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RESEARCH ARTICLE

Renewable energy, urbanization, and ecological footprint in the Middle East and North Africa region

Solomon Nathaniel[1] · Ogochukwu Anyanwu[2] · Muhammad Shah[3]

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Abstract
The countries in the Middle East and North Africa (MENA) region have the greatest potential for renewable energy consumption in the world and is likely to be the most vulnerable to the horrendous effects of climate change. Unfortunately, only a few of the countries have tapped into this potential, as non-renewable energy still dominates the total energy mix of these countries. This study explores the effect of renewable and non-renewable energy consumption on the environment in MENA countries from 1990 to 2016 by applying the Augmented Mean Group algorithm while accounting for urbanization, financial development, and economic growth. The panel result suggests that financial development, economic growth, and urbanization add to environmental degradation. Also, findings reveal that renewable energy does not contribute meaningfully to environmental quality, while non-renewable energy consumption significantly adds to environmental degradation. A uni-directional causality flows from urbanization, economic growth, and energy use to environmental degradation. One way to abate this damage is for countries in this region to embrace and promote the consumption of clean energy sources.

Keywords Renewable energy · Ecological footprint · Urbanization · Financial development · MENA

JEL codes Q43 · Q32 · O13

Introduction

The challenges facing the world are hydra-headed. The two core challenges relate to environmental preservation and sustainable growth/development (Dogan et al. 2019). Of the two, matters relating to environmental preservation have captured the interest of the world's economies in recent times due to an increase in global mean temperature which informed both the Kyoto Protocol of 1997 and the Paris Agreement of 2015. The importance of nature to man calls for the protection of the biodiversity (Nathaniel and Iheonu 2019). One sure way to protect the biodiversity is to reduce greenhouse gas emissions (GHGs), of which CO_2 emissions are a major contributor to it (Bekun et al. 2019a). The desire to reduce global warming has necessitated the ubiquitous call for the adoption of renewable energy (Khan et al. 2020; Destek and Okumuş 2019; Alola et al. 2019a, b; Sarkodie 2018; Sarkodie and Adams 2018; Sarkodie and Strezov 2018) because they are clean (Nathaniel et al. 2019; Baloch et al. 2019b) and low in emissions (Nguyen and Kakinaka 2019).

The role and importance of energy consumption in growth, poverty eradication, and development of a country cannot be overemphasized as it affects every sector of the economy. This is because the energy sector is a major contributor to industrial and economic accomplishments, as well as, a pre-requisite for providing basic human needs. Energy is consumed in various forms and recently, its consumption has increased globally (BP 2017). This could, however, be traced to the rapid increase in economic growth and urbanization in various countries of the world (Wu et al. 2019; Ahmad et al. 2019). The

Responsible editor: Eyup Dogan

✉ Solomon Nathaniel
nathaniel_solomon21@yahoo.com

Ogochukwu Anyanwu
Ogochukwu.anyanwu@unn.edu.ng

Muhammad Shah
ibrahimecondu@gmail.com

[1] Department of Economics, University of Lagos, Akoka, Lagos, Nigeria
[2] Department of Economics, University of Nigeria, Nsukka, Nigeria
[3] Department of Economics, University of Dhaka, Dhaka, Bangladesh

global energy consumption is dominated by fossil-fuels (Sinha et al. 2017). These conventional energy sources are finite and polluting thereby damaging economic activities, human life, the environment (Hanif et al. 2019; Ali 2018), and ultimately contributing to climate change and global warming.

The link between environmental quality and energy consumption is well established in the literature. Kahia et al. (2019) opined that in recent times, the meager consumption of renewable energy (RE) is responsible for the changes in the climate. The ever increasing deterioration in environmental quality has constituted a challenge to the quality of life across the world. As a result of these environmental challenges, the need for safe and clean energy becomes imperative. Researchers and policymakers have recognized the benefits of shifting from non-RE consumption to RE consumption. RE resources are capable of regenerating themselves within a relatively short period of time. Examples include wind, tides, solar, hydropower, and geothermal energy (Nathaniel 2019).

The MENA region is made up of approximately 22 countries. The region is by no means a homogenous region, but despite the differences between countries, they still face some common challenges. These include a young population with a high rate of unemployment, weak research capabilities, increased demand for electricity, and limited investments in energy (Saidi et al. 2018). The region has been on the radar because it has the greatest potential for RE in the world and is likely to be the most vulnerable to climate change (Gorus and Aslan 2019; Saidi et al. 2018). As noted by Kahia et al. (2019), despite its enormous potentials, the region has greatly suffered from poor environmental quality due to the massive use of non-RE. One of the objectives of government and policymakers in this region has been to achieve sustainable development through sustainable energy. This is because energy, sustainable development, and the environment are highly interconnected. Achieving sustainable development entails utilizing environment-friendly energy sources and higher efficiency process leads to less resource utilization and pollution.

There is a dire need to investigate the role of RE and non-RE on the ecological footprint (EF), our proxy for environmental degradation, in this particular region because of its rich oil wealth which has the tendency of deteriorating the environment by adding significantly to climate change. Another importance of this study hinges on the fact that sustainable development is needed for all MENA countries (Alshehry and Belloumi 2017), and though the use of energy can add to economic and social development, it can also promote environmental degradation on a global scale. Environmental degradation, on the other hand, inhibits growth, through different avenues like reducing agricultural productivity, contributing to ill-health, and making government policies erratic.

This study is plausible in the following ways: (i) Previous studies that considered the MENA region used CO_2 emissions to capture environmental degradation. We used EF for the same purpose. EF is a better proxy for environmental degradation since the negative effects of human activities are not limited to the atmosphere (Charfeddine 2017; Nathaniel et al. 2019; Bello et al. 2018). (ii) In order to avoid biased estimates and estimator inefficiency which could result from ignoring cross-sectional dependence (CD) among the countries, we used both first and second-generation unit root and cointegration tests, and estimation techniques that are robust for CD. (iii) We also used the Augmented Mean Group (AMG) estimation technique which accounts for CD and country-specific heterogeneity in order to avoid being trapped in the guise of overgeneralization that marred previous studies.

The remainder of the study takes the following formats. After examining the issues relating to energy, trade, and urbanization in MENA, "Literature review" presents the literature review. "Methodology and model specification" addresses the methodology. "Presentation and discussion of results" involves the presentation and discussion of results. "Conclusion and policy direction" concludes with policy directions.

Issues relating to energy, trade, and urbanization in MENA

MENA is a region with lots of natural gas and petroleum reserves (World Bank 2015). As of 2018, about half of the OPEC members were from the MENA region. The Oil and Gas Journal had earlier stated in 2009 that MENA has 60% and 45% of the global oil and natural gas reserves, respectively. This amounts to 810.98 billion barrels and 2,868,886 billion cubic feet of oil and natural gas reserves, respectively (USDOE 2011). Source: Adapted from Zhang et al. (2017).

However, as of 2016, the region's oil reserve had reduced to about 51% as shown in Fig. 1, while its natural gas reserve depleted to 41%. In Egypt, Yemen and Morocco, subsidies on fuel are more than thrice larger than government spending on health (World Bank 2012). In 2007 alone, Iran pumped in 56×10^{12} USD into fuel subsidy which happened to be the largest in the world (IEA 2008). Over the years, petroleum products have also been under-priced in the MENA region. The gasoline price gaps between the price of gasoline in Algeria, Qatar, Libya, Kuwait, Iran, Saudi Arabia, Egypt, Bahrain and Yemen and the average world price of gasoline were 77%, 89%, 97%, 87%, 58%, 95%, 62%, 90%, and 81% per liter in 2008 (World Bank 2012). Kahia et al. (2019) attributed these discrepancies, which has cumulated into inefficient resource allocation, to a large amount of subsidies pumped into the energy sector in these countries.

Cheap energy inhibits the use of clean technology, as well as, energy-efficient means of transportation (Janaun and Ellis 2010). This explains why the IEA (2010) posited that the removal of subsidy is germane for climate change mitigation in the MENA region. In 2011, six MENA countries (Qatar, Kuwait, Oman, UAE, Saudi Arabia, and Bahrain) were ranked among the top 20 emitters of CO_2 per capita in the world (CDIAC 2011). Countries in this region depend heavily on oil and gas, and energy-intensive industrial projects that increase the utilization of hydrocarbons, which in turn impacts on the region's carbon footprint (World Bank 2016). The heavy dependence on oil has made MENA countries vulnerable to shocks in global oil price. In 2016, for instance, the global oil price averaged 43 USD, and no single MENA country was able to fiscally break even. However, as the global oil price slightly increased in 2018 (to around 65 USD), countries like Qatar, UAE, Algeria, Kuwait, and Iran were able to break even. The remaining countries in the region require a higher oil price to be able to ease the tension on their current accounts.

As of 1990, the region's share in global trade was 3.5%. It increased to 4.8% in 2017. Merchandise trade in the region was 75.9% in 2017, 48% for developing countries, and 60% for advanced countries. Saudi Arabia and UAE were the leading exporters in the region. In terms of import, UAE was the 18th largest importer globally, in the same year. All these re-emphasizes the region's openness to trade (OECD 2018; International Trade Centre 2017). Service trade, in terms of the global total, increases from 2.59% in 2005 to 3.5% in 2017 (WTO 2018). However, for greater integration into the global value chain, the region has to improve its technology, competitive wage, and improve its production efficiency (IMF 2016). FDI inflows into the region were meagre between 2009 and 2010 mainly due to regional turbulences, the "Arab Spring," and financial crisis. It worsens in 2015 due to the fall in the global oil price which impedes energy investments. As a result, region FDI inflows were only 1.3% in 2017 (Saidi and Prasad 2018). The MENA region is made up of economies that are resource-poor but labor-abundant, and resource-rich and labor-abundance, with each displaying its own idiosyncrasies (Saidi and Prasad 2018). As a result, the urbanization rate in the region has been unprecedented. About one hundred and seventy million (170 million) of the region's estimated population of three hundred million (300 million) resides in the urban areas. According to the UN projections, the region's population is expected to hit four hundred and thirty million by 2020, of which two hundred and eighty million will inhabit the urban areas. This suggests a 65% increase in urban population, with its negative antecedents.

Literature review

The desire to maintain a stable growth/development have made developing countries to derail from the pathways of being a low carbon society (Ali et al. 2019b). The connectivity between energy, environmental quality, and growth is very strong. The efficient management of these variables is germane for human wellbeing, sustainable development and viable policy direction (Temiz Dinç and Akdoğan 2019). For this reason, the literature is not shut of studies that have examined the interconnectivity of the aforementioned variables, and the possible effect of RE on environmental sustainability. Previous studies have proxy environmental quality with CO_2 emissions (see Azizalrahman 2019; Gokmenoglu and Sadeghieh 2019; Bekun et al. 2019b; Saint Akadiri et al. 2019; Li et al. 2019; Sarkodie et al. 2019; Wang et al. 2019; Fan and Zhou 2019; Salahuddin et al. 2019; Saud et al. 2019; Cheng et al. 2019a, b; Chen et al. 2019a; Hanif et al. 2019; Ho and Iyke 2019; Destek and Okumuş 2019; Nkengfack and Fotio 2019; Alola 2019a, b; Salahuddin et al. 2018; Ali et al. 2017a, b; Chen et al. 2019b; Cheng et al. 2018), deforestation (Nathaniel and Bekun 2019; Maji et al. 2017;

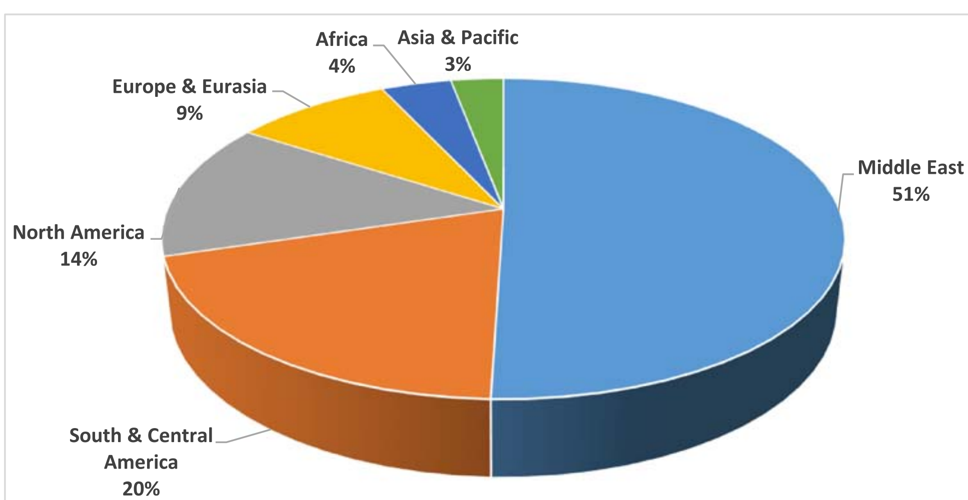

Fig. 1 Shares of oil reserve by regions in 2016

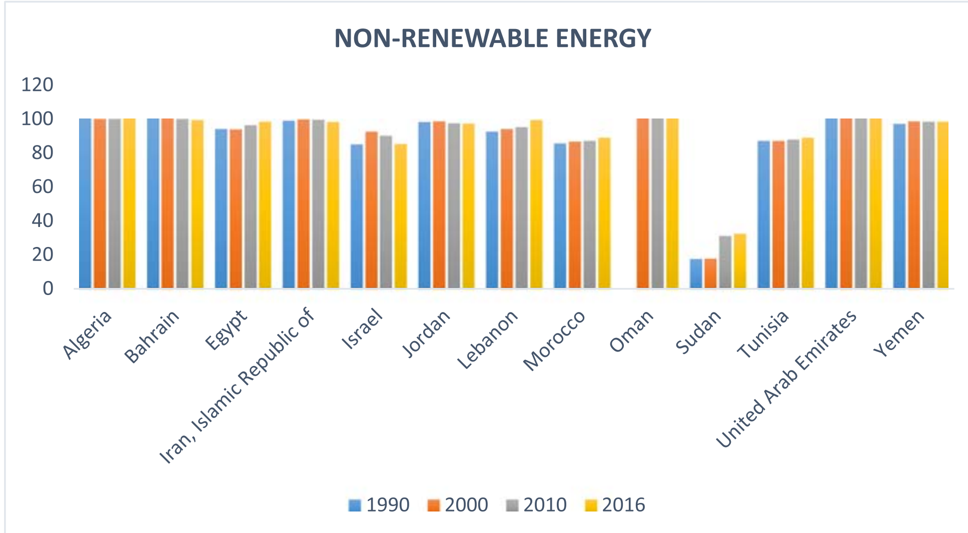

Fig. 2 Non-renewable energy by country from 1990 to 2016

Faria and Almeida 2016), and most recently, EF (Alola et al. 2019b; Hassan et al. 2019).

Of recent, the use of CO_2 emissions to proxy environmental quality has been criticized on the ground that, it is not all-encompassing since the individual effect on the environment is not considered. Therefore, attention has been shifted to EF as a better proxy. There are quite a handful of studies that have explored the effect of RE and non-RE on EF (see, for instance, Destek and Sarkodie 2019; Baloch et al. 2019a; Dogan et al. 2019; Ozcan et al. 2018; Bello et al. 2018; Destek et al. 2018). All these studies discovered that RE consumption reduces EF thereby promoting environmental quality. The above-listed studies further discovered non-RE add to environmental deterioration and therefore called for the promotion and usage of clean energy sources if sustainable development is to be achieved.

Saidi et al. (2018) explored the link between the quality of institutions, RE and economic growth in MENA countries. Findings showed that RE and all institutional measures increase growth, except bureaucracy. A similar result was discovered by Abdouli and Hammami (2017) who explored the link between non-RE and economic growth in 17 MENA countries from 1990 to 2012. Findings suggest that energy consumption is important in raising economic growth.

Charfeddine and Kahia et al. (2019) investigated the effect of RE consumption on CO_2 emissions in the MENA region from 1980 to 2015 using the panel VAR technique. Findings showed that RE has little influence on CO_2 emissions. Also, in the same region, Gorus and Aslan (2019) assessed the determinants of environmental degradation in MENA from 1980 to 2013. It was revealed that non-RE adds to environmental degradation. Jin and Kim (2018) investigated the determinants of CO_2 emissions in 30 countries from 1990 to 2014. The study discovered that unlike RE, nuclear energy adds to CO_2 emissions. Thus, the development of RE is essential to prevent global warming. de Souza et al. (2018) explored the impact of RE, non-RE consumption and income on the environment in five MERCOSUR countries Findings showed the importance of RE in mitigating CO_2 emissions. The study also showed that non-RE is culpable

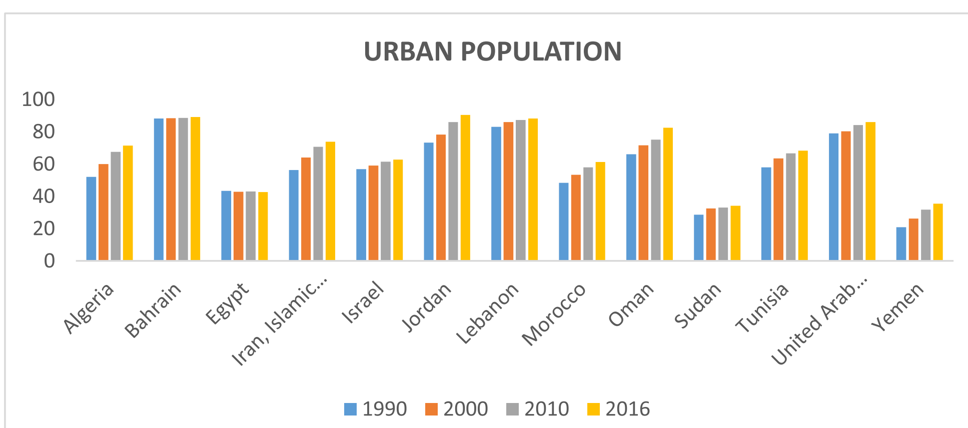

Fig. 3 Urban population (percentage of total population) from 1990 to 2016

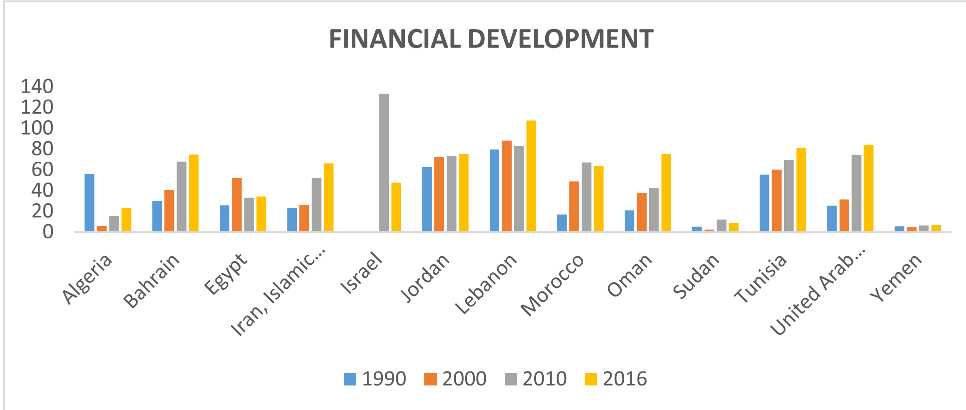

Fig. 4 Financial development by country from 1990 to 2016

for CO_2 emissions. A similar result was discovered by Kahia et al. (2019) for MENA.

Hassine and Harrathi (2017) explored the causal link between RE consumption, trade and economic growth in the GCC countries from 1980 to 2012. They concluded that RE, exports and financial development can actually trigger economic growth. Sinha et al. (2017) investigated the energy-environment nexus in the N-11 countries. Evidence from the GMM technique showed that RE reduces economic growth while the opposite was true for non-RE. They attributed their findings to the cost of implementing RE systems, as the N-11 nations depend on non-RE sources. In line with other similar studies, but for the case of 12 selected Commonwealth States, Rasoulinezhad and Saboori (2018) provided evidence, from both the FMOLS and DOLS results, that RE reduces CO_2 emissions. Financial development also exacted the same impact on CO_2 emissions.

Other studies in support of the inverse relationship between CO_2 emissions and financial development include (Katircioğlu and Taşpinar 2017; Shahbaz et al. 2012; Boutabba 2014; Shahbaz et al. 2013) while (Al-Mulali et al. 2015; Pao et al. 2011; Pao and Tsai 2011; Farhani and Ozturk 2015) discovered a positive relationship between both. Zafar et al. (2019) disaggregated energy into its two major sources and examined how each has driven growth in Asia countries. The Continuously Updated FMOLS technique revealed that RE, R&D, and trade add to growth, but the same was not true for non-RE consumption. Nathaniel and Iheonu (2019) did a similar study like that of Zafar et al. (2019), but for the case of Africa omitting the R&D variable. They discovered that RE has contributed minimally to CO_2 abatement in Africa.

For a single country case, Riti and Shu (2016) explored the interconnectedness between RE and energy efficiency for eco-friendly environment. Findings affirmed that RE enhances environmental quality in Nigeria. Lau et al. (2018) applied the ARDL cointegration approach to probe the factors affecting RE consumption in Malaysia from 1980 to 2015. Findings revealed that in Malaysia, the main drivers of RE consumption are economic growth and FDI. For Turkey, the result turns out the same, as reported in the studies of Temiz Dinç and Akdoğan (2019) were interested in establishing the direction of causality between RE production, growth and total energy consumption for Turkey from 1980 to 2016. A feedback causality was discovered between RE and growth, while a one-way causality flow from non-RE consumption to economic growth. Meanwhile, Khoshnevis Yazdi and Ghorchi Beygi (2018) had earlier investigated the contributions of RE to CO_2 emissions in Africa. Findings suggest that both trade

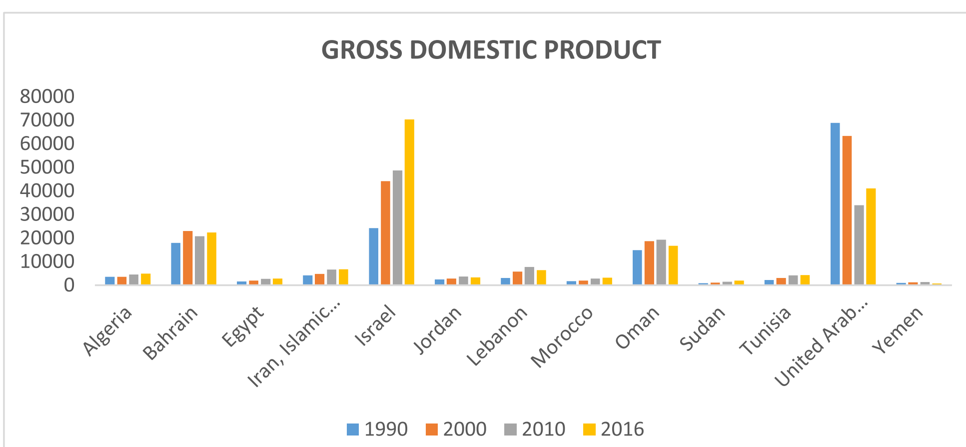

Fig. 5 Gross domestic product by country from 1990 to 2016

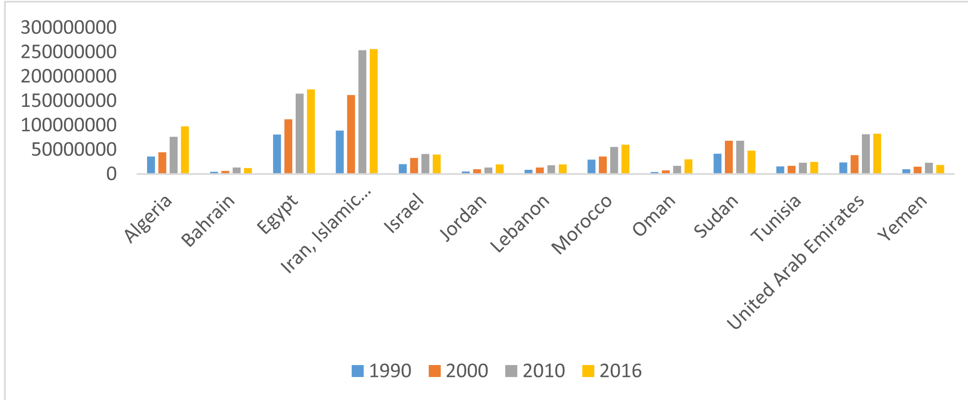

Fig. 6 Ecological footprint (global hectares per capita) by country from 1990 to 2016

and RE promote environmental quality by reducing CO_2 emissions. Ali et al. (2019a) assessed the awareness of variant urban communities of Xiamen to RE and energy conservation. They discovered a significant correlation between household size, income, and energy use. Ali et al. (2018) investigated the valuation and validation of carbon sources for the Bangkok metropolitan area. They discovered that more than 60% of the metropolitan area has been taken up by the urban area.

Methodology and model specification

Method

The study proceeds with the summary statistics of the variables. This will expose the basic characteristics of the data that would be used for the empirical analysis. We use various econometric procedures including the test for CD. This test was examined using three different approaches. The null hypothesis of the CD test is shown in Eq. 1 as;

$$H_0 : \rho_{ij} = corr\left(\mu_{it}, \mu_{jt}\right) = 0 \forall i \neq j \quad (1)$$

The study also examines the unit root properties of the variables in order to avoid spurious regression. We performed both the first-generation unit root tests (which assumed no CD) and the second-generation tests (that accounts for CD). The Levin et al. (2002) test is specified as

$$\Delta y_{it} = \Psi_i + \pi_i y_{i,t-1} + \sum_{j=1}^{p} P_i \Delta y_{it-j} + e_{it} \quad (2)$$

The difference of y_{it} is Δy_{it} for all ith country for the time period $t = 1 \ldots$T. This test assumes heterogeneity such that

$H_0 : \beta = \beta_i = 0.$

The Cross-sectional augmented IPS (CIPS) test initiated by Pesaran (2007) is employed. Following Pesaran (2007), the Cross-sectionally Augmented Dickey-Fuller (CADF) regression is stated as

$$\Delta y_{it} = \varphi_i + \beta_i y_{i,t-1} + \tau_i \bar{y}_{t-1} + d_i \Delta \bar{y}_t + \varepsilon_{it} \quad (3)$$

The introduction of a one-period lag into Eq. 3 results in Eq. 4.

$$\Delta y_{it} = \varphi_i + \beta_i y_{i,t-1} + \tau_i \bar{y}_{t-1} + \sum_{j=0}^{1} \Psi_{ij} \Delta \bar{y}_{t-j} + \Psi_{i1} \Delta y_{i,t-1} + \varepsilon_{it} \quad (4)$$

Table 1 Descriptive statistic and correlation results. The pairwise correlations and the descriptive statistics are reported in the table. We discovered that volatility in EF is high compared to energy use and urbanization. RE is less volatile than GDP and financial development

	EF	URB	GDP	RE	Non-RE	FDV
Panel A						
Mean	19.11	5.321	9.110	2.224	8.111	4.427
Minimum	14.22	4.654	7.623	2.987	5.654	5.410
Maximum	20.11	1.324	15.92	4.223	9.534	6.546
Std. dev.	1.130	0.567	1.987	1.342	1.490	0.312
Panel B						
EF	1					
URB	− 0.511	1				
GDP	− 0.088	0.204	1			
RE	0.160	− 0.301	− 0.277	1		
Non-RE	0.200	0.272	0.444	− 0.361	1	
FDV	− 0.182	0.346	0.415	− 0.011	0.517	1

Source: Authors computation

Table 2 Cross-sectional dependence tests. In panel data estimation, CD have gained much attention in energy-environment literature (Dong et al. 2018). We did three tests to identify the existence of CD. Ignoring CD will produce results that are not reliable (Pesaran 2004). The results in in the table affirms CD

Test	Statistic	Probability
Breusch-Pagan LM	867.35	0.0000
Pesaran scaled LM	67.713	0.0000
Pesaran CD	16.214	0.0000

Source: Author's computation

Table 3 First-generation unit root tests (Levin et al. (2002) and Im et al. (2003))

Variables	LLC				IPS			
	Intercept		Intercept and trend		Intercept		Intercept and trend	
	Levels	First diff.	Levels	First diff.	Levels	First diff.	Levels	First diff.
EF	1.532	− 3.112a	0.223	− 4.432a	2.775	− 10.12a	1.564	− 8.221a
Non-RE	− 0.050	− 6.245a	− 1.290	− 4.866a	3.567	− 9.234a	1.673	− 7.167a
FDV	− 0.667a	− 15.31a	− 8.335a	− 15.44a	2.167	− 10.67a	1.089	− 9.534a
GDP	1.325	− 3.664a	1.546	− 3.332a	3.619	− 8.112a	− 1.382	− 7.125a
RE	− 1.389	− 10.40a	− 0.669	− 10.34a	− 2.298	− 11.45a	− 0.268	− 11.25a
URB	− 0.645	− 5.391a	− 1.367	− 10.55a	− 2.198	− 12.91a	− 1.378	− 10.21a

Source: Author's computation

Note: a shows significance at 1% level

We can obtain the CADF statistics from both Eq. 3 and Eq. 4, but the CIPS statistic would be derived from the simple average of the former. We employed three cointegration techniques proposed by (Pedroni 1999, 2004; Maddala and Wu 1999; Westerlund 2007) to ascertain the cointegrating relationship among the variables. The first two tests assume no CD while the Westerlund (2007) deals with CD using robust critical values through bootstrapping. To explore the impact of RE and non-RE on EF, we employ the AMG algorithm of Bond and Eberhardt (2013). The AMG is capable of handling CD, and it is also very flexible even in the presence of non-stationary variable(s) (Destek and Sarkodie 2019; Baloch et al. 2019b). Since the issue of causality is necessary for drawing relevant policy recommendation(s), and since the AMG technique does not account for causality, the Dumitrescu and Hurlin (2012) test is used for this purpose. This test accommodates CD and heterogeneity which are one of the weaknesses of the VECM causality test.

The model for the test is presented in Eq. 5 as;

$$y_{i,t} = \omega_i + \sum_{i=1}^{p} \lambda_i^{(p)} y_{i,t-n} + \sum_{i=1}^{p} \vartheta_i^{(p)} x_{i,t-n} + \mu_{i,t} \tag{5}$$

$\vartheta_i^{(p)}$ and $\lambda_i^{(p)}$ are the regression coefficient across countries and the autoregressive parameters, respectively. x and y are underlying variables for n cross-section in t time. The two hypotheses associated with the test are;

$H_0 : \beta_1 = 0$

$H_1 : \{^{\beta_i = 0}_{\beta_i \neq 0}$ $\forall_i$ = 1,2...N and $\forall_i$ = N + 1, N + 2…N

Data and model specification

A set of annual data for thirteen (13) MENA countries are used in this study. The data extends from 1990 to 2016. The choice for the time period is consistent with the availability of data. All data were obtained from the World Development Indicator (WDI) (2019). However, data on EF was derived from the Global Footprint Network (2019). The econometric model for the study takes the form;

$$EF_{it} = \vartheta_0 + \vartheta_1 RE_{it} + \vartheta_2 non{-}RE_{it} + \vartheta_3 FDV_{it} + \vartheta_3 URB_{it} + \vartheta_3 GDP_{it} + \varepsilon_{it} \tag{6}$$

Table 4 Second-generation unit root test (Cross-sectional augmented IPS (CIPS)). The first-generation tests (LLC and IPS, except PP-Fisher) maintained that all the variables, apart from financial development which is I(0), are I(1). The second-generation test (CIPS) confirmed I(1) for all variables

Variables	PP-Fisher				CIPS			
	Intercept		Intercept and trend		Intercept		Intercept and trend	
	Levels	First diff.	Levels	First diff.	Levels	First diff.	Levels	First diff.
EF	32.55	312.9a	32.12	245.4a	− 1.241	− 4.657a	− 2.543	− 4.231a
Non-RE	32.34	322.5a	42.19	513.2a	− 1.718	− 4.674a	− 2.758	− 5.454a
FDV	32.22	351.2a	41.43	424.7a	− 1.324	− 5.657a	− 1.458	− 4.657a
GDP	28.32	145.4a	43.22	325.2a	− 2.659	− 4.768a	− 2.331	− 3.645a
RE	36.32	334.7a	58.67	455.1a	− 0.123	− 6.657a	− 2.153	− 4.675a
URB	47.67	221.5a	33.68	377.5a	− 2.764	− 6.546a	− 2.453	− 5.465a

Source: Author's computation

Note: a and b imply significance at 1%, and 5%, respectively

Table 5 Panel Cointegration Test (Pedroni). From the 11 statistics values shown in the table, six are significant. Therefore, cointegration exists

Statistics	Within-dimension (Panel)		Between-dimension (group)
	Statistics	Weighted statistics	Statistics
V-Statistic	− 1.4563 (0.971)	− 1.2013 (0.550)	
Rho-Statistic	3.5647 (0.234)	1.0000 (0.887)	4.3156 (0.670)
PP-Statistic	− 5.1162 (0.000)	− 3.3400 (0.003)	− 4.4838 (0.002)
ADF-Statistic	− 4.5616 (0.002)	− 4.7654 (0.002)	− 6.1562 (0.000)

Source: Author's computation

Note: *p* values in parentheses

Here, *EF* is ecological footprint (global hectares per capita), *RE* is renewable energy (% of total energy consumption), non-RE is non-renewable energy (kg of oil equivalent), *URB* is urbanization (percentage of total population), *GDP* is GDP per capita (constant 2010 US$), *FDV* is financial development (% of GDP). The principal component analysis was used to create an index for *FDV*. The variables that were used to create this index include: domestic credit to the private sector, domestic credit to the private sector by banks, and foreign direct investments.

Presentation and discussion of results

This section proceeds with the features of some selected variables, in the selected MENA countries. Source: Author's Computation from WDI (2019).

From Fig. 2, all the countries in the region consume more of non-RE than Sudan. However, the consumption of non-RE appears to be increasing gradually in Sudan, but relatively constant in the remaining countries. The UAE, Algeria, Bahrain, Iran, Jordan, and Yemen are among the top consumers of non-RE. Source: Author's Computation from WDI (2019).

From Fig. 3, the top three urbanized countries are Bahrain, Lebanon, and the UAE. Urbanization is also increasing rapidly in Tunisia, Iran, Algeria, Jordan, and Oman. However, Yemen and Sudan are still less urbanized. Source: Author's Computation from WDI (2019).

Figure 4 shows that few of the countries in the region are financially developed. These countries include: Lebanon, Jordan, Israel, Bahrain, Tunisia, and the UAE. Yemen and Sudan are among the least financially developed countries in the region. Source: Author's Computation from WDI (2019).

From Fig. 5, the UAE, Israel, and Bahrain have the highest GDP in the region, while Sudan, Yemen, Egypt, and Morocco are the countries with low GDP. GDP has grown dramatically over the last few decades in Israel.

The EF accounts for how much water and land area is needed to produce all the goods consumed. Simply put, it denotes the bioproductive area required to sustain a population. Source: Author's Computation from WDI (2019).

In this study, EF was used to proxy environmental degradation. As shown in Fig. 6, environmental degradation appears to be on the increase in almost all the countries over the last few decades. The situation is more devastating in Algeria, Egypt, Iran, and the UAE (Tables 1, 2, 3, and 4).

The correlation result reveals that non-RE and RE are positively associated with EF, while urbanization, GDP and financial development are negatively correlated with EF. GDP is positively correlated with urbanization. Non-RE and financial development are inversely associated with RE and positively associated with GDP. On the other hand, RE is negatively linked with both urbanization and GDP.

Table 6 Panel cointegration test (Johansen Fisher). The results in this table re-affirms our findings in Table 5. The maximum eigenvalue and the trace test suggest at most five and four cointegrating equations at 1% level, respectively

Hypothesized no. of CE(s)	Trace test	Max-Eigen test
None	536.2 (0.000)	354.2 (0.000)
At most 1	332.1 (0.000)	155.4 (0.000)
At most 2	145.2 (0.000)	97.51 (0.000)
At most 3	123.4 (0.000)	79.22 (0.000)
At most 4	53.43 (0.001)	65.23 (0.000)
At most 5	53.45 (0.345)	50.45 (0.000)

Source: Author's computation

Note: *p* values in parentheses

Table 7 Panel cointegration test (Westerlund)

Statistic	Value	Z-value	Robust *P* value
Gt	− 1.843	5.542	0.610
Ga	− 3.251	7.234	0.000
Pt	− 15.11	− 3.141	0.000
Pa	− 4.352	6.829	0.040

Source: Author's computation

Note: Ga and Gt are the group mean tests. Pt and Pa are the panel mean tests

Table 8 Augmented mean group estimate result. The panel result suggests that financial development, economic growth, and urbanization add (insignificantly) to environmental degradation. The growth in the MENA region is not environmentally friendly. Growth contributes about 0.01%, while financial development and urbanization contribute 0.03% and 0.16%, respectively. These findings are not surprising, but rather intuitive as growth, most often than not, comes with financial development. This is in line with the findings of Charfeddine and Kahia et al. (2019) who discovered that financial development exacts no meaningful influence on the environment in MENA. Unlike financial development, urbanization and growth, non-RE increases environmental degradation by about 46%. This finding complements (Gorus and Aslan 2019; Kahia et al. 2019) who also discovered the same for MENA. The predominant energy source is MENA is largely non-renewable. As initially stated, non-RE consumption, especially fossil fuels, are high in emissions (Destek and Sarkodie 2019; Hanif et al. 2019; Wang and Dong 2019; Feron et al. 2019). One way to achieve environmental sustainability is for countries in this region to invest and promote the use of RE, while concomitantly minimizing the consumption of non-RE. The need for safe and clean energy is imperative in MENA countries. Findings further revealed that RE insignificantly promotes environmental quality, just like the findings of Charfeddine and Kahia et al. (2019) for the same region. Despite having the greatest potential for RE in the world (Abdouli and Hammami 2017; Waterbury 2017), this is evidence that in terms of investment and consumption of RE sources, the region still has a lot to do. Dependent Variable: EF

Variables	Full	Algeria	Bahrain	Egypt	Iran	Israel	Jordan	Lebanon	Morocco
FDV	0.032	0.030	0.056	− 0.039	**0.326b**	− 0.312	0.104	− 0.116	− 0.059
	(0.401)	(0.347)	(0.102)	(0.340)	**(0.021)**	(0.152)	(0.183)	(0.279)	(0.534)
Non-RE	**0.176a**	**0.325a**	− 0.213	0.101	**0.231b**	0.410	0.012	− 0.231	0.132
	(0.001)	**(0.008)**	(0.534)	(0.435)	**(0.041)**	(0.061)	(0.222)	(0.176)	(0.721)
GDP	0.026	− 0.142	0.216	0.034	**0.012b**	0.021	**0.239b**	**0.146b**	0.278
	(0.867)	(0.231)	(0.134)	(0.342)	**(0.028)**	(0.314)	**(0.045)**	**(0.041)**	(0.091)
RE	− 0.120	− 0.051	− 0.453	− 0.016	− 0.045	**− 0.292a**	**− 0.229a**	− 0.077	− 0.231
	(0.081)	(0.434)	(0.324)	(0.867)	(0.076)	**(0.009)**	**(0.000)**	(0.657)	(0.298)
URB	0.162	0.324	0.103	**1.005a**	− 0.033	**0.342a**	**− 0.145a**	0.509	0.499
	(0.762)	(0.543)	(0.106)	**(0.001)**	(0.325)	**(0.002)**	**(0.009)**	(0.325)	(0.435)
CONS.	**17.42a**	**− 11.13a**	**35.64a**	**9.890a**	19.51	− 0.811	**35.48a**	**13.20a**	**0.255a**
	(0.000)	**(0.000)**	**(0.007)**	**(0.000)**	(0.726)	(0.750)	**(0.000)**	**(0.002)**	**(0.000)**
Variables	Oman	Sudan	Tunisia	UAE	Yemen				
FDV	**0.289a**	**0.396a**	0.067	**0.228b**	− 0.460				
	(0.004)	**(0.000)**	(0.241)	**(0.050)**	(0.173)				
Non-RE	**0.202a**	0.213	**0.123b**	**0.321a**	**0.231a**				
	(0.001)	(0.202)	**(0.041)**	**(0.000)**	**(0.000)**				
GDP	**0.211a**	0.043	0.124	**0.205a**	0.023				
	(0.006)	(0.564)	(0.324)	**(0.008)**	(0.088)				
RE	0.546	− 1.003	− 0.132	− 1.645	− 0.453				
	(0.564)	(0.453)	(0.091)	(0.342)	(0.453)				
URB	**2.001a**	**1.010a**	**0.218a**	**0.005a**	**0.549a**				
	(0.000)	**(0.000)**	**(0.060)**	**(0.000)**	**(0.004)**				
CONS.	− 0.324	− 2.342	**1.010a**	− 1.011	**1.410a**				
	(0.221)	(0.456)	**(0.000)**	(0.221)	**(0.008)**				

Source: Authors computation

Data in bold represent variables that are significant

Note: a and b imply significance at 1 and 5%, respectively. p values in parentheses

Table 9 Dumitrescu and Hurlin (2012) test. From this table, non-RE, economic growth, and urbanization drive environmental degradation. There is no form of causality from either RE or financial development to environmental degradation in MENA

Null Hypothesis	W-bar	Z-bar	Probability
Non-RE ⇏ EF	4.543	4.453	0.000
FDV ⇏ EF	3.342	0.637	0.733
RE ⇏ EF	2.261	0.362	0.545
GDP ⇏ EF	3.367	2.333	0.004
URB ⇏ EF	5.453	6.342	0.000

Source: Author's computation

Note: ”⇏“stands for no causality. Lag order selected: 2

Table 10 Results of Robustness analysis. The mean group (MG) estimator and the common correlated effects mean group (CCEMG) estimator were used to check for robustness in our findings. Both tests confirmed the robustness of the results in Table 8

Variables	MG	CCEMG	AMG
FDV	2.345 (0.654)	4.453 (0.345)	0.032 (0.401)
Non-RE	0.2845(0.000)	0.124 (0.042)	0.176 (0.001)
GDP	0.4343 (0.785)	0.564 (0.997)	0.026 (0.867)
RE	− 0.345 (0.091)	− 0.004 (0.069)	− 0.120 (0.081)
URB	0.564 (0.934)	0.213 (0.231)	0.162 (0.762)

Source: Author's computation. Note: p values in parentheses

The Westerlund (2007) test is robust amidst CD. Therefore, from the results of the Westerlund (2007) test, there is a long-run relationship among the variables.

For a country-specific case, it was revealed that RE does not contribute meaningfully to environmental quality in Sudan, Tunisia, UAE, Oman, Morocco, Lebanon, Iran, Egypt, Bahrain, Algeria, and Yemen. This accounts for about 84% of the countries sampled for the study. The energy mix of the aforementioned countries is dominated by fossil fuels. This finding is in tandem with that of Nathaniel and Iheonu (2019) who used the same estimation technique (AMG) and discovered that RE has no significant impact on environmental quality in Morocco, Tunisia, Egypt, Sudan, and Algeria.

Though Morocco has invested heavily in RE by housing one of the world's largest solar power plant in Noor-Ouarzazate, this investment is yet to yield any meaningful impact on the environment. In Algeria, fossil fuels contributed about 93% of the country's total energy mix in 2010. This explains why RE still does not exact a meaning impact on the environment in Algeria. As a result, Algeria has set a target to generate 22,000 MW of power from RE sources between 2011 and 2030. The same for Bahrain that hopes to generate 5% of electricity from RE sources in 2030. Iran currently produces only 0.2% of its energy from RE sources compared to Israel and Jordan with 2.6% and 11%, respectively. We also discovered that energy consumption (non-RE) promotes environmental degradation in Oman, Yemen, Algeria, Iran, Tunisia and, the UAE, while economic growth is not environmentally friendly in Iran, Jordan, Lebanon, Oman, and the UAE. Urbanization also appeared to be a serious problem in the MENA region. It adds significantly to environmental degradation in about 56% of the countries sampled, with a more devastating impact in Oman.

One factor that has influenced urbanization in Oman is civilization dated back to about 5000 years ago by the autochthone population (Benkari 2017). The centralization of facilities, decision making, and services in the capitals have encouraged de-population in villages and small towns. Urbanization in Oman increased from 30% to 50% between 1970 and 1980. As of 2017, it was 80%. It is expected to hit 85% by 2040 (Benkari 2017). Urbanization in MENA should be treated with utmost urgency as about 280 million of the region's population is expected to be urban in 2020 according to the UN projection.

Conclusion and policy direction

The study examined the role of non-RE and RE on the environment in MENA while accounting for urbanization and financial development from 1990 to 2016. The presence of CD informed the use of estimation techniques (like the AMG, and the Westerlund cointegration test) that are robust amidst CD. Findings revealed that RE does not contribute meaningfully to environmental quality in about 84% of the countries sampled. On the other hand, non-RE consumption contributes about 17% of environmental deterioration in the region. Urbanization, economic growth, and financial development contribute to environmental degradation in the region, though insignificantly, while non-RE, economic growth and urbanization drive EF. One way to abate this damage is for countries in this region to embrace and promote the consumption of clean energy sources like tide, wind, solar, and hydropower (Tables 6, 7, 8, 9, and 10).

Policymakers can also initiate and support policies that enhance investment in new technologies, especially technologies that are environmentally friendly. The region further needs substantial changes in order to achieve an eco-friendly environment. There is a need for each of the countries to set mandatory RE targets that are feasible. Though these targets have been set by some MENA countries, only a few are on track to achieving it. The creation of a RE agency that will promote RE development and improve the transparency of the system will also be of help (Charfeddine and Kahia 2019). The discrepancies between the gasoline prices in MENA and the average world price of gasoline are enormous. This could be attributed to the inefficient resource allocation, and a large amount of subsidies pumped into the energy sector in MENA countries. Since cheap energy discourages the use of clean technology, the gradual removal of subsidies will ensure the growth of renewables. Urbanization arises mainly from discrepancies in development factors like access to amenities, household income, and provision of infrastructures. Therefore, the provision of the needed amenities and infrastructures in the rural areas will go a long way in curbing the upward surge in urbanization and the anomaly associated with it.

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Sudan, Tunisia, UAE, Oman, Morocco, Lebanon, Iran, Egypt, Bahrain, Algeria, Yemen, Jordan, and Israel.