possible to appear short-run imbalances. These short-run dynamics can be investigated by means of an error correction model (Error Correction Model - ECM) which essentially connects the long- run and short- run behavior of the variables. In this step, and based on the optimal ARDL, the corresponding, restricted error correction model of the following general specification is estimated:

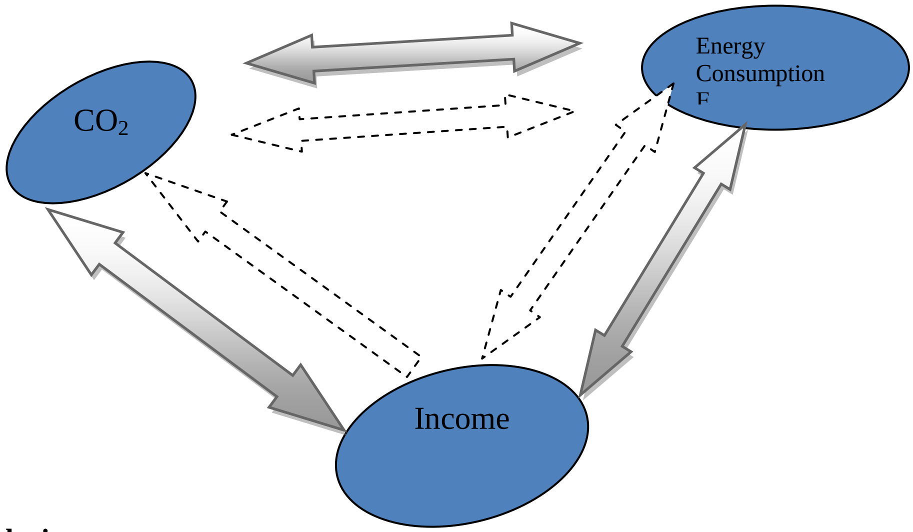
$$\Delta Y_t = \delta_0 + \lambda \hat{u}_{t-1} + \sum_{i=1}^{p} \delta_{1,i} \Delta Y_{t-i} + \sum_{i=0}^{q} \delta_{2,i} \Delta X_{t-i} + \sum_{i=0}^{r} \delta_{3,i} \Delta Z_{t-i} + e_t \qquad (4)$$

Where $\hat{u}_{t-1}$ is the error correction term resulting from long-term equilibrium relationship and the parameter λ is the adjustment coefficient, which indicates the speed at which any deviation from the long-run due to possible exogenous shocks is restored within a time period.
In the last step it is possible to test for Granger causality (Granger, 1969) between the variables. Table 4 below, shows a) the error correction models in conjunction with the results of Wald X^2 tests for the detection of significant short-term effects among the test series in the form of lagged first differences and also the direction of causality and b) the t statistics used to test the significance of the error correction term as well as the direction of the long-run causality.

Table 4: Error Correction Models

Independent Variables	DependentVariables		
	Test-Value [prob-value]		
	DLRYPC	DLCOPC	DLEUPC
Lags of DLRYPC	-	X^2= 110.0391[.000]	X^2= 12.4741[.029]
Lags of DLCOPC	X^2 = 3.3508[.067]	-	X^2= 49.6212[.000]
Lags of DLEUPC	X^2= 12.0198[.035]	X^2= 74.3298[.000]	-
ECT(-1)	t = -3.1594[.006]	t = -3.1569[.007]	t=-2.9604[.010]

The results in Table 4, are summarized in the following figure with the external arrows to show bidirectional (for all pairs of variables) long-run causal effects, while the internal with broken outline arrows to show the short-run causal effects which are bidirectional with an exception in the relationship between CO_2 and GDP which reveals that the effect is unidirectional running from GDP to CO_2 emissions.



4. Conclusion

This paper attempted to analyze the short-and long-run causal dynamic linkages between energy consumption, CO_2 emissions and economic growth in Greece, using time-series techniques. According to the results, that was found long-run causality running towards all involved variables revealing feedback effects.

The long-run effect from electricity consumption to economic growth, usually characterizes economies dependent on energy. An increase in electricity consumption leads to higher GDP because, apart from the direct effect on the energy required and consumed for commercial use, it also creates higher economic growth rates. Moreover, high consumption of electricity increases energy production, which indirectly creates employment and infrastructure in energy services. The results also show that the degradation of the environment has a positive relationship with economic growth in the long term. This is due to emissions from the production process and reflects a very common experience of many industrialized countries. Of course, this does not imply that environmental degradation is the way forward for promoting economic development. Moreover, based on the relevant literature that focuses on sustainability, the state policy should be primarily addressed to social welfare and not only to per capita income. (Gowdy, 2004 and 2005). In addition, a continuing degradation of the environment can create negative externalities for the economy by reducing the health of human capital and therefore the long-term productivity (Ang, 2008).

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