Energy Consumption and Ecological Footprint in the World's Major Suppliers of Crude Oil: Does Difference in Oil Production Status Between Subgroups Count?

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1 **Energy consumption and ecological footprint in the world's major suppliers of crude**
2 **oil: Does difference in oil production status between sub-groups count?**

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10 **Abstract**

11 The need to maintain quality environment despite the increasing human activity and
12 pressure on energy resources remains a topical issue in the field of Environmental
13 Economics. However, we observe that the impact of energy consumption on ecological
14 footprint in the Organization of Petroleum Exporting Countries (OPEC) has not
15 received keen attention in the literature. This study thus delves into the nexus for the
16 country group. For a more robust policy bearing, we partition the countries into
17 Middle-East and non-Middle-East members because of their huge energy supply and
18 consumption differences. Summarizing the results, energy consumption increases
19 environmental degradation across all samples. However, despite the Middle-East
20 countries being the highest per capita energy consumers, their energy consumption
21 contributes less to environmental degradation compared to the non-Middle-East

22 countries. For completeness, we report the long-run country-specific estimates and find
23 that only in Congo is environmental quality enhanced by energy consumption.

24

25 **Keywords:** Energy consumption; Ecological footprint; OPEC; AMG

26

1. Introduction

Without any doubt, a significant part of our world today is still shaped by energy, particularly non-renewable energy. Regardless of the level of development of countries, energy consumption remains a crucial indicator of economic activity in both developed and developing countries, thus driving a significant part of their economic growth processes. Unfortunately, consumption of energy cannot be disconnected from environmental concerns, as it does not guarantee a fair environmental balance. Tran et al. (2019) note that the economy concurrently relies on natural resources at higher development levels, and then releases pollution that directly impairs the natural ecosystem or environment. In another regards, Uddin et al. (2017) disclose that due to the rapid industrial growth over the past two centuries, the global economy has succumbed to significant and unavoidable increase in the demand for energy that led to the trade-off between economic development and environmental effect to be really challenging to deal with as the demand has rather been largely met by non-renewable energy production that causes greenhouse gas emissions. Following the pursuit of high economic growth by most countries therefore, their use of energy for such purpose results in increasing emission of wastes into the environment (Lee and Chang, 2008).

Thus, in the face of rising energy consumption need to aid economic growth, the major challenge of humanity seems to be related to the preservation of the global environment (Uddin et al., 2017). In recent years, the environment has found its way into the forefront of modern contemporary concerns and has thus come under serious policy

designs. This is because of the greenhouse gases accumulated in the atmosphere which then advance climate change. Based on this, there is increasing national and international policies, including the noble Sustainable Development Goals (SDGs) and Kyoto Protocols, on the ways to mitigate environmental degradation and reduce pressure on environmental resources. In fact, among other noteworthy goals, the reduction of pressure on ecological resources and maintenance of conducive and safe environment is at the heart of the SDGs scheme (Nunan, 2015).

In view of the need to address environmental concerns, the literature is alarmingly witnessing a plethora of studies on energy consumption-environmental nexus, with mixed findings following. However, it remains yet a weakness of most of these past studies to use carbon emissions as an indicator of environmental degradation (Wackernagel and Rees, 1996), as it only accounts for a minute part of the overall environmental impairment induced by higher energy consumption (Al-Mulali et al., 2015a). Thus, recent years have witnessed the expansion of environmental degradation base for empirical analyses by using ecological footprint as a more representative indicator. Apart from acting as an all-inclusive indicator of anthropogenic pressure on the environment (see Kassouri and Altintas, 2020; Vackar, 2012; York et al., 2009), ecological footprint provides insights into the actual ecological biocapacity budget, as well as the degree of the impact of human activities (production, consumption and investment) on environment's regenerative strength (see Vanham et al., 2019; Galli et al., 2020).

69 The main goal of this study therefore is to examine the energy consumption-ecological
70 footprint nexus in the Organization of Petroleum Exporting Countries (OPEC). We
71 observe that despite the assessment of this nexus for a number of economic groups,
72 nothing is known about the OPEC which constitutes the world's largest producers of
73 crude oil. Apart from being significant producers of the said commodity, they also
74 significantly consume it and depend on it for the functioning of their economies.
75 Meanwhile, it is noteworthy that crude oil is the world's most traded and most
76 consumed commodity. It also falls in and constitutes the largest share of the non-
77 renewable energy group which is known as a great source of environmental
78 degradation. In addition to the full sample analysis, we further divide the countries into
79 Middle-East and non-Middle-East groups so that a distinct estimation is done for both.
80 This is because the Middle-East countries account for about one-third of global crude oil
81 exports and over one-sixth of the total OPEC production (see Table 1 for 2018
82 estimates). However, they appear not to be the largest consumers of energy, probably
83 due to their developing statuses and small population sizes. This further informs their
84 huge per capita primary energy consumption compared to other OPEC member
85 countries. It is thus worthwhile to examine if the marginal contribution of their huge
86 per capita energy consumption to environmental degradation is significantly different
87 from other members of the OPEC. In addition to this, we examine if the long-run
88 impacts vary across the member countries since energy consumption and efficiency
89 levels differ.

90 **Table 1: Crude oil exports and primary energy consumption in the Middle-East**

Considered Middle-Eastern countries	% of oil exports in total world exports in 2018	% of oil exports in OPEC total exports in 2018	% of primary energy consumption in world total	Per capita primary energy consumption
Iran	4.04	7.50	2.06	145.86
Iraq	8.43	15.65	0.38	57.2
Saudi Arabia	16.09	29.88	1.87	323.4
United Arab Emirates	5.01	9.31	0.81	492.3
Total	33.57	62.34	5.12	

91 Source: Exports values are computed by the authors, underlying data from the 2019 OPEC Annual
 92 Statistical Bulletin, while energy consumption are from BP Statistical Review.

93 If all the Middle-Eastern countries are to be considered, they accounted for about 41.29% of globally
 94 exported crude oil, and about 76.67% of OPEC total crude oil exports.

95

96 The structuring of the remainder of this paper is as follows: Section 2 reviews relevant
 97 studies, Section 3 describes the data and develops the methodology, Section 4 presents
 98 and discusses the estimated results, Section 5 gives the conclusion, and Section 6 draws
 99 the policy implications

100 **2. Review of the literature**

101 As earlier noted in the background to the study, empirical studies on the energy
 102 consumption and environmental degradation are increasingly becoming prominent in

the general literature especially in recent times due to the ongoing global drive in ensuring an environment devoid of harmful substances, and the need to mitigate the likely occurrence of climate change. These studies also vary in terms of proxies for environmental degradation, methodologies, countries or economic regions and scope, thus resulting into lack of consensus on the established findings.

The oldest consideration in the literature connects energy consumption with carbon emissions, where the latter acts as the proxy for environmental degradation. Al-Mulali (2014) use the Vector Error Correction Model (VECM) and Granger-causality test for the examination of the relationship between nuclear energy consumption and carbon emissions for 30 countries known for high consumption of the energy. The study finds evidence in support of a favourable effect of nuclear energy consumption on the environment as a negative relationship exists between the variables. Examining five countries belonging to the Association of Southeast Asian Nations (ASEAN), Chandran and Tang (2013) discover a bidirectional relationship between energy consumption of the transportation sector and carbon emissions in Malaysia and Thailand. Using a different methodology-simultaneous equation model, a unidirectional causal effect running from energy consumption to carbon emissions is confirmed for 14 Middle East and North Africa (MENA) countries by Omri (2013).

The recent study of Zoundi (2017) considers the renewable energy consumption-carbon emissions nexus for 25 African countries and establishes an expected decreasing impact in the release of carbon emissions in the region. The study further shows that renewable

energy can act as substitute for fossil fuels which have been the major sources of production inputs and domestic use for a long time. Dong et al. (2017a) supports these findings by revealing that the consumption of both renewable and natural gas mitigates carbon emissions in BRICS countries. For different countries, other studies that confirm the significant effect of energy consumption on carbon emissions, either positively or otherwise include Dong et al. (2018a), Dong et al. (2017b), Kasman and Duman (2015), etc.

The most recent line of studies on the energy consumption-environmental degradation involves using ecological footprint instead of carbon emissions. In their attempt to the main drivers of environmental degradation in sub-Saharan African countries, Wang and Dong (2019) reveal that both non-renewable and renewable energy consumption are among the determinants. In particular, non-renewable energy consumption exerts positive influence on ecological footprint, while the impact is negative for renewable energy consumption. Similarly, Destek et al. (2018) and Dogan et al. (2019) find that environmental degradation worsens with rising energy consumption in both EU and MINT countries respectively. Meanwhile, a few studies favour country-specific analysis. For instance, Imamoglu (2018) confirms energy consumption as one of the driving factors of ecological footprint in Turkey. The findings of Khan et al. (2020) appear similar to that of Imamoglu (2018), although it additionally puts asymmetries into consideration. Their nonlinear Autoregressive Distributed Lag (NARDL) model suggests asymmetric relationship between energy consumption and ecological footprint

in Pakistan in the long-run. However, Ozcan et al. (2019) reveal contrary evidence with respect to non-renewable consumption. Their findings show that the patterns of energy consumption enhance the environmental performance of the OECD countries, indicating that the environmental policies of the countries are beginning to be aligned with through their efficient energy consumption patterns.

Thus, it remains true based on the above reviews that there is scarcity of empirical information on the impact of energy consumption on the ecological footprint in the OPEC countries. As noted earlier, these countries play significant role in the production (and consequently the consumption due to their energy-dependent status) of crude oil which doubles as the most consumed commodity globally and the highest component of the non-renewable energy group. We fill this gap in this study.

3. Data metrics and methodology

3.1 Data and preliminary analysis

Out of the 13 member countries of the Organization of Petroleum Exporting Countries (OPEC), our panel study includes 10 countries for which data are taken over the period of 1990 to 2014. As much as we are willing to consider all the OPEC member countries and obtain data for a larger scope, we are limited by data availability. The full sample is further divided into the Middle-East and non-Middle-East countries comprising of 4 (Iran, Iraq, Saudi Arabia and United Arab Emirates) and 6 (Algeria, Angola, Democratic

164 Republic of Congo, Gabon, Nigeria and Venezuela) cross-sections respectively.¹ Thus,
165 we analyze the effect of energy consumption on ecological footprint for the full sample
166 and the two sub-samples. The main data are per capita ecological footprint (global
167 hectares), per capita energy consumption (kg of oil equivalent), while the control
168 variables against omission bias in the estimates are per capita GDP and urban
169 population.

170 Our choice of ecological footprint as a more robust measure of environmental
171 sustainability in empirical analysis than carbon-emissions follow recent and prominent
172 studies like Ulucak and Apergis (2018), Kassouri and Altintas (2020), Wang and Dong
173 (2019), etc. Its preference over the commonly used carbon emissions as a measure of
174 environmental quality is because it encompasses more components including carbon
175 footprint, forest footprint, grazing land footprint, water footprint, cropland footprint
176 and Built-up land footprint in assessment of human impacts on nature. Additionally, it
177 helps to reveal the exact budget –biocapacity of the ecosystem, and the degree of human
178 influence on the regenerative strength of the environment (see Galli et al., 2020). Next is
179 energy consumption which is measured as the aggregate non-renewable energy
180 demand (particularly fossil fuels, including oil, coal and natural gas). Expectedly,
181 higher energy consumption should impair on environmental quality due to the

¹ Our consideration for the division of the OPEC countries into Middle-East and non-Middle-East is motivated by the fact that nearly one-third of the total world oil exports is accounted for by the Middle-East-based OPEC countries (see Table 1). In addition, we foreshadow our descriptive statistics and find that despite being smaller in number than the non-Middle-East countries, the Middle-East countries have higher average per capita ecological footprint and per capita energy consumption. So, we intend to discover whether the energy consumption of the region with the highest crude oil exports contribute more or less to environmental degradation, compared to their oil exporting counterparts.

associated emission rate. Hence, a positive relationship is hypothesized between energy consumption and ecological footprint. Apart from the energy consumption, we consider other two macroeconomic indicators as potential regressors that have been adjudged to have significant influence on environmental quality. They are economic growth and degree of urbanization (see Kassouri and Altintas, 2020; Ozcan et al., 2019, Wang and Dong, 2019). We are limited to these two due to insufficient data for other series empirically identified to impact on ecological footprint. The value of Gross domestic products (GDP) is conventionally used to measure the level of economic growth of a country, while urban population is the most suitable for the degree of urbanization. Expectedly, these they should also have positive effect on ecological footprint because as an economy grows and its urban population rises, there seems to be more pressure on environmental resources that eventually causes environmental degradation. The exemption to this assertion is if the resources are efficiently utilized, and urbanization plan ensures easy access to efficient and cleaner technology.

The data for all the regressors are sourced from the World Development Indicators (WDI)², while per capita ecological footprint is obtained from Global Footprint Network³.

The preliminary analyses of the data are provided in Tables 2-3, and Figures 1-2 for the full sample and the sub-samples (which are the Middle-Eastern and non-Middle-Eastern countries). Interestingly, the Middle-Eastern countries report higher average

² See <https://www.datacatalog.worldbank.org/>

³ See <https://www.footprintnetwork.org/#/>

values for all the variables than their non-Middle-Eastern countries counterparts (see Table 2). In other words, they seem to cause higher environmental degradation, consume more non-renewable energy and have higher economic growth on average, and higher degree of urbanization. For the correlation analysis reported in Table 3, the coefficients are significant in all cases, except for ecological footprint and urbanization under the non-Middle-Eastern group. While the correlation is positive for ecological footprint and GDP in all cases, negative results are obtained for the correlation between ecological footprint and urbanization. For most of the countries, the graphical illustration shows an upward co-movement between ecological footprint and energy consumption (see Figures 1 and 2).

Table 2: Descriptive statistics

	Mean	Maximum	Minimum	Std. Dev.	Jarque-Bera	Observation
Full sample						
EF	2.9122	13.8500	0.0126	3.3415	342.7760	250
ENG	2509.1328	12172.4	295.2240	2888.5829	235.7397	250
GDP	11422.8816	68780.6	276.0560	15740.5459	450.7591	250
URB	20526932	83000000	656504	16343684	97.8211	250
Middle-East						
EF	5.0931	13.8500	1.0700	4.3086	19.0610	100

ENG	4629.5459	12172.4	891.9120	3541.4404	11.9472	100
GDP	20587.2494	68780.6	1432.17	21185.1429	20.6902	100
URB	20829000	56000000	1400000	15317642	10.1766	100
Non-Middle-East						
EF	1.4582	3.8500	0.0126	1.0023	5.7494	150
ENG	1095.5242	3129.0800	295.2240	762.5331	21.2688	150
GDP	5313.3031	14920.4	276.0560	4680.1077	18.9760	150
URB	20325554	83000000	656504	17040969	100.7204	150

214

215 **Table 3: Correlation results**

	EF	ENG	GDP	URB
Full sample				
EF	1			
ENG	0.8282*** (0.0000)	1		
GDP	0.8972*** (0.0000)	0.9252*** (0.0000)	1	
URB	-0.1806*** (0.0042)	-0.2694*** (0.0000)	-0.4077*** (0.0000)	1
Middle-East				
EF	1			

ENG	0.9521*** (0.0000)	1		
GDP	0.9208*** (0.0000)	0.9585*** (0.0000)	1	
URB	-0.7091*** (0.0000)	-0.6702*** (0.0000)	-0.7479*** (0.0000)	1
Non-Middle-East				
EF	1			
ENG	0.7984*** (0.0000)	1		
GDP	0.8907*** (0.0000)	0.9030*** (0.0000)	1	
URB	-0.1338 (0.1027)	-0.2729*** (0.0007)	-0.3922*** (0.0000)	1

216 Values in parentheses are probabilities. *** indicates significance at 1% critical level.

217

218 **Figure 1: Trends in ecological footprint and energy consumption in Middle-Eastern**

219 **countries**

220

221

222 **Figure 2: Trends in ecological footprint and energy consumption in non-Middle-**
 223 **Eastern countries**

224 3.2 Methodology

Prior to recent times, the empirical techniques applied in panel data analysis could not account for some inherent characteristics of panel series, such as cross-sectional dependence and heterogeneity. In order to ensure better estimates, our analysis in this study relies on the second generation estimators that are able to handle these statistical features. On this note, our methodological framework begins with the specification of the test for cross-sectional dependence in the panel series. If we are able to establish that dependence is inherent among the cross-sections, we proceed to assessing the stationarity properties of the panel series using panel unit root tests that can accommodate cross-sectional dependence. From the unit root test, we will be able to establish integration order of the panel series. If all the series are non-stationarity results, i.e. $I(1)$, then we check for the possibility of long-run relationship among the variables using the technique of Westerlund (2007). Lastly, long-run estimation among is carried out using standard econometric estimators that conveniently account for the statistical and econometric issues raised above. For clarity, we employ the Common Correlated Effects Mean Group (CCEMG) due to Pesaran (2006) and the Augmented Mean Group (AMG) proposed by Eberhardt and Bond (2009). Although the results of both estimators are presented for estimation, we rely essentially on the latter for discussion because of its superiority over the former.

Therefore, for our empirical analysis, the econometric relationship between ecological footprint and the regressors is specified thus:

$$EF_{it} = \omega_0 + \omega_1 ENG_{it} + \omega_2 GDP_{it} + \omega_3 URB_{it} + \varepsilon_{it}; \quad i = 1, 2, \dots, N; \quad t = 1, 2, \dots, T \quad (1)$$

where EF , ENG , GDP and URB represent ecological footprint per capita, non-renewable energy consumption per capita, gross domestic products per capita and urban population respectively. ε is the error term. All the variables are logarithmically transformed.

3.2.1 Cross-sectional dependence tests

Cross-sections among panel members can be caused by a host of factors including spatial effects and socioeconomic interactions, policy interplay. Not accounting for them could cause estimation bias (see Dong et al. 2018d). In light of this, we test for cross-sectional dependence using approaches of Breush and Pagan (1980) and Pesaran (2004).

We start with the specification of the Langrange Multiplier (LM) statistic put forward by Breush and Pagan (1980) thus:

$$LM_{BP} = \sum_{k=1}^{N-1} \sum_{l=k+1}^N \hat{\beta}_{il}^2 \quad (2)$$

where $\hat{\beta}_{il}^2$ denotes the estimated sample of the coefficient of the pair-wise correlation of the residuals obtained from the Ordinary Least Squares (OLS) estimations. LM_{BP} is assumed to be asymptotically distributed with the chi-square degrees of freedom of $\frac{1}{2}(N^2 - N)$. Meanwhile, the validity of the LM test for the null hypothesis of absence of cross-sectional dependence relates to panel series in which $T \rightarrow \infty$ and N is fixed. If on the other hand $N \rightarrow \infty$ and T is fixed, the rescaled version of the LM_{BP} test is developed by Pesaran (2004) thus:

$$LM_{PS} = \sum_{k=1}^{N-1} \sum_{l=k+1}^N (\hat{\beta}_{il}^2 - 1) \sim N(0,1) \quad (3)$$

It is further noted for large N and small T panel series that the LM_{PS} test in equation (3) can show significant size distortions. This eventually results in the development of an improved test that is capable of handling large T and large N (i.e. $N \rightarrow \infty$ and $T \rightarrow \infty$) by Pesaran (2004):

$$CD_{PES} = \sqrt{\left(\frac{2T}{N^2 - N}\right)} \left(\sum_{k=1}^{N-1} \sum_{l=k+1}^N \hat{\beta}_{il}^2 \right) \sim N(0,1) \quad (4)$$

The last cross-sectional dependence test is the bias-adjusted LM statistic developed by Pesaran et al. (2008). According to Pesaran (2004), the CD_{PES} test in equation (4) is consistent for heterogeneous dynamic panel models that include structural breaks in the error variances and/or slope coefficients. However, when the average cross-section of the factor loading tends to zero, the CD_{PES} test becomes inconsistent. Therefore, the bias-adjusted kind of the LM tests which considers the variance and the exact mean of the LM statistic was proposed by Pesaran et al (2008). This is given as:

$$LM_{ADJ} = \sqrt{\left(\frac{2}{N^2 - N}\right)} \sum_{k=1}^{N-1} \sum_{l=k+1}^N \hat{\beta}_{il}^2 \frac{(T-k)\hat{\beta}_{il}^2 - \mu_{Tkl}}{\sqrt{v_{Tkl}^2}} \sim N(0,1) \quad (5)$$

where the number of explanatory variables is denoted by k , while the exact mean and variance of $(T-k)\hat{\beta}_{il}^2$ are respectively μ_{Tkl} and v_{Tkl}^2 .

3.2.2 Panel unit root tests

Our next focus is the examination of the stationarity properties of the panel series. We engage the Cross-sectionally Augmented Dickey-Fuller (CADF) and Cross-sectionally Augmented Im, Pesaran and Shin (CIPS) panel unit root tests developed by Pesaran (2007)

$$\Delta y_{it} = \alpha_0 + \alpha_1 y_{i,t-1} + \alpha_2 \bar{y}_{t-1} + \sum_{k=1}^p \beta_{1ik} \Delta \bar{y}_{i,t-k} + \sum_{l=0}^q \beta_{2ik} \Delta y_{t-k} + \varepsilon_{it} \quad (6)$$

where $\bar{y}_{t-k}$ and $\Delta \bar{y}_{t-k}$ denote the averages of the cross-sections in their lagged levels and first differences. Following this, the CIPS panel unit root is now given thus:

$$CIPS = N^{-1} \sum_{i=1}^N CADF_i \quad (7)$$

The critical values of the CIPS panel unit root test are computed in Pesaran (2007). Another notable advantage of the CIPS test is that it can account for autocorrelation (see Kassouri and Altintas, 2020).

3.2.3 Westerlund (2007) panel cointegration test

Conventional panel cointegration tests, such as the Pedroni cointegration test, break down if the panel members show evidence of cross-sectional dependence. Accordingly, we employ an advanced cointegration test due to Westerlund (2007) that is able to handle this issue. It is specified thus:

$$\Delta y_{it} = \gamma_i' d_t + \vartheta_i y_{i,t-1} + \lambda_i' x_{i,t-1} + \sum_{j=1}^{p_i} \vartheta_{1ij} \Delta y_{i,t-j} + \sum_{j=-k_i}^{q_i} \vartheta_{2ij} \Delta x_{i,t-j} + \varepsilon_{it} \quad (8)$$

where d_t denotes the deterministic component, which can be of three forms. The first case is when $d_t = 0$, implying equation (8) has no deterministic terms. In the second scenario, $d_t = 1$, implying that Δy_{it} is generated with an intercept. The last case scenario is when Δy_{it} is generated with both intercept and trend, such that $d_t = (1, t)'$. ϑ_i is the parameter that determines the speed of adjustment to long-run equilibrium. If $\vartheta_i < 0$, error correction exists, indicating that y_{it} and x_{it} have long-run relationship. On the other hand, if $\vartheta_i = 0$, error correction does not hold, hence there is no cointegration. The overall null hypothesis of no cointegration is thus given as $H_0: \vartheta_i = 0$ for all i . In addition, Westerlund (2007) developed two pairs of statistics in relation to the cointegration test. The first pair is for the group mean which does not require the equality of the ϑ_i s. This further indicates that the testing of H_0 against the alternative $H_1^g: \vartheta_i < 0$ is only for at least one i . The second pair, called the panel tests, is for the case of ϑ_i being equal for all i . Hence, H_0 is tested against the alternative $H_1^p: \vartheta_i = \vartheta < 0$ for all i .

3.2.4 Panel long-run estimators

In order to obtain estimates that are free of potential bias due to the aforementioned properties of panel series, the long-run estimators favoured in this study are the CCEMG and AMG. They both observe two-stage estimation procedure. Starting with the CCEMG estimator, it augments the baseline regression model with cross-section means of the dependent variable and the observed regressors, so that they are made as proxies for the unobserved common factors. It is specified thus:

$$320 \quad \text{Stage 1:} \quad y_{it} = \varphi_i + \phi_i x_{it} + \sigma_i \bar{x}_t + \rho_i \bar{y}_t + \varepsilon_{it} \quad (9a)$$

$$321 \quad \text{Stage 2:} \quad \hat{\phi}_{CCEMG} = N^{-1} \sum_{i=1}^N \hat{\phi}_i \quad (9b)$$

322 where y_{it} is the dependent variable, which in this case is ecological footprint, and the
 323 regressors are contained in x_{it} . $\hat{\phi}_{CCEMG}$ is the estimated coefficient of the CCEMG
 324 estimator. As rightly noted by Seven et al. (2018), the CCEMG estimator provides
 325 consistent estimates even when there is correlation between the observed regressors
 326 and the common factors. In addition, it is robust to heterogeneity of slope parameters,
 327 endogeneity, cross-sectional dependence, non-stationarity and structural breaks.

328 On its own, the AMG estimator differentiates the impact of the observed and
 329 unobserved common factors in the panel group. To consider cross-sectional dependence
 330 of the panel members, Eberhardt and Bond (2009) introduced a common dynamic effect
 331 which is in form of year dummy coefficients in order to indicate how the unobserved
 332 common factors of the cross-sections evolve in their levels-equivalent form. The two-
 333 stage specification is given thus:

$$334 \quad \text{Stage 1:} \quad \Delta y_{it} = \varphi_i + \phi_i \Delta x_{it} + \sigma_i f_t + \sum_{t=2}^T \rho_i \Delta D_t + \varepsilon_{it} \quad (10a)$$

$$335 \quad \text{Stage 2:} \quad \hat{\phi}_{AMG} = N^{-1} \sum_{i=1}^N \hat{\phi}_i \quad (10b)$$

336 where country-specific parameters are indicated by ϕ_i , the unobserved common factor
 337 with heterogenous feature is denoted by f_t , and the time dummy parameters of D_t
 338 which are also called the common dynamic process is represented by ρ_i . $\hat{\phi}_{AMG}$
 339 represents the augmented mean group estimator. A major advantage of the AMG

estimator over the CCEMG estimator, however, is that the former gives economic meaning to the unobserved factors treated as nuisance parameters in the latter.

4. Empirical findings and discussion

For the sake of brevity, the results are presented and discussed under relevant headings. We begin with the discussion of the relevant characteristics of panel data that inform our choice of estimator.

4.1 Cross-sectional dependence tests results

It is important to check for interdependence of the cross-sections, which in this case are the countries under consideration, as not accounting for this feature can induce significant bias to the estimates. For robustness, we employ four notable tests to check for this tendency, and the results are presented in Table 4 for the full and sub-samples. Evidently, the null hypothesis of no cross-sectional dependence is resoundingly rejected in all cases. This suggests that, irrespective of the sub-sample, cross-sectional dependence is found for all the panel members, and so, second generation unit root and cointegration tests that are consistent with this issue are employed. The results are discussed in the next sub-section.

4.2 Unit root tests results

Having discovered the presence of cross-sectional dependence in our panel members, we employ two standard unit root tests which have been adjudged to produce unbiased results to determine the stationarity levels of the panel series. Presented in Table 5, both

Pesaran CADF and Pesaran CIPS tests show that the unit root null hypothesis cannot be rejected for all the series across all the sub-samples, except urban population. This further implies that, except urban population that observes level-stationary (i.e. $I(0)$), they are non-stationary (i.e. $I(1)$). Usually, non-stationary series can either be cointegrated or produce spurious results. Hence, we apply the cointegration test in the next section to determine if the series have long-run relationship.

4.3 Cointegration test results

Subsequent on the evidence of mixed integration order of series, with most indicating non-stationarity, we utilize the cointegration test due to Westerlund (2007) in order to trace out any possible long-run relationship among the panel series. The choice of this test, as against the commonly utilized ones in former panel studies, is due to the initial evidence of cross-sectional dependence of our panel members. While the test has the null hypothesis of no cointegration, the alternative hypothesis is dependent on the specific test. The alternative hypothesis of at least one cointegrated unit is examined by the group-mean tests (symbolized by G_t and G_a), while the alternative hypothesis of panel cointegration as a whole is examined by the panel tests (symbolized by P_t and P_a) (see Burret et al., 2014). Meanwhile, owing to the fact that the results may be sensitive to lags, leads and kernel width choices due to the limited number of cross-sections, especially for the sub-samples, different specifications (unrestricted and restricted cases) of each cointegration test are estimated. In addition, we first conduct the test following the original consideration of Westerlund (2007) which considers only one regressor

(which in this case is the energy consumption), and then extend it to include other regressors (which are gross domestic products and urban population). The results are provided in Table 6. In the upper panel of Table 6, the results for the approach of Westerlund (2007) approach suggests for both the unrestricted and restricted cases that the null hypothesis of no cointegration is rejected in virtually all cases. In the lower panel which reports for the multiple regressors, there is evidence of cointegration among the variables for only the group mean under the unrestricted case. Undoubtedly, the reason for the insignificance of the panel tests is because of the sensitivity of the tests to number of lags and leads. When this is put into consideration in the restricted case, a better cointegration performance is obtained for the panel tests.

In essence, it is worth concluding that there is significant evidence of long-run relationship among our panel series. Based on this evidence, it is appropriate to proceed to the regression analysis where the impact of energy consumption (and other regressors, namely gross domestic products and urban population) on ecological footprint is examined.

Table 4: Results of cross-sectional dependence tests

	EF	ENG	GDP	URB	OIL
Full sample					
LM_{BP}	396.0990***	475.2956***	493.9363***	1100.5635***	1125.0000***
LM_{PS}	35.9550***	44.3031***	46.2680***	110.2121***	112.7879***
LM_{ADJ}	35.7467***	44.0947***	46.0596***	110.0037***	112.5796***

CD_{PES}	2.7477***	9.2178***	2.8564***	33.1737***	33.5410***
Middle-East					
LM_{BP}	51.0228***	62.4193***	53.3079***	145.1818***	150.0000***
LM_{PS}	11.8423***	15.1321***	12.5019***	39.0236***	40.4145***
LM_{ADJ}	11.7589***	15.0488***	12.4186***	38.9402***	40.3312***
CD_{PES}	-1.7430*	-1.9685**	-1.9363*	12.0486***	12.2475***
Non-Middle-East					
LM_{BP}	120.6069***	160.3966***	162.0705***	368.3891***	375.0000***
LM_{PS}	18.1856***	25.4502***	25.7558***	63.4243***	64.6313***
LM_{ADJ}	18.0606***	25.3252***	25.6308***	63.2993***	64.5063***
CD_{PES}	2.2815**	12.2336***	2.0454**	19.1931***	19.3649***

397 *** and ** indicate significance at 1% and 5% critical levels respectively.

398

399 *Table 5: Results of Panel unit root tests*

		CADF			CIPS	
	Level	Ist Diff.	I(d)	Level	Ist Diff.	I(d)
Full sample						
EF	-1.904	-3.453***	I(1)	-1.984	-4.900***	I(1)
ENG	-2.004	-3.528***	I(1)	-2.556	-5.397***	I(1)
GDP	-1.845	-3.120***	I(1)	-2.219	-3.879***	I(1)
URB	-2.863**	-2.730***	I(0)	-3.993***	-5.898***	I(0)

Middle-East						
EF	-1.226	-3.428***	I(1)	-2.352	-5.960***	I(1)
ENG	-0.603	-3.260**	I(1)	-2.703	-5.889***	I(1)
GDP	-2.116	-3.184**	I(1)	-1.652	-4.158***	I(1)
URB	-4.225***	-3.724***	I(0)	-5.928	-5.561***	I(0)
Non-Middle-East						
EF	-1.888	-3.599***	I(1)	-1.861	-4.765***	I(1)
ENG	-2.042	-3.881***	I(1)	-2.496	-5.689***	I(1)
GDP	-1.548	-0929*	I(1)	-1.280	-3.621***	I(1)
URB	-2.872*	-5.633***	I(0)	-3.871***	-6.420***	I(0)

400 For the CIPS unit root test, the critical values are computed by Pesaran (2007) as -3.1, -
401 2.86 and -2.73 for 1%, 5% and 10% significance levels respectively. Also, ***, ** and *
402 indicate significance at 1%, 5% and 10% critical levels respectively.

403

404 **Table 6: Results of Westerlund (2007) panel cointegration test**

Statistics	Unrestricted case (AIC-based selection)			Restricted case (Fixed lag and lead)		
	Full sample	Middle-East countries	Non-Middle-East	Full sample	Middle-East countries	Non-Middle-East
Replication of Westerlund (2007)						

G_t	-3.307***	-3.232***	-3.358***	-2.971***	-2.944*	-2.989**
G_a	-22.889***	-15.650	-27.715***	-21.718***	-13.825	-26.979***
P_t	-9.128***	-6.122**	-6.961**	-9.205***	-7.027***	-6.773**
P_a	-18.085***	-17.051***	-18.451***	-18.880***	-16.987***	-19.459***
Multiple regressors						
G_t	-13.291***	-23.579***	-6.433***	-12.991***	-23.294***	-6.123***
G_a	-0.564	-0.289	-0.748	-0.296	-0.252	-0.326
P_t	-4.456	-2.166	-4.350	-10.014***	-4.331	-9.360***
P_a	-3.218	-5.129	-2.944	-0.298	3.100	-0.287

G_t and G_a denote group mean tests, while P_t and P_a denote panel mean tests. ***, ** and *

indicate significance at 1%, 5% and 10% critical levels respectively.

4.5 Estimated results

We report the results of both CCEMG and AMG estimators for the full sample as well as the sub-samples, i.e. MENA and non-MENA countries. With respect to the impact of energy consumption on ecological footprint, the results of both models are really similar, particularly in terms of significance (see Table 7). However, a few differences are found in the significance of GDP and urban population, as the results of the AMG produce better results than those of the CCEMG. This perhaps justifies our preference of the AMG estimator which has been empirical adjudged to perform better than the

416 CCEMG estimator (see Eberhardt and Bond, 2009). We therefore base our explanation
417 on the results of the AMG estimates.

418 Starting with the full sample results, it is seen from Table 6 that ecological footprint
419 responds positively to energy consumption. This means that for the entire OPEC group,
420 the move for higher level of energy consumption has significant increasing effect on
421 environmental degradation, thereby inducing challenges for environmental balance. For
422 specificity, a unit percent increase per capita energy consumption raises per capita
423 ecological footprint by 0.7595%. In the same vein, urbanization is also found to have
424 significant and increasing impact on ecological footprint, but such evidence is not
425 established for economic growth. Our findings are consistent with those of Wang and
426 Dong (2019), Solarin and Al-Mulali (2018), Wang et al. (2016), and Li and Lin (2015),
427 among others, who disclose a positive relationship between environment degradation
428 with either or both of energy consumption and urbanization.

429 Turning to the sub-samples, similar findings as the full sample are found for both cases,
430 i.e. MENA and non-MENA countries. In other words, both energy consumption and
431 urbanization are significant positive influencers of ecological footprint, while economic
432 growth seems not to matter still. However, the differences relate to the magnitude of
433 effect, which is the major reason for the partitioning. We find from Table 7 that despite
434 the MENA countries being the highest exporters of crude oil, highest per capita
435 consumers of energy (as reported in Table 2 under descriptive statistics), and highest
436 producer of per capita ecological footprint (see Table 2), the marginal contribution of

437 their energy consumption to environmental degradation seems smaller than that of the
438 non-Middle-East countries. For instance, while a 1% increase in energy consumption of
439 the non-Middle-East countries increases ecological footprint by 0.8081%, energy
440 consumption increase of the same magnitude in the Middle-East countries only increase
441 ecological footprint by 0.7486%. It could only imply therefore that, although the Middle-
442 Eastern countries are still largely energy inefficient following their high carbon release
443 (see Bayomi and Fernandez, 2019), they still seem to perform better in energy efficiency
444 than other OPEC member countries.

445 Considering the control variables, while economic growth remains insignificant still,
446 urbanization is positively significant in both cases, with greater effect going to the non-
447 Middle-East countries again. We can rationalize the positive impact of urbanization on
448 ecological footprint on the argument that increasing level of urban population mounts
449 pressure and consequently increases human demands on ecological resources. The
450 resultant effect is increasing degradation of the environment.

451 In order to add precision to our analysis, we further provide the long run estimates of
452 the group-specific parameters based on our AMG estimator. The essence is to discover
453 the contribution of each country in addition to the estimates of the common dynamic
454 process of the AMG estimator. The results are reported in Tables 8 and 9 for the Middle-
455 East and non-Middle-East countries respectively. In the Middle-East group, energy
456 consumption of Iran seems to have higher impact on ecological degradation (0.8907%)
457 followed by Saudi Arabia (0.8796%). UAE is seen to impact ecological footprint the

lowest. However, the highest effect of urbanization seems to be in favour of Saudi Arabia with a value of 1.0076% while UAE still the least contribution still (0.1839%). Across board, GDP is not found to be significant except in Iran where the impact is negative.

For the category of the countries not belonging to the Middle-East, energy consumption has the highest impact on ecological footprint in Angola (2.1841%). In fact, the impact is more than twice as Nigeria that has the second highest impact with a value of 1.0218%. Interestingly, Democratic Republic of Congo seems to be the only country whose energy consumption does not have adverse impact on environmental quality. The negative relationship between her energy consumption and ecological footprint (-0.7388) suggests that energy consumption has reducing effect on environmental degradation. Also, economic growth in Nigeria helps to mitigate environmental degradation by the negative coefficient of GDP, while contrary evidence is found for Venezuela. Expectedly, ecological footprint is found to respond positively to urbanization in all the countries, except Democratic Republic of Congo where the impact is insignificant.

Table 7: Panel regressions results of CCEMG and AMG

Variable	Full sample		Middle-East countries		Non-Middle-East countries	
	CCEMG	AMG	CCEMG	AMG	CCEMG	AMG
ENG	0.6816***	0.7595***	0.7805***	0.7486***	0.6918***	0.8081**

	(0.2157)	(0.2258)	(0.1687)	(0.0789)	(0.2229)	(0.3843)
GDP	0.1806 (0.1630)	0.1412 (0.1268)	0.2517 (0.1540)	-0.0221 (0.1150)	-0.0779 (0.2993)	0.2283 (0.2101)
URB	0.7311 (0.4450)	0.8440*** (0.1656)	0.9329** (0.4378)	0.6552*** (0.2071)	0.2754 (0.3209)	0.9469*** (0.1976)
Constant	-4.3757 (5.2832)	-20.4115*** (3.0919)	-4.7292 (6.6243)	-15.6341*** (3.1505)	-4.5884 (7.5980)	-23.1606*** (4.9370)
Diagnostics						
Wald chi-sq.	14.05***	35.98***	49.57***	92.40***	114.19***	23.50***
[Prob.]	[0.0028]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
RMSE	0.0644	0.0846	0.0405	0.0595	0.0638	0.0926
<i>Cross sections</i>	10	10	4	4	6	6
<i>Periods</i>	25	25	25	25	25	25
<i>Total Obs.</i>	250	250	100	100	150	150

475 Values in brackets are standard errors, while those in parentheses are probabilities. ***

476 and ** indicate significance at 1% and 5% critical levels respectively.

477

478 **Table 8: Country-specific estimates for Middle-East countries from AMG**

	Iran	Iraq	Saudi Arabia	UAE
ENG	0.6170**	0.8907***	0.8796**	0.6071***

	(0.2498)	(0.0604)	(0.4219)	(0.2322)
GDP	-0.3307* (0.1771)	0.0382 (0.0617)	-0.0187 (0.3621)	0.2227 (0.1826)
URB	0.9989*** (0.3761)	0.4304*** (0.1068)	1.0076*** (0.3147)	0.1839*** (0.0647)
Constant	-18.3830*** (5.0183)	-13.2822*** (1.5290)	-22.7135*** (4.1853)	-8.1576*** (2.7762)

479 Values in parentheses are probabilities. ***, ** and * indicate significance at 1%, 5% and
480 10% critical levels respectively.

481

482 **Table 9: Country-specific long-run estimates for non-Middle-East countries from**
483 **AMG**

	Algeria	Angola	Congo, Dem.	Gabon	Nigeria	Venezuela
ENG	0.8081** (0.3843)	2.1841*** (0.4698)	-0.7388** (0.3731)	0.6332** (0.2485)	1.0218** (0.5188)	0.7016** (0.3518)
GDP	0.2283 (0.2101)	0.0802 (0.2018)	0.1181 (0.1373)	0.6752 (0.7934)	-0.6128*** (0.1397)	0.8464*** (0.1861)
URB	0.9469*** (0.1976)	0.8089*** (0.1018)	0.0868 (0.0997)	0.9872*** (0.2765)	1.0772*** (0.0763)	1.5211*** (0.1387)
Constant	-23.1606*** (4.9370)	-26.9124*** (2.4412)	-1.4385 (1.3350)	-23.6923** (9.8390)	-20.6835*** (2.1164)	-37.6217*** (2.1164)

Values in parentheses are probabilities. *** and ** indicate significance at 1% and 5% critical levels respectively.

5. Concluding remarks

Our major objective in this study is to examine the role that energy consumption plays in the environmental quality of the OPEC countries. Motivated by their highest share of crude oil exports of the Middle-Eastern countries of the OPEC group, as well as their huge share in per capital energy consumption and per capita ecological footprint, we further partition the full sample into two sub-samples namely Middle-Eastern and non-Middle-Eastern countries. The essence is to discover if such high level of per capita energy use by the Middle-East countries will accordingly lead to high environmental degradation compared to other countries, or otherwise. To do this, we collect annual data for 10 OPEC countries over the period of 1990 to 2014. Putting certain features of panel series, such as cross-sectional dependence and heterogeneity, into consideration, we employ second generation estimation techniques that can conveniently handle these inherent issues. Accordingly, we begin the estimation process by testing for the presence of cross-section dependence among the panel members using a battery of cross-sectional dependence tests. Upon ascertainment of strong interdependencies among the series, our unit root tests which are consistent with the issue reveal that the series are largely non-stationary across all the sub-samples, with the only exemption being urban population. Consequent on this, the cointegration test suggests that long-

run relationship exists among the variables, thus informing our preference for the Augmented Mean Group that is able to account for all these aforementioned concerns.

We find that energy consumption significantly and positively impacts ecological footprint across all the samples. However, the marginal contribution of energy consumption in the Middle-Eastern countries that are apparently the highest exporters of crude oil and highest per capita consumers of energy in the OPEC group is smaller than that of the non-Middle-Eastern countries. Similarly, the established impact of the degree of urbanization on ecological footprint is expectedly higher for the non-Middle-Eastern countries due to their higher population. Economic growth seems not to matter at all in impacting environmental quality in all cases. We further add precision to our analysis by considering country-specific estimates of the AMG estimator. In the Middle-East group, energy consumption has the greatest adverse effect on environmental quality while UAE records the least. On the other hand, only the Democratic Republic of Congo has their energy use reduce environmental degradation following the coefficient of per capita energy consumption (-0.7388%). However, the scenario is particularly worse for Angola whose increasing energy consumption effect on environmental degradation (2.1841%) is more than double of the country (Nigeria) ranking next to it (1.0218%).

6. Policy implications

Our findings definitely have instructive policy suggestions for in a number of ways. The increasing effect of energy consumption on environmental degradation in the OPEC

countries is a clear indication of their energy intensity. Of equal importance is that due to the huge deposits of non-renewable energy resources, especially crude oil in their borders, the use of fossil fuels outpaces renewable energy consumption. The carbon generated from the consumption of the fossil fuels is perhaps the major cause of the huge environmental concerns. At the same time, it has no economic sense to strictly suggest that attention should be shifted away from the consumption of fossil fuels due to its immense contribution to the economic growth and development of these countries. Hence, we recommend a proper energy reshuffling or energy mix between the renewable energy and non-renewable energy sources. This will not only ensure an enhanced environmental quality through mitigation of carbon release, but the renewable energy sources have been regarded as the solution to challenges of future energy security and unemployment (see Mu et al., 2018; Proenca and Fortes, 2020; and Edenhofer et al., 2011). Additionally, the non-Middle-Eastern countries should ensure improved energy use efficiency following their higher impact on environmental degradation despite having lower average per capita energy consumption. The governments of the countries can also introduce carbon cuts through placing limits on the amount of carbon that can be emitted by the firms. The excess can then be traded. In keeping with the carbon cuts policy, firms with excess carbon emissions can be appropriately taxed.

Other policy focus relates to the demographic feature of the OPEC countries, irrespective of the sub-samples they fall into. Having discovered the strong significance

of the urban population in inducing environmental degradation, probably due to increased demand or higher pressure on natural resources, the impact can yet be favourable if the government introduces relevant urban plans that give rise to easy access to efficient and clean technology.

Declarations

A. Ethics approval and consent to participate

All research ethics have been duly followed, and all the authors give their consents to participate.

B. Consent for publication

All the co-authors have given their consents for publication.

C. Availability of data and materials

The data are available upon reasonable request.

D. Competing interests

None of the authors have any competing interest.

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Not applicable.

F. Authors' contributions

Oluwasegun B. Adekoya: Conceptualization, Methodology, Analysis, Discussion of results.

Joshua K. Olabode: Writing, Data curation, Editing.

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Figures

Figure 1

Trends in ecological footprint and energy consumption in Middle-Eastern countries

Figure 2

Trends in ecological footprint and energy consumption in non-Middle-Eastern countries