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## Abstract

The imperative to reduce $Co_2$ emissions is stronger than ever. According to many studies, renewable energy (electricity) has one of the most significant cost-effective potentials for reducing energy-related greenhouse gas emissions. Increasing the supply of renewable energy would allow for the replacement of carbon-intensive energy sources and significantly reduce pollutant emissions. The major focus of this article is to investigate the causal relationship between renewable and non-renewable electricity consumption, GDP and $CO_2$ emissions for the North and South shores of Mediterranean over the period 1980-2012. Panel unit root tests, cointegration technique allowing cross-section dependence among the panel and causality tests are used to investigate this relationship. The results provide panel empirical evidence that there is a short-run bidirectional causality between GDP, renewable electricity consumption and $CO_2$ emissions; and between non-renewable electricity consumption, GDP and renewable electricity consumption. As for the long-run causal relationship, the result indicates that there is bidirectional causality between non-renewable electricity consumption and $CO_2$ emissions. However, there is evidence of unidirectional causal relationship running from GDP to $CO_2$ emissions and non-renewable electricity consumption; from renewable electricity consumption to $CO_2$ emissions. The findings imply that non-renewable electricity consumption and economic growth stimulate $CO_2$ emissions in Southern and Northern Mediterranean countries while renewable electricity reduces it. Therefore, expansion of renewable energy sources is a strategic plan for addressing energy security and reducing carbon emissions to protect the environment for future generations.



**JEL Classification:** O4, Q5

**Keywords:** Renewable energy consumption, non-renewable energy consumption, $CO_2$ emissions, Panel cointegration, Mediterranean countries.



## ملخص

حتمية الحد من انبعاثات ثانى أكسيد الكربون هى أقوى من أي وقت مضى. وفقا للعديد من الدراسات، والطاقة المتجددة (الطاقة الكهربائية) لديها واحد من إمكانات أهم فعالة من حيث التكلفة للحد من انبعاثات غازات الدفيئة المرتبطة بالطاقة. أن زيادة المعروض من الطاقة المتجددة تسمح لاستبدال مصادر الطاقة الكثيفة الكربون والحد بشكل كبير من انبعاثات الملوثات. التركيز الرئيسي لهذه الورقة هو دراسة العلاقة السببية بين معدلات استهلاك الكهرباء، والناتج المحلي الإجمالي لثانى أكسيد الكربون المتجددة وغير المتجددة للشواطئ شمال وجنوب البحر الأبيض المتوسط خلال الفترة 1980-2012. وتستخدم المسح، بتقنية التكامل المشترك والسماح المقطع العرضي الاعتماد بين الاختبارات والسببية للتحقيق في هذه العلاقة. توفر نتائج الأدلة التجريبية أن هناك علاقة سببية على المدى القصير ثنائية الاتجاه بين الناتج المحلي الإجمالي، وانبعاثات ثانى أكسيد الكربون واستهلاك الكهرباء والمتجددة؛ وبين استهلاك الكهرباء غير قابلة للتجديد، الناتج المحلي الإجمالي واستهلاك الكهرباء المتجددة. أما بالنسبة للعلاقة السببية على المدى الطويل، فان النتيجة تشير إلى أن هناك علاقة سببية ثنائية الاتجاه بين انبعاثات ثانى أكسيد الكربون استهلاك الكهرباء الغير قابلة للتجديد. ومع ذلك، هناك أدلة على العلاقة السببية وحيدة الاتجاه تنحدر من الناتج المحلي الإجمالي لانبعاثات ثانى أكسيد الكربون واستهلاك الكهرباء الغير قابلة للتجديد من استهلاك الكهرباء المتجددة في انبعاثات ثانى أكسيد الكربون. النتائج تدل على أن استهلاك الكهرباء غير قابلة للتجديد وتحفيز النمو الاقتصادي تزيد من انبعاثات ثانى أكسيد الكربون في دول جنوب وشمال البحر المتوسط بينما يقلل الكهرباء المتجددة ذلك. لذلك، فان التوسع في مصادر الطاقة المتجددة خطة استراتيجية لمعالجة أمن الطاقة وتقليل انبعاثات الكربون لحماية البيئة للأجيال المقبلة.

## 1. Introduction

Research has shown that the level of pollutants released into the atmosphere has increased significantly since the beginning of the industrial era. Climate change, now widely recognized as the major environmental problem facing the globe, is an intricate phenomenon arising from complex interactions between three distinct parameters — economics, energy and the environment. Energy is necessary for economic production and, therefore, economic growth and the development of society, but also a major source of greenhouse gas emissions.

Fossil fuels remain the backbone of the world's energy system. At present, about 81% of all primary energy in the world is derived from fossil fuels, with oil accounting for 31.1%, coal for 28.9% and natural gas for 21.4% (IEA, 2015). Only 0.8% of the world's primary energy is derived from geothermal, wind, solar or other alternative energy sources. More specifically, wind power accounted for only 0.2% of the global primary energy supply with its 23 Mtoe contribution in while direct solar energy accounted for 0.1% with a 12 Mtoe output (SRREN, 2011).

A country's carbon emissions from electricity generation depend on both the quantity of electricity produced and the generation mix. The mix, or types of sources used, determines the carbon intensity – the amount of $CO_2$ emitted per unit of electricity.

The exponential increase of energy consumption and the rapid growth of pollutant emissions is expected to have a noticeable effect on the global environment: rising of global temperatures, erratic climate and weather extremes and altered ecosystems and habitats. All of these effects present increasing challenges for energy production and use and are increasingly playing a role in the design of future energy systems and energy policies.

In this context, several countries are paying close attention to climate change impacts and are considering ways to adapt to adverse impacts by developing strategies with the aim of finding concerted solutions to the problem. Incentivizing investments in renewable energy and low-carbon technologies will be a key challenge to achieve pollutant reduction targets.

However, increasing the use of renewable energy has many potential benefits, including a reduction of global warming emissions, the diversification of energy supplies and a reduced dependency on the fossil fuel energy market. In addition, renewable energy projects allow the replacement of carbon-intensive energy sources. Renewable energy industry is more labor-intensive, thus increasing renewable energy supply has the potential to stimulate employment, through the creation of jobs in new 'green' technologies.

The Mediterranean region *is endowed with a huge renewable energy (solar and wind) potential. Meanwhile, the electricity generation mix is still predominated by fossil fuels and renewable energy is poorly exploited. But d*uring the last decades, efforts are being exerted and Mediterranean countries are trying to implement different actions and strategies to resolve the energy and environmental problems and to develop renewable energy. We can cite the Mediterranean Strategy for Sustainable Development (MSSD), the Mediterranean Solar Plan (MSP) and recently the Renewable Energy Solution for the Mediterranean (RES4MED). *In fact,* the development of large-scale renewable energy projects, in this region, would have a many advantages, such as meeting the rising electricity demand at a lower cost, sustaining long-run economic growth, reducing energy bills in importing countries, creating new job opportunities, enhancing the quality of the environment and enhancing energy exchange cooperation both between Mediterranean countries and the EU.

Many researches have attempted to understand and to define the causality relationship between energy consumption, economic growth and $CO_2$ emissions. The objective is to analyze the effect of economic growth and energy consumption on the environment, but few studies have

focused on the causal relationship between CO2 emissions, renewable/or non-renewable energy (electricity) consumption and economic growth.

The purpose of this paper is to explore the dynamic relationship between renewable electricity consumption, non-renewable electricity consumption, $CO_2$ emissions and GDP for a panel of 9[1] Mediterranean countries over the period 1980-2012 using the recently developed panel data methods. Therefore, the empirical estimates of this study are important to guide policy-makers' decisions in terms of energy use, sustainable growth and CO2 emissions reduction in the Mediterranean countries.

The choice of the Mediterranean countries is motivated by the fact that little attention has been paid to these countries. There is a common interest between the two shores of the Mediterranean to develop north-south energy exchange. In addition, like in many other countries, the literature on causality between renewable and non-renewable and other variables of Mediterranean countries is rather limited. However, to the best of our knowledge, none of the empirical studies have focused to investigating the dynamic link between renewable and non-renewable electricity consumption–carbon emissions–GDP in this region. This paper sheds light on the possible sources and directions of the relationship between pollutant emissions, economic growth, renewable and non-electricity consumption. The study can also provide ideas on the design and the implementation of future economic and energy policies in the region.

However, this study aims to provide information that answers the following questions:

- What is the role of the renewable electricity consumption in reducing carbon emissions in the Mediterranean countries?
- Is there a possibility of substitution of renewable electricity for non-renewable electricity in the region both in GDP growth process?
- How renewable energy can contribute to reduce the pollutant emissions and sustain long run economic growth?
- What is the impact of the increasing electricity demand on the environmental quality in the Mediterranean countries?

In addition to the introductory section (Section 1), the rest of the paper is organized as follows: Section 2 presents the literature on the subject. Section 3 provides a brief overview of renewable energy in Mediterranean countries. Section 4 describes the data and the econometric model. We report our empirical findings in Section 5. Based on the results of the model, we draw conclusions and provide some policy implications in Section 6.

## 2. Literature Review

There is an impressive body of literature concerning the relationship between energy consumption, economic growth and pollutant emissions. The studies date back to the seminal work of Kraft and Kraft (1978) and this theme was particularly stimulated by the worldwide energy context: increasing the awareness of global warming, climate change, rising oil prices in recent years and issue of fossil fuels depletion. This issue is not recent concerns, hailing back to the 18th century when Malthus (1798) discussed the impact of growing exploitation of natural resources in an environment with limited capacity to sustain an ever increasing populace.

In the literature of energy economy, we can distinguish between three strands. The first group of studies has focused on the relationship between economic growth and environmental pollutant nexus. It tries to verify the validity of the Environmental Kuznets Curve (EKC) hypothesis. The EKC hypothesis postulates an inverted-U-shaped relationship between

[1]Algeria, Egypt, France, Greece, Italy, Morocco, Spain, Tunisia and Turkey.

different pollutants and per capita income (i.e., environmental degradation increases up to a certain level as income goes up; after that, it starts declining after a turning point). Therefore, the EKC hypothesis expresses a well-defined relationship between growth and environmental quality (see Grossman and Krueger (1991), Dinda (2004)). A second set of studies has focused on the relationship between energy consumption and economic growth. Since the pioneering study by Kraft and Kraft (1978), a voluminous causality literature has emerged (Liz and Montfort (2007), Belloumi (2009), Tsani (2010), Omri (2013)) and there is no consensus in results. The third strand has emerged from the two last set of studies that seek to analyze the relationship between economic growth, energy consumption and pollutant emissions. We can mention Ang (2007), Halicioglu (2009), Arouri et al. (2012), Cowan et al. (2014) and Kosamn and Duman (2015). The results of these studies are different from one country to another. The mixed findings reflect several factors, including institutional differences between countries, model specification and econometric approach (See Table 1).

In the latest decades, some researches have focused on renewable energy and its role in enhancing growth and fighting against global warming. The new trend in the literature of energy economics is to decompose the effects of renewable and non-renewable energy consumption on the economy, but there are few studies that have focused on the causal relationship between $CO_2$ emissions, renewable and/or non-renewable energy (electricity) consumption and economic growth. In this section, we will outline some results of this field of research (see Table 2).

Sadorsky (2009) analyzes the relationship between renewable energy consumption, GDP and $CO_2$ emissions in G7 countries from 1980-2005. Panel cointegration estimates show that 1% increases in real income per capita increase renewable energy consumption in G7 countries by 8.44% or 7.24% according to the estimation technique is FMOLS or DOLS, and 1% increases in $CO_2$ emissions per capita increase renewable energy consumption in G7 countries by 5.23 % (FMOLS technique). So, real GDP and $CO_2$ emissions had positive effects on renewable energy consumption.

Menyah and Wolde-Rufael (2010) explored the causal relationship between $CO_2$ emissions, nuclear energy, renewable energy and growth in USA over the period 1960-2007 using a Toda and Yamamoto (1995) test. The investigation confirms a unidirectional causality running from nuclear to carbon emissions. This result confirms the negative impact of non-renewable energy on the environment. The second important result is the unidirectional causality running from $CO_2$ emissions to renewable energy consumption.

Salim and Rafiq (2012) analyzed the relationship between $CO_2$ emissions and renewable energy consumption and income for six emerging countries using the dynamic OLS and fully modified OLS techniques. They conclude that renewable energy consumption is significantly determined by income and $CO_2$ emissions in Brazil, China, India and Indonesia. For the same countries, the Granger causality test confirms a bidirectional causality between renewable energy consumption and $CO_2$ emissions in the short run and bidirectional causality between income and $CO_2$ emissions in Brazil, China and Turkey. The latest result implies that decrease $CO_2$ emissions can effect negatively economic growth in these countries.

Sebri and Ben Salha (2014) investigated the relationship between renewable energy consumption, $CO_2$ emissions and economic growth for the BRICS countries over the period 1971 and 2010 within multivariate frameworks. The ARDL bounds testing approach to cointegration and Vector Error Correction Model are used to examine the long-run and causal relationships. The ARDL approach confirms the positive impact of renewable energy consumption on economic growth and vice versa. The causality test concludes on bidirectional causality between economic growth and renewable energy consumption in short and long run

excepting India. They also find bidirectional causality running among all the variables in the long run.

Shafiei and Salim (2014) explored the relationship between non-renewable and renewable energy consumption and $CO_2$ emissions in OECD countries using STIRPAT model over the period 1980 and 2011. Their results support the existence of an Environmental Kuznets Curve between $CO_2$ emissions and urbanization. They find that renewable energy consumption has a negative impact on $CO_2$ emissions, whereas non-renewable energy consumption has a positive and significant impact on carbon emissions. They conclude that policy makers should design and develop effective support policies to promote investment in new renewable energy technologies.

Unfortunately, there is no consensus on the results of these studies and the findings are diverse. The results regarding the direction of causality are inconclusive.

The potential innovations of this paper are as follows: this paper investigates the relationship among renewable and non-renewable electricity consumption, $CO_2$ emissions and economics growth for Mediterranean countries, using more recent developed panel data methods. We also explore the mutual influence between these variables through Granger causality test.

## 3. Brief Overview of Energy Context in Mediterranean Countries

The Mediterranean basin faced many environmental and energy challenges. The population has about 450 million (more than half live in Egypt, Turkey, France and Italy), who consume almost 1,000 million tons of oil equivalent (Mtoe) of energy each year (i.e., around 8.2% of global demand). To date, about 94% of the energy consumption of MED-11 countries has been covered by hydrocarbons. In the North, more than 90% of fossil fuels are imported while the South enjoys an export capacity of 26%.

The two shores of the Mediterranean are complementary, and energy constitutes a strong link between them: the European Union depends on the South for 35% of its gas and 22% of its oil, which represents respectively around 85% and 50% of the South exporting volumes. The Southern Mediterranean region is the third largest supplier of natural gas to the EU.

The first consequence of this strong production and consumption is the global warming caused by pollutant emissions. The carbon emissions have grown dramatically over the last few decades **(**see Figure 1**)** and the largest single source of $CO_2$ emissions in the Southern Mediterranean region is the combustion of fossil fuels to generate electricity. Indeed, the trend scenario of the Energy World Organization shows that the energy consumption in Mediterranean region will be based on oil in 2030. These countries will import 39% of their oil needs and 28% of natural gas. This consumption will increase $CO_2$ emissions, and according to different reports and studies the south shore of the Mediterranean is particularly vulnerable to global warming because of its geographical position and its dependence on climate sensitive economic sectors (like agriculture, fisheries and tourism). Climate change affects all of the area and common risks are already detected. It is an example of common contrast between the northern part of a country (developed) and the southern part of a country (still in development).

However, electricity is at the heart of economic and social development of many countries and its plays a crucial role in Mediterranean regions especially in south shore, where consumption grew by an annual growth rate of about 6% between 1990 and 2010 -- three times more than north Mediterranean countries who grew at an annual growth rate of 1.8% (FEEM, 2015). In the future, the higher level of economic growth and population will push up demand for electricity and will put additional pressure on the existing electricity infrastructure, requiring major investments in the construction of new electricity generation facilities, transmissions lines and distribution networks. On the other hand, the regional electricity generation mix is still predominated by fossil fuel.

In this overall situation, the development of renewable energy and efficient energy represents an important contribution to the much-needed sustainability path of the region, particularly due to the existence of a huge potential of renewable energy resources, such as wind and solar and biomass energies.

The South shore of Mediterranean countries has a high rate of sunshine between 2,700 and 3,400 hours per year, and the average annual radiation is between 1,900 Kwh per $m^2$ in the coastal areas and 3,200 Kwh per m² in the desert areas. In the framework of the "Solar Atlas for the Mediterranean" the economic potential of CSP in the overall south shore could be estimated at 431,382 TWh/year in 2030 and in the North Mediterranean region could be estimated at 1,450TWh/year. The potential of photovoltaic is calculated to 122 TWh/year in the South shore, and only 22TWh/year in the North shore. The wind potential is also high; the wind speed is between 6 and 11 meters per second. The technical potential is estimated to 21,967 TWh/year in Southern and 648 TWh/year in Northern (FEEM 2015). Nevertheless, of these high potentials, the share of renewable energy production is still below needs. So, the cooperation between both of them can have many advantages. The North shore has the human skills, the technology and the experience while the south shore has abundant natural resources.

Over the world, renewable energy represented in 2012[2] 20% of global final energy consumption and a share of electricity production by renewable energy in 2012 represent 21.7%, is lower comparatively to fossil fuel 68.1% and nuclear 10.9%. In Mediterranean countries, the share is fluctuating from one country to another**.** In 2012, Spain consumed 35.34% of its electricity through renewable energy, in Turkey 33.3%, in Italy 28.89% and France and Greece around 18%. The share is higher in developed countries compared to developing countries. Only Morocco is making efforts to increase a renewable electricity consumption, which rose from 5.94% in 2000 to 9.47% in 2012. The share is still low for Tunisia (2.38%) and Algeria (1.61%).

Figure 2 illustrates the change in renewable electricity consumption in Mediterranean countries between 1980 and 2012. There are only three developed countries that increased their renewable electricity consumption through this period: Italy 46.85%, Spain 65.99% and Turkey 82.54%.

In the last decades, many renewable energy projects were developed in this region. The aim is to extend cooperation between the two shore of Mediterranean countries to export to Europe the electricity potentially produced by South countries via solar and wind energy resources through HVDC (high voltage direct current) electricity interconnection. We can name TREC (Trans Mediterranean Renewable Energy Cooperation) developed in 2003, DESERTEC in 2009, MSP (Mediterranean Solar Plan) in 2008, MEDGRID created in 2010 and RES4MED (Renewable Energy for Mediterranean) in 2012. Almost all governments adopted their own national renewable energy plans with the aim to enhance their domestic exploitation of renewable energy resources. And many countries in the south of Mediterranean put in place dedicated agencies to support their renewable energy plans and implement the policy of the government on the ground.

Despite the big potential of renewable energy and all efforts deployed in this region, the share of renewable energy remains low and projects fail to start. This is explained essentially by the different prevailing barriers (commercial, infrastructural regulatory and financial), particularly on the Southern shore. The most blocking barrier is the energy subsidies. The justification of this political economy of energy, among other reasons, is to limit energy poverty and also to boost domestic supply. But there is a negative consequence of these subsidies: discourage

[2] Key World Energy Statistics, 2014, IEA.

efficient energy use, limit financial resources available to invest in the energy sector, and limit the competitiveness of renewable energy sources (FEEM, 2012).

Starting from all these facts, we will try through econometric modeling to verify if the development of renewable energy really limits $CO_2$ emissions and boosts economic growth in the Mediterranean countries.

## 4. Methodology

### *4.1 Data and model*

Our empirical analysis is based on annual time series data over the period 1980-2012 for nine Mediterranean countries. Data on electricity consumption, renewable and non-renewable (billion kilowatt hours) are obtained from the International Energy Agency (IEA, 2012). The data on real GDP per capita (constant 2005 US$) and $CO_2$ emissions (metric tons) are taken from World Development Indicator for the World Bank (WDI 2015).

In this paper, we investigate the causality between renewable and non-renewable electricity consumption, $CO_2$ emissions and GDP. Consequently, the logarithmic form of the estimated equation is as follow:

$$Ln\mathrm{CO}_{2it} = \alpha_{it} + lnGDP_{it} + lnNREC_{it} + \ln REC_{it} + e_{it} \qquad (1)$$

Where $CO_2$, GDP, NREC, REC denote $CO_2$ emissions, Gross Domestic Product, Non Renewable Electricity Consumption, Renewable Electricity Consumption, respectively. e is the error term. The subscript *i* refers to countries and *t* denotes the year.

### *4.2 Estimation strategy*

To explore the dynamics of the relationships between both $CO_2$ emissions, electricity consumption and GDP the following steps are performed. The steps of the model are summarized in Figure 3**.**

#### *4.2.1 Testing cross section dependence*

One important issue in a panel causality analysis is to take into account possible cross-section dependence across regions. First, the cross-section dependence is tested to decide which unit root test would be appropriate. We use the Lagrange Multiplier test (LM) developed by Breusch and Pagan (1980). This test is favorable if T is larger than N. Pesaran's (2004) cross-sectional dependence (CD) test is valid when $T<N$ and can be used with balanced and unbalanced panels. A growing body of the panel-data literature concludes that panel-data models are likely to exhibit substantial cross-sectional dependence in the errors (De Hoyos and Sarafidis (2006)). Cross correlations of errors could be due to omitted common effects, spatial effects, or could arise because of the presence of common shocks and unobserved components that ultimately become part of the error term (Robertson and Symons (2000), Pesaran (2004), Anselin (2001); Baltagi (2005)).

The presence of some form of cross-sectional correlation of errors in panel data applications in economics is likely to be the rule rather than the exception. According to De Hoyos and Sarafidis [2006], one reason for this result may be that during the last few decades we have experienced an ever-increasing economic and financial integration of countries and financial entities, which implies strong interdependencies between cross-sectional units. This is because high degree of economic and financial integrations makes a region to be sensitive to the economic shocks on the region.

However, ignoring cross-sectional dependence of errors (as it is commonly done by practitioners) can have serious consequences. It is well known that ignoring cross-sectional dependence may affect the first-order properties (unbiasedness, consistency) of standard panel estimators and lead to incorrect statistical inference. The decrease in estimation efficiency can

become so large that, in fact, the pooled (panel) least-squares estimator may provide little gain over the single-equation ordinary least squares (Phillips and Sul (2003)).

*4.2.2 Panel unit root tests*

As a first step, it is necessary to check whether each variable of interest is stationary. Since the seminal works of Levin and Lin (1992, 1999) and Quah (1994), the investigation of integrated series in panel data has known a great development, and panel unit root tests have been applied to various fields of research. For this purpose, it is common practice in the literature to perform several panel unit root tests, given the shortcomings of any single test with regard to sample size and power properties.

A number of panel unit root tests have been developed in the literature (Levin and Lin (1992), Im, Pesaran and Shin (1997), Harris and Tzavalis (1999), Madala and Wu (1999), Choi (1999), Hadri (2000), Levin, Lin and Chu (2002), Pesaran (2007)).

Two generations of tests can be distinguished. The first generation of panel unit root tests is based on the cross-sectional independency hypothesis and includes the contributions of Maddala and Wu (1999), Choi (2001), Hadri (2000), Im et al. (2003).

Various tests have been proposed in response to the need for panel unit root tests that relax the cross-sectional independence assumption and allows for cross-sectional dependence. The second generation unit root tests include the contributions of Bai and Ng (2004), Moon and Perron (2004), Smith et al. [2004], Pesaran (2007) or Pesaran et al. (2008). This last category of tests is still under development, given the diversity of the potential cross-sectional correlations. In the presence of cross-section dependence, "first generation" panel unit root tests tend to reject the null hypothesis of a unit root excessively.

Hence, we propose two different panel unit root tests: the Breitung [2000] test, which assume homogeneity among each cross section, and a more recent CADF test suggested by Pesaran [2007].

*4.2.3 Panel cointegration tests*

The next step in our analysis is to apply the cointegration test. When both series of the same order are integrated, we can proceed to test for the presence of cointegration (i.e., whether there is a long-run relationship between the variables). Consequently, a panel cointegration test can be used to study the long-run equilibrium process. For this purpose, we recently used Durbin Hausman group mean cointegration test developed by Westerlund and Edgerton (2008). This test allows for cross-sectional dependence and they do not rely heavily on a priori knowledge regarding the integration orders of the variables which allows the stability ranks of the independent variables to be different. Thus, it can be applied under very general conditions.

*4.2.4 Estimation of long-run relationship*

As stated by Philips and Sul (2007), when models suffer from the problem of cross-section dependence, heteroskedasticity and serial correlation panel estimators can results in misleading inference and even inconsistent estimators. Pesaran have suggested an estimation method to alleviate some of these difficulties, called Common Correlated Effects (CCE), which has been further developed by Kapetanios et al. (2011), and Chudik et al. (2011). The Pesaran (2007) CCE estimator exhibits more advantages. It does not involve estimation of unobserved common factors and factor loadings. It allows for unobserved factors to be correlated with exogenous regressors and idiosyncratic components to be independent across countries. Furthermore, the proposed estimator is still consistent under different situations such as serial correlation in errors, unit roots in the variables and possible contemporaneous dependence of the observed regressors with the unobserved factors (Chudik et al. (2011)).

In this step we employ Common Correlated Effects Mean Group (CCEMG) estimator, proposed by Pesaran (2007), to estimate the long-run estimators that account for cross sectional dependence. Eberhardt (2002) stated that CCEMG approach is robust to the presence of a limited number of "strong" factors and an infinite number of "weak" factors. In addition, the estimator is robust to non-stationary common factors (Kapetanios et al. (2011)).

*4.2.5 Granger causality test: Panel short-run and long-run causality test*

Given the existence of a cointegration relationship, the next step is to determine the source and the direction of causality between the variables. Panel Granger causality is tested following the two-step Engle-Granger causality procedure (Engle and Granger (1987)). To identify the sources of causality and distinguish between short-run and long-run relationships we apply the Pooled Mean Group (PMG) estimator proposed by Pesaran et al. (1997). The PMG estimator (see Pesaran et al. (1997), (1999)) relies on a combination of pooling and averaging of coefficients. This particular estimator allows us to deal with an important problem that confronts empirical panel studies: that of parameter heterogeneity. The major advantage of PMG is that it allows short-run coefficients, including the intercepts, the speed of adjustment to the long-run equilibrium values, and error variances to be heterogeneous country by country, while the long-run slope coefficients are restricted to be homogeneous across countries. In addition, the PMG estimation technique is robust to outliers and the choice of lag orders.

The basic PMG estimator involves estimating an ARDL model of order (pi, qi). In this case, the ARDL dynamic panel specified as follows:

$$y_{it} = \sum_{j=1}^{p} \lambda_{ij} y_{i,t-j} + \sum_{j=0}^{q} \delta_{ij}^{*} X_{i,t-j} + \mu_i + \varepsilon_{it} \qquad (2)$$

Where $X_{it}(k * 1)$ is the vector of explanatory variables; $\mu_i$ represent the fixed effects; $\lambda_{ij}$ are scalars; and $\delta_{ij}^{*}$ are $(k * 1)$ coefficient vectors. It is convenient to work with this following re-parameterization (see Pesaran et al. (1997)) of Eq. (2):

$$\Delta y_{it} = \varphi_i \left( y_{i,t-1} + \theta_i' X_{it} \right) + \sum_{j=1}^{p-1} \lambda_{ij}^{*} \Delta y_{i,t-1} + \sum_{j=0}^{p-1} \delta_{ij}'^{*} \Delta X_{i,t-j} + \mu_i + \varepsilon_{it} \qquad (3)$$

Where:

$$\varphi_i = -\left( -\sum_{j=1}^{p} \lambda_{ij} \right)$$

$$\theta_i = \sum_{j=0}^{q} \delta_{ij} \Big/ (1 - \textstyle\sum_k \lambda_{ik})$$

$$\lambda_{ij}^{*} = -\sum_{m=j+1}^{p} \lambda_{i,m} \; ; j = 1, 2, \dots, p-1$$

$$\delta_{ij}'^{*} = \sum_{m=j+1}^{q} \delta_{i,m} \; ; j = 1, 2, \dots, q-1$$

$\varphi_i$ represents the error-correction speed adjustment term. The long run equilibrium relationship can be tested statistically using the significance of $\varphi_i$. If the null hypothesis $\varphi_i = 0$ then there would be evidence of long-run equilibrium, (i.e., the variables are cointegrated and there is evidence of long run causality running from independent to dependent variable). The direction of short-run causality can be determined by testing the significance of the coefficients of each explanatory variable, that is, $\delta_{ij}'^{*} = 0$ in Eq.3. In our case we can specify Eq.4 in terms of variables in Eq.1 as follows:

$$\Delta \mathrm{LnCO}_{2it_{it}} = \varphi_i\left(y_{i,t-1} + \theta_i' X_{it}\right) + \sum_{j=1}^{p-1} \lambda_{ij}^{*}\, \Delta \mathrm{LnCO}_{2i,t-1} + \sum_{j=0}^{p-1} \delta_{ij}'^{*} \Delta X_{i,t-j} + \mu_i + \varepsilon_{it} \quad (4)$$

Where X is the vector of explanatory variables: LnGDP, LnNREC and LnREC. In the same way we can specify equation for other variables.

## 5. Empirical Analysis and Results Discussion

### *5.1 Cross dependence tests*

To test for cross-sectional dependency, the LM test of Breusch and Pagan (1980) has been used in this study. The Breusch and Pagan test statistic is asymptotically distributed as chi-squared with $N(N-1)/2$ degree of freedom, under the null hypothesis of cross-sectional independence. From Table 3, it is clear that the null hypothesis of no cross-sectional dependency across the countries is decisively rejected at the 5% significance level. This finding implies that a shock occurring in one of these Mediterranean countries seems to be transmitted to other countries. To assess whether the cross-section independence assumption of the "first generation" tests is valid, we start with a test for error cross-sectional dependence (CD) as suggested by Pesaran (2004).

### *5.2 Unit-root test*

In order to examine the stochastic properties of the four series (unit roots and stationarity), the Pesaran CADF (2007) and Breitung (2000); Breitung and Das (2005) tests have been applied as we can see in Table 4.

After we found the presence of dependence in the variables, we studied their order of integration using different tests that account for dependence. All are representative of the "second generation" panel unit root tests. These tests relax the restrictive assumption of cross sectional independence.

First, we apply Pesaran's (2007) CADF test (Cross Augmented Dickey Fuller). To eliminate the cross dependence, the standard DF regressions are augmented with cross-sectional averages of lagged levels and first differences of the individual series. The proposed test has the advantage of being relatively robust with respect to cross-sectional dependence, even if the autoregressive parameter is high. In addition, the approach is intuitive and simple to implement. It is also valid for panels where N and T are of the same orders of magnitudes. Second, we also apply Breitung test (2000) (Breitung and Das (2005)) a suitable approach when cross-correlation is pervasive, as in this case. The Breitung test assumes that the error term $\varepsilon_{it}$ is uncorrelated across both i and t. Breitung test adjusts the data before fitting a regression model so that bias adjustments are not needed. In addition, the Breitung procedure allows for a prewhitening of the series before computing the test. The null hypothesis of these unit root tests is that all series contain a unit root.

### *5.3 Cointegration tests*

Given that each of the variables presents a panel unit root, we need then to check whether there is a long-run relationship between the variables using the error correction based cointegration test for (unbalanced) panels developed by Westerlund (2007). The existence of negative error correction term is taken as proof for cointegration. To accommodate cross-sectional dependence, critical values are obtained through bootstrapping.

The test is meaningful for application in our case for the following reasons: First, it is general enough to allow for a large degree of heterogeneity, both in the long-run cointegration relation and in terms of short-run dynamics (Persyn and Westerlund (2008)). Second, it is developed to cope with cross-sectionally dependent data. Third, the test comes along with an optional bootstrap procedure that allows for multiple repetitions of the cointegration tests, which is

meaningful since we have indications for cointegration in the panel. While, the group-mean tests (Gt and Ga) examine the alternative hypothesis that at least one unit is cointegrated, the panel tests (Pt and Pa) have the alternative hypothesis that the panel is cointegrated as a whole (Persyn and Westerlund (2008)).

As we can see in Table 5, the results of Westerlund's test shows that Groupe-t and Panel-a test statistics are significant and reject the null hypothesis of no cointegration, indicating some evidences of cointegration.

### *5.4 Long-run estimation*

Empirical evidence suggests that $CO_2$, GDP, REC and NREC are cointegrated. To further explore the sustainability condition, we estimate the long-run parameters in the cointegration relation of each panel using the Cross Correlated Effects (CEE) and the Common Correlated Effects Mean Group (CCE-MG) estimation procedures developed by Pesaran (2007) CCE-MG estimations. In Table 6, we report estimates of Pesaran's long-run CCEMG. The results chow that GDP per capita and non-renewable electricity have positive and significant effects on $CO_2$ emissions, implying that an increase in both GDP per capita and non-renewable electricity consumption in Mediterranean countries leads to increases in $CO_2$ emissions. In addition, we can observe that the coefficient for GDP is greater than that for NREC. This result demonstrates that in the long run, GDP per capita contributes more to increased pollutant emission than NREC in Mediterranean countries. The coefficient of GDP suggests that a 1% increase in this factor leads to in an increase in $CO_2$ emissions by 0.35%. Similar results have been found by Shafiei and Salim (2014]) for the OECD countries. However, it is found that renewable electricity consumption has a negative effect on $CO_2$ emissions, thus a 1% increase in renewable electricity consumption reduces $CO_2$ emissions by 0.002% in the long run. This finding is consistent with the negative relationship found by Shafiei and Salim (2014) for the OECD countries.

### *5.5 Short-run and long-run causality test*

The result of short and long run Granger causality test are reported in Table 7. The findings are essentially interpreted for the relationships between $CO_2$and the others variables.

Regarding the long-run causality, ECT's coefficients are negative and statistically significant where $CO_2$ and non-renewable electricity are the dependent variables. This implies that there is a bidirectional long-run causality between $CO_2$ emissions and non-renewable electricity consumption. This result is consistent with the findings of Shafiei and Salim (2014]). In addition, we also find unidirectional long-run causality running from renewable electricity consumption to $CO_2$ emissions is in contrast with the results of Shafiei and Salim (2014) for OECD countries and Menyah and Wolde-Rufael (2010) for the US. The finding of unidirectional causal relationship running from GDP to $CO_2$ emissions is in line with the results of Acaravci and Ozturk (2010) and Akpan and Akpan (2012). This result indicates that controlling and reducing $CO_2$ emissions does not affect economic growth for this panel. Similarly, there is unidirectional causality running from GDP to non-renewable electricity consumption. This result was found by Apergis and Payne (2011) and Tugcu et al. (2012) for Japan and England. This implies that energy conservation policies may be efficient to reduce pollutants and will have no adverse effect on the real output growth. When the dependent variable is GDP, the ECT coefficient is negative but not significant, so there isn't causality running from $CO_2$ emissions, renewable and non-renewable electricity consumption to GDP in the long run. The same conclusion can be made if the dependent variable is the renewable electricity consumption. There is no causality running from $CO_2$ emissions, non-renewable electricity consumption and GDP to renewable electricity consumption. The non-causality between renewable electricity consumption and GDP is found by Payne (2009) and Menegaki (2011). This finding is in line with the low share of renewable electricity consumption in this

panel. Figure 4 recapitulates the long-run causal relationship between the four series for the panel.

Turning to the short-run Granger causality relationship, the empirical results indicate the existence of bidirectional causality running between renewable electricity consumption and GDP. This result is similar to the finding by Sadorsky (2009), Apergis and Payne (2012), Beldiriçi (2013) and Sebri and Ben Salha (2014). This indicates that economic growth and renewable energy consumption mutually influence each other in Mediterranean countries. Therefore, the development of renewable energy resource may lead to a significant positive impact on economic growth. However; any negative shock in the process may have a negative impact on economic growth in the region.

Renewable energy is one determinant of growth in Mediterranean countries and the increase in income is a core factor driving the development of the renewable energy sector. So governments of Mediterranean countries considered in this study should develop more renewable energy consumption and promote investment in new renewable energy technologies. Similarly, we find bidirectional causality between $CO_2$ emissions and renewable electricity consumption. This result is in line with the findings of Salim and Rafiq (2014). Thus, $CO_2$ emissions push policy makers to take different policy and measures to scale down fossil energy consumption and develop more renewable energy. A bidirectional causal relationship is confirmed between $CO_2$ emissions and GDP and this result is consistent with the findings of Salim and Rafiq (2012) for six emerging countries and Omri (2013) for MENA countries. This implies that degradation in the environment has an impact on economic growth. The evidence seems to suggest that to reduce pollutant emissions countries may sacrifice their economic growth. We find unidirectional. Finally, the empirical result suggests that there is bidirectional causal relationship between renewable electricity consumption and non-renewable electricity consumption.

As shown in Table 7, there is unidirectional causality running from non-renewable electricity consumption to GDP. This same result is found by Hamit-Haggar (2012). The unidirectional causality from non-renewable electricity consumption to dioxide carbon emissions without feedback implies that energy conservations policies are determinant to limit pollutant and environment degradation. Figure 5 recapitulates the short-run causal relationship between the four series for the panel.

## 6. Conclusion

In this study, we aimed to explore the dynamic relationship between renewable, non-renewable electricity consumption, $CO_2$ emissions and GDP for nine Mediterranean countries over the period 1980-2012. To address the limitation of prior research we used the recent developed panel data methods that take into account cross section dependence across regions. In addition, statistical techniques used in this study allow us to better distinguish between the short- and long- term causality; and take into account possible endogeneity and heterogeneity. Our panel cointegration and causality test found several interesting findings and the results have clear implications for the implementation of future policies on promoting renewable energy in combination with macroeconomic policies in Mediterranean countries.

First, the results indicate the presence of a short-run bidirectional causality running from $CO_2$ emissions to GDP, and renewable electricity consumption. We find also a feedback hypothesis between real GDP and renewable electricity consumption. So, renewable energy is a determinant factor of growth and vice versa. The unidirectional causality running from non-renewable electricity consumption to GDP confirms that energy conservation policy will have an adverse effect on real output in the short run. And the unidirectional causality running from non-renewable electricity consumption to $CO_2$ emissions confirms the role of non-renewable electricity in affecting the environment; so it's important to limit this kind of energy that is

more pollutant than renewable energy and move towards substitutability from non-renewable to renewable energy consumption.

Second, in the long-run, there seems to be on the one hand a bidirectional causal relationship between non-renewable electricity consumption and dioxide carbon emissions. On the other hand, there is a non-causal relationship found running from $CO_2$ emissions and non-renewable electricity consumption to real GDP. These results imply that energy conservation policy can be conducted without affecting real output in the long run. The inexistence of a causal relationship between renewable energy consumption and real GDP is the result of the low share of the renewable energy in the energy mix of the Mediterranean countries.

The results of this research will be interesting in the sense that they provide an important energy and economic policy implication for the Mediterranean countries. Our results imply that the adoption of policies designed to encourage the development of renewable energy sources (e.g., wind and solar) and increased energy efficiency are the primary ways to reduce pollutant emissions and sustain economic growth in Mediterranean countries. The results of this study could provide policymakers with a better understanding of energy demand trends and allow them to measure progress towards energy efficiency and renewable to better target new developments, thus offering some guidance on energy performance policy. The projections for growth in demand for energy, and especially electricity, in the EU Mediterranean neighborhood until 2020 are very high. In this context, expanding renewable energy sources is a cornerstone of the MED-09 countries' efforts to address energy security of supply, $CO_2$ emissions, and climate change issues.

These findings suggest that increasing the supply of renewable energy would allow the replacement of carbon-intensive energy sources and significantly reduce global warming emissions in the North and South Mediterranean countries. Policy makers should encourage more efforts to promote renewable energy and energy efficiency across countries between the north and south shores of the Mediterranean. It is more than urgent to promote deeper regional energy cooperation and developing concrete strategies to exploit the strong levels of complementarities and interdependence between the different Northern and Southern countries by taking into account the peculiarities of each country in the region. The huge potential of renewable energy sources in the Mediterranean basin might provide mutual benefits to both sides of the Mediterranean in terms of energy security, replacing carbon-intensive energy sources, providing affordable electricity, stabilizing energy prices, economic growth and job creation.

This is an ambitious vision, which will require intelligent solutions to complex technical problems, including high-voltage interconnection, renewable energy integration, smart grids and storage. Additionally, all of the Mediterranean partners will need to work together to put in place the institutions and procedures to allow for an equitable partnership.

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**Figure 1: Per Capita $CO_2$ Emissions by Country between 1980 -2011**

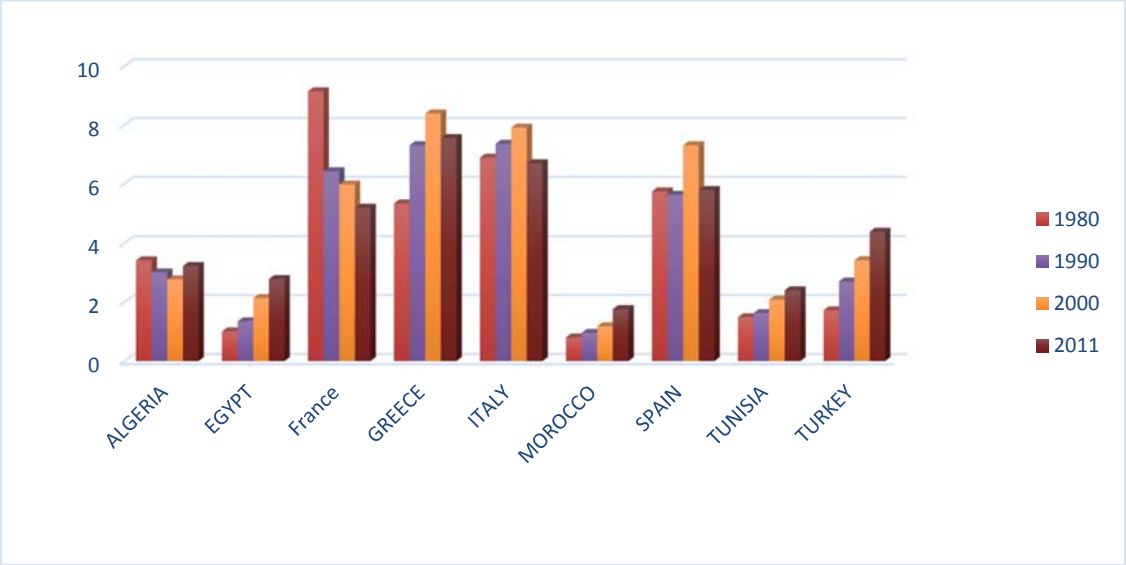
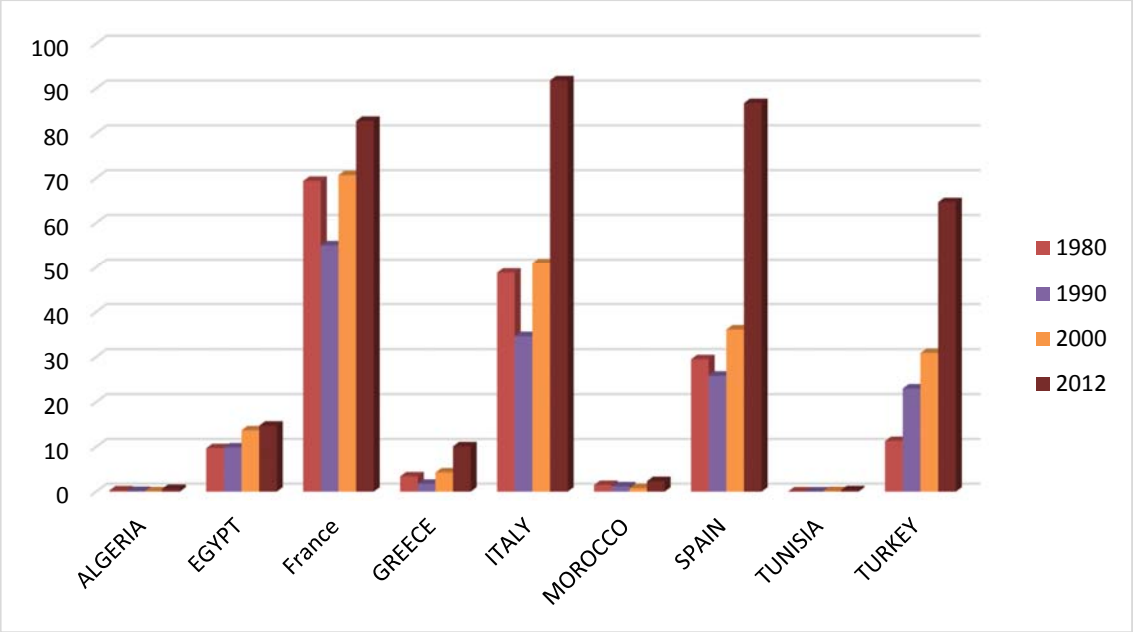



**Figure 2: Renewable Electricity Consumption**




Source: IEA2015

**Figure 3: Modeling Approach Steps**

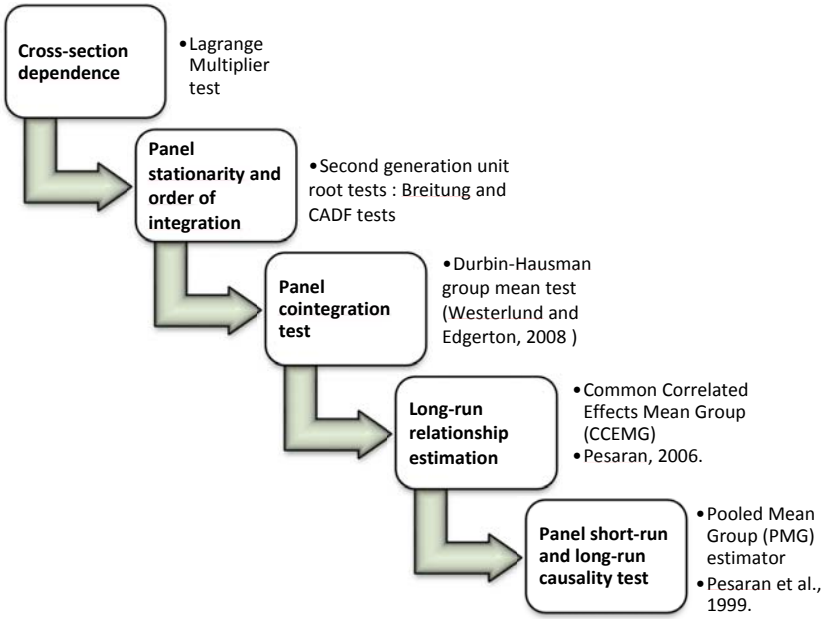



**Figure 4: Interaction between Variables in Long-Run**

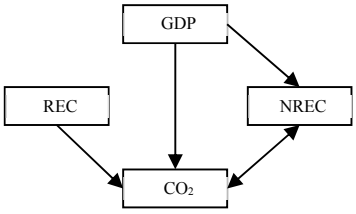
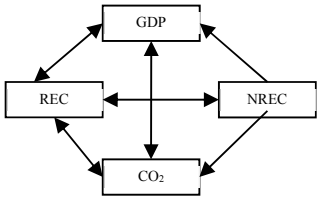



**Figure 5: Interaction between Variables in Short-Run**



## Table 1: Summary of the Existing Empirical Studies on the Relationships Between $CO_2$ Emissions, Energy Consumption and GDP

| Authors | Year | Country and period | Variables | Methodology | Results |
|---|---|---|---|---|---|
| Ang | 2007 | France 1960-2000 | GDP, $CO_2$, EC | EKC, VECM, ARDL | GDP→EC |
| Ang | 2008 | Malaysia 1971-1999 | GDP, $CO_2$, EC | VAR | EC→ $CO_2$ |
| Apergis and Payne | 2009 | 6 central American countries 1971-2004 | GDP, $CO_2$, EC | EKC, panel VECM | $CO_2$ ↔GDP EC→ $CO_2$ |
| Haliacioglu | 2009 | Turkey 1960-2005 | GDP, $CO_2$, EC | VECM, ARDL | $CO_2$ →GDP |
| Soytas and Sari | 2009 | Turkey 1960-2000 | GDP, $CO_2$, EC, K,L | VAR | $CO_2$ →EC |
| Zhang and Cheng | 2009 | China 1960-2007 | GDP, $CO_2$, EC,K,URBAN POPULATION | Toda and Yamamoto procedure | GDP→EC EC→ $CO_2$ |
| Lean and Smyth | 2010 | 5 Asean countries 1980-2006 | GDP, $CO_2$, ELEC | EKC, VECM | $CO_2$ →EC |
| Lotfalipour et al. | 2010 | Iran 1967-2007 | GDP, $CO_2$, EC | Toda-Yamamoto | GDP→ $CO_2$ |
| Ozturk and Acaravci ) | 2010 | Turkey 1965-2006 | GDP, $CO_2$, EC,L | VECM, ARDL | $CO_2$ →GDP |
| Arouri et al | 2012 | MENA 1981-2005 | GDP, $CO_2$, EC | Panel unit root tests and cointegration | EC→ $CO_2$ |
| Omri | 2013 | MENA 1990-2011 | GDP, $CO_2$, EC, K,L | GMM | EC→ $CO_2$ $CO_2$ ↔GDP |
| Ozcan | 2013 | 12 Middle East countries 1990-2008 | GDP, $CO_2$, EC | Panel unit root test, panel cointegration method and panel causality tests | GDP→EC ST GDP→ CO2 LT EC→CO2 LT |
| Cowan et al. | 2014 | BRICs 1990-2010 | GDP, $CO_2$, ELEC | Panel causality analysis | GDP↔ELEC Russia No causality for Brazil GDP↔CO2 Russia GDP→ $CO_2$ South Africa $CO_2$→GDP Brazil EC→ $CO_2$ India |
| Kasman and Duman | 2015 | 15 European countries 1992-2010 | GDP, $CO_2$, EC, trade openness, urban population | Panel unit root test, panel cointegration method and panel causality tests | EC→ $CO_2$ ST GDP→EC ST GDP↔ EC LT GDP↔CO2 LT EC↔CO2 LT |
| Alshehry and Belloumi | 2015 | Saudi Arabia 1971-2010 | EC, $CO_2$,GDP, energy price | Johansen multivariate cointegration technique | EC→ $CO_2$ EC →GDP GDP↔CO2 |

Note: EC,$CO_2$ and GDP indicate Energy Consumption, $CO_2$ emissions and Gross Domestic Product, →, ↔ indicate unidirectional causality and feedback hypothesis respectively.

## Table 2: Summary of the Existing Empirical Studies on the Relationships between $CO_2$ Emissions, Renewable/Non Renewable Energy Consumption and GDP

| Authors | Year | Country and period | Variables | Methodology | Results |
|---|---|---|---|---|---|
| Sadorsky | 2009 | G7 1980-2005 | GDP, $CO_2$, REC | Panel cointegration | GDP, CO2 affect (+) REC |
| Menyah and Woldrufael | 2010 | Afrique du Sud 1965-2006 | GDP, $CO_2$, REC, Nuclear Energy Consumption | ARDL | $CO_2$ ↔GDP NEC→ $CO_2$ GDP→ REC |
| Payne | 2012 | US 1949-2009 | GDP, $CO_2$, REC | TY procedure | No causality on REC |
| Salim and Rafiq | 2012 | 6 emerging countries 1980-2006 | GDP, $CO_2$, REC | OLS FMOLS | $CO_2$ ↔GDP $CO_2$ ↔REC |
| Sebri and Ben Salha | 2014 | BRICS countries 1971-2010 | GDP, REC, NREC, $CO_2$, Trade | VECM, ARDL | $CO_2$ →GDP GDP↔REC CO2↔REC LT |
| Shafiei and Salim | 2014 | OCDE countries 1980-2011 | GDP, $CO_2$, REC,NREC, urbanization, population size, industrialization, population density | STIRPAT | CO2→REC GDP→ CO2 CO2↔NREC |

Note: NREC,REc, $CO_2$ and GDP indicate Nonrenewable and Renewable Energy Consumption, $CO_2$ emissions and Gross Domestic Product, →, ↔ indicate unidirectional causality and feedback hypothesis respectively.

## Table 3: Correlation Matrix of Residual

| | e1 | e2 | e3 | e4 | e5 | e6 | e7 | e8 | e9 |
|---|---|---|---|---|---|---|---|---|---|
| __e1 | 1.0000 | | | | | | | | |
| __e2 | -0.2937 | 1.0000 | | | | | | | |
| __e3 | 0.6518 | -0.6267 | 1.0000 | | | | | | |
| __e4 | -0.6203 | 0.5313 | -0.8018 | 1.0000 | | | | | |
| __e5 | 0.3280 | -0.1962 | 0.5606 | -0.0357 | 1.0000 | | | | |
| __e6 | -0.2217 | -0.2420 | -0.2955 | 0.2845 | -0.2370 | 1.0000 | | | |
| __e7 | -0.4815 | -0.1588 | 0.1532 | 0.1107 | 0.3007 | -0.0907 | 1.0000 | | |
| __e8 | -0.1518 | 0.1227 | 0.1052 | 0.3263 | 0.5816 | 0.0945 | 0.4762 | 1.0000 | |
| __e9 | -0.6080 | 0.4918 | -0.8670 | 0.8326 | -0.4081 | 0.2497 | -0.0463 | -0.1158 | 1.0000 |

*Breusch-Pagan LM test of independence: chi2(36) = 205.742, Pr = 0.0000*

*Based on 32 complete observations over panel units*

## Table 4: Unit Root Test

| **Breitung** | **$PCO_2$** | **GDP** | **REC** | **NREC** |
|---|---|---|---|---|
| Level | 3.7212 | 4.9795 | 0.1513 | 4.1085 |
| | **(0.9999)** | (1.0000) | (0.5601) | (1.0000) |
| First difference | -2.8656 | -5.6083 | -7.4590 | -5.1068 |
| | (0.0021)*** | (0.0000)*** | (0.0000)*** | (0.0000)*** |
| **Pesaran** | **$PCO_2$** | **GDP** | **REC** | **NREC** |
| Level | -0.313 | 0.271 | -1.292 | 2.248 |
| | ( 0.377) | (0.607) | (0.098) | (0.988) |
| First difference | -7.085 | -4.317 | -7.518 | -4.591 |
| | (0.000)*** | (0.000)*** | (0.000)*** | (0.000)*** |

Notes: The lambda-statistics and the standardized Zt-bars are reported for the Breitung (2000) and Pesaran (2007) unit root tests, respectively; p-values in parentheses; the null hypothesis for all tests is ‘‘Panels contain unit roots’’.

## Table 5: Westerlund Cointegration Test

| **Statistic** | **Value** | **Z-value** | **P-value** | **Robust P-value** |
|---|---|---|---|---|
| Group-t | -2.157 | -1.313 | 0.095 | 0.027** |
| Group-a | -7.208 | 0.290 | 0.614 | 0.293 |
| Panel-t | -5.109 | -0.883 | 0.189 | 0.393 |
| Panel-a | -11.662 | -3.511 | 0.000 | 0.002*** |

Notes: *** and ** indicate the test statistics are significant at 1% and 5% levels, respectively. Following Westerlund [59] (2007), the maximum lag length is selected according to 4(T/100)2/9. See Persyn and Westerlund (2008) for the details.

## Table 6: $CO_2$ Coefficients for the CCE-MG Estimator

| | | Wald chi2(3) = 8.93 | | | |
|---|---|---|---|---|---|
| | | Prob> chi2 = 0.0302 | | | |
| $CO_2$ | Coef. | Std. Err. | Z | P>\|z\| | [95% Conf. Interval] |
| GDP | 0.433 | 0.205 | 2.12 | 0.034 | 0.324 .834 |
| REC | -.003 | 0.001 | 0.54 | 0.092 | -.037 .031 |
| NREC | 0.353 | 0.173 | 2.04 | 0.041 | 0.137 .691 |

Notes: Root Mean Squared Error (sigma): 0.0187 (RMSE uses residuals from group-specific regressions: unaffected by 'robust').

## Table 7: Results of Granger Causality Test

| Dependent variables | Sources of causation (independent variable) | | | | |
|---|---|---|---|---|---|
| | Short-run | | | | Long-run |
| | $\Delta CO_2$ | ΔGDP | ΔNREC | ΔREC | ECT |
| $\Delta CO_2$ | – | .4135<br>(0.000) *** | -.00160<br>(0.000)*** | .1205<br>(0.006)*** | -.2329<br>(0.002)*** |
| ΔGDP | .1197<br>(0.033)** | – | .0093<br>(0.074)* | .0794<br>(0.079)* | -.0272<br>(0.143) |
| ΔNREC | .2188<br>(0.114) | 0.0213 (0.886) | – | -.0069<br>(0.058)* | -.1692<br>(0.017)** |
| ΔREC | -1.0273<br>(0.022)** | 8.0581<br>(0.005)** | -4.8901<br>( 0.000)*** | – | -.0035<br>(0.141) |

Note: p-value are given in parentheses. ***, ** and * indicate the test statistics are significant at 1%, 5% and 10 % levels, respectively