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## Article

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## Provided in Cooperation with:

International Journal of Energy Economics and Policy (IJEPP)

*Reference:* Maku, Owen Affor/Ikpuri, Promise Oghenevwede (2020). A multivariate analysis between renewable energy, carbon emission and economic growth : new evidences from selected Middle East and North Africa countries. In: International Journal of Energy Economics and Policy 10 (6), S. 440 - 450.

<https://www.econjournals.com/index.php/ijeep/article/download/10074/5478>.

doi:10.32479/ijeep.10074.

This Version is available at:

<http://hdl.handle.net/11159/8051>

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# A Multivariate Analysis between Renewable Energy, Carbon Emission and Economic Growth: New Evidences from Selected Middle East and North Africa Countries

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Received: 12 June 2020

Accepted: 07 September 2020

DOI: <https://doi.org/10.32479/ijeeep.10074>

## ABSTRACT

The paper investigated cross-cutting issues relating to renewable energy, carbon-emission and economic growth for a group of 8 MENA countries covering the period 1990-2018. Adopting a modified linear Cobb-Douglas production function, the study adopted the Fully-Modified and the Dynamic OLS estimation technique in examining the aforementioned relationship. Findings from the panel FMOLS and DOLS for the region confirm that a significant relationship exists between CO<sub>2</sub> emission and economic growth and that renewable energy consumption triggers a significant effect on economic growth as well. Conversely, the panel of the FMOLS result reveals that while economic growth reacts positively from the effect of CO<sub>2</sub> emission, CO<sub>2</sub> emission reacts negatively from the effect of renewable energy consumption, as against the positive outcome between renewable energy consumption and CO<sub>2</sub> emission as reported by the DOLS. This goes to point out that most economies within this region are yet to uncover best and appropriate policies which can control the regulation of renewable energy prices, that can help take into consideration the stability in economic growth structure and at the same time, mitigate the emission of Greenhouse Gases (GHG).

**Keywords:** Non-renewable Resources, Renewable Resources, Economic Growth, Environment, Pollution

**JEL Classifications:** L72, Q20, O40, R11, Q52

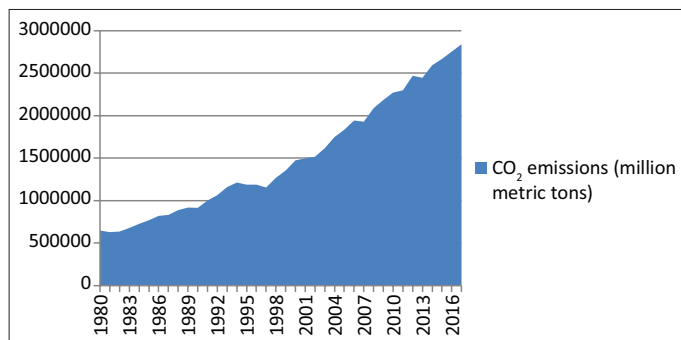
## 1. INTRODUCTION

Climate change has been attributed to the massive use of polluting energy sources (fossil fuels) in recent times. This change caused unwittingly several effects on human and natural condition. If Greenhouse gases (GHG) emissions continue its upward trajectory, it will further global warming and long-lasting changes in all components of climate arrangement. The carbon emissions growth rate has generated several issues relating to the health of the population and on the quality of the environment (Jebli, 2016). The impact of emissions on environmental quality has remained a topical issue developed by series academic and scientific researchers (UNFCCC, 2014). The World Bank has played essential roles in supporting efforts to declining pollution rate and endorsed low level of emissions growth. The efforts of

the World Bank are mainly focused on enhancing countries to use clean energy generation by giving financial incentives (World Bank, 2013). It is relevant to note that the Middle East and North Africa (MENA) region has around 57% of the world's proven oil reserves and 41% of proven natural gas reserves (Menichetti, et al., 2018). About 85% of all GHG emissions in this region are mainly derived from energy produced and consumed. CO<sub>2</sub> emissions (measured in Millions kilotons) has increased largely in MENA countries since 1980 (Figure 1). The associated environmental problems are aggravated through heavy subsidies on petroleum products which promote excessive and inefficient use of fossil-fuels (Farzanegan and Markwardt, 2012).

In this perspective, energy subsidies in the 20 largest non-OECD countries stretched to (\$ 310\*10<sup>12</sup>) in 2007. Eleven (11) countries

**Figure 1:** The evolution of CO<sub>2</sub> emission (million metric tons) in MENA region over the period 1980-2018



out-of-the-total of 20 countries in the world that financially supported the gasoline consumption were from the MENA region (IEA, 2008; Brown 2011). As assessed by the World Bank (2012), fuel subsidies alone are 2 to 7.5 times larger than the public spending on health in Morocco, Yemen and Egypt. In 2007, Iran was the largest fossil fuel subsidizer in the world with (\$ 56\*10<sup>12</sup>) per year, followed by Russia with (\$ 51\*10<sup>12</sup>) per year. Venezuela, Saudi Arabia, China, Egypt, India, Indonesia, and Ukraine represent the other large subsidizers, with annual subsidies exceeding (\$ 10\*10<sup>12</sup>) yearly (IEA, 2008); a reflection that underpricing of petroleum products in the MENA region is considerable. According to the World Bank (2012), the price gaps between the price of gasoline in Yemen, Bahrain, Egypt, Saudi Arabia, Iran, Kuwait, Libya, Qatar and Algeria and the average world price of gasoline were 81%, 90%, 62%, 95%, 58%, 87%, 97%, 89% and 77% per liter in 2008. The mammoth subsidies distort the price-system and cause inefficient allocation of resources. The towering energy-intensity of production and use of fossil-fuels represents a natural significance of such subsidies (Farzanegan and Markwardt, 2012). The existence of cheap-energy impedes investment in clean-technology and energy efficient means of transportation (Ellis 2010; Moltke et al., 2004). The IEA, 2010 emphasizes that the removal of fuel subsidies remains the crux for the overall mitigation of climate change for the MENA region. According to the Carbon-Dioxide Information Analysis Center (CDIAC, 2011), six Middle Eastern countries ranked among the top twenty emitting nations based on CO<sub>2</sub> per capita in 2011: Qatar (1), Kuwait (4), Oman (7), UAE (9), Saudi-Arabia (10) and Bahrain (11), (global ranking in parentheses). The MENA region dependence on oil and gas, as well as their energy-intensive industrial projects which promote the use of domestically produced hydrocarbons; has left an inefaceable mark on the region's carbon footprint. These problems have significantly risen since the 1960s side-by-side rapid rates of energy-intensive industrialization, urbanization and rising living standards (World Bank, 2016).

The drive for sustainable development is therefore urgently needed for all MENA countries. On one hand, energy used in economic activities may enable such social and economic development, but on the other hand, can have negative impact on the environment resulting to climate changes at the global scale (Alshehry and Belloumi, 2017). Conventional energy consumption may contribute to the relation between CO<sub>2</sub> emission and economic growth via two channels. Conventional energy use may lead to an

increase in economic activities, and at the same time, affect CO<sub>2</sub> emission positively. The replacement of a part of conventional energy by renewable energy can trigger the negative effects caused by the overuse of fossil fuels in MENA countries. Based on the above premise, this study attempts to fill the gap by examining the cross-cutting relationship between economic growth, renewable energy consumption and CO<sub>2</sub> emissions using a modified Cobb-Douglas production function which is expanded to include the energy component as an additional production factor as developed by Ismail and Mawar, (2012).

The MENA region is chosen for two basic premise that, environmental quality has worsened in the recent decades in this region due to the extensive use of fossil fuels. Most of the MENA countries use hugely fossil fuel energy without taking into account the necessary preconceptions to avoid the growth of CO<sub>2</sub> emissions. Quite a number of indicators are directly correlated with CO<sub>2</sub> emissions growth, and it is imperative to look for the input of these variables in the progress of emissions. Renewable energy resources (mainly solar and wind energies) are important in MENA countries that can be harnessed to overcome environmental pollution in the region, and even in the world. Compared to the previous studies in the region, this study considers the case where renewable energy is used for production. The empirical analysis employs the FMOLS and DOLS estimation technique developed by Kao and Chang (2001) in a bid to generate unbiased and consistent long run estimates. The other sections of this paper are organized as follows; section 2 discusses relevant literature, while section 3 presents highlights the econometric methodology. In section 4, we present the results and discussion, while section 5 concludes the study and provides relevant policy recommendations.

### 1.1. Renewable Energy in the MENA Region

Most of the region's greenhouse gas (GHG) emissions are largely linked to the region's role as an energy producer. IEA (2018) estimates total GHG-emissions from fuel combustion in MENA was equal to 1.860 million metric tons of CO<sub>2</sub> equivalent in 2008, accounting for 6.3% of the global emissions. By 2010, emissions from the region's power sector were estimated to have risen to 2.101 million metric tons of CO<sub>2</sub> equivalent (World Bank, 2012). As reported from Table 1, renewable electricity net consumption has not been stable within this period (1980-2018), while the per capita CO<sub>2</sub> emissions varies around 50 million metric tons per capita. For some countries, the consumption of electricity has the tendency to rise across time such as Egypt and Iran. Egypt is said to be largest consumer of electricity adopting renewable energy with Iran as the second. Their respective annual averages of electricity net consumption are 14.19% and 11.38% respectively. Saudi Arabia, Qatar and Oman are the three smallest consumers of electricity with 0.062%, 0.055% and 0.003% respectively. Indeed, Qatar and UAE are the two biggest in per capita CO<sub>2</sub> emissions from the energy consumption. Their annual averages of CO<sub>2</sub> emissions from the consumption are 46.05% and 27.57% respectively. We thus conclude that if the use of renewable energy increases, the rate of per capita CO<sub>2</sub> emissions will decrease. One of the solutions proffered in the sustainability and improvement of the energy market is the use of renewable energy. But the pressing

**Table 1: Total renewable net electricity consumption (billion kilowatt-hours) and CO<sub>2</sub> emission from the consumption of energy (million metric tons per capita) for MENA countries**

Countries	1990	1995	2000	2005	2010	2015	2016	2017	2018
Algeria									
ELEC	0.135	0.193	0.054	0.555	0.182	0.222	0.336	0.579	0.730
CO <sub>2</sub>	2.088	3.314	2.830	3.236	3.313	3.846	3.979	4.113	4.247
Egypt									
ELEC	9.953	11.192	14.259	13.155	14.389	15.620	16.133	16.120	16.958
CO <sub>2</sub>	1.353	1.536	2.053	2.214	2.449	2.155	2.045	1.934	1.823
Iran									
ELEC	7.381	8.323	3.818	14.519	10.472	13.512	15.713	17.561	11.191
CO <sub>2</sub>	3.734	4.442	5.672	6.720	7.769	8.490	8.638	8.786	8.934
Iraq									
ELEC	4.650	7.120	3.197	5.750	3.615	2.603	3.429	2.233	3.165
CO <sub>2</sub>	2.738	3.690	3.083	4.217	3.772	5.204	5.380	5.557	5.734
Israel									
ELEC	0.003	0.025	0.033	0.039	0.170	1.346	1.838	1.840	2.038
CO <sub>2</sub>	7.789	9.215	9.582	8.218	9.035	7.573	7.139	6.705	6.270
Morocco									
ELEC	1.220	0.611	0.782	1.171	4.127	4.410	4.657	4.635	6.484
CO <sub>2</sub>	0.949	1.125	1.178	1.503	1.730	1.747	1.731	1.715	1.699
Oman									
ELEC	0.000	0.000	0.000	0.000	0.000	0.004	0.004	0.009	0.014
CO <sub>2</sub>	6.283	7.212	9.654	11.904	15.591	15.031	14.541	14.051	13.561
Qatar									
ELEC	0.000	0.000	0.000	0.000	0.000	0.121	0.123	0.124	0.124
CO <sub>2</sub>	24.722	61.914	58.619	57.006	39.060	42.297	42.954	43.611	44.268
Saudi Arabia									
ELEC	0.000	0.000	0.000	0.000	0.004	0.129	0.129	0.142	0.155
CO <sub>2</sub>	11.445	16.908	14.370	17.111	17.610	19.601	19.991	20.381	20.771
U.A.E									
ELEC	0.000	0.000	0.000	0.000	0.018	0.309	0.338	0.539	0.954
CO <sub>2</sub>	28.445	29.250	35.916	25.314	18.809	33.973	24.234	25.495	26.756
MENA									
ELEC	15.321	18.757	10.860	24.203	17.987	20.311	25.231	26.899	23.214
CO <sub>2</sub>	3.594	4.148	4.671	5.283	5.885	6.271	6.365	6.459	6.553

Source: International Energy Agency, 2019

challenge is how to harness it; and how to turn the economy in this region into a sustainable path. The Intergovernmental Panel on Climate Change (IPCC, 2011) reveals that the relatively share of renewable energy can be attributed not only from a single resource, but to the deployment of a number of renewable resources. As with the rest of the global community, MENA's rich-endowment of renewable energy resources far exceeds its annual energy needs. In 2010, the region's energy demand was approximately 1,121 TWh.

By 2050, this demand is approximately projected to reach 2,900 TWh (Fichtner, 2011). But only recently, renewable resources across the region have been accorded priority. Governments of the MENA countries make efforts to use this potential in order to acquire additional technological improvements, cost reductions, and the adoption of favorable policy regimes. The use of renewable energy (hydro, wind, biomass, geothermal, and solar) seems the greatest solution to reduce the severity of the environmental problems, to ensure the improvement of social-welfare, and to innovate and advance the green-technology of the industrial firm's payoffs.

## 2. LITERATURE REVIEW

Few studies have focused on the connection between renewable energy consumption, economic growth and CO<sub>2</sub> emissions

(Sadorsky, 2009; Apergis et al., 2010; Menyah and Wolde-Rufael, 2010). Sadorsky (2009) estimates an empirical model of renewable energy consumption, oil prices and CO<sub>2</sub> emissions for the G7 countries from 1980 to 2005 using Panel Vector Error correction Model (VECM). The Panel cointegration techniques estimates show that in long term, GDP per capita and emissions are the two major-drivers behind renewable energy per capita. In the short run, variations in renewable energy consumption per capita are driven essentially by movements back to long run equilibrium as opposed to short run shocks. In other works, Apergis et al. (2010) examined the causal relationship between CO<sub>2</sub> emissions, nuclear energy, renewable energy, and economic growth for a pool of 19 developed and non-developed countries for the period, 1984-2007. They find a long run relationship between emissions and renewable energy consumption. Whereas, results from the panel Granger causality test suggests that renewable energy consumption does not contribute to reducing CO<sub>2</sub> emissions in the short run. In the same way, Menyah and Wolde-Rufael (2010) explore the causal relationship between CO<sub>2</sub> emissions, nuclear energy consumption and renewable and real GDP for the United States for the period 1960-2007. The empirical result supports a uni-directional and negative causality running from nuclear energy consumption to CO<sub>2</sub> emission and proves that nuclear energy consumption can help ameliorate CO<sub>2</sub> emissions.

Bhattacharya et al. (2017) suggest that, from 85 developed and developing countries, both renewable energy deployment and institutions play a significant role in stimulating economic growth and reducing CO<sub>2</sub> emissions. For a panel of twenty-five selected African countries, Zoundi (2017) recommend that CO<sub>2</sub> emissions are found to increase with income per capita. It (2017) suggest that, for a panel of forty-two developed countries, non-renewable energy consumption leads to a negative effect on growth for developing countries. In the long-run, renewable energy consumption positively contributes to economic growth. Previous studies have been examined in order to highlight the contribution of each variable to the evolution of CO<sub>2</sub> emissions, but by considering different sets of variables under consideration. In previous empirical studies, different statistical approaches and econometric methods are used (two steps generalized method of moments (GMM), fixed effect regression, PVAR, autoregressive distributed lag (ARDL) model, Granger causality, etc.) either for the case of panel or time series. From previous studies, the findings are different and depend mainly on the methodologies, periods, sample sizes and countries. The directions of both long and short-run causalities among the variables have been examined in many studies. Table 2 summarizes some previous empirical studies and presents their contributions according to the methodology, variables, samples and the period used, which are discussed under growth pollution nexus and renewable energy pollution nexus.

### 2.1. Growth-pollution Nexus

For the case of Algeria, Bouznit and PabloRomero (2016) considered the ARDL approach to examine the validity of the Environmental Kuznets Curve (EKC) hypothesis over the period 1970–2010. The results showed that the EKC hypothesis is thus validated and that increasing economic growth in Algeria has increased emissions. Ahmad and Du (2017) adopted the ARDL

bound approach to investigate the dynamics existing between energy production, CO<sub>2</sub> emissions and economic growth in Iran. Although the production of energy positively has contributed to economic growth, CO<sub>2</sub> emissions are positively linked to economic growth. Adopting a dynamic-panel model based on the GMM technique, Jalil (2014) investigated the determinants of CO<sub>2</sub> emissions in 18 MENA countries for the period 1971–2009. Their results showed that real GDP, fossil fuel energy consumption, FDI and agriculture production had significant effects on CO<sub>2</sub> emissions.

### 2.2. Renewable Energy–pollution Nexus

Various empirical studies have critically examined the role renewable energy consumption may contribute in mitigating CO<sub>2</sub> emissions in the world. Empirical studies have found that renewable energy use can decrease in CO<sub>2</sub> emissions. Table 3a and b reports some studies that investigated the renewable energy–pollution nexus. Apergis and Payne (2014) examine the determinant of renewable energy for a panel of seven Central-American countries. The results from their estimation suggest that a long run relationship exists between carbon emissions per capita, renewable energy consumption per capita, real coal prices, real GDP per capita and real oil prices with the respective coefficients statistically significant. Jebli and Youssef (2015) employed the Granger-causality test and the panel cointegration approach for a group of North-Africa countries for the period 1971–2008. Their findings suggest the existence of a unidirectional short-run causality running from renewable energy consumption to CO<sub>2</sub> emissions. For a panel data set of seventeen OECD countries, Bilgili et al. (2016) use panel DOLS and FMOLS estimations. The results revealed that renewable energy consumption yields negative impact on CO<sub>2</sub> emissions. Bölük and Mert (2015) use the ARDL approach to examine the potential of renewable energy sources in reducing the impact of GHG emissions in Turkey. The results show that the coefficient of electricity production as generated from renewable sources with respect to CO<sub>2</sub> emissions is negative and statistically significant in the long-run.

## 3. MATERIALS AND METHODS

The study takes a step further to investigate empirically the relationship between renewable energy, carbon emission and economic growth; evidenced for a balanced panel of 8 MENA countries for the period 1990–2018, generated from the World Bank (2019) database and the BP statistical Review of World Energy (2019) database. Data used are for the variables per capita GDP (constant 2010, PPP), a proxy for economic growth, CO<sub>2</sub> emission per capita (metric tons per capita) and renewable energy consumption (REW), expressed as the share of consumption from renewable energy sources in total final energy. All the variables are transformed into natural logarithm so as to obtain unbiased and consistent results by overcoming the heteroscedasticity problem among the variables (Vogelvang, 2005; Shahbaz et al., 2012; Salahuddin et al., 2015). The 8 MENA economics included in the sample are: Algeria, Egypt, Iran, Israel, Jordan, Lebanon, Morocco and Tunisia. These countries were selected based on data availability on the variables on interest.

**Table 2: Estimated renewable electricity potential (TWh per year) for MENA countries**

Countries	Year	Solar	Wind	Geothermal, Hydro biomass and others	Hydro
Algeria	2010	0.009	0.000	0.000	0.173
	2018	0.603	0.01	0.000	0.117
Egypt	2010	0.025	1.409	0.000	12.954
	2018	1.035	2.438	0.000	13.483
Iran	2010	0.0007	0.208	0.010	10.252
	2018	0.037	0.361	0.021	10.77
Iraq	2010	0.000	0.000	0.000	3.615
	2018	0.057	0.000	0.000	3.107
Israel	2010	0.07	0.008	0.061	0.031
	2018	1.793	0.105	0.115	0.024
Kuwait	2010	0.000	0.000	0.000	0.000
	2018	0.088	0.017	0.000	0.000
Morocco	2010	0.0001	0.692	0.000	3.467
	2018	0.950	3.840	0.000	1.693
Oman	2010	0.000	0.000	0.000	0.000
	2018	0.013	0.000	0.000	0.000
Qatar	2010	0.000	0.000	0.000	0.000
	2018	0.009	0.000	0.114	0.000
Saudi Arabia	2010	0.004	0.000	0.000	0.000
	2018	0.154	0.000	0.000	0.000
U.A.E	2010	0.018	0.000	0.000	0.000
	2018	0.946	0.0007	0.005	0.000

Source: IEA, 2019

**Table 3a: Summary of related studies**

Authors	Sample	Period	Estimation technique	Findings
<b>Regional studies</b>				
Wang (2012)	98 countries	1971-2007	Dynamic panel threshold model	EKC is supported. Economic growth negatively affects CO <sub>2</sub> emission
Farhani and Rejeb (2012a)	15 MENA countries	1973-2008	Panel cointegration methods and panel cointegration	No causal link between GDP and energy consumption and between CO <sub>2</sub> emission and energy consumption in the short run. In the long-run, there is a uni-directional causality running from GDP and CO <sub>2</sub> emission to energy consumption
Arouri et al. (2012)	12 MENA countries	1981-2005	Unit root test and cointegration techniques	Energy consumption had a positive and significant effect on CO <sub>2</sub> emission. Economic growth had a positive impact on CO <sub>2</sub> emission
Apergis and Payne (2014)	7 Central American countries	1980-2010	Panel cointegration with structural breaks	CO <sub>2</sub> emission affects renewable energy consumption
Jalil (2014)	18 MENA countries	1971-2009	GMM	Gross domestic product (GD), energy consumption, foreign direct investment and agricultural production have significant effect on CO <sub>2</sub> emissions in the region
Saidi and Hammami (2015)	58 countries	1990-2012	Dynamic panel data model with GMM	All variables exhibited positive and mostly significant impact on energy consumption in all four panels
Al-mulali et al. (2016)	18 Latin America and Caribbean countries	1980-2010	KAO panel cointegration test, FMOLS, VECN granger causality test	EKC between GDP and CO <sub>2</sub> supported. Energy consumption had no long run effect on CO <sub>2</sub>
Salahuddin et al. (2015)	Six Gulf Cooperation Council (GCC) countries	1980-2012	DOLS, FMOLS, dynamic fixed effect, panel granger causality test	Electricity consumption and economic growth have a positive long run relationship to CO <sub>2</sub>
Jebli and Youssef (2015)	North African countries	1971-2008	Panel cointegration approach and Granger causality test	Short-run unidirectional causality running from renewable energy to CO <sub>2</sub> emission
Magazzino (2016)	10 Middle East countries	1971-2006	Panel VAR	For 6 countries, the effect of CO <sub>2</sub> emission on growth is negatively related. CO <sub>2</sub> emission is driven by energy consumption. CO <sub>2</sub> emission and energy consumption have no impact on growth in the remaining four countries
Apergis (2016)	15 countries	1960-2013	Panel, time series and time-varying approaches of cointegration	EKC hypothesis holds in 12 out of the 15 countries
Kais and Mbarek (2017)	3 North African countries	1989-2012	Panel cointegration test and panel VECM	Unidirectional causality running from economic growth to CO <sub>2</sub> and also from energy consumption to CO <sub>2</sub> emission
Bhattacharya et al. (2017)	85 developed and develop countries	1991-2012	System GMM and fully modified OLS	Renewable energy sources play a significant role for CO <sub>2</sub> emission

Source: Compiled by Author

The model to be estimated is succinctly hinged on the simple Cobb-Douglas production framework, which is shown to be a function of capital ( $K$ ) and Labour ( $L$ ), written as;

$$Y = f(K, L) \tag{1}$$

Previous studies (Ismail and Mawar, 2012) included energy,  $N$ , as the third factor of production function, thus equation (1) is augmented to be;

$$Y = f(K, N, L) \tag{2}$$

For modeling purposes, this paper adopts a Cobb-Douglas production function;

$$Y = K^\beta * N^\theta * L^\eta \tag{3}$$

Where  $\beta$ ,  $\theta$  and  $\eta$ , represents output elasticity to changes in capital, energy and labour; where  $\beta+\theta+\eta=1$ . Converting equation (1) into logarithm, the empirical equation is modeled thus;

$$\ln GDP_{pcap_{it}} = c_i + \alpha_i \ln K_{it} + \beta_i \ln L_{it} + \lambda_i \ln E_{it} + \varpi_i \ln CO_{2it} + u_{it} \tag{4}$$

Where  $\ln GDP_{pcap_{it}}$  represents gross domestic product per capita;  $\ln K_{it}$  represents capital formation;  $\ln L_{it}$  represents labour participation;  $\ln E_{it}$  represents renewable energy;  $\ln CO_{2it}$  represents per capita Greenhouse gas emission;  $u_{it}$  represents the error term assumed to be normally distributed with zero mean and constant variance.

## 4. EMPIRICAL RESULTS

The analysis begins with the summary statistics of variables used in the sample of 8 MENA countries which is presented in Table 4. Then we investigate the variables time series plots (in logarithm form) for each country.

Figure 2 shows the time plots of renewable energy consumption for each of the countries. On the average, Morocco is the biggest

**Table 3b: Summary of related studies**

Authors	Sample	Period	Estimation technique	Findings
Zoundi (2017)	25 African countries	1980-2012	Panel cointegration approach	No evidence of total validation of EKC. Renewable energy use negatively related to CO <sub>2</sub> emission
Country-specific studies				
Authors	Sample	Period	Estimation technique	Findings
Omotor (2008)	Nigeria	1970-2005	Johansen cointegration, Hsiao granger causality	There existed a bi-direction causality between energy consumption and growth
Halicioglu (2009)	Turkey	1960-2005	Panel cointegration test	Economic growth has significant effect impact on CO <sub>2</sub> emission
Chang (2010)	China	1982-2004	Multivariate cointegration and VECM	Energy consumption and GDP had positive and significant relationship
Saboori and Sulaiman (2011)	Iran	1971-2007	Cointegration approach; ARDL	EKC hypothesis assumes an inverted U-shaped relationship. Energy consumption had a positive and significant effect on CO <sub>2</sub> emission
Saboori and Sulaiman (2013)	Malaysia	1980-2009	ARDL and VECM	Energy consumption and GDP had positive and significant relationship
Shahbaz et al. (2015)	Tunisia	1971-2010	VECM and ARDL	Energy consumption and GDP had positive and significant relationship
Long et al. (2015)	China	1952-2012	Unit root and cointegration; granger causality	Energy consumption and GDP had positive and significant relationship
Bouznit and Pablo-Romero (2016)	Algeria	1970-2010	ARDL	EKC curve confirmed. Income has not yet reach the required threshold
Ahmad and Du (2017)	Iran	1971-2011	ARDL-FMOLS and Dynamic OLS	There is a positive relationship between CO <sub>2</sub> emission and economic growth
Dogan and Ozturk (2017)	USA	1980-2014	EKC model structural break ARDL model	Renewable energy consumption mitigates environmental degradation
Ishioro (2018)	Nigeria	-	Multivariate unit root, Johansen cointegration and Granger causality test	Energy consumption has improved the performance of manufacturing, health, agriculture, transport, utilities and finance sectors in Nigeria
Ishioro (2019)	Nigeria	-	VAR	For each of the energy components and growth variables, own shocks were more profound and there were evidences of substitutability of shocks

Source: Compiled by author

**Table 4: Descriptive statistics**

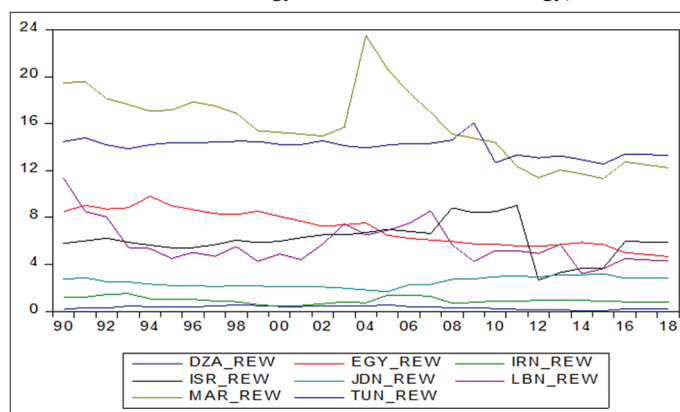
Statistics	LNGDP <sub>peap</sub>	LNCAP	LNLAB	LNREW	LNCO <sub>2</sub>
Mean	9.255	3.190	3.887	1.300	1.167
Maximum	10.422	3.762	4.240	3.157	2.290
Minimum	8.262	2.521	3.609	-2.830	-0.052
Std. Dev.	0.495	0.217	0.152	1.311	0.588
Skewness	0.450	-0.078	0.389	-0.855	0.255
Kurtosis	2.872	3.221	2.140	2.899	2.359
Jarque-Bera	8.006	0.708	10.000	28.420	6.487
Probability	0.018	0.701	0.001	0.000	0.039
Observation	232	232	232	232	232

Source: Author's computation using E-views 10

renewable consumer, followed by Tunisia and Algeria is the least consumer of renewable energy. However, most of the countries still have undulating trends of renewable energy consumption. Figure 3 show the time series plots of GDP per capita for each country. In fact, most countries have experienced increased GDP per capita for the period under study. Israel has the biggest GDP per capita size, followed by Algeria, while Morocco is at the bottom of the ladder. Figure 4 shows the time series plot of carbon emission per capita. On the average, Israel has the highest CO<sub>2</sub> emission overt the period, followed by Iran, while Morocco is at the tail end of the emission ladder.

Table 5 shows the average annual growth rates for each variable over the period 1990-2018. We can deduce that the annual growth

**Figure 2:** Plot of renewable energy (share of consumption from renewable energy sources in total final energy)



rate for renewable energy consumption vary between countries and ranges from as low as -1.976 in Egypt, to as high as 9.235 in Algeria. For all countries used for this study do not exceed 5% per year except for Algeria. This result confirms that most of the aforementioned countries have not yet sufficiently invested in green technologies using renewable energy. In fact, some countries such as Egypt, Iran, Lebanon, Morocco and Tunisia stand out for having high growth rate per capita. Succinctly, the average annual growth rate of renewable energy consumption in these countries is similar to their average annual GDP per capita growth rate. In

Algeria, Iran and Jordan, the average growth rate for renewable energy consumption tends to grow more rapidly culminating in a positive average growth rate of CO<sub>2</sub> emission. Also, negative growth rate of renewable energy in Lebanon, Morocco and Tunisia also produce positive CO<sub>2</sub> emission. Only Israel generates negative growth rate of CO<sub>2</sub> emission, which is traceable to a positive annual growth rate of renewable energy.

Figure 3: Plot of CO<sub>2</sub> emission per capita (metric tons per capita)

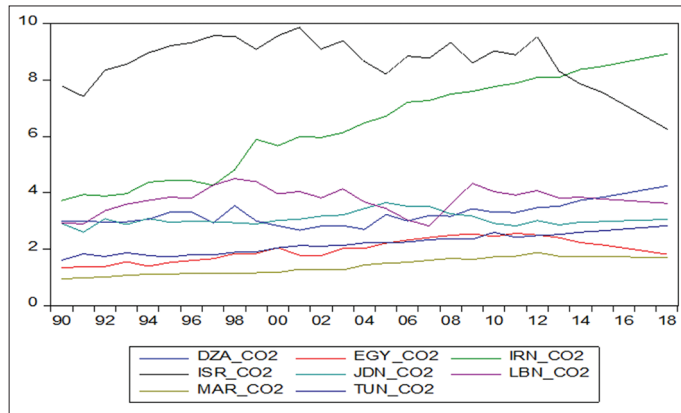


Figure 4: Plot of GDP per capita (constant 2010, PPP)

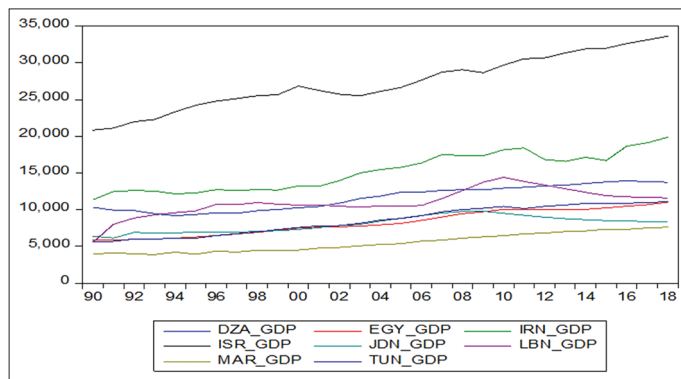


Table 5: Average growth rates over the period 1990-2018

Country	Renewable energy consumption	GDP per capita	CO <sub>2</sub> emission
Algeria	9.235	1.059	1.538
Egypt	-1.976	2.269	1.300
Iran	0.998	2.096	3.284
Israel	2.685	1.742	-0.593
Jordan	0.497	1.054	0.332
Lebanon	-1.333	2.979	1.158
Morocco	-1.111	2.460	2.181
Tunisia	-0.166	2.486	2.135

Source: Author's computation

Table 6: Panel unit root test results

Method	REW	CO <sub>2</sub>	GDP <sub>pcap</sub>	Labour	Capital
LLC-t* (level)	-0.647 (0.258)	1.764 (0.961)	2.119 (0.983)	1.050 (0.853)	0.147 (0.558)
(1 <sup>st</sup> Diff.)	-4.517 (0.000)**	-2.132 (0.016)**	-5.171 (0.000)**	-5.582 (0.000)**	-4.668 (0.000)**
IPS-@ stat. (level)	-1.053 (0.146)	2.435 (0.992)	0.922 (0.821)	0.885 (0.812)	0.326 (0.627)
(1 <sup>st</sup> Diff.)	-5.710 (0.000)**	-5.898 (0.000)**	-2.156 (0.015)**	-2.248 (0.012)**	-5.022 (0.000)**

Source: Author's Computation using E-views 10. N.B: The variables are expressed in natural logarithms; \*\*Denotes significant at 5% level; lag selection based on akaike information criterion

### 4.1. Panel Unit Root Analysis

In this paper, the panel unit root tests are computed in order to assess the stationarity of variables including Levin et al. (2002) and Im et al. (2003) test. Levin et al. (2002) proposes a panel based on augmented Dickey-Fuller (ADF) test that assumes homogeneity in the dynamics of the autoregressive coefficients for all panel units with cross sectional independence. The following equation is considered;

$$\Delta Y_{it} = \beta_i + \eta_i Y_{i,t-1} + \varpi_i H + \sum_{j=1}^k \vartheta_{ij} \Delta Y_{i,t-1} + \mu_{it} \quad (5)$$

Where  $\Delta$  is the first difference operator,  $Y_{it}$  is the dependent variable,  $\mu_{it}$  is a white-noise disturbance with a variance,  $i$  represents indexes country, and  $t$  represents indexes on time. The test involves the null hypothesis ( $H_0: \eta_i = 0$ ) for all  $i$  against the alternative ( $H_1: \eta_i \neq 0$ ) for all  $i$ . Im et al. (2003) test is not restrictive as Levin et al. (2002) test, since it allows for heterogeneous coefficients. The null hypothesis is that all individuals follow a unit root process, ( $H_0: \eta_i = 0$ ) for all  $i$ . The alternative hypothesis allows some of the individuals to have unit roots, then  $H_1: \left\{ \begin{matrix} \eta_i < 0; i = 1, \dots, N_i \\ \eta_i = 0; i = N_i + 1, \dots, N \end{matrix} \right\}$ . The results of the unit root test in Table 6 indicate that each variable is integrated of order one, I(1).

### 4.2. Panel Cointegration Test

We employ the Pedroni (2004) cointegration test. The panel cointegration test result of Pedroni (2004) is presented in Table 7. Pedroni proposes two cointegration tests based on the within approach which include four statistics (panel test) and the between approach which includes three statistics. However, the Pedroni cointegration test is based on the residuals and variants of Phillips and Perron (PP, 1988) and Dickey and Fuller (ADF, 1979). The Pedroni's cointegration result indicates that we reject the null-hypothesis of no cointegration at 5% significant level, which implies that there exist a long run relationship between renewable energy, carbon emission and economic growth in MENA countries.

### 4.3. Panel Fully Modified OLS and Dynamic OLS

Although, OLS estimators of the cointegrated vectors are convergent, their distribution is asymptotically biased and thus depends on nuisance parameters connected with the presence of serial correlation in the series (Pedroni, 2001). Such problems, existing in the time series arise for the panel data and tend to be more pronounced even in the presence of heterogeneity. In



carrying out tests on the cointegrated vectors, it is necessary to use an effective estimation technique. Various techniques exist such as the fully modified ordinary least square (FMOLS) as initially suggested by Phillips and Hansen (1990) or the dynamic ordinary least square (DOLS). In the case of the panel data, these two techniques lead to normally distributed estimators, implying that both the OLS and FMOLS exhibit small-sample bias and that DOLS estimator appears to out-perform both estimators (Phillips and Moon, 1999 and Pedroni, 2001). Thus our empirical model

is based on the regression analysis between the three variables as evident in equation 4.

Table 8 presents results of individual and panel FMOLS and DOLS. The estimated coefficient from the long run cointegration relationship can be interpreted as long run elasticities. Beginning with the country specific results, we find that renewable energy exhibits significant impact on GDP for countries like Algeria, Egypt, Iran and Jordan under the FMOLS while the other countries exhibited insignificant relationship to GDP. For the DOLS, only Algeria, Egypt and Morocco exhibited significant effect on GDP. From the FMOLS results, only Algeria, Iran and Jordan had positive and significant renewable energy consumption effect on GDP, while for the DOLS, Algeria, Egypt and Morocco exhibited positive and significant in relation to renewable energy consumption to GDP. Turning to the effect of CO<sub>2</sub> emission on GDP, Egypt, Israel, Jordan and Morocco exhibited positive and significant effect on GDP under the FMOLS. As regards the DOLS results, Algeria, Egypt and Morocco exhibited positive and effect on GDP. From Table 8, it is evident from the FMOLS that GDP has positive and significant impact on renewable energy for countries such as Algeria, Iran and Jordan, while it exhibited negative and significant impact in Egypt and Tunisia. From the DOLS, GDP showed a positive and significant impact on renewable energy

**Table 7: Pedroni's (2004) cointegration result (GDP<sub>pcap</sub> as dependent variable)**

Pedroni cointegration test				
Common AR coefficients (within dimensions)				
Group coefficients	Statistics	P-value	Weighted Statistics	P-value
Panel v-Statistics	4.458	0.000**	4.937	0.000**
Panel rho-Statistics	-0.273	0.392	0.647	0.741
Panel PP-Statistics	-5.648	0.000**	-2.399	0.008**
Panel ADF-Statistics	-8.133	0.000**	-4.432	0.000**
Individual AR coefficients (within dimensions)				
Group rho-Statistics	1.707	0.956		
Group PP-Statistics	-2.059	0.019**		
Group ADF-Statistics	-3.776	0.000**		

Source: Author's Computation using E-views 10. \*\*Denotes significant at 5% level

**Table 8: Long run elasticity result**

Panel/Countries	GDP <sub>pcap</sub> as dependent variable				REW as dependent variable			
	FMOLS		DOLS		FMOLS		DOLS	
	REW	CO <sub>2</sub>	REW	CO <sub>2</sub>	GDP	CO <sub>2</sub>	GDP	CO <sub>2</sub>
Panel	0.035 (1.463)	0.289 (4.268)**	0.058 (3.327)**	0.160 (1.870)***	0.698 (1.489)	-0.811 (-2.776)**	1.411 (1.706)***	-0.795 (-1.463)
Algeria	0.032 (2.446)**	-0.001 (-0.022)	0.058 (3.327)**	0.160 (1.878)***	6.495 (2.623)**	-0.563 (-0.562)	0.068 (0.007)	-6.066 (-1.836)**
Egypt	-0.146 (-2.104)**	0.167 (5.763)**	-0.217 (-3.904)**	0.270 (12.644)**	-1.243 (-2.547)**	0.216 (1.909)***	-0.630 (-0.311)	-0.742 (-1.243)
Iran	0.074 (2.149)**	0.026 (0.129)	0.209 (1.249)	-1.529 (-1.658)	2.071 (1.853)***	-1.376 (-1.291)	-0.648 (-0.428)	-10.502 (-3.436)**
Israel	-0.006 (-0.450)	0.115 (2.676)**	0.004 (0.076)	0.524 (1.391)	-0.985 (-0.305)	-0.849 (-1.166)	-0.472 (-0.067)	-6.338 (-2.458)**
Jordan	0.305 (2.650)**	0.698 (3.100)**	0.367 (1.488)	0.269 (0.373)	0.675 (2.702)**	-1.379 (-5.626)**	1.275 (3.051)**	-1.929 (-2.501)**
Morocco	-0.029 (-0.749)	0.435 (2.970)**	-0.100 (-3.604)**	0.545 (5.693)**	-0.695 (-0.702)	0.626 (0.679)	4.467 (1.500)	0.480 (0.322)
Tunisia	-0.209 (-1.556)	0.015 (0.108)	-0.208 (-0.247)	-0.248 (-1.005)	-0.368 (-1.961)***	-0.234 (-1.942)***	-1.951 (-3.191)**	-0.465 (-1.598)

Source: Author's computation using E-views 10. \*\*,\*\*Denotes significant at 5% (10%) level; t-statistics in parenthesis

**Table 9: Long run elasticity result**

Panel/Countries	CO <sub>2</sub> as dependent variable			
	FMOLS		DOLS	
	REW	GDP <sub>pcap</sub>	REW	GDP <sub>pcap</sub>
Panel	-0.096 (-2.960)**	0.596 (4.053)**	0.020 (0.353)	0.341 (1.457)
Algeria	-0.022 (-0.578)	0.088 (0.159)	-0.227 (-4.458)**	2.447 (4.537)**
Egypt	0.564 (1.713)	3.528 (5.927)**	0.460 (1.331)	2.418 (3.359)**
Iran	-0.049 (-1.665)	0.014 (0.078)	0.008 (0.116)	-0.182 (-0.791)
Israel	-0.065 (-1.197)	2.514 (3.566)**	0.111 (1.850)	-0.347 (-0.650)
Jordan	-0.359 (-7.176)**	0.368 (3.697)**	-0.264 (-3.016)**	0.441 (2.604)**
Morocco	0.054 (1.082)	0.529 (2.677)**	0.014 (0.151)	1.103 (2.448)**
Tunisia	-0.300 (-1.499)	0.162 (0.479)	-1.106 (-1.160)	-1.057 (-1.296)

Source: Author's computation using E-views 10. \*\*,\*\*Denotes significant at 5% (10%) level; t-statistics in parenthesis

consumption in Jordan only and a negative and significant effect in Tunisia.

As regards CO<sub>2</sub> emission-renewable energy consumption relationship, it is observed that from the FMOLS, there was a positive and significant relationship in Egypt only, while Jordan and Tunisia exhibited negative and significant relationship. Under the DOLS, for countries such as Algeria, Iran, Israel, and Jordan, CO<sub>2</sub> emission exhibited negative and significant effect on renewable energy consumption. Under both the FMOLS and DOLS panel results, with renewable energy as dependent variable, we find out that the elasticity of CO<sub>2</sub> emission exhibits negative effect at 5% significant level. This implies that with the increase in CO<sub>2</sub> emission, demand for renewable energy decreases. Furthermore, the results proves that most of the aforementioned countries do not utilize renewable energy mainly as a result of the investment cost in green technologies; as such government do not encourage their respective economies to adopt clean technologies using renewable energy.

Table 9 shows the relationship between renewable energy, GDP and CO<sub>2</sub> emission. From the Fully Modified OLS, it is evident that renewable energy shows negative relationship to carbon emission. Thus implies that renewable energy consumption plays a vital role in decreasing CO<sub>2</sub> emission. Critically, GDP in most of the countries triggers significant increase in CO<sub>2</sub> emission as evident from both the FMOLS and DOLS.

## 5. CONCLUSION AND POLICY IMPLICATION

In this paper, we have examined the relationship among renewable energy, CO<sub>2</sub> emission and GDP in 8 MENA countries from 1990 to 2018. To specify what matter, the study adopted the panel unit root test, cointegration test and the FMOLS/DOLS test. Our panel cointegration results reveal the existence of panel long run equilibrium between renewable energy, CO<sub>2</sub> emission and GDP. An important emerging result from the analysis is that renewable energy consumption plays a vital role in lowering CO<sub>2</sub> emission. Furthermore, we can say that policies in these countries may stabilize output and income while attempting to consume more efficient energy. As such policy makers should then take it into consideration the degree of output (growth) in each country when renewable energy policy is formulated. In this case, policy makers should encourage a multilateral effort in promoting and increasing output in each country where renewable energy and thus reduce CO<sub>2</sub> emission in the region. Regional cooperation on the development of renewable energy markets between public and private sector stakeholders could begin with sharing fundamental information across countries with respect to technologies as well as financing and investment strategies (Apergis and Payne, 2010)

In addition, pollution can be reduced if governments improve the industrial sector by importing cleaner technology to attain maximum benefit from international trade (Shahbaz et al., 2012; Tiwari et al., 2013) and also implement effective economic and

financial development policies which improves the environment, which will help in redirecting resources to environmental friendly projects.

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