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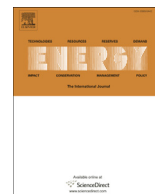
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Impact of renewable and non-renewable energy consumption on economic growth: New evidence from the MENA Net Oil Exporting Countries (NOECs)



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ABSTRACT

This study explores the economic growth – energy consumption nexus for two samples of MENA Net Oil Exporting Countries (NOECs) during the period 1980–2012. Using panel cointegration approach, we found strong evidence for the existence of a long-run relationship between real GDP, renewable and non-renewable energy consumption, real gross fixed capital formation, and the labor force. Moreover, empirical results from the estimation of the panel error correction model indicate evidence of a unidirectional causality running from economic growth to renewable energy consumption in the short-run. In the long-run, the results show evidence of a bidirectional causality for the entire group of MENA NOECs. For the 5 selected MENA NOECs sample, we found strong evidence for bidirectional causality between renewable energy and economic growth. Additionally, our results confirm bidirectional causality between renewable and non-renewable energy consumption with negative and significant coefficient in the short-run indicating substitutability between these two types of energy. Finally, the paper discusses the economic implications of the results and proposes certain policies recommendations.

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1. Introduction

According to the International Energy Agency [34], the world will face severe problems related to the depletion of traditional (non-renewable) energy resources. This expected depletion of non-renewable energy is the result of an unbalanced availability between finite energy resources, population growth and industrial development. Following the World Resource Institute [84], the available quantity of finite-based energy resources is expected to last between 30 and -150 years. Additionally, the production of gas and oil reserves will drop to roughly 40–60% by 2030 (see also [34]). In recent years, international communities are not only concerned about the finite availability of energy resources, but also by the effect of these non-renewable energies on the environmental

degradation. It is now well established that oil and coal exploitation have ultimately led to forest destruction, biodiversity extinction and natural disasters. The MENA¹ Net Oil Exporting Countries (Hereafter MENA NOECs) are primarily concerned with these disaster effects of non-renewable energy on environment degradation and the impact that energy availability will have on the future economic growth of the region.

To overcome these complexities, particularly the scarcity of non-renewable energy resources in the future, in recent years many MENA NOECs have explored the potential of producing energy from renewable resources such as solar, wind among many others. Several key factors have resulted in this growing interest on green energy resources (renewable energy) in MENA NOECs such as: (1) water scarcity and the rapid increase of energy demand due to rapid urbanization, population growth, and economic growths; (2) renewable energy can improve and contribute significantly in the

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energy security enhancement of countries; (3) the important role that can play renewable energy as a potential means of industrial diversification, employment, transfer of technology and in improving the environmental quality. As a consequence of this growing interest, the MENA NOECs have increased and implemented a lot of policies to promote a rapid deployment of renewable energy; and finally, (4) the declining cost of modern renewable energy technologies, such as wind and solar, may meet growing energy needs of all NOECs in the region.

Despite growing interest among the MENA NOECs regarding the importance of renewable energy relatively little attention has been given to the impact of renewable energy on economic growth. Empirically, the causal relationships between energy consumption and economic growth have been largely examined in the last two decades (see Refs. [16,20,49,69,79,65]). However, until now, scholars have not agreed about the causal direction between energy consumption and economic growth. Past studies distinguish between four different hypotheses that explain energy consumption – economic growth nexus, growth, conservation, neutrality and feedback hypotheses. The primary challenge for researchers at this level is to determine which of these hypotheses apply for a single country or panel group of countries as each hypothesis implies different policies implications.

According to Tugcu et al. [79]; prior empirical studies regarding the causality direction between energy consumption and economic growth have been clustered into three groups. The first group includes studies that scrutinize the link between energy consumption and economic growth without considering any qualitative differentiation such as the one that exists between renewable and non-renewable energy (e.g. [1,51,77,86], and so forth). The second group comprises studies that investigate the link between renewable energy consumption and economic growth (e.g. [2,3,5,10,20,54,69], and so forth). The last group corresponds to the recent trend, where both types of energy consumption, renewable and non-renewable energy, has been simultaneously used to separately assess the relative effect of each source on the economic growth (e.g., [4,6,12,23,44,48,52,78,79]). Generally, studies regarding this issue utilize four testable hypotheses [6,12,79,86]. The first hypothesis is the growth hypothesis, which supposes a unidirectional causality running from energy consumption to economic growth. In this case, energy conservation policies aimed at decreasing the amount of energy consumption and improving environmental quality will have detrimental impacts on economic growth (e.g., [12,54,72,19]). The second hypothesis is the neutrality hypothesis which provides no evidence for causality between energy consumption and economic growth (e.g., [43,44,50]). The third hypothesis is the conservation hypothesis which provides evidence for the presence of unidirectional causality running from economic growth to energy consumption. Evidence for this hypothesis imply that an increase (decrease) in real GDP increases (decreases) energy consumption (e.g., [44,69,27]). Finally the fourth hypothesis is the feedback hypothesis, which suggests bidirectional causality between energy consumption and economic growth. Evidence for feedback hypothesis suggest that energy consumption affects economic growth and that the improvement of economic activities will affect significantly energy consumption [3,11,74,79].

Our present investigation fall into the last group of studies, which aims to explore the relative impact of renewable and non-renewable energy sources on economic growth for a two distinct groups of MENA NOECs during the period from 1980 to –2012. Although most previous studies lump different countries together in their analysis regardless of the state of development, our analysis economically extends previous research by allowing for heterogeneity among MENA countries. Consequently, MENA countries were clustered into two sub-groups based on oil abundance (Oil versus

Non-Oil Exporting Countries),² and we originally analyzed only MENA Net Oil Exporting Countries. Moreover, we investigate this effect by considering a 5 selected MENA NOECs that are characterized by a significant share of renewable energy on the total energy mix.

To the best of our knowledge, the causal relationship between renewable energy consumption, non-renewable energy consumption, and economic growth for MENA countries and particularly for MENA NOECs has not been previously studied. Thus, to fill this gap, we propose to investigate the relative impact of renewable and non-renewable energy consumption on economic growth for MENA NOECs in addition to evaluating the casual direction between all variables. Moreover, our paper differs from existing studies in that we utilize both panel unit roots and panel cointegration tests that assume cross-sectional independence and cross-sectional dependence. The use of multiple tests under different assumption is mainly motivated by possible bias of the results toward a specific test procedure. For instance, certain studies assume that the individual time series in a panel are cross-sectionally independently distributed which does not occur in real-world scenarios (see Refs. [62,31]).

The rest of the paper is structured as follows. Section 2 analysis renewable energy consumption in MENA NOECs in term of relative share and it discusses the potential of renewable energy in this region. Section 3 presents the data, the model specification, and the unit root, panel cointegration and the Granger causality tests in the panel context. Section 4 discusses the empirical results. Finally, Section 5 concludes and proposes policy implications.

2. Potential and evolution of renewable energy in the MENA NOECs

In recent years, the emerging of renewable energy as a green energy and possible alternative to the traditional non-renewable energy sources has attracted the interest of several international institutions, governments and local policymakers around the World. As a consequence, many MENA NOECs have engaged in a process that encourages installation of renewable energy infrastructure including hydropower, wind, solar and biomass. For instance, Iran and Egypt lead the MENA NOECs in term of capacity installed of hydropower with 9.5 and 2.8 GW (GW), respectively, followed jointly by Iraq, and Syria with over 1 GW of installed capacity. In absolute numbers, according to data produced by the Renewable Energy Policy Network for the 21st Century [67], hydropower remains the primary renewable energy source for power generation in the MENA NOEC region today.

The potential for renewable electricity production in the region by wind is very promising. For instance, in 2012, Egypt came in the first position with a total capacity of installed wind power of 550 Megawatt (MW), followed by Iran with a total capacity of 91 MW and Bahrain with 0.5 MW (see Ref. [26]). Unfortunately, in the recent years certain socio-political events mainly linked to the Arab Spring revolutions have slowed the development of wind plants in certain countries of the MENA NOECs [85].

Additionally, the potential of solar photovoltaic (PV) energy is promising and may play a major role in the electrification of rural areas in the MENA exporting region. Indeed, the United Arab Emirates (UAE) is the leader after doubling its installed capacity from 11 MW in 2010 to 22.5 MW in 2012. In the second position came Egypt after tripling its capacity between 2009 and 2012 to attain nearly 15 MW of installed capacity. In the third position came Saudi Arabia with a total installed capacity of 7 MW. For Bahrain

² The list of MENA NOECs is taken from REN21 [68].

and Libya, each country possess approximately 5 MW of installed capacity [67]. In addition, concentrating solar (thermal) power (CSP) contributes considerably to the increase of solar energy in the MENA NOECs. In 2011, the only MENA NOECs operating CSP plants are: Algeria, Egypt, and Iran [67]. In 2013, the UAE was joined this group of countries and it became one of the major player in the CSP market when Shams 1 CSP plant, the largest CSP plan in the world with the total installed capacity of 100 MW, began operation in March of 2013.

Despite that the potential of previous types of renewable energy are very promising, the potential of biomass and geothermal for power remains limit and has not well exploited in the MENA NOECs, e.g. presently only Qatar and UAE which produce electricity from modern biomass [67].

Moreover, despite that the MENA NOECs have witnessed a rapid and continuous increase in term of growth rate and total production of renewable energy production, we believe that an analysis based on the share of renewable energy is more suitable and generate interest in explaining the importance of renewable energy sources in the total energy mix.

Fig. 1 below displays the share evolution of renewable energy consumption in relation to the total energy consumption of a 5 selected MENA NOECs namely Algeria, Egypt, Iran, Syria and Iraq during the period from 1980 to 2012.

Fig. 1 demonstrates that the share of renewable energy consumption is high at the beginning of 1980 particularly for Syria, Egypt and Iran. The share of renewable energy in the energy mix is approximately equal to 65% of total energy consumption for Syria, 52% for Egypt, 25% for Iran and between 4% and 6% for Algeria and Iraq at the beginning of 1980. These shares of renewable energy decreased rapidly after that time to approximately 12% for Egypt, Iraq and Syria. For Algeria, the share of renewable energy has stabilized at a level of approximately 2%. This rapid decrease in the share of renewable energy is explained primarily by the discovery of large amounts of non-renewable energy resources since 1980.

Moreover, we note that since 2004 the share of renewable energy in the total energy mix for Iraq has increased rapidly from 2% in 2004 to approximately 22% in 2005, to stabilize around 10–11% during the last 5 years of our study. This unexpected high increase of renewable energy share is mainly attributed to two reasons that are related to the Iraq War in 2003. The first reason is related to the rapid drop of the non-renewable energy production and consumption during the which led to rapid increase in the share of

renewable energy in the total mix during the same period. The second reason is related to the fact that many consumers have moved to renewable energy despite their higher costs due to the absence of oil and gas.

Regarding other MENA NOECs not reported in Fig. 1 above, a deep analysis of their renewable energy sector show that the share of renewable energy in the total energy mix is extremely small as the majority of these countries have only recently started to explore the opportunity of renewable energy.

Overall, two main factors can explain this low level of renewable energy share: (1) the high level of renewable energy costs compared to non-renewable energy such as oil and gas, and (2) the absence of policy regulation and the subsidies of the conventional fuel.

Regarding costs, most of renewable energy technologies are characterized by a high level of initial capital cost which make them less competitive compared to non-renewable energy such as oil and gas. This explains the difficulty that face renewable energy compared to other types of energy sources in terms of costs due to the lengthy lifecycles needed to recover the high initial capital.

However, in the MENA countries and particularly in the MENA NOECs, the regional lifecycle costs for renewables are well below those in most other regional markets [75,81,38,59]. Moreover, it appears that the level of costs do not significantly vary between MENA NOECs as they are all the characterized by the same nature and deploying levels of renewable energy [25,29,45]. In addition, as most of the MENA NOECs place their priorities on solar PV and CSP, recent studies show that the costs of such renewables energy have been rapidly decreased in the last few years [21,45]. This speedily declining of the costs of renewable energy technologies is mainly attributed to the substantial technological advances and manufacturing capacities in the world. For instance, the installation cost of utility-scale solar PV power has dropped significantly from \$7.00/watt in 2008 to reach the level of \$1.50/watt in 2014 in Abu Dhabi. Several studies suggest that the MENA NOECs will benefit from the economics of scales generated by the large size of recent renewable energy projects in the MENA NOECs.

Given this, it is clear that why the share of renewable energy has been decreased during the period 1980 till 2008 and why it begins to increase after that. This analysis also explains also why it is expected that in the upcoming few years the share will be more pronounced. As an example, recent reports of IRENA indicate that renewable energy prices of Solar PV module have fall by about 75%

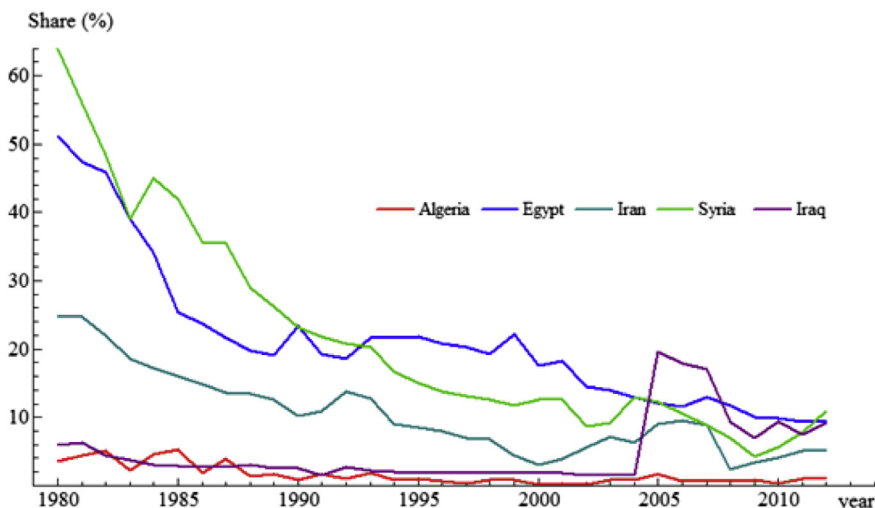


Fig. 1. Share of renewable energy in a selected MENA NOECs, Source, Energy Information Administration [80].

in 2014 compared to their levels at the end of 2009. The IRENA [35] report indicates that the price of electricity delivered by most competitive utility scale solar PV projects is around USD 0.08 per kilowatt-hour (kWh) without financial support. This level of price fall in the price range of the fossil fuel power e.g. USD 0.045 to USD 0.14/kWh.

In terms of policy regulation and subsidies, the MENA NOECs should be aware of the constraints that can hinder the development of renewable energy sector; especially energy subsidies for fossil fuels, which remains a key challenge as they negatively affect the price competitiveness of renewable energy sources and hence distort the energy markets.

3. Empirical methodology

3.1. Data description

Two data set of panel groups of MENA NOECs are employed for this paper. The first data set consist of balanced annual data of 429 observations for 13 MENA NOECs. The second data set consists of balanced annual data of 165 observations for five MENA NOECs that are characterized by more significant share of renewable energy.³ For both data sets the period of the study spans from 1980 to 2012. All variables are collected from the U.S. Energy Information Administration [80], the Penn World Table [60] and the World Bank Development Indicators (WDI) online databases. The 13MENA NOECs used in the sample include Algeria, Bahrain, Egypt, Iran, Iraq, Kuwait, Libya, Oman, Qatar, Saudi Arabia, Syria, the United Arab Emirates, and Yemen.

In this study, five macroeconomic variables are utilized and include the real GDP, total renewable and non-renewable electricity consumption, gross fixed capital formation (capital, K) and labor force (LF). All variables meet the international standard definition.

The real GDP is the dependent variable and is measured in millions of constant 2005 U.S. dollars. Explicative variables include capital, labor force and both renewable and non-renewable energy. As a proxy of capital, we use the real gross fixed capital formation which is measured in millions of constant 2005 U.S. dollars. The labor variable is measured by the total labor force defined as the economically active population including people ages 15 and older [83]. To clarify, the total labor force includes all individuals who supply labor for the production of goods and services during a specified period and is measured in millions of people. The third explicative variable is the total renewable electricity consumption (REC) which is defined as net geothermal, solar, wind and biomass energy and is measured in millions of kilo watt hours (MkWh) (see Refs. [6,79]. The last explicative variable is total non-renewable electricity consumption defined as the total coal, natural gas, and petroleum used for the production of electricity measured in MkWh.

In order to better understand how the five variables used in this study are linked, we report in Table 1 below the results of the pairwise correlation between real GDP, the renewable and non-renewable energy, the capital and labor per capita variables. In Table 1, the estimated correlation coefficients and their corresponding t-statistics are reported under and above the first diagonal, respectively.

The results show that for the whole MENA NOECs sample, all the

correlation coefficients are significant at the conventional level of 5% except for the correlation between renewable energy and gross fixed capital formation. The insignificant of the correlation coefficient between renewable energy and capital can be explained by the low level of the capital invested in renewable energy by the majority of the countries of the whole sample. However, when focusing in the 5 selected MENA NOECs, all correlation coefficients become significant at the 5% level. Moreover, the fact that the correlation coefficient between renewable energy and real GDP is very low compared to the correlation between non-renewable energy and real GDP indicates that renewable energy markets in the MENA NOECs are not well developed and their contributions to the real GDP is minimal compared to non-renewable energy sources. In addition, the results show that the correlation coefficient between renewable and non-renewable energy is large for the 5 selected MENA NOECs compared to the whole sample.

Consequently, this previous analysis confirms that the four explicative variables, as suggested by the economic theory, are determinant of the real GDP. Thus, our empirical model is based on these four factors of production.

3.2. Model specification

Following previous studies in this area, we employ a production model that integrates energy as an additional factor of production with the traditional capital and labor factors (see Refs. [6,8,9,18]. More precisely, we augment the neoclassical Cobb-Douglas production function by adding both renewable and non-renewable energy consumption. This will enable us to examine the relative impact of each type of energy sources on the economic growth.

The inclusion of capital and labor factors are incorporated in the model to control for potential omitted variable bias [40]. However, the use of different types of energy in the production function as additional factors of production with the labor and capital traditional factors may question about how all these variables are correlated. In fact, while the economic literature do not provide a clear explanation about how capital and labor factors are linked to each type of energy consumption, several empirical studies have showed that, in term of employment, renewable energy sources are more labor intensive than traditional (non-renewable) energy sources e.g. in term of per unit of power produced, installed capacity, and per US dollar invested [47].⁴ Moreover, in term of capital, renewable energy are also recognized to have a leveled cost of energy (LCOE) which is overwhelmingly dominated by the high level of initial capital costs compared to traditional energy sources. In addition, several studies suggest that renewable energy technologies are more capital intensive than the non-renewable energy generating technology [24,66,47].

Consequently, we believe that the transition toward renewable energy will cause a substantial increase in employment and require strong investment at least in the short-to-medium term. Thus, we expect that for the second sample, the 5 selected MENA NOECs sample, the effect of both labor and capital factors on real GDP will be more pronounced compared to the whole sample.

To begin, consider the following production function defined by,

$$Y_t = f(A, E_t, K_t, LF_t) = A E_t^\alpha K_t^\beta LF_t^\theta \quad (1)$$

³ The selection of these five countries (Algeria, Egypt, Iran, Syria and Iraq) is primarily motivated by the fact that only these countries among all MENA NOECs are characterized by continuous production and consumption of renewable energy during the period of this study. Moreover, these are the only countries among all MENA NOECs that possess a significant share of renewable energy.

⁴ For instance, the OECD report of 2013 states that for the production of the same quantity of megawatt hours, solar photovoltaic (PV) plants on average utilize seven times more labor than coal-fired plants; and wind energy use on average 1.33 times more labor than natural gas. Moreover, there is some evidence on the fact that job creation in the traditional energy sector is diminishing over time due to factors such as improved recovery techniques as well as automation.

Table 1
Pair-wise correlation results.

All MENA NOECs						Selected MENA NOECs					
Var.	LRGDP	LREC	LNREC	LK	LLF	Var.	LRGDP	LREC	LNREC	LK	LLF
LRGDP	1.00	6.62	11.2	1.97	11.9	LRGDP	1.00	4.15	16.5	10.3	17.8
LREC	0.30	1.00	9.33	0.75	20.0	LREC	0.31	1.00	9.18	1.99	10.6
LNREC	0.48	0.41	1.00	16.4	16.1	LNREC	0.79	0.58	1.00	8.71	18.1
LK	0.09	0.04	0.62	1.000	3.47	LK	0.63	0.10	0.56	1.00	4.57
LLF	0.50	0.69	0.62	0.17	1.00	LLF	0.81	0.64	0.82	0.34	1.00

Note: The correlation coefficients are reported under the first diagonal and their corresponding t-statistics are above the first diagonal.

Where Y_t refers to the total production at t , A represents the total factor productivity (i.e. technological progress), E_t , K_t and LF_t denote the gross fixed capital formation (capital), the labor force and the energy inputs, respectively. The α , β and θ represent the output elasticities of energy, capital and labor, respectively.

In this study, we disaggregate the energy consumption into two different types of energy sources namely renewable energy consumption (REC) and non-renewable energy consumption (NREC) (see Refs. [7,73]. Under this disaggregation the production function takes the following form,

$$Y_t = f(A, REC_t, NREC_t, K_t, LF_t) = A REC_t^{\beta_1} NREC_t^{\beta_2} K_t^{\beta_3} LF_t^{\beta_4} \quad (2)$$

After taking the natural logarithm in both sides of equation (2) and by adding the error term, we can write our model as,

$$Y_{it} = \alpha_i + \delta_i t + \beta_{1i} LREC_{it} + \beta_{2i} LNREC_{it} + \beta_{3i} LK_{it} + \beta_{4i} LLF_{it} + \varepsilon_{it} \quad (3)$$

Where $i \in [1, \dots, N]$ for each country in the panel, and $t \in [1, \dots, T]$ refers to the year. The two parameters α_i and δ_i refer to the country-specific fixed effects and deterministic trends, respectively. $\beta = (\beta_{1i}, \beta_{2i}, \beta_{3i}, \beta_{4i})$ is the vector of parameters and ε_{it} are the estimated residuals representing deviations from the long run relationship. Given that all variables are expressed in natural logarithms, then these parameters, β , can be interpreted as the long run elasticities.

3.3. Panel unit root tests

Several panel unit root tests have been proposed in the literature to examine the stationarity hypothesis (see for instance [39,13,28,33,41,61]). These panel unit root tests can be classified in many ways. In this paper, we adopt the same classification as in Hurlin and Mignon [32] and [17] where we use the terminology of first and second generation panel unit roots tests. Following this classification, the first generation tests include all tests that assume cross-section independence and the second generation includes all tests that assume cross-section dependence.

To facilitate the understanding of the classification difference between these two types of classes as well as differences in panel cointegration tests that can be applied in that cases, we report in Fig. 2 a chart description of these tests.

3.3.1. First generation of panel unit root tests

The first generation unit root tests assumes cross-section independence in the dynamics of the autoregressive coefficients (see, [13,39,28,33,41]). Two kinds of tests that fall under this generation are used in this paper: (1) tests assuming common persistence parameters across cross-section (homogeneity), and (2) tests assuming non common persistence parameters across cross-section or individual unit root processes (heterogeneous). The main difference between these two classes is the way under which

the alternative hypothesis is presented. Two cases are considered depending on whether the persistence parameters are common or not.

In this paper, we limit our presentation and analysis to three panel unit root tests statistics namely: the [39] test statistic for the homogeneity case, and to the [33]; and Maddala and Wu [41] tests statistics for the heterogeneous case.

To present these tests statistics, consider the following basic model given by,

$$\Delta y_{it} = \alpha_i + \rho_i y_{i,t-1} + \delta_i t + \sum_{j=1}^k \pi_{ij} \Delta y_{i,t-j} + \varepsilon_{it} \quad (4)$$

Where Δ is the first difference operator, y_{it} is the dependent variable, ε_{it} is the error term of the model supposed to be a white-noise with a variance of σ^2 , with $i = 1, 2, \dots, N$ and $t = 1, 2, \dots, T$ are the country and time index respectively. α_i , ρ_i , δ_i , π_{ij} are the parameters of the model.

The null hypothesis is common under both homogenous and heterogeneous cases,

$$H_0 : \rho_1 = \rho_2 = \dots = \rho_N = 0 \quad (5)$$

Under this hypothesis all y_{it} time series have a unit root. However, under the alternative hypothesis, we distinguish between two cases depending on whether the persistence parameters are common or not.

To deal with this we consider two alternatives,

$$H_{1a} : \rho_1 = \rho_2 = \dots = \rho_N = \rho \quad \text{and} \quad \rho < 0 \quad (6)$$

and,

$$H_{1b} : \rho_1 < 0, \dots, \rho_{N_0} < 0, \quad 0 < N_0 \leq N \quad (7)$$

It is important to note that for consistency of the panel unit root tests, it is assumed that the N_0/N fraction of the stationary individual processes is non-zero and gets to a fixed value that vary between 0 and 1 as N tends to infinity.

Under H_{1a} hypothesis all autoregressive parameters are assumed to be common for all cross section units. Under this assumption, we can found the Levin et al. [39], Breitung [13] and Hadri [28]. In economics, this hypothesis of homogeneity represents evidently a too restrictive assumption, which can lead to spurious results. However, as pointed by many researchers, the concept of heterogeneity is an extremely important problem in panel data (see for instance [33,41,32,17,53]). Consequently, when dealing with macroeconomic data, it is hard to admit the existence of dynamic properties for all series of the same variable, independently of the country concerned. This case of heterogeneity corresponds to the alternative hypothesis, H_{1b} . Following this alternative hypothesis, a significant fraction of the series y_{it} are not characterized by the presence of unit root tests (see Refs. [33,41]).

A probable difficulty with the [33]; test statistics concerns their

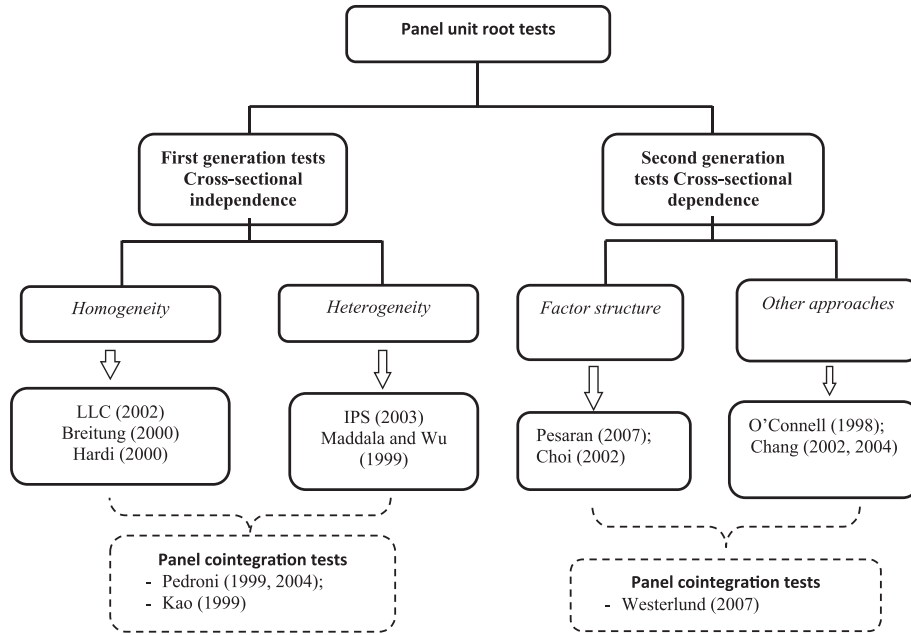


Fig. 2. Chart description of panel unit root and cointegration tests.

power distortion when the data is cross-sectional dependent. However, Im et al. [33] suggest that the standardized demeaned IPS statistic converges to the standard normal distribution. In contrast, Maddala and Wu [41] show that the IPS test of Im et al. [33] is not effective in many real world applications with cross sectional correlations.

Maddala and Wu [41] proposed a non-parametric panel Fisher-ADF and a panel Fisher-PP tests that are basically based on the p-values of the test statistic for a unit root in each residual cross-sectional unit. The test proposed by Maddala and Wu [41] has a chi-square distribution with $2N$ degrees of freedom, where N is the number of cross sectional.

Compared to Im et al. [33] test, the main advantage of Maddala and Wu [41] tests is that it does not rely on different lag lengths. Based on Monte Carlo simulations, Maddala and Wu [41] computed show that their test has a high power compared to the IPS test.

3.3.2. Second generation of panel unit root tests

The literature for testing for panel unit root by assuming cross-section dependence have been recently developed (see for instance [14,15,46,61,30]). In the literature several factors have been advanced to explain possible existence of cross section dependence such as omitted observed or unobserved common factors, spatial spillover effects, or remaining residual interdependence.

In this paper, to test for cross section dependence, we use the cross-sectionally augmented IPS (CIPS) panel unit root test proposed by Pesaran [61]. To derive the CIPS statistic, Pesaran [61] augments the standard augmented DF (ADF) regression with the cross-section averages of lagged levels and first differences of the individual series. Then the CIPS = $N^{-1} \sum_{i=1}^N CADF_i$ where $CADF_i$ represents the individual cross-sectionally augmented Dickey-Fuller statistic for the time series or individual.

To present briefly the CADF and CIPS statistics construction, we start by considering the simple dynamic linear heterogeneous panel data model given by,

$$\Delta y_{it} = \alpha_i + \rho_i y_{i,t-1} + \gamma_i f_t + \varepsilon_{it} \quad (8)$$

Where ε_{it} is the individual-specific error, f_t is the unobserved common factor, and α_i , ρ_i , and γ_i are the parameters of the model.

Under this previous model, the null hypothesis of unit root is as given in (5) and the alternative is as given in (7).

Pesaran [61] proposes a simple modification of the model given in (8) to calculate the CADF test. The new regression is given by,

$$\Delta y_{it} = \alpha_i + \rho_i y_{i,t-1} + b_i \bar{y}_{t-1} + c_i \Delta \bar{y}_t + \varepsilon_{it} \quad (9)$$

Where $\bar{y}_t = N^{-1} \sum_{i=1}^N y_{it}$ and $\Delta \bar{y}_t = N^{-1} \sum_{i=1}^N \Delta y_{it}$. Following Pesaran [61] the common factor f_t in (8) is proxied by the cross-section mean of y_{it} , $\bar{y}_t$, and its lagged values. Moreover, Pesaran [61] shows that in the simple case where ε_{it} are serially uncorrelated, $\bar{y}_t$ and $\bar{y}_{t-1}$, and $\Delta \bar{y}_t$ and $\Delta \bar{y}_{t-1}$ are sufficient for asymptotically filtering out the effects of the unobserved variables.

3.4. Panel cointegration tests analysis

As noted before, once all panel time series are characterized the presence for one unit root in the level, $I(1)$, then the next step will consist in examining the existence of long-run relationship. In the empirical literature, several panel cointegration tests have been proposed (see for instance [36,37,42,55,58,64,71,76,82]). Some these tests are based on group-mean estimates [55,58], others on pooled estimates [37,64]. Some take into account cross-sectional dependencies [82], whereas others do not [36,37,42,55,58,64,71,76].

In this paper, we use three panel cointegration tests of [36,55,58]; and the recent test of [82]. The use of these different tests enable us to check for more robustness of the cointegration results before estimating the short and long run relationship and testing for causality direction.

The first set of tests of panel cointegration is those proposed by Refs. [55,58]. They consist of seven panel cointegration tests statistics that are based on the residuals of the following estimation,

$$y_{it} = \alpha_i + \theta_i t + \sum_{j=1}^q \beta_{ji} x_{ji,t} + u_{i,t} \quad (10)$$

With $t = 1, \dots, T$ and $i = 1, \dots, N$. T is the time series dimension and N is the cross section dimension. The y_{it} and $x_{ji,t}$ for $j = 1, \dots, q$ are supposed to be integrated of order one in level, i.e. $I(1)$. The coefficients α_i

(individual intercept) and θ_i (individual trend) are member-specific that varies across each cross-section and define the deterministic trend specification. u_{it} are the residuals of the model.

The Pedroni's (1999, 2004) tests are two types. The first group, entitled panel tests, is based on the within dimension approach and contains. Four tests statistics are proposed into the first group namely panel v -statistic(Z_v), panel rho-statistic(Z_ρ), panel PP-statistic(Z_{pp}), and panel ADF-statistic(Z_{ADF}). The second group, named group mean panel cointegration tests. The latter is based on the between dimension approach and contains three tests statistics: group rho-statistic ($\bar{Z}_\rho$), group PP-statistic ($\bar{Z}_{pp}$), and group ADF-statistic ($\bar{Z}_{ADF}$).

The null hypothesis assumed that all seven tests specify the nonexistence of cointegration. $H_0 : \rho_i = 1$ for all i , while the alternative hypothesis is defined as $H_1 : \rho_i < 1$ for all i , where ρ_i is the autoregressive term of the estimated residuals of eq. (10), that is,

$$u_{it} = \rho_i u_{it-1} + v_{it} \quad (11)$$

Pedroni [55] shows that all seven statistics asymptotically have the standard normal distribution as a limit distribution. For more details about these tests we refer to [55,58].

In order to ensure the robustness of our results and to confirm the existence of a cointegration relationship, we computed the bootstrap panel cointegration tests proposed by Westerlund [82]. Indeed, Westerlund [82] developed four new panel cointegration tests (G_t , G_a , P_t , P_a) that do not impose any restriction regarding common. Westerlund [82] tests the null hypothesis of no cointegration against the alternative of cointegration. The author test the null hypothesis by examining whether the error-correction term in a conditional panel error-correction model is significantly different from zero or not? Westerlund [82] shows analytically that all these new four tests are normally distributed. Moreover, he shows that they are general enough to accommodate unit-specific short-run dynamics, unit-specific trend and slope parameters, and cross-sectional dependence as well as offer p-values that are robust against cross-sectional dependencies passing through bootstrapping. Two tests are designed to test the alternative hypothesis that at least one unit is cointegrated (G_t , G_a), while the other two tests (P_t , P_a) the alternative that the panel is cointegrated as a whole. Indeed, the Westerlund [82] error-correction tests consider the following equation,

$$\Delta y_{it} = \delta'_i d_t + \alpha_i y_{i,t-1} + \lambda'_i x_{i,t-1} + \sum_{j=1}^{p_i} \alpha_{ij} \Delta y_{i,t-j} + \sum_{j=-q_i}^{p_i} \gamma_{ij} x_{i,t-j} + e_{it} \quad (12)$$

Where $t = 1, \dots, T$ and $i = 1, \dots, N$ indicate the time-series and cross-sectional units, correspondingly, while d_t represents the deterministic components, $d_t = 0$ (no deterministic components in (12)), $d_t = 1$ (with constant), and $d_t = (1, t)$ (with constant and trend). α_i determines the speed at which the system corrects back to the equilibrium after an unexpected shock. Additionally, Westerlund [82] supposes that K -dimensional vector x_{it} is modeled as a pure random walk such that Δx_{it} is independent of e_{it} . Moreover, the author assumes that e_{it} is the error term that is independent across both i and t . All dependence on i is carried by using bootstrap methods.

The testing procedure of Westerlund [82] assumes the same null hypothesis for both group-mean and panel tests. The null hypothesis is given by,

$$H_0 : \alpha_i = 0 \text{ for all } i$$

However, the alternative hypothesis differs following the tests used. For instance, for the group-mean tests (G_t , G_a) the alternative hypothesis corresponds to,

$$H_1^g : \alpha_i < 0 \text{ for at least one } i,$$

Under this hypothesis these tests does not require that the α_i 's are equal. However, the second pair of tests that Westerlund [82] called panels tests (P_t , P_a) assume that α_i 's is equal for all i . Then, the alternative hypothesis can be stated as follow,

$$H_1^p : \alpha_i = \alpha < 0 \text{ for all } i.$$

3.5. Panel FMOLS estimates and Granger causality test

In the recent literature, a variety of estimation methods for panel cointegration model have been proposed such as the OLS, FMOLS and DOLS. Although the OLS estimator is super-convergent even under panel cointegration, it has a second order asymptotic bias and relies on nuisance parameters related to the existence of serial correlation in the data [56,57]. To build valid t-statistics, numerous alternative estimation techniques have been proposed in the literature such as the Fully Modified OLS (FMOLS) estimator developed by Phillips and Hansen [63] and Dynamic OLS (DOLS) estimator proposed by Saikkonen [70] and Stock and Watson [76]. In the case of panel data, Phillips and Moon [64] proved that the OLS technique shows signs of small sample bias, while the FMOLS estimator emerges to outperform both estimators.

Given the evidence of panel cointegration among variables, we perform the fully modified OLS (FMOLS) technique. Subsequently, we estimate a panel vector error correction model (VECM) to examine causality direction using Granger-causality tests.

The two-step procedure of Engle and Granger [22] has been used to investigate the causal relationship between variables. In the first step, the long run relationship is estimated as specified by Eq. (3). Then, in second step, the first lag of residuals from Eq. (3) is used as the error correction terms, ECT_{t-1} , for the dynamic error correction model. The error correction terms, ECT_{t-1} is obtained as,

$$ECT_{i,t-1} = \left(LR GDP_{i,t-1} - \hat{\beta}_{1,i} LREC_{i,t-1} - \hat{\beta}_{2,i} LNREC_{i,t-1} - \hat{\beta}_{3,i} LK_{i,t-1} - \hat{\beta}_{4,i} LLF_{i,t-1} \right) \quad (13)$$

where, $\hat{\beta}_{l,i}$, $l = 1, \dots, 4$ are the estimated coefficients of long-run relationship. The second step consists of estimating the VECM for both samples.

The models to estimate for each sample is given by,

$$\begin{aligned} \Delta LR GDP_{it} = & \alpha_{1i} + \sum_{k=1}^q \theta_{11ik} \Delta LR GDP_{it-k} + \sum_{k=1}^q \theta_{12ik} \Delta LREC_{it-k} \\ & + \sum_{k=1}^q \theta_{13ik} \Delta LNREC_{it-k} + \sum_{k=1}^q \theta_{14ik} \Delta LK_{it-k} \\ & + \sum_{k=1}^q \theta_{15ik} \Delta LLF_{it-k} + \lambda_{1i} ECT_{i,t-1} + v_{1it} \end{aligned} \quad (14a)$$

$$\begin{aligned}\Delta LREC_{it} = & \alpha_{2i} + \sum_{k=1}^q \theta_{21ik} \Delta LR GDP_{it-k} + \sum_{k=1}^q \theta_{22ik} \Delta LREC_{it-k} \\ & + \sum_{k=1}^q \theta_{23ik} \Delta LNREC_{it-k} + \sum_{k=1}^q \theta_{24ik} \Delta LK_{it-k} \\ & + \sum_{k=1}^q \theta_{25ik} \Delta LLF_{it-k} + \lambda_{2i} ECT_{i,t-1} + \nu_{2it}\end{aligned}\quad (14b)$$

$$\begin{aligned}\Delta LNREC_{it} = & \alpha_{3i} + \sum_{k=1}^q \theta_{31ik} \Delta LR GDP_{it-k} + \sum_{k=1}^q \theta_{32ik} \Delta LREC_{it-k} \\ & + \sum_{k=1}^q \theta_{33ik} \Delta LNREC_{it-k} + \sum_{k=1}^q \theta_{34ik} \Delta LK_{it-k} \\ & + \sum_{k=1}^q \theta_{35ik} \Delta LLF_{it-k} + \lambda_{3i} ECT_{i,t-1} + \nu_{3it}\end{aligned}\quad (14c)$$

$$\begin{aligned}\Delta LK_{it} = & \alpha_{4i} + \sum_{k=1}^q \theta_{41ik} \Delta LR GDP_{it-k} + \sum_{k=1}^q \theta_{42ik} \Delta LREC_{it-k} \\ & + \sum_{k=1}^q \theta_{43ik} \Delta LNREC_{it-k} + \sum_{k=1}^q \theta_{44ik} \Delta LK_{it-k} \\ & + \sum_{k=1}^q \theta_{45ik} \Delta LLF_{it-k} + \lambda_{4i} ECT_{i,t-1} + \nu_{4it}\end{aligned}\quad (14d)$$

$$\begin{aligned}\Delta LLF_{it} = & \alpha_{5i} + \sum_{k=1}^q \theta_{51ik} \Delta LR GDP_{it-k} + \sum_{k=1}^q \theta_{52ik} \Delta LREC_{it-k} \\ & + \sum_{k=1}^q \theta_{53ik} \Delta LNREC_{it-k} + \sum_{k=1}^q \theta_{54ik} \Delta LK_{it-k} \\ & + \sum_{k=1}^q \theta_{55ik} \Delta LLF_{it-k} + \lambda_{5i} ECT_{i,t-1} + \nu_{5it}\end{aligned}\quad (14e)$$

Where α_{mi} for $m = 1, \dots, 5$ (5 is the number of variables including the dependent variable) represent the fixed country effect; $k = 1, \dots, q$ is the lag length which is determined by the Schwarz Information Criterion (SIC). $ECT_{i,t-1}$ is the first lag of the estimated error correction term, which is obtained after estimating the long-run relationship given by Eq. (3). The coefficients λ_{mi} represent the adjustment coefficient toward the long run equilibrium. ν_{mit} are the disturbance term assumed to be uncorrelated with zero means. The short-run causality is assessed by examining the statistical significance of the lagged variables in Eq. (14a)–(14e) using the Wald-statistic test. For instance, there is evidence for causality running from renewable energy consumption to economic growth if the joint null hypothesis, $\theta_{12ik} = 0$, for all ik is rejected via the Wald test whereas causality runs from non-renewable energy to economic growth if the joint null hypothesis, $\theta_{13ik} = 0$, for all ik is rejected. In the same way evidence for causality, we can test short run causality between all variables. Regarding the long-run causality, it is determined by the statistical significance of the respective error correction terms, λ_{1i} , for all i using a t -test. The adjustment factor is the inverse of the absolute value of the coefficient associated to the error correction term. Then, the adjustment factor can be interpreted as the number of years that it takes any deviation from the equilibrium to return back to equilibrium see for instance [69,2,4,6].

4. Results and discussion

4.1. Panel unit root tests results

As previously discussed, a necessary condition before testing for possible existence of long-run relationship between the real GDP, renewable energy, non-renewable energy, capital, and the labor force variables is that all variables should be integrated in the first order. To examine this condition, we perform the [39], Im et al. [33] and Maddala and Wu [41] tests in addition to the Pesaran [61] tests. As previously discussed, these three tests incorporate both cross-sectional independence (LLC, IPS and Maddala and Wu tests) and cross sectional dependence cases [61]. The results of these tests are presented in Table 2. From this table it can be noted that the null hypothesis of the unit root cannot be rejected at the 1% level of significance for the five panel time series taken in level. However, by testing for the unit root in the first difference, all panel unit root tests reject the null hypothesis at the 1% level of significance. Based on these results, we conclude that all panel time series are integrated with the first order. These results of non-stationarity in level and stationarity in first difference are confirmed by the Breitung [13] and Hadri [28] unit root tests reported in Table A (see the supplementary document of this paper).

To summarize, we note that regardless of the type of tests employed, cross-sectional independence or cross-sectional dependence, and the group of countries used, the entire sample MENA NOECs or the 5 selected MENA NOECs, the results demonstrate strong evidence for non-stationarity at level and stationarity at first difference.

4.2. Panel cointegration tests results

After the panel unit root tests confirm that all variables are $I(1)$ in level, then the next step is to test for evidence of a long-run relationship. The panel cointegration tests used in this study test the null hypothesis of the nonexistence of cointegration against the alternative of cointegration. As noted in Section 3.4, three panel cointegration tests including the Kao's [36] residual cointegration tests, the seven panel cointegration tests of [55,58] and the Westerlund [82] tests are employed in this study. Empirical results from the application of these tests provide strong evidence for panel cointegration between the real GDP, renewable energy, non-renewable energy, the capital and the labor force. For instance, the Kao's [36] residual cointegration tests show that for both groups of countries, all MENA NOECs and the 5 selected MENA NOECs, the hypothesis of cointegration cannot be rejected at the 1% level of significance. We observe also that the eleven tests proposed by the [55,58] provide evidence for cointegration for the MENA NOECs group and that only nine out of the eleven tests demonstrate evidence for panel cointegration for the 5 selected MENA NOECs group. (see Table 3 and 4).

Results of the panel cointegration tests, that account for cross-sectional dependence, show that the G_t , G_a , P_t , and P_a statistics of Westerlund [82] possess p-values and robust p-values that are less than the value of 1% level of significance indicating the rejection of the null hypothesis of absence of cointegration Table 5.

4.3. Long run dynamics

Upon confirming evidence for the existence of long run relationship between the real GDP, renewable energy consumption, non-renewable energy consumption, real gross fixed capital formation, and the labor force, then the next step consists of estimating the long run dynamics between these variables.

Results of the FMOLS method for the entire and the 5 selected

Table 2
Results of panel unit root tests.

All MENA NOECs						Selected MENA NOECs				
Var.	LLC	IPS	ADF fisher	PP fisher	Pesaran	LLC	IPS	ADF fisher	PP fisher	Pesaran
LRGDP	−1.16 (0.12)	−1.41 (0.07)	11.11 (0.99)	20.27 (0.77)	−2.06 (0.87)	−0.98 (0.16)	−1.30 (0.09)	16.58 (0.08)	10.05 (0.43)	0.22 (0.58)
ΔLRGDP	−3.79*** (0.00)	−5.53*** (0.00)	81.49*** (0.00)	172.4*** (0.00)	−2.72*** (0.00)	−4.71*** (0.00)	−9.53*** (0.00)	85.10*** (0.00)	456.29*** (0.00)	−2.33** (0.01)
LREC	−0.49 (0.31)	0.07 (0.53)	16.82 (0.26)	9.25 (0.81)	−1.18 (1.00)	−1.57 (0.06)	−1.33 (0.09)	16.28 (0.09)	12.13 (0.27)	−0.55 (1.00)
ΔLREC	−8.43*** (0.00)	−6.69*** (0.00)	66.26*** (0.00)	161.63*** (0.00)	−3.65*** (0.00)	−7.14*** (0.00)	−6.44*** (0.00)	54.42*** (0.00)	476.52*** (0.00)	−3.96*** (0.00)
LNREC	12.52 (1.00)	2.19 (0.97)	0.06 (1.00)	0.03 (1.00)	−2.56 (0.17)	−0.86 (0.19)	−1.18 (0.11)	13.09 (0.21)	14.48 (0.15)	−0.63 (0.26)
ΔLNREC	−4.60*** (0.00)	−6.95*** (0.00)	96.22*** (0.00)	340.5*** (0.00)	−2.77** (0.03)	−1.90** (0.02)	−2.74*** (0.00)	23.47*** (0.00)	106.47*** (0.00)	−8.18*** (0.00)
LK	1.77 (0.96)	2.96 (0.99)	23.28 (0.62)	11.14 (0.99)	−1.91 (0.12)	3.04 (0.99)	3.90 (1.00)	2.73 (0.98)	2.45 (0.99)	1.27 (0.89)
ΔLK	−4.72*** (0.00)	−4.48*** (0.00)	64.86*** (0.00)	92.06*** (0.00)	−2.98*** (0.00)	−1.73** (0.04)	−5.53*** (0.00)	41.67*** (0.00)	50.06*** (0.00)	−2.05** (0.02)
LLF	−1.10 (0.32)	−1.90 (0.98)	21.71 (0.70)	38.32 (0.06)	−2.44 (0.34)	−0.91 (0.18)	0.22 (0.58)	11.14 (0.34)	5.58 (0.84)	1.82 (0.89)
ΔLLF	−4.10*** (0.00)	−6.34*** (0.00)	316.2*** (0.00)	389.1*** (0.00)	−3.25*** (0.00)	−2.48*** (0.00)	−2.13** (0.01)	20.69** (0.02)	41.40*** (0.00)	−3.19*** (0.00)

Notes: Δ = First difference operator. Ps denotes the Pesaran unit root test. Panel unit root tests include intercept and trend. *** and ** denote significance at 1% and 5% level, respectively. (.): Probabilities.

Table 3
Kao [36] cointegration test, 1980–2012.

	All MENA NOECs		Selected MENA NOECs	
	t-Statistic	Prob.	t-Statistic	Prob.
ADF	−5.191	0.00***	−4.413	0.00***
Residual variance	0.0095		0.0341	
HAC variance	0.0089		0.0068	

Notes: Null hypothesis: No cointegration. Trend assumption: No deterministic trend. Automatic lag selection based on SIC with maxlag of 6. *** denotes critical values at the 1% significance level.

MENA NOEC samples are reported in Table 6. These results indicate that all estimated coefficients for both samples are, as expected, positive and statistically highly significant (p-value < 0.01) with the exception of the labor force variable which is significant at the conventional level of 5%. Interestingly, as expected, we found that the estimated coefficient associated to non-renewable energy

variable for the 5 selected MENA NOECs sample is smaller than of the whole MENA NOECs sample, respectively, 0.241 and 0.772. These results may be explained by the fact that most of the whole MENA NOECs sample use non-renewable energy as main source of producing electricity, as input in the production process and for water desalination. Moreover, our empirical findings show that the estimated coefficient associated to renewable energy for the whole MENA NOECs is 0.058 which is about half the estimated coefficient for the 5 selected MENA NOECs, 0.11. This result is mainly explained by the higher share of renewable energy consumption in the total energy consumption for 5 selected MENA NOECs compared to the whole MENA NOECs sample.

Furthermore, our empirical results indicate that the estimated coefficients associated to the real gross fixed capital formation and the labor force variables are positive and highly significant (p-value > 0.01). These results indicate the importance of these two variables in determining the level of real GDP. Moreover, the fact renewable energy are known to be more labor and capital intensive

Table 4
Pedroni [55,58] cointegration tests, 1980–2012.

	All MENA NOECs		Selected MENA NOECs		Selected MENA NOECs		Selected MENA NOECs	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
Within-dimension								
Panel v-Statistic	4.129	0.00***	2.971	0.03**	−1.478	0.93	−0.452	0.67
Panel rho-Statistic	−3.128	0.00***	−1.958	0.02**	−2.185	0.01***	−2.027	0.02***
Panel PP-Statistic	−3.355	0.00***	−2.590	0.00***	−8.344	0.00***	−6.829	0.00***
Panel ADF-Statistic	−4.338	0.00***	−2.743	0.00***	−7.958	0.00***	−6.791	0.00***
Between-dimension								
Group rho-Statistic	−1.704		0.04**		−1.547		0.06*	
Group PP-Statistic	−2.503		0.00***		−7.655		0.00***	
Group ADF-Statistic	−2.658		0.00***		−7.368		0.00***	

Notes: Null hypothesis: No cointegration. Trend assumption: Deterministic intercept and trend. Lag selection: Automatic SIC with a max lag of 5. ***, ** and * denote critical values at the 1%, 5% and 10% significance level, respectively.

Table 5
Westerlund [82] ECM panel cointegration tests, 1980–2012.

Statistic	All MENA NOECs				Selected MENA NOECs			
	Value	Z-value	P-value	Rob. P-value	Value	Z-value	P-value	Rob. P-value
Gt	−10.569	−2.812	0.00***	0.02**	−4.819	−4.820	0.00***	0.00***
Ga	−54.343	−15.422	0.00***	0.00***	−27.165	−2.535	0.00***	0.00***
Pt	−12.522	−3.051	0.00***	0.03**	−13.955	−8.086	0.00***	0.00***
Pa	−47.749	−14.180	0.00***	0.00***	−39.199	−6.573	0.00***	0.00***

Notes: Optimal lag and lead length determined by Akaike Information Criterion with maximum lag and lead length of 2. We allow for a constant and deterministic trend in the cointegration relationship. Number of bootstraps to obtain bootstrapped p-values which are robust against cross-sectional dependencies set to 400. Results for H0: No-cointegration. The Bartlett kernel window width set according to $4(T/100)^{2/9}$. *** and ** denote critical values at the 1% and 5% significance level, respectively.

Table 6
Parameter estimation using FMOLS, 1980–2012.

Variables	All MENA NOECs		Selected MENA NOECs	
	Coefficient	Prob.	Coefficient	Prob.
LREC	0.058	[0.000]***	0.110	[0.000]***
LNREC	0.772	[0.000]***	0.241	[0.000]***
LK	0.548	[0.009]**	0.877	[0.000]***
LLF	0.479	[0.000]***	0.896	[0.030]**
HE	2.56	[0.32]	17.93	[0.21]
RESET	0.74	[0.52]	1.16	[0.32]
R ²	0.996		0.895	
Adj. R ²	0.993		0.892	
DW	2.081		1.961	

Notes: Method: Fully-modified OLS (FMOLS). Panel method: Grouped estimation. Cointegrating regression contains constant and trend. HE is White's Heteroscedasticity test. RESET is Ramsey's regression equation specification error test. DW is the Durbin-Watson test for serial correlation. *** and ** denote the significance at 1% and 5% level. Null hypothesis: H_0 : model has no omitted variables and H_0 : Homoscedasticity for Ramsey RESET test and White's Heteroscedasticity test, respectively. [·]: Probabilities.

than non-renewable energy my explains the results that the estimated coefficients associated to capital and labor factors are more pronounced in the case of the 5 selected MENA NOECs sample compared to the whole MENA NOECs sample.

Economically, these coefficients of the long run relationship is interpreted as the long-run elasticity since all variables are expressed in natural logarithms. Table 6 indicates that a 1% increase in renewable energy consumption will increases the real GDP by 0.058% and 0.11% for the whole and 5 selected MENA NOECs samples, respectively. A 1% increase of the renewable energy consumption will result in an increase of the real GDP by approximately 0.772% and 0.241% for the whole and the 5 selected MENA NOECs samples, respectively. The results for the gross fixed capital formation indicate that an increase of 1% of the gross fixed capital formation increases the real GDP by 0.548% and 0.877% for the whole and 5 selected MENA NOECs samples, respectively. Finally, an increase by 1% of the labor force results in an increase of the real GDP by 0.479% and 0.896% for the whole and 5 selected MENA NOECs samples, respectively.

4.4. Short run dynamics

Important steps that follow the establishment of long-run equilibrium include estimating the panel error correction model (ECM) and examining of the causality direction between variables. The econometric theory states that at least one causal relationship must exists between the real GDP, renewable and non-renewable energy consumption, gross fixed capital formation and the labor force variables as the cointegration hypothesis has not been rejected.

The results of estimation of the panel ECM, the partial F-statistic results with respect to short run changes in the independents variables and the estimated sum of the lagged coefficients for the respective short-run changes are reported in Tables 7 and 8 for the whole and the 5 selected MENA NOECs samples, respectively. The results show that the estimated coefficients of the error correction terms in Eqs. (14a)–(14e) are all statistically significant. These results indicate that all variables used in this study respond to deviations from long-run equilibrium. In term of speed of adjustment towards the long-run equilibrium, we found that, for the whole sample, the real GDP, renewable energy and non-renewable energy, gross capital formation and labor force respond to deviations from long-run equilibrium with 4.08 years, 10 years, 11.76 years, 12.2 years and 3.66 years respectively. The results for the five selected

MENA NOECs group sample reported in the last column of Table 8 show that the speed of adjustment is equal to 5, 4.35, 4.5, 5.2, 4.75 years respectively for the same order of variables as before. From this later results it appears that for the renewable and non-renewable energy as well as for the gross fixed capital formation the time necessary for adjustment have significantly decreased for the 5 selected MENA NOECs sample which is known to be highly intensive in labor and capital compared to the non-renewable energy.

Empirical results of the short-run estimation for the whole MENA NOECs sample, confirm that, in the short-run, the impact on economic growth of non-renewable energy consumption, the capital, and the labor force is positive and statistically significantly different from zero. However, the results show that renewable energy consumption is statistically insignificant and does not have any impact on economic growth in the short run, see Eq. (14a) in Table 7. In addition, Eq. (14b) shows that each of the economic growth, real gross fixed capital formation and labor force variables have a positive and statistically significant impact on renewable energy consumption whereas non-renewable energy consumption yields a statistically insignificant impact. In terms of Eq. (14c), economic growth, real gross fixed capital formation and the labor force have a positive and statistically significant impact on non-renewable energy consumption but renewable energy consumption is statistically insignificant. Eq. (14d) reveals that economic growth, non-renewable energy consumption, and the labor force have a positive and statistically significant impact on real gross fixed capital formation in the short-run while renewable energy consumption has a statistically insignificant impact. Finally, Eq. (14e) exposes that economic growth, non-renewable energy consumption, and capital have a positive and statistically significant impact on the labor force. In the other hand, results from Eq. (14e) show that renewable energy consumption do not have any effect on labor force as the associated short run coefficient of renewable energy consumption is statistically insignificant.

In contrast, empirical results of the selected MENA NOECs sample show that for all equations, (14a)–(14e), the estimated short run coefficients are significant at the 1% level of significance.

Two important results emerge from the short run analysis. First, despite that for the whole sample MENA NOECs, there is no significant effect of one type of energy on the other type, when focusing on the selected MENA NOECs the results is more interesting and show evidence for bidirectional effects. Moreover, the results show that the impacts are significant both negative and have approximately the same magnitude, e.g. 0.30 in absolute value. This result indicates the substitutability between non-renewable energy consumption and renewable energy consumption. This evidence is confirmed by both equations 14.b and 14.c in Table 8. Second, the effects of gross fixed capital formation as well as labor force are significant on the two types of energy sources and for both samples. However, the inverse effect is insignificant for renewable energy for the case of the whole sample. This result is of particular interest as it indicates that the bidirectional effect become significant for the renewable energy with the capital and labor variables when considering the case of the 5 selected sample as this sample is characterized by a significant share of renewable energy.

4.5. Causality analysis

The results of testing for causality direction are reported in Tables 7 and 8 In these two tables, we report the Partial F-statistics with respect to the short run changes in the independent variables. For the entire sample of MENA NOECs, we found strong evidence for bi-directional causality between real GDP, non-renewable

Table 7
Panel causality tests for MENA NOECs, 1980–2012.

Dependent variable	Source of causation (Independent variables)					Long-run
	Short-run					
	Δ LRGDP	Δ LREC	Δ LNREC	Δ LK	Δ LLF	ECT
Δ LRGDP (Eq. (14a))	—	0.328 [0.56] (0.035) [0.59]	4.894** [0.03] (0.076)** [0.02]	12.437** [0.00] (0.178)** [0.00]	7.841** [0.00] (0.070)** [0.04]	−0.245** [0.00]
Δ LREC (Eq. (14b))	4.950** [0.02] (0.175)** [0.00]	—	1.361 [0.24] (−0.090) [0.72]	3.999** [0.04] (0.134)** [0.03]	4.016** [0.04] (0.120)** [0.01]	−0.100** [0.00]
Δ LNREC (Eq. (14c))	8.149** [0.00] (0.449)** [0.00]	0.098 [0.75] (−0.082) [0.79]	—	9.004** [0.00] (0.159)** [0.03]	9.860** [0.00] (0.117)** [0.02]	−0.085** [0.00]
Δ LK (Eq. (14d))	5.124** [0.02] (0.196)** [0.00]	0.464 [0.49] (0.007) [0.71]	7.312** [0.00] (0.238)** [0.00]	—	4.128** [0.04] (0.116)** [0.00]	−0.082** [0.00]
Δ LLF (Eq. (14e))	11.916** [0.00] (0.021)** [0.04]	0.516 [0.59] (0.040) [0.67]	21.011** [0.00] (0.112)** [0.00]	6.471** [0.01] (0.192)** [0.02]	—	−0.273** [0.00]

Notes: Partial F-statistics reported with respect to short-run changes in the independent variables. The sum of the lagged coefficients for the respective short-run changes is also performed and is denoted in parentheses. ECT denotes the estimated coefficient on the error correction term. The vector error correction model is estimated using panel regression techniques with fixed effects for cross section. Probability values, which represented the probability values of the partial F-statistic and the Wald chi-square tests, are in brackets and reported underneath the corresponding partial F-statistic and sum of the lagged coefficients, respectively. ** denotes the significance at 5% level.

Table 8
Panel causality tests for Selected MENA NOECs, 1980–2012.

Dependent variable	Source of causation (Independent variables)					Long-run
	Short-run					
	Δ LRGDP	Δ IREC	Δ LNREC	Δ LK	Δ LLF	ECT
Δ LRGDP (Eq. (14a))	—	10.297** [0.00] (0.112)** [0.00]	11.912** [0.00] (0.258)** [0.00]	9.069** [0.00] (0.301)** [0.00]	4.600** [0.03] (0.229)** [0.00]	−0.201** [0.00]
Δ IREC (Eq. (14b))	12.305** [0.00] (0.348)** [0.00]	—	10.484** [0.00] (−0.310)** [0.00]	8.292** [0.00] (0.638)** [0.02]	9.836** [0.00] (0.356)** [0.00]	−0.230** [0.00]
Δ LNREC (Eq. (14c))	5.211** [0.02] (0.408)** [0.00]	8.854** [0.00] (−0.291)** [0.00]	—	8.539** [0.00] (0.418)** [0.02]	12.602** [0.00] (0.382)** [0.00]	−0.223** [0.00]
Δ LK (Eq. (14d))	9.272** [0.00] (0.213)** [0.00]	11.469** [0.00] (0.088)** [0.02]	6.293** [0.01] (0.067)** [0.01]	—	8.507** [0.00] (0.982)** [0.00]	−0.192** [0.00]
Δ LLF (Eq. (14e))	10.030** [0.00] (0.283)** [0.01]	8.937** [0.00] (0.103)** [0.00]	7.037** [0.00] (0.218)** [0.00]	8.163** [0.00] (0.325)** [0.00]	—	−0.210** [0.00]

Notes: Partial F-statistics reported with respect to short-run changes in the independent variables. The sum of the lagged coefficients for the respective short-run changes is also performed and is denoted in parentheses. ECT denotes the estimated coefficient on the error correction term. The vector error correction model is estimated using panel regression techniques with fixed effects for cross section. Probability values, which represented the probability values of the partial F-statistic and the Wald chi-square tests, are in brackets and reported underneath the corresponding partial F-statistic and sum of the lagged coefficients, respectively. ** denotes the significance at 5% level.

energy, gross fixed capital formation and the labor force. These results are expected because these three inputs are the most used in the production process. A notable result demonstrated by these data is that the feedback hypothesis (bidirectional causality) between non-renewable energy consumption and real GDP holds for this group of countries. In addition, empirical results provide strong evidence for the feedback hypothesis between non-renewable energy, gross capital formation and the labor force. This identical result occurs between gross capital formation and the labor force.

Empirical results demonstrate that there is unidirectional causality stemming from economic growth, gross capital formation and the labor force to renewable energy consumption in the short-run. This implies that the renewable energy sector in these exporting countries is in an immature stage.

Regarding the five selected MENA NOECs sample, the causality results reported in Table 8 provide strong evidence for bidirectional causality among all variables in the short-run.

For the 5 selected MENA NOECs sample, we note the following:

1. That the unidirectional causality stems from economic growth, gross capital formation and the labor force to renewable energy consumption in the short-run for the whole MENA NOECs sample becomes bidirectional with a high significant level of 1%. This result demonstrates the importance of using homogenous countries in a study such as this.
2. Evidence of a negative and significant bi-directional causality between renewable and non-renewable energy consumption indicates that an increase in one type of energy will reduce consumption of the other. This evidence of the short-run bi-directional causality between renewable and non-renewable energy consumption indicates the substitutability between these two types of energy sources. Notably, this overall effect is symmetric. The results indicate that a 1% increase of non-renewable energy induces a 0.31% reduction in renewable energy. In contrast, a 1% in renewable energy decreases non-renewable energy consumption by 0.29%.
3. The non-significant causality runs from renewable energy consumption to economic growth for the entire sample of MENA NOECs becomes significant at the 1% level of significance. This causal direction may be hidden by the inclusion of other MENA countries.
4. The coefficient of the renewable energy in Eq. (14a) is equal to 0.112 which is approximately the half of the coefficient of non-renewable energy (0.258). This is notable because for the selected MENA countries both renewable and non-renewable energy are primary drivers of economic growth.

The results of long-run causality direction tests for both samples indicate strong evidence of bidirectional causality for all Eq. (14a)–(14e) suggesting that the respective error correction terms are statistically significant. However, empirical results show that the percentage of deviation that is corrected each year for the real GDP equation is approximately equal for both samples. This percentage of deviation for the 5 selected MENA NOECs sample compared to the entire MENA sample, is double for the renewable equation, triple for non-renewable equation, double for the gross capital formation and approximately equal for labor force equation.

5. Conclusions and policy implications

Well concerned by the recent fall of oil prices and the subsequent decreasing government revenues since the middle of 2014, the MENA NOECs are currently more worried than ever before about the decreasing of the future role that will play non-renewable energy on the development of their economies. MENA NOECs are concerned about environmental challenges related to the massive use of non-renewable energy. Consequently, it appears that the transition towards renewable energy has become indispensable to meet the rising energy needs and mitigate the risks of oil prices volatility. Moreover, the transition towards the renewable energy is also required to better achieve a sustainable energy mix that can not only support a continuous supply of energy but also support human development over the long run.

Hence, this article investigated the relative impact of renewable and non-renewable energy sources on economic growth for two panel groups of MENA NOECs from 1980 to 2012 within a multivariate panel error correction model. The results of the panel cointegration tests allowing for cross-sectional independence of [55,58] and Kao [36]; and for cross-sectional dependence of Westerlund [82] provide evidence for long-run equilibrium between real GDP, renewable and non-renewable energy consumption, real gross fixed capital formation and labor force. Moreover, as expected, the estimated long run elasticities are positive and statistically significant. The results reveal also that the relative effect of

renewable energy is higher for the 5 selected MENA NOECs compared to the whole MENA sample. In term of capital and labor factors, the results show that the impact of real gross fixed capital formation and the labor force variables are more important for the for 5 selected MENA NOECs sample compared to the whole MENA NOECs sample.

In addition, the results show that, in the short run, the estimated coefficients between the two types of energy sources are negative and highly significant for the 5 selected countries group. For the whole MENA NOECs sample, the results show that the coefficients of renewable and non-renewable energy are non-significant. This result indicate that for the non-selected MENA NOECs, the level of renewable energy is still not significant and not a key determinant of production. This implies that the non-selected MENA NOECs should improve and promote the development of renewable energy sector to be one of the main contributor to the economic growth and benefits from its positive effects on economic growth and environment.

Moreover, it is highly important to note that energy subsidies for fossil fuels are considered as primary constraints against the development of renewable energy in the MENA NOECs. Consequently, reducing energy subsidies for fossil fuels is politically challenging and requires a pragmatic approach, that may include increased social and educational spending, creating more employment and business opportunities. In addition, in the absence of relative legal and policy framework, greater initial capital costs coupled with a lack of fuel-price risk assessment, the exclusion of environmental externalities in the cost, the shortage of infrastructure for renewable energy and lack of commercial skills and information are all common constraint in the exporting region. Furthermore, the political instability in certain parts of the MENA exporting region, the rigidity of regulations, the low level of public awareness and the financial uncertainty due to the high volatility of oil prices remain the most important barriers against a real improvement of the investment level in these countries.

The government of the MENA exporting countries should undertake alternative ways in order to foster the deployment of renewable energy industries by developing important regional based institutions. This will serve as a dedicated framework to promote and strengthen regional partnerships regarding renewable energy development. It will also foster the development of the most promising renewable energy technologies. Finally, it will allow also to identify the barriers and the obstacles impede renewable energy development in the MENA NOECs. Successful, effective, and efficient policies depend on the visibility, the predictability, the transparency, and the stability conditions.

Despite the notable empirical results regarding the causality direction between variables for the whole MENA NOECs sample and particularly for the 5 selected MENA NOECs, this study may contain certain limitations such as missing observations and the non-availability of data due to the non-development of the renewable sector. However, this paper remains a first good attempt in investigating the relative impact of renewable and non-renewable energy on economic growth. Thus a possible extension of this study is to include more MENA countries from the importer group to increase the number of observations and use a dummy variable to assess the effect of oil exporting versus oil importing countries to obtain a more efficient result of the estimated true values from the analysis of our data set.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at <http://dx.doi.org/10.1016/j.energy.2016.07.126>.

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