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How Effective Are Renewable Energy in Addition of Economic Growth and Curbing CO_2 Emissions in the Long Run? A Panel Data Analysis for Four Mediterranean Countries

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Abstract This paper aims to examine the long-term causal relationship between renewable energy, CO_2 emissions, and economic growth in the four Mediterranean countries; including France, Spain, Italy, and Turkey over the 1980–2012 period. The results of Pedroni and Kao co-integration tests indicate a long-term relationship between these variables. In fact, the results of the long-term model show that the growth has a significant and positive impact on CO_2 emissions in the four countries. VECM Granger causality analysis offer conflicting evidence on the links between renewable energy use and economic growth which supported the feedback hypothesis. This finding has vital consequences regarding energy and economic policy, as it suggests that renewable energy use do not seem to damage economic growth and development in these countries.

Keywords Economic growth · CO_2 emissions · Renewable energy · Co-integration test · VECM Granger causality

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Introduction

The existing studies show that there is an over correlation between the economic growth and the available energy (see, e.g., Jbir and Zouari-Ghorbel (2009); Apergis and Payne (2010a, b); Shahbaz et al. (2012); Shahiduzzaman and Alam (2014); Abid (2014); Abid and Mraihi (2014); Mbarek et al. (2014); Saidi and Hammami (2015). Economically, energy economics is a brief overview of energy and its historic role in the economy and why energy is inextricably linked to our economic future. While, environmental economics is a sub-field of economics that is concerned with environmental issues. Today, we cannot transform inputs into output (goods and services) without using energy. Energy is a vital and important input in the production process. This quantity over includes oil and gas. However, the traditional energy use has two problems: First, the problem of importing and then the problem of the greenhouse effect. For the import, oil is a strategic and very expensive good. This is why, over the years, after an oil shock, economic difficulties arise in the world. Developed countries like Europe and North America have programmed to consume renewable energy because this energy reduces dependence on foreign countries and is safe and sound (Menegaki 2011). It should be noted that the analysis of the determinants of environmental degradation and climate change has become a very exciting topic in the economic and ecological literature and most of the works are endeavoring to test the hypothesis of the environmental Kuznets curve between economic development and indicators environmental degradation (Panayotou 1993, 1995; Grossman and Krueger 1995). In addition, the greenhouse effect has become a global problem. Actions such as the Kyoto Protocol were conducted in order to reduce this effect (Lee and Chang 2008). The consumption of fossil fuels is the main reason for the emission of CO_2. But limiting the consumption of fuel by states and protocols creates a problem in the process of economic growth, so a solution is the spread of renewable energy consumption.

In the last two decades, the interactions between economic growth and the environment have become a topic of increasing importance both national and international (see, e.g., levels, Jia et al. (2013); Mbarek et al. (2014); Lo and Chow (2015); Saidi and Hammami (2015); Tavakoli et al. (2015)). These interactions between growth and the environment are both multiple, complex, and important. It is the latter that come all the basic inputs (metals and minerals, soil, forest cover, and fisheries) and the energy required for processing. This is also the environment that receives waste from economic activity. However, due to the increase in the production scale, it turns a degradation of the environment.

For authors like Georgescu-Roegen (1971) and Meadows et al. (1974), the environmental degradation is mainly due to economic activity (production and consumption), which causes the depletion of natural resources, concentration of pollutants, and waste accumulation that exceeds the ability of the biosphere. By cons, Beckerman (1992) shows a strong correlation between income and environmental protection measures; it demonstrates the long term, economic growth is the best way that guarantees the quality improvement of the environment.

The link between renewable energy and economic growth, and economic growth and CO_2 emissions, has been extensively studied in recent years. Studies in this regard can be divided to three principal lines of research. Starting with the first link, is closely related between renewable energy and economic growth dating the pioneering study of Sadorsky (2009) estimates the links between renewable energy use and income for a selection of emerging economies. Their results show that the increases in real income have a positive and significant impact on renewable energy consumption. However, the study of Apergis and Payne (2010a, b) studied the causal relationship between renewable energy consumption and economic growth for a panel of twenty OECD countries. Their findings reveal a long-run equilibrium relationship between economic growth, renewable energy, gross fixed capital formation, and labor force with positive and statistically significant coefficients. The Granger causality tests indicate bidirectional links between renewable energy and economic growth in the short and long run. Similarly, Apergis and Payne (2010a, b), using variables such as capital formation, GDP, labor, and renewable energy consumption, have shown that in Eurasia there is a bidirectional relationship between economic growth and consumption renewable energy. They reported the same result for the OECD countries in 2010. In another work, Apergis and Payne, (2010a, b) examined the relationship between economic growth and renewable energy consumption for a panel of Central American countries. Their finding from the panel VECM indicates a bidirectional causality between economic growth and renewable energy consumption. In an early study, Shahbaz et al. (2012) investigated the relationship between energy renewable consumption and economic growth of Pakistan. Their results shown that renewable energy consumption add in economic growth. The VECM Granger causality analysis validates the existence of feedback hypotheses between renewable energy consumption and economic growth.

A bidirectional causation was established between renewable energy and growth by Apergis and Payne (2010a, b) for selected emerging economies (including 20 countries) during the period 1985–2005.con. Unlike the study by Apergis and Payne (2010a, b), in our study, the countries selection for the panel is more specific (four Mediterranean countries such as France, Spain, Italy, and Turkey). For this purpose, we utilize a different and new database.

The second line of research focuses on the causal link between environment and economic growth, consider the inverted-U relationship between pollutants and growth to check the validity of the EKC curve (hypothesis the environmental Kuznets). Empirical studies by various authors drew different findings. Selden and Song (1994) supplied empirical evidence on the validity of the EKC curve. Nevertheless, Holtz-Eakin and Selden (1995) found a monotone ascending curve, Friedl and Getzner (2003) found a shaped curve N-other, whereas Richmond and Kaufman (2006) concluded that there is no significant links between growth and pollutants. In a study of eight developed economies and two emerging economies, Andersson and Karpestam (2013) analyzed the determinants of energy intensity, carbon intensity, and scale effects. The findings show that there is a difference between the short-term and the long-term results and that climate policy are more likely to affect emission over the long term than over the short term. But the findings also suggest that a carbon tax is likely to be insufficient decouple emission from economic growth. Such a decoupling is likely to require a structural transformation of the economy. Saboori et al. 2012 examined the dynamic links between economic growth and carbon dioxide (CO2) emissions for Malaysia. The empirical findings suggest the existence of a long-term links between CO2 emissions and per capita GDP when the carbon dioxide emissions level is the dependent variable. Their results affirmed that there is an inverted-U shape relationship between carbon dioxide (CO2) emissions and economic growth in the short and long-term, thus supporting the hypothesis of (EKC). The Granger causality based on the error correction model (ECM) shown an absence of any links between CO2 emissions and economic growth measured by GDP in the short run while there is a unidirectional causality relationship running from the growth to emissions in the long run. In fact, Burnett et al. (2013) analyzed the relationship of the carbon Kuznets curve. However, these authors estimate a dynamic ordinary least squares model of monthly carbon dioxide emissions, personal income, and energy production in the USA. The results suggest that economic growth drives emissions intensities, not absolute emissions as is often implied in past studies. Hilaire and Fotio (2015) analyze the effects of economic growth on the carbon dioxide (CO2) emissions for the Congo Basin. Their empirical results present a positive impact of the economic growth on carbon dioxide (CO2) emissions in these countries. As well, the population density, the consumption of energy, and industrial activities increase the carbon dioxide (CO2) emissions significantly, their findings shown also that the commercial opening does not affect the carbon dioxide emissions.

The third line of this overview explores the relationship between the environmental degradation (pollution), renewable energy use, and economic growth by simultaneously considering a modeling and data framework. These empirical studies searched and analyzed the dynamic relationships between these variables by combining the theory of the environmental Kuznets curve "EKC" with the growth and of the energy consumption. Some previous studies indicate the various windows results that depend on the campaign period and the time was held in the analysis and econometric techniques used. For example, Yazdi and Mastorakis (2011) examine the potential of renewable energy consumption in decreasing the impact of carbon emission in Iran and the greenhouse gas emissions, which leads to global warming. The co-integration analysis affirmed that there is evidence of long-run links between the studied variables. The validity of the EKC hypothesis has been tested for these countries. The Granger causality tests represent the existence of a unidirectional causality running from the square of per capita output to per capita CO_2 emissions and renewable energy. The renewable energy consumption and economic growth has a positive bidirectional causality and contribution on carbon dioxide emissions in the short run. This study emphasizes the important role of renewable energy use on the both carbon dioxide emissions and economic growth. Kulionis (2013) analyzed the causal links between renewable energy use, economic growth measured by real GDP and the environmental degradation measured by carbon dioxide emissions (CO2) in Denmark. The results from Toda Yomamoto-causality and Granger causality test using supported the existence of unidirectional relationship running from renewable energy (REC) consumption to carbon dioxide (CO2) emissions. The findings supported also the absence of any links between the renewable energy consumption and economic growth, which supports the neutrality hypothesis during the relationship between renewable energy and growth. Apergis and Payne (2014) by another study examined the determinants of renewable energy consumption per capita for selected countries of Central America. Their empirical analysis affirmed the existence of a long-term co-integration between per capita renewable energy consumption, per capita real GDP, per capita dioxide carbon (CO2) emissions, real oil prices, and prices of real coal, with positive and significant coefficients restrictive. Leitão (2014) studied the existence of causal relationship between carbon dioxide emissions, renewable energy use, economic growth, and globalization for Portuguese. The Granger causality reports a unidirectional causality between renewable energy and economic growth. Sbia et al. (2014) investigated the relationship between foreign direct investment, clean energy, trade openness, carbon emissions and economic growth in case of UAE. Their empirical results affirmed the existence of a long-run co-integration between the used series. They showed that trade openness (TO), foreign direct investment (FDI), and carbon dioxide (CO2) emissions decline the energy demand, in addition, the clean energy and economic growth and have positive and significant impact on energy consumption.

The previous research makes several important contributions towards the links between renewable energy and growth in the literature related to energy economics. Almost all studies in the literature have considered panels of countries in explaining the causality relationship between the two variables. A major criticism related to these empirical studies, we notice, is the selection of panels. Countries within the considered panel have a greater degree of heterogeneity, and the difference between countries (in terms of economic strength). To overcome this problem, in this paper, we select four developed Mediterranean countries that have almost the same characteristics. In addition, this is the first piece of research dealing with emissions, renewable energy, and growth using panel co-integration analysis for these four top renewable energy consuming countries.

The difference between our study and the previous studies mentioned in the literature review that along with traditional explanatory variables, we selected both renewable and non-renewable energy consumption in order to identify the relative effect of each of these in the economic growth and Co2 emissions for the selected countries. Unlike the previous studies, in our study, the country selection for the panel is more specific (four Mediterranean countries such as France, Spain, Italy, and Turkey). For this purpose, we utilize a different and new database over the period 1980–2012.

The objective of this study is to investigate on the dynamic link between renewable energy (REC) consumption, carbon dioxide (CO2) emissions, and economic growth measured by (GDP) for four Mediterranean countries for the period 1980–2010 using co-integration test and the causality test. This study extends the existing literature specifically on the nature of causal links between renewable energy, CO_2 emissions and economic growth; in the literature, there is no study that examined this relationship in four Mediterranean countries. The rest of the paper is organized as follows: the second section discusses the methodology, data and descriptive statistics, the third section presents the panel unit root test, the fourth section presents the panel co-integration results, the fifth section is reserved for the Granger causality results and the sixth section presents the long-run relationship with FMOLS and DOLS estimations. Finally, the conclusion and some policy recommendations are given in the sixth section.

Methodological and Data

It is important to detect the dynamic links between renewable energy consumption and economic growth in order to know the economic effect of the substitution between renewable and non-renewable and the keeping of green economy.

On the basis of modern econometric techniques, we study the causal relationship between gross domestic growth (GDP), renewable energy consumption (REC), total energy consumption (TEC) and CO2 emissions (Co2). The test procedure involves the following steps. First, we determine the order of integration of the series using unit root tests in panel. Whether the variables contain a unit root, the second step used panel co-integration tests in order to examine the existence of a long-term relationship between the studied series and to estimate the long-term equations fully modified OLS (FMOLS) and dynamic ordinary least squares. Finally (DOLS) estimators, if a long-term relationship between the variables will have found; we study the size and direction of the causal link between the series following a dynamic approach to the panel estimation. Finally, we apply the Granger causality test to detect the direction of causality links between the variables. Table 1 summarizes the descriptive statistics and the correlations associated with the four variables. The variables are downloaded from the International Monetary Fund (IMF) and International Energy Agency (IEA) for the period 1980–2012. The empirical investigation is based on 132 annual observations. The correlation result suggests that output had higher correlation with total energy consumption and Co2 emissions, and the lowest correlation with renewable energy consumption. These findings indicate that total energy consumption played a significant role in addition of Co2 emissions across the countries. However, results also suggest that total energy consumption had the highest correlations with GDP which indicates that it also plays an important role in economic growth.

Table 1 Descriptive statistics

	CO2	GDP	REC	TEC
Mean	313.5258	935.3862	47.81678	6117.762
Median	355.3560	730.7345	45.65500	6124.960
Maximum	488.9173	2845.111	97.90800	11401.52
Minimum	63.11985	80.64200	11.13000	976.4600
Std. Dev.	112.1474	697.9670	19.93372	2911.777
Skewness	−0.573691	0.837079	0.193344	0.120463
Kurtosis	2.161738	2.945010	2.322732	2.060573
Jarque-Bera	11.10544	15.43205	3.345208	5.173128
Probability	0.003877	0.000446	0.187758	0.075278
Sum	41385.41	123471.0	6311.814	807544.5
Sum Sq. Dev.	1647592.	63817695	52053.25	1.11E + 09
Observations	132	132	132	132
Correlations for the panel data set				
CO2	1.000000			
GDP	0.731192	1.000000		
REC	0.714193	0.740001	1.000000	
TEC	0.869329	0.832510	0.805753	1.000000

Panel Unit Root Testing

Harris and Sollis (2003) noted that since the use of standard regression techniques ordinary least squares (OLS) with no stationary (a unit root) series can lead to the problem of spurious regressions involving invalid statistical inferences. Firstly, we apply the unit root tests in the panel under the assumptions of common univariate time series and individual autoregressive processes (AR) to examine the stationarity of the variables. If the studied variables are established as stationary (I (1)) at the first difference, we apply the co-integration analysis in order to detect the long-run relationship between these variables. Next, the panel Granger causality test was used to determine the direction of the causal relationship. Finally, we employ the dynamic ordinary least squares (DOLS) and the fully modified ordinary least squares (FMOLS) methods on panel data under the both homogeneous and heterogeneous variance structures. The results of the panel unit root tests from Levin, Lin, and Chu (LLC), Breitung, Im, Pesaran, and Shin (IPS) and Hadri, Maddala, and Wu (Hadri Z-stat) for the both level and first differenced of GDP, REC, TEC, and CO_2 are reported in the Table 2. According to Table 2, for the four studied variables in level form, we cannot reject the null hypothesis of unit root for Levin, Lin, and Chu test (LLC), Im, Pesaran, and Shin test (IPS) and Maddala and Wu test (MW), Hadri test at the 1 % level. In the

Table 2 Unit root results for GDP, REC, TEC, and CO_2 on panel

		Unit root			*No unit root*	
Variables	Levin, Lin, and Chu (LLC)	Im, Pesaran, and Shin (IPS) W-stat	MW-ADF Fisher chi-square	MW-PP Fisher chi-square	Hadri Z-stat	Heteroscedastic consistent Z-stat
Level						
GDP	1.22988 (0.8906)	3.12971 (0.9991)	0.91710 (0.9987)	0.63940 (0.9997)	6.85863 (0.0000)*	6.68451 (0.0000)*
REC	3.20616 (0.9993)	2.85117 (0.9978)	10.2624 (0.2471)	10.1811 (0.2525)	6.20109* (0.0000)	5.04275* (0.0000)
TEC	0.35885 (0.6401)	2.18945 (0.9857)	2.31071 (0.9700)	2.28767 (0.9709)	6.34256 (0.0000)	6.28560 (0.0000)
CO2	−0.12154 (0.4516)	0.18309 (0.5726)	11.3512 (0.1826)	11.0468 (0.1991)	5.53402 (0.0000)	3.91205 (0.0000)
First difference						
GDP	−6.47306* (0.0000)	−6.49483* (0.0000)	52.3448* (0.0001)	52.2323* (0.0000)	−0.80532 (0.7897)	−0.15954 (0.5634)
REC	−12.2096* (0.0000)	−11.9298* (0.0000)	101.200* (0.0000)	104.625* (0.0000)	2.39610* (0.0083)	2.49939* (0.0062)
TEC	−7.96978 (0.0000)	−7.75456 (0.0000)	64.0751 (0.0000)	67.5515 (0.0000)	1.16363 (0.1223)	1.63924 (0.0506)
CO2	−7.23664 (0.0000)	−7.87969 (0.0000)*	65.3498 (0.0000)*	77.6316 (0.0000)*	0.98197 (1.36109)	1.36109 (0.0867)

The null hypothesis is that the variable has a unit root, except for the Hadri Z-stat and the Heteroscedastic

**, * represents significance at the 1 and 5 % levels, respectively, of significance (italicized entries) first difference, the null hypothesis of unit root is rejected for all utilized tests at the 1 % of significant level, except the Hadri test and heteroscedastic consistent test which rejects the null hypothesis (H0) at the 1 % level for REC. In fact, all the panel unit test reject the null hypothesis of unit root for the differenced series and thus show that GDP, REC, TEC, and CO_2 are integrated of order one I(1).

Panel Co-integration Analysis

The co-integration term can be defined as a co-movement among two or more time series over the long run. Considering two time series X_t and Y_t, if the series X_t and Y_t are each non-stationary, but are both integrated of the same order, the co-integration links between these variables can be performed as $Y_t = \alpha_0 + \alpha_1 X_t + \varepsilon_t$. Once the variables are non-stationary according to the used unit root tests, i.e., they are integrated I (1), then we apply the co-integration tests in order to examine the existence of long-run links among the variables. Given the benchmark results in Table 3, the panel co-integration results are shown according to statistics of Pedroni (2004) and Kao (1999). The results indicated an overwhelming evidence for co-integration between GDP, REC, TEC, and CO_2. Indeed, the findings suggest rejection of the null (no co-integration) at 5 % level for the majority of tests.

Results of Granger Causality Test

Johansen co-integration result implies that the long-run causality exists among the selected variables, but the co-integration test does not determine the direction and

Table 3 Pedroni and Kao co-integration tests

Methods	Series: GDP, REC, TEC and CO_2					
	Within dimension (panel statistics)			Between dimension (individuals statistics)		
	Test	Statistics	Prob	Test	Statistics	Prob
Pedroni (2004)	Panel v-statistic	−1.093040	0.8628	Group ρ-statistic	−3.407372	0.0003*
	Panel rho-statistic	−3.218891	0.0006*	Group pp-statistic	−5.767304	0.0000*
	Panel PP-statistic	−4.422651	0.0000*	Group ADF-statistic	−5.853644	0.0000*
	Panel ADF-statistic	−4.400727	0.0000*			
	(weighted statistic)					
	Panel v-statistic	−0.956654	0.8306			
	Panel rho-statistic	−3.225511	0.0006*			
	Panel PP-statistic	−4.407316	0.0000*			
	Panel ADF-statistic	−4.355677	0.0000*			
Kao (1999)	ADF	−0.577445	0.2818			

*, ** indicate the rejection of the null hypothesis (H0) at 1 %, 5 %, where the H0 is that the variables are not cointegrated

nature of the causal relationship. The Granger causality is devoted to investigate the links and the direction of relationship between the variables. Engle and Granger (1987) proved that the causality test based on a VAR model in the first differences (I(1)) will be incorrectly specified when the studied variables are cointegrated. In this study, GDP, REC, TEC, and CO_2 are integrated of order one I(1) and so cointegrated. To overcome this problem, we specify a model with a dynamic error correction representation in order to estimate a vector error correction model (VEC) by augmenting (VAR) model with a one period lagged ECM. The dynamic error correction model is based on the following regressions to investigate the long-run causal linkages in a panel data (see Apergis and Payne 2009 for more information).

$$\Delta \ln REC_{it} = \alpha_{i1} + \sum_{p=1}^{k} \beta_{1ip} \Delta \ln REC_{it-p} + \sum_{p=1}^{k} \delta_{1ip} \Delta \ln TEC_{t-p} + \sum_{i=1}^{k} \lambda_{1ip} \Delta \ln GDP_{t-p}$$
$$\sum_{p=1}^{k} \mu_{1ip} \Delta \ln CO2_{t-p} + \psi_{1i} ECT_{it-1} + \xi_{1it}$$
$$\Delta \ln GDP_{it} = \alpha_{i2} + \sum_{p=1}^{k} \beta_{2ip} \Delta \ln REC_{it-p} + \sum_{p=1}^{k} \delta_{2ip} \Delta \ln TEC_{t-p} + \sum_{i=1}^{k} \lambda_{2ip} \Delta \ln GDP_{t-p}$$
$$\sum_{p=1}^{k} \mu_{2ip} \Delta \ln CO2_{t-p} + \psi_{2i} ECT_{it-1} + \xi_{2it}$$
$$\Delta \ln TEC_{it} = \alpha_{i3} + \sum_{p=1}^{k} \beta_{3ip} \Delta \ln REC_{it-p} + \sum_{p=1}^{k} \delta_{3ip} \Delta \ln TEC_{t-p} + \sum_{i=1}^{k} \lambda_{3ip} \Delta \ln GDP_{t-p}$$
$$\sum_{p=1}^{k} \mu_{3ip} \Delta \ln CO2_{t-p} + \psi_{3i} ECT_{it-1} + \xi_{3it}$$
$$\Delta \ln CO2_{it} = \alpha_{i4} + \sum_{p=1}^{k} \beta_{4ip} \Delta \ln REC_{it-p} + \sum_{p=1}^{k} \delta_{4ip} \Delta \ln TEC_{t-p} + \sum_{i=1}^{k} \lambda_{4ip} \Delta \ln GDP_{t-p}$$
$$\sum_{p=1}^{k} \mu_{4ip} \Delta \ln CO2_{t-p} + \psi_{4i} ECT_{it-1} + \xi_{4it}$$

Where Δ is the difference operator, *ECT* is the lagged error correction term derived from the long-run cointegrating relationship; $\alpha, \beta, \delta, \lambda,\ \mu\ and\ \phi$ are parameters for estimation, *k* is the lag order determined by the SIC (Schwarz information criterion). To test whether the causality runs from (GDP) to (*REC*), the null (H_0) hypothesis is $H_0 : \lambda_{1ip} = 0$, for all (*i*) and (*p*). If H_0 is rejected, i.e., at least one of λ_{1ip} different to zero, then it suggests that the past value of (*GDP*) has a significant and linear predicative power on the current value of (*REC*). It normally denotes that (GDP) Granger causes (REC), and vice versa.

Table 4 reports the results of the short-run and long-run Granger-causality tests. We found strong evidence of unidirectional Granger causality in the short-run running from economic growth to CO_2 emissions at 1 % level. Nevertheless, when we tested the dynamic links between renewable energy consumption and GDP, we found evidence of bidirectional Granger causality relationship in the short and long run at 1 % level. The

Table 4 The VECM Granger causality results

Short run					Long run
Dependent variables	D(GDP)	D(REC)	D(TEC)	D(CO2)	ECM_{t-1}
D(GDP)		14.00332* (0.0009)	2.098671 (0.3502)	6.595320** (0.0370)	−0.130273* [−4.61265]
D(REC)	23.47196* (0.0000)		2.700373 (0.2592)	6.607201** (0.0368)	−0.010886* [−5.15470]
D(TEC)	2.262238 (0.3227)	12.26631* (0.0022)		1.363228 (0.5058)	−0.205362* [−3.80474]
D(CO_2)	10.25199* 0.0059	3.188814 0.2030	0.113486 0.9448		−0.005131 [−1.28928]

ECT represents the coefficient of the error correction term

*, ** indicates that the parameter estimates are significant at the 1 and 5 % level, respectively

evidence of a bidirectional links between economic growth and renewable energy consumption confirms the value of renewable energy sources within the energy consumption mix of France, Germany, Italy, and Turkey. Furthermore, these findings reinforce the extent of economic development for the continued use of renewable energy. In fact, there is a unidirectional links running from renewable energy use to the total energy consumption is found. This result provides extra support for the assertion that renewable energy use can serve as an important source in the development of long-run energy and environmental policies that meet growing future energy needs.

Long-Run Links with FMOLS and DOLS

Since, there is evidence of co-integration between renewable energy use, total energy use, CO_2 emissions, and economic growth. In order to estimate the long-run effect of independent variables on dependent variables, we use the both fully modified ordinary least squares and dynamic ordinary least squares estimators, (FMOLS) and (DOLS), respectively, as suggested by Pedroni (2001). In fact, Pedroni 2000 and 2001 highlighted numerous advantages of between-dimension group-mean-based estimators over the within-dimension approach. (FMOLS) and (DOLS) estimators have the advantage that they make unbiased estimates even with dependent regressors and that they afford the coefficients to differ countries. The DOLS approach, however, allows us to confirm the direction and general trend of causality relationship obtained by the FMOLS estimation approach. Table 5 reports the long-run elasticity estimates from FMOLS and DOLS for the four sectors/panels. Findings revealed that the GDP is explained by the total energy consumption and CO_2 emissions at 1 % level according to FMOLS estimations. Whereas economic growth is explained by the total energy consumption only at 1 % level according to DOLS estimations. We find that a 1 % increase in economic growth measured by GDP increases the total energy consumption by 1.14–1.1 % according to FMOLS and DOLS, respectively, at 1 % level, while a 1 % increase in energy consumption increases real CO2 emissions by 0.03–0.04 %. Results show also that CO_2 emissions affect the renewable energy consumption at 10 % according to FMOLS estimations.

Conclusion and Recommendations

In this paper, we applied panel co-integration test, panel Granger causality test based on VECM analysis and panel FMOLS and DOLS estimation to investigate the dynamic links between renewable energy consumption, economic growth, and carbon dioxide (CO2) emissions for France, Spain, Italy, and Turkey on période1980-2012. Panel data estimation is employed to find long-run relationship among renewable energy consumption, total energy consumption, carbon dioxide emission and economic growth through co-integration, panel group FMOLS and DOLS estimations. The results of panel co-integration analysis reveal that there is an evidence long-run causality links among REC, TEC, GDP, and CO_2 as evident from the statistically significant Panel rho (PR), Panel (ADF), and Panel (PP) statistics. The results of both FMOLS and DOLS estimators suggest that CO_2 and TEC are significantly related with GDP, where a weak relationship found between REC and GDP.

The result of Granger causality test reveals that there is a positive relationship between economic growth and renewable energy consumption at short and long run which supported the feedback hypothesis. This result is similar with the result of Apergis and Payne (2011). The results reveal a unidirectional relationship running from CO_2 emissions to renewable energy consumption at 5 % level. Within the panel of

Table 5 FMOLS and DOLS

Dependent variables	Independent variables	Panel group			
		FMOLS		DOLS	
		Coefficient	Prob	Coefficient	Prob
GDP	REC	3.320747	(0.3182)	−2.935371	(0.5918)
	TEC	0.523827	(0.0000)*	0.511256	(0.0000)*
	CO2	−5.171250	(0.0001)*	−3.283408	(0.0685)
REC	GDP	0.007324	(0.1059)	0.000293	(0.9506)
	TEC	0.003777	(0.2488)	0.007520	(0.0344)**
	CO2	0.086557	(0.0805)	0.054191	(0.3155)
TEC	GDP	1.140957	(0.0000)*	1.106829	(0.0000)*
	REC	4.364510	(0.3718)	14.71648	(0.0230)**
	CO2	11.33843	(0.0000)*	10.10210	(0.0000)*
CO2	GDP	−0.033750	(0.0223)**	−0.047195	(0.0094)*
	REC	1.823739	(0.0001)*	1.088700	(0.0568)
	TEC	0.039952	(0.0000)*	0.045000	(0.0000)*

*, **, and ***rejects the null hypothesis of no co-integration at the 1, 5, and 10 % significance level, respectively

countries examined, the interdependence between renewable energy consumption and economic growth on the one hand and CO_2 emissions in other hand suggests that energy policies designed to increase the generation and using of renewable energy in order to reduce the pollutions and to keep the economic green and a sustainable environment.

In the light of our discussion, this empirical study proposed some suggestions to these Mediterranean countries towards sustainable development and green economy.

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