Environmental Science and Pollution Research (2020) 27:19616–19629
https://doi.org/10.1007/s11356-020-08466-0

RESEARCH ARTICLE

Renewable energy, urbanization, and ecological footprint linkage in CIVETS

Solomon Nathaniel[1] · Ozoemena Nwodo[2] · Gagan Sharma[3] · Muhammad Shah[4]

Received: 8 November 2019 / Accepted: 16 March 2020 / Published online: 26 March 2020

Abstract
Emerging economies are mostly plague by a massive consumption of non-renewable energy amidst an ever inceasing urbanization rate with little or no attention to the quality of the environmental. As such, this paper investigates the relationship between renewable energy, urbanization, economic growth, trade openness, and ecological footprint in CIVETS countries, namely, Colombia, Indonesia, Vietnam, Egypt, Turkey, and South Africa. The study employs augmented mean group estimator, panel cointegration, and causality tests. The findings reveal that renewable energy improves environmental quality, and trade is not particularly harmful to the environment. However, non-renewable energy consumption and urbanization are the chief contributors to environmental degradation in the CIVETS countries. Economic expansion mitigates environmental deterioration in Colombia, South Africa, and Turkey, but contributes to pollution in Egypt, Indonesia, and Vietnam. Finally, the causality test suggests that urbanization drives environmental degradation. Policy directions are discussed.

Keywords Urbanization · Renewable energy · Ecological footprint · AMG · CIVETS

Introduction

The recent global concern of environmentalists has been the dehumanizing effect of the pressure inflicted by the exploitative tendencies of humanity on the ecosystems. As trivial as it may sound, these human activities have been attributed to be the major factors behind the evils of climate change, environmental degradation, and ecological distortions currently ravaging today's world (Alola 2019a; Bekun et al. 2019). It has also been projected that the world is yet to witness the worst effect of climate change on the environment as more lives, more farm output, and more wealth will, and are being wasted at the altar of environmental degradation. Humanity is facing her greatest threat ever and there is urgent need for affirmative actions to curb this doom.

However, environmentalists have pre-occupied themselves in response to the global climate change with researches on population changes, energy use, trade and urbanization, and their effects on the environment (Alola 2019b; Saint Akadiri et al. 2019; Alola and Alola 2018; Sarkodie 2018; Shahbaz and Sinha 2019; Wang and Dong 2019; Nathaniel 2019). Economic growth increases energy demand and drives industrialization which in turn promotes trade. Since CIVETS countries are naturally endowed, the need to facilitate trade promotes natural resource extraction. The extraction and exploitation of natural resources give rise to income increase on one hand while decreasing biocapacity and increasing ecological footprint (EFP) on the other (Panayotou 1993). Just like industrialization, economic growth increases urbanization. Urbanization raises the demand for industrialization and transportation, intensifies fossil fuel consumption, and increases EFP (Ulucak and Khan 2020). Urbanization can improve the

Responsible editor: Eyup Dogan

✉ Solomon Nathaniel
nathaniel_solomon21@yahoo.com

Ozoemena Nwodo
nwodo.ozoemena.pg68442@unn.edu.ng

Gagan Sharma
angrishgagan@gmail.com

Muhammad Shah
ibrahimecondu@gmail.com

1 Department of Economics, University of Lagos, Akoka, Nigeria

2 Department of Economics, University of Nigeria, Enugu, Nigeria

3 University School of Management Studies, Guru Gobind Singh Indraprastha University, New Delhi, India

4 Department of Economics, University of Dhaka, Dhaka, Bangladesh

purchasing power of urban dwellers which will inform the demand for renewables thereby reducing EFP (Danish and Wang 2019).

Economies are adopting renewable energy (REN) strategies to mitigate CO_2 emission effect on the environment (Aliyu et al. 2018; Nathaniel and Iheonu 2019; Moutinho et al. 2018; Sharif et al. 2019), such that the investment in REN was in excess of 214 billion USD as of 2013. As a result, REN consumption has increased from 16% of the total energy consumption in 2007 to 18% in 2016 (World Bank 2017). It is also expected that this percentage will double by the year 2022 owing to the increased concern of economies to adopt cleaner energy and embrace green economy (IEA 2017).

Developing countries mostly focus on how to attain growth through an increase in national output without considering the adverse effects of such growth on the environment. Energy consumption, mainly of non-renewable sources, is observed to be on the increase in these countries, CIVETS inclusive. Non-renewable energy (NREN) is a pollutant. They contribute to greenhouse gas emissions (GHGs) thereby damaging human health, economic activities, and distorting environmental sustainability. This study focused on the CIVETS countries because of their resource endowments, NREN consumption, REN potentials, and vulnerability to climate change. The CIVETS countries are among the highest emitters of carbon dioxide in the world because of their continuous consumption of NREN, mainly fossil fuels. South Africa, for instance, is the 14th highest emitter of CO_2 emissions in the world mainly due to increased consumption of coal, a NREN source (Liu et al. 2020a, b). The Living Planet Report (LPR) of 2014 revealed that the EFP in Indonesia fall shut of the world's average (1.7 gha) biocapacity per person mainly as a result of its continuous consumption of NREN. Turkey emits 500 megatonnes of GHGs each year, more than 1% of the world's total. The country's average growth rate was 2.795% for the period 1965 to 2015 and 2.089% for the OECD countries within the same period (World Bank 2018). The average primary energy use per capita growth was 2.627% between 1965 and 2015 in Turkey, whereas for the OECD countries, the same growth rate averaged only 0.585% (Karasoy 2019). As of 2014, total final (energy) consumption (TFC) in Turkey was dominated by fossil fuels: 35.6%, 2.6%, and 12.3% of TFC were from oil, natural gas, and coal, respectively (IEA 2016). In 2016, the energy sector in Turkey contributed the largest share (86.1%) to CO_2 emissions (Turkish Statistical Institute 2018). CIVETS, like other developing country, needs sustainable growth and environmental sustainability. The persistent usage of NREN, accompanied by harmful trade and an upward surge in urbanization, will truncate environmental sustainability and inhibit sustainable development in these countries. Hence, the motivation for this study.

Relatively, just a few attempts have been made to examine REN in a framework of population changes and their effects on environment degradation. Some of the studies found that REN reduces environmental degradation, protects the environment, and promotes economic development (Emir and Bekun 2019; Balsalobre-Lorente et al. 2018; Apergis et al. 2018). However, there are studies that discovered no meaningful effect of REN on environmental degradation (Frondel et al. 2010; Marques and Fuinhas 2012) while a few others revealed that REN do not reduce environmental pollution (Al-Mulali et al. 2015a; Pata 2018c).

Most of the studies in the literature on the effect of REN on the environment narrowed the measure of environment degradation to CO_2 emissions without considering the effect on the environment of human activities expressed on the available land space for sustained natural resource use. These effects of humanity on the ecosystem, referred to as EFP, reveals human economy dependence on natural capital and it serves as a better measures of environmental degradation than just CO_2 emissions (Lin et al. 2015).

The new contributions of this study to the existing literature are in the following ways: (i) there are a lot of studies on the energy-growth-environment nexus on each of the individual CIVETS countries with mixed results. This study is the first to consider the determinants of EFP such as REN, NREN, economic growth, trade, urbanization for CIVETS countries as a group. While most previous studies adopted CO_2 emissions (a negative indicator), the present study used EFP (a positive indicator) to measure environmental quality. EFP includes six categories of bio productive land use type (grazing land, forest land, carbon footprint, cropland, built-up land, and ocean). The EFP is arguably the only metrics that compare the resource demand of government, businesses, and individuals against what Earth can renew. Since the CIVETS countries have maintained a fairly stable growth through production over the years, the use of EFP becomes ideal because it measures the environmental consequences of the production of commodities, both goods and services, to promote a required lifestyle (Rashid et al. 2018). (ii) This study is unique in the adopted panel data estimation methods that produce more robust and reliable estimations. We used the Augment Mean Group (AMG) estimator which is consistent with cross-sectional dependence (CSD) and country-specific heterogeneity. The AMG estimator was further complemented with the mean group (MG) and the common correlated effects mean group (CCEMG) estimator that takes care of endogeneity problems.

The remaining parts of this article are grouped in this order: "Review of literature" presents the literature review. "Methodology" addresses the methodology. Results are presented and discussed in "Results and discussion of findings". "Conclusion and policy directions" concludes with relevant policy directions.

Review of literature

The remarkably increasing economic growth and accelerating process of urbanization have resulted in the increase of energy needs, which is closely related to human activities and thus, lead to environmental degradation (Wang and Dong 2019). Urbanization plays a significant role in influencing the environmental quality via various channels. Industrialization brings along the establishment of new factories and plants providing employment opportunities, leading to people migrating to urban cities from rural areas, and hence increasing the urban population, which ultimately leads to accelerated demand for energy, and subsequently increases CO_2 emissions (Sinha et al. 2019). In addition to this particular channel, urbanization also causes environmental degradation in several other ways including transportation, vehicular congestion, international trade, health care, landscape pattern, terrorism, and real income (Saint Akadiri et al. 2019; Alvarado et al. 2018; Farhani and Ozturk 2015; Hanif et al. 2019; Li et al. 2018; Mohamed et al. 2019; Wang et al. 2019). Hence, it is imperative to consider urbanization in the empirical framework while analyzing the ecological footprint across countries.

The economic growth and energy nexus have been widely studied and extensively investigated empirically (Alshehry and Belloumi 2015; Balcilar et al. 2018; Tiba and Omri 2017) following the very first work of Kraft and Kraft (1978). However, such empirical findings seeking to measure the impact of urbanization on the environment are persuasive but unambiguous due to the implementation of various forms of econometric methods such as correlation analysis (Alam et al. 2015), multivariate and panel cointegration tests (Hatzigeorgiou et al. 2011; Pedroni 1999), regression analysis (Dong et al. 2018; Shafiei and Salim 2014), causality tests (Chang et al. 2015; Mutascu 2016), vector error correction model (Sebri and Ben-Salha 2014; Zhou et al. 2018), and ARDL approach (Dogan et al. 2019; Lau et al. 2018; Rauf et al. 2018; Yang et al. 2018). Hence, such inconclusive empirical evidences cannot assist economic policymakers in planning and developing appropriate plans and programs for long-term economic growth (Ozturk and Acaravci 2010; Payne 2010). Lv and Xu (2019) employed the pooled mean group (PMG) approach to examine the impact of urbanization and trade openness on CO_2 emissions and report that urbanization improves environmental quality. Conversely, Destek and Sarkodie (2019) and Wang and Dong (2019) use the augmented mean group (AMG) to investigate the relationship between economic growth, energy consumption, and EFP for 11 newly industrialized countries and 14 Sub-Saharan Africa (SSA) countries and find bidirectional long-run causality among economic growth, non-REN, urbanization, and the EFP. Zafar et al. (2019) conducted a Granger causality analysis among the Asia-Pacific Economic Cooperation (APEC) countries for a period extending from 1990 to 2015 and discovered a unidirectional causal relationship running from REN to economic growth and from economic growth to NREN. Alternatively, both Nathaniel et al. (2019) and Rasoulinezhad and Saboori (2018) employed the FMOLS and DOLS estimation technique for South African data spreading from 1965 to 2014 and for 12 states under the Commonwealth region from 1992 to 2015, respectively, and reported that urbanization and energy use promote environmental quality in the long term. Additionally, Bao and Xu (2019) and Ozcan and Ozturk (2019) employed the bootstrap panel causality test to analyze the cause and effect of REN on the urbanization and economic growth and discovered non-existence of causality indicating that energy-saving policies do not have any negative impact on the growth rates.

In addition to the use of varied econometric analysis, different results also arise due to different variables used and the different sample of countries or cities under study (Azizalrahman 2019). With respect to the variables, Yang et al. (2018) included climate factors based on the socio-economic factors and adopted the extended STIRPAT model to study the Chinese economy during the period 1995–2014, and prove urbanization and economic development as the main drivers of CO_2 emissions. On the other hand, Andrés and Padilla (2018) analyzed the structural characteristics of transport activity in terms of transport energy intensity of transport modes and transport volume, as the factors of greenhouse gas emissions for European Union-28 from 1990 to 2014, to highlight on the significant factors and their magnitude of impact. Alvarado et al. (2018) analyzed the real per capita output using 151 countries from 1980 to 2016 and find an inverted U-shaped relationship between the output and CO_2 emissions by grouping countries globally on the basis of income levels. While analyzing the long and short run impact of fossil fuel consumption and FDI on CO_2 emissions in 15 Asian countries from 1990 to 2013, Hanif et al. (2019) discovered that both fossil fuel consumption and FDI contribute to CO_2 emissions deteriorating the environment.

The other strand of the existing literature in this field provides empirical evidence on the relationship between economic growth and CO_2 emissions, called as the environmental Kuznets curve (EKC), which states the relationship as non-linear and inverted U-shaped, implying that economic growth increases CO_2 emissions initially and then gradually declines it, once it matures (Muhammad et al. 2013). Existing studies validated the existence of EKC including Heidari et al. (2015) and Saboori and Sulaiman (2013) for ASEAN countries; Acaravci and Ozturk (2010), Bento and Moutinho (2016), and Ho and Iyke (2019) for selective European countries;

Khoshnevis Yazdi and Ghorchi Beygi (2018) and Sarkodie (2018) for African countries; Dogan et al. (2019) for MINT countries; Hanif (2018c) for East Asia and Pacific countries; and Zhu et al. (2018) for BRIC countries. However, there are also studies that highlight on the non-existence of the U-shaped EKC such as in the case of Turkey where the CO_2 emissions increased due to the usage of fuel oil and other traditional energy consumption patterns related to urban development (Katircioğlu and Katircioğlu 2018). Consistently, empirical tests in Russia suggest changes in pollutant emissions due to increased energy usage, concluding no support for EKC hypothesis (Pao 2011). Similarly, EKC hypothesis is not valid for USA as well, as proven by Dogan and Ozturk (2017), where REN mitigates environmental degradation while an increase in NREN contributes to CO_2 emissions. Further, EKC literature mostly uses CO_2 emissions as a single indicator for environmental degradation, but there exists a gap that environmental degradation cannot be captured by CO_2 emissions alone, and hence, there is a need for a broader variable namely, EFP to study the existence of EKC hypothesis (Destek et al. 2018; Dogan et al. 2019). The estimates of EFP rationalize the approach of assessing environmental degradation, since it is a more comprehensive indicator (Rashid et al. 2018; Wang and Dong 2019). This study ameliorates for these deficiencies by using EFP, instead of CO_2 emissions, as a broader proxy for environmental degradation.

Finally, the third strand deals with the relationship between urbanization, EFP, and energy consumption. Baloch et al. (2019a, b) investigated the impact of financial development on EFP and discovered that economic growth, energy consumption, FDI, and urbanization pollute the environment by increasing the EFP. Correspondingly, Wang and Dong (2019) investigated the determinants of environmental degradation using a dataset of 14 Sub-Saharan African countries from 1990 to 2014. They reported that economic growth, NREN, and urbanization exert positive effects on the EFP, while REN plays a negative role in the EFP. Considering EFP as a measure of human demand on earth's ecosystem, Hassan et al. (2019) opined that natural resources have a positive effect on the EFP, indicating that it deteriorates environmental quality, but also proves the EKC hypothesis. By examining 93 countries, categorized by income, Al-Mulali et al. (2015a, b) reported that energy consumption, urbanization, and trade openness increase environmental damage by exerting positive impact on the EFP of the countries.

Extensive literature is conducted covering either a panel of countries, for instance, for MENA countries (Nathaniel et al. 2020; Saidi et al. 2018); for Sub-Saharan African countries (Boutabba et al. 2018; Hanif 2018a, b, c; Ozturk 2017; Wang and Dong 2019), for N-11 countries (Sinha et al. 2019), for G-20 countries (Destek and Okumus 2019), and for BRIC countries (Zhu et al. 2018). For a single country case, such as for China (Ahmad et al. 2019; Bao and Xu 2019; Chen et al. 2019a, b), for Turkey (Katircioğlu and Katircioğlu 2018; Ozcan et al. 2018), for the US (Alola 2019a), for Europe (Alola et al. 2019; de Souza et al. 2018; Destek et al. 2018; Ho and Iyke 2019), and for Pakistan (Hassan et al. 2019; Luqman et al. 2019).

Methodology

Method

The study proceeds with the CSD test in order to avoid estimator inefficiency and biased estimates. The CSD test is vital especially when variables are nonstationary. It also gives direction as regards the unit root tests to apply. Three different tests (Breusch-Pagan LM, Pesaran scaled LM, and Pesaran CD) are used for this purpose. The null hypothesis of the CSD test is presented in Eq. 1 below:

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

In the presence of CSD, the conventional unit root tests will give misleading results. Therefore, there is a need to use unit root tests that accounts for CSD. This study applies both first-and-second generation unit root tests. The former does not account for CSD among the countries, while the later does. Levin et al. (2002) test assumes no changes in the autoregressive parameters for all the cross sections, while the PP-Fisher and the Im et al. (2003) unit root tests assume the exact opposite. The LLC (Levin et al. 2002) test is estimated from the equation below:

$$\Delta y_{it} = \phi_i + \pi_i y_{i,t-1} + \sum_{j=1}^{p} P_i \Delta y_{it-j} + e_{it} \tag{2}$$

Δy_{it} is the difference of y_{it} for all ith country. The study further utilized the cross-sectional augmented IPS (CIPS) test of Pesaran (2007) which is robust for CSD. The test equation is given as

$$\Delta y_{it} = \varphi_i + \beta_i y_{i,t-1} + \tau_i \overline{y}_{t-1} + d_i \Delta \overline{y}_t + \varepsilon_{it} \tag{3}$$

The CIPS statistic is derived from the sample average of Eq. 3 above. Apart from other first-generation cointegration tests, the Westerlund (2007) was used to examine the presence of a cointegrating relationship among the variables. The error correction approach of the test is presented in below as

$$\Delta y_{it} = \delta_i' d_t + \alpha_i y_{it-1} + \lambda_i' x_{it-1} + \sum_{j=1}^{pi} \alpha_{ij} \Delta y_{it-j} + \sum_{j=0}^{pi} \gamma_{ij} \Delta x_{it-j} + e_{it} \tag{4}$$

α_i is the error correction parameter. $d_t = (1, t)'$ comprises the deterministic components (constant and trend) with $\delta_t = (\delta_{i1}, \delta_{i2})'$ representing vector of parameters. Four tests (based on the OLS estimates of α_i in Eq. 4) were developed to investigate the existence of cointegration. Two of these four tests are the group mean statistics given as

$$G_{\tau}=\frac{1}{N}\sum_{i=1}^{N}\frac{\widehat{\alpha}_i}{SE\left(\widehat{\alpha}_i\right)}\text{ and }G_{\alpha}=\frac{1}{N}\sum_{i=1}^{N}\frac{T\,\widehat{\alpha}_i}{\widehat{\alpha}_i(1)}$$

The standard error of $\widehat{\alpha}_i$ is represented by $SE(\widehat{\alpha_i})$. The semiparametric kernel estimator of $\alpha_i(1)$ *is* $\widehat{\alpha}_i(1)$. The remaining two tests are the panel mean tests which suggest that the whole panel is cointegrated. They are given as follows:

$$P_{\tau}=\frac{\widehat{\alpha}_i}{SE\left(\widehat{\alpha}_i\right)}\text{ and }P_{\alpha}=T\widehat{\alpha}$$

The study employed the AMG algorithm estimator of Bond and Eberhardt (2013) to examine the effects of each of the variables on the dependent variable. The AMG technique accommodates nonstationary variable(s) (Destek and Sarkodie 2019) and CSD (Solarin and Al-Mulali 2018; Baloch et al. 2019a). We also used the Dumitrescu and Hurlin (2012) Granger non-causality test to ascertain the direction of causality among the variables. The D-H equation is shown in Eq. 5 below.

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

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

$H_0:\beta_1=0$ and $H_1:\{^{\beta_i=0}_{\beta_i\neq 0}$ $\forall_i=1,2...\mathrm{N}$ and $\forall_i=\mathrm{N}+1,\mathrm{N}+2\ldots\mathrm{N}$.

Data and model specification

The data spans 1990–2014. The time period is consistent with data availability. The data on EFP was derived from the Global Footprint Network (2019), while the remaining data were obtained from the World Bank (2018). The model for the study is given as

$$EFP_{it}=\varphi_0+\varphi_1REN_{it}+\varphi_2NREN_{it}+\beta_0Z_{it}+\varepsilon_{it} \quad (6)$$

where *EFP* is the ecological footprint (global hectares per capita), *REN* is the renewable energy (% of total energy consumption), *NREN* is the non-renewable energy (kg of oil equivalent), while Z_i represents the other control variables. By adding the control variables into Eq. 6 gives Eq. 7.

$$EFP_{it}=\varphi_0+\varphi_1REN_{it}+\varphi_2NREN_{it}+\varphi_3GDP_{it}++\varphi_4TRD_{it}+\varphi_5URB_{it}+\varepsilon_{it} \quad (7)$$

For uniformity, the per capita form of the variables was used. This was achieved by dividing each of the variables by population.

$$efp_{it}=\varphi_0+\varphi_1ren_{it}+\varphi_2nren_{it}+\varphi_3gdp_{it}+\varphi_4trd_{it}+\varphi_5urb_{it}+\varepsilon_{it} \quad (8)$$

The lower-case letters *efp*, *ren*, *nren*, *gdp*, *trd*,and *urb* are the per capita terms of the variables. The linearized model, after taking the log of each of the variables, is shown in Eq. 9.

$$lnefp_{it}=\varphi_0+\varphi_1lnren_{it}+\varphi_2lnnren_{it}+\varphi_3lngdp_{it}+\varphi_4lntrd_{it}+\varphi_5lnurb_{it}+\varepsilon_{it} \quad (9)$$

where *TRD* is the trade (% of GDP), *URB* is the urbanization (percentage of total population), *GDP* is the GDP per capita (constant 2010 US$). ε_i is the error term.

Results and discussion of findings

The results in Table 1 show the smallest and largest mean values of EFP as 18.22 and 19.25 for Indonesia and Colombia, respectively. Considering the mean GDP values, Vietnam is the poorest country (6.774) and Turkey is the richest (9.069). Moreover, on the average, Vietnam has consumed more REN (3.939) than the remaining countries, while Egypt consumed the lowest (1.983). Finally, Vietnam has minimum NREN energy use (5.563), while South Africa has the maximum (7.989).

Table 2 provides enough evidence that CSD exist among the CIVETS countries. For this reason, the study considers unit root, cointegration, and estimation techniques that account for CSD.

Table 3 shows the result of the first-generation, along with the second-generation (CIPS) unit root tests. The four tests (LLC, IPS, and PP-Fisher) affirm that all the variables are I(1). Since these three tests are not robust amidst CSD, the results were complemented with the CIPS tests, to make up for the flaws of the three tests. The findings of the CIPS test revealed that all the variables are I(1). These findings give reason to proceed with the cointegration tests.

Table 4 shows the Pedroni cointegration test. The findings suggest that 6 statistics out of 11 statistics presented are significant at 1%. This confirms the presence of cointegration among the variables. The Johansen Fisher cointegration test in Table 5 is also in harmony with the results in Table 4.

Since both tests (Johansen Fisher and Pedroni) do not account for CSD, the Westerlund cointegration test provides a better option as the test gives robust estimates in the presence of CSD.

Table 1 Descriptive statistics

Countries	Statistics	EFP	GDP	NREN	REN	TRD	URB
Colombia	Mean	18.22	8.597	6.536	3.386	3.576	4.312
	Std.D	0.077	0.152	0.070	0.119	0.046	0.041
	Max	18.35	8.914	6.636	3.644	3.655	4.374
	Min	18.06	8.403	6.424	3.196	3.486	4.241
	Obs	25	25	25	25	25	25
Egypt	Mean	18.60	7.620	6.551	1.983	3.898	3.760
	Std.D	0.263	0.194	0.194	0.188	0.194	0.004
	Max	18.99	.881	6.815	2.285	4.272	3.772
	Min	18.21	7.338	6.292	1.714	3.608	3.753
	Obs	25	25	25	25	25	25
Indonesia	Mean	19.25	7.793	6.592	3.800	4.029	3.741
	Std.D	0.171	0.200	0.144	0.144	0.160	0.166
	Max	19.82	8.178	6.784	4.070	4.566	3.963
	Min	19.20	7.442	6.298	3.623	3.817	3.420
	Obs	25	25	25	25	25	25
South A	Mean	18.85	8.736	7.851	2.846	3.942	4.059
	Std.D	0.148	0.156	0.062	0.057	0.183	0.065
	Max	19.07	8.931	7.989	2.950	4.288	4.163
	Min	18.64	8.214	7.736	2.745	3.624	3.951
	Obs	25	25	25	25	25	25
Turkey	Mean	19.04	9.069	7.104	2.851	3.785	4.189
	Std.D	0.208	0.193	0.166	0.254	0.172	0.064
	Max	19.35	9.460	7.367	3.199	4.006	4.291
	Min	18.71	8.811	6.854	2.541	3.416	4.080
	Obs	25	25	25	25	25	25
Vietnam	Mean	18.32	6.774	6.032	3.939	4.724	3.245
	Std.D	0.396	0.403	0.341	0.262	0.304	0.153
	Max	18.89	7.364	6.506	4.331	5.133	3.499
	Min	17.70	6.071	5.563	3.549	4.192	3.008
	Obs	25	25	25	25	25	25
Panel	Mean	18.75	8.093	6.778	3.134	3.993	3.884
	Std.D	0.495	0.826	0.602	0.690	0.405	0.368
	Max	19.82	9.460	7.989	4.331	5.133	4.374
	Min	17.70	6.071	5.563	1.714	3.416	3.008
	Obs	150	150	150	150	150	150

Source: Author's computation

The group mean tests (Gt and Ga) and the panel mean tests (Pt and Pa) in Table 6 support a cointegrating relationship among the variables. See Table 7 for the effects of each of the variables on the dependent variable (EFP).

Table 2 Cross-sectional dependence tests

Test	Statistic	Probability
Breusch-Pagan LM	257.7847	0.0000
Pesaran scaled LM	44.32622	0.0000
Pesaran CD	15.82147	0.0000

Source: Author's computation

From the results in Table 7, NREN increases environmental degradation by about 57%. As earlier mentioned, NREN is the dominant energy source in these countries. The consumption of NREN energy is responsible for environmental deterioration in these countries. Some of the NREN sources consumed in these countries include coal, natural gas, crude oil, and uranium. NREN sources do not ensure environmental sustainability. These NREN sources cannot be readily replaced by natural means at a quick enough pace to keep

Table 3 Unit root tests

	EFP	NREN	GDP	REN	URB	TRD
Levels						
LLC	− 2.357	− 1.612	− 3.760	− 1.721	− 0.241	− 3.321
IPS	1.332	− 3.214	0.425	− 2.617	3.657	1.543
PP-FISHER	23.76	13.54	12.65	23.65	12.42	14.23
CIPS	− 1.546	− 0.342	− 2.153	− 1.598	− 0.129	− 2.154
1st difference						
LLC	− 8.435**	− 10.24**	− 14.87**	− 12.12**	− 13.65**	− 15.43**
IPS	− 7.237**	− 8.645**	− 9.342**	− 15.65**	− 9.342**	− 14.34**
PP-FISHER	109.3**	102.4**	112.3**	111.5**	101.1**	122.1**
CIPS	− 2.343**	− 4.536**	− 3.512**	− 4.645**	− 3.167**	− 3.456**

Source: Author's computation

** Significance at 1% level

up with consumption. This finding is in consonance with earlier studies that concentrated on emerging economies/developing economies. See, for instance, Zhang et al. (2019) and Oganesyan (2017) for BRICS, Muhammad (2019), Gorus and Aydin (2019), Gorus and Aslan (2019), and Al-Mulali and Che Sab (2018) for MENA, Ssali et al. (2019), Nathaniel and Iheonu (2019), and Esso and Keho (2016) for SSA, Sinha et al. (2019) and Sinha et al. (2017) for the Next-11countries, Dogan and Turkekul (2016) and Dogan and Ozturk (2017) for the United States, and Dogan and Seker (2016) for the European Union.

Findings further revealed that economic growth is not particularly harmful to the environment in these countries, rather it adds to environmental quality. However, the impact of economic growth on environmental quality is not significant. The insignificant influence of economic growth on environmental quality is consistent with the studies of Nathaniel et al. (2020) for MENA countries and Khan et al. (2020) for Pakistan, but contradicts those of Ulucak et al. (2020) for BRICS countries, Liu et al. (2020a, b) and Ahmed et al. (2020) for G7 countries.

On the other hand, the consumption of REN mitigates environmental degradation (though insignificantly). This points to the meager investment and inadequate usage of REN in these countries. This finding suggests that environmental quality could be enhanced if these countries invest and promote the usage of REN. The CIVETS countries, over the years, have concentrated more on how to enhance economic growth without paying adequate attention to the quality of their environment. These do not in any way suggest that these countries have not invested in REN, but the investment in REN is still meager, and its consumption remains inadequate. On the flipside, urbanization contributes about 0.20% to environmental degradation in the CIVETS countries. This is indeed revealing. Urbanization increases energy demand. Since NREN is mostly consumed by these countries, the tendency for energy consumption to add to environmental degradation abounds. This is the tale of the CIVETS countries. Policies are indeed needed to curb this upward surge in urbanization, since the demand for energy is not expected to decline any time soon.

Unlike energy consumption and urbanization, trade exacts no harmful impact on the environment. A 1% increase in trade is expected to increase environmental quality by 0.10%. This is an indication that the CIVETS countries are not involved in trade activities that deteriorate environmental quality. This outcome is consistent with the findings of Sinha et al. (2019) for both BRICS and N-11 countries.

Table 4 Panel cointegration test (Pedroni)

Statistics	Within-dimension (panel)		Between-dimension (group)
	Statistics	Weighted statistics	Statistics
V-statistic	− 0.7659	− 1.7795	
Rho-statistic	0.2061	− 0.2657	0.8978
PP-statistic	− 2.1902**	− 3.4240**	− 2.7277**
ADF-statistic	− 2.9382**	− 3.6081**	− 3.8527**

Source: Author's computation

** Significance at 1% level

Table 5 Panel Johansen Fisher cointegration test

Hypothesized No. of CE(s)	Trace test	Max-eigen test
None	278.3**	164.5**
At most 1	138.2**	86.24**
At most 2	69.63**	42.90**
At most 3	35.90**	24.07***
At most 4	22.53**	17.54
At most 5	23.25***	23.25***

Source: Author's computation

, * Significance at 1% and 5% level, respectively

Table 6 Panel cointegration test (Westerlund)

Statistic	Value	Robust *P* value
Gt	− 2.943***	0.040
Ga	− 2.538***	0.031
Pt	− 5.036**	0.000
Pa	− 3.123**	0.001

Source: Author's computation

, * Significance at 1% and 5% levels

For country-specific cases, NREN promotes environmental degradation in all the countries, but the situation is even more severe in Turkey. Studies like Pata (2018a), Karasoy (2019), and Pata (2018b) have confirmed the horrendous effects of NREN on environmental quality in Turkey. On the other hand, Román et al. (2018), Kurniawan et al. (2018), Shahbaz et al. (2019) and Al-Mulali et al. (2015a, b), Ibrahiem (2016), and Rafindadi and Usman (2019) have discovered a similar results for Colombia, Indonesia, Vietnam, Egypt, and South Africa, respectively. This confirms the negative impact of NREN on environmental quality and also justifies the ubiquitous calls for the consumption of REN in emerging economies like the CIVETS countries. Economic growth improves environmental quality in Colombia, South Africa, and Turkey, but not in Indonesia, Vietnam, and Egypt. This affirms that Colombia, South Africa, and Turkey are not growing at the expense of their environment, while growth is particularly harmful in the remaining countries. Earlier studies like Kurniawan and Managi (2018) and Alam et al. (2016) discovered that economic growth is not environmentally friendly in Indonesia.

Interestingly, REN consumption reduces environmental degradation insignificantly in Colombia, South Africa, Turkey, Indonesia, and Egypt. Pata (2018c) had earlier reported that REN was not at a desirable level to reduce environmental degradation in Turkey. This goes to show that investment in REN among these countries is still infinitesimal. REN investment in CIVETS countries has not yielded the desire impact, which is to reduce environmental deterioration. There is a dire need for the CIVETS countries to increase their investments in 'clean' energy sources in order to achieve sustainable growth amidst low emissions (Chen et al. 2019a; Ghazali and Ali 2019; Baloch et al. 2019a; Ma et al. 2019; Chen et al. 2019b; Baloch et al. 2019b).

Urbanization happens to be a significant problem in most of the counties; more severe in Indonesia, but less severe in Colombia. A 1% increase in urbanization reduces environmental quality by 0.50% in Egypt, 0.71% in Indonesia, 0.56% in South Africa, 0.33% in Turkey, and 0.20% in Vietnam. Indonesia, for instance, has experienced an unprecedented increase in urbanization over the years. More than one half of Indonesians settles in the urban areas (UNDP 2017). It has also been projected that coal (NREN) will be the major source of energy to meet the energy demand of the urban population in Indonesia mainly due to its large reserve (Kurniawan and Managi 2018). The same problem (urbanization) is witnessed in Vietnam where basic facilities and economic activities are concentrated in Ho Chi Minh and Hanoi City. Fan et al. (2019) discovered the same result for Vietnam, while Al-Mulali et al. (2015a) noted that urbanization, energy consumption, industrialization, and natural resource consumption are culpable for the increasing environmental pressure in Vietnam. Also, South Africa is the most urbanized country in SSA (Salahuddin et al. 2019). Recent studies like Salahuddin et al. (2019) and Sarkodie and Adams (2018) discovered that urbanization deteriorates the environment in South Africa. Trade increases environmental quality significantly in Egypt, Indonesia, and Turkey, insignificantly in Colombia and South Africa, but adds to environmental quality in Vietnam. This suggests that the Vietnamese government has been involved in harmful trade with its trading partners. This is in line with the findings of Shahbaz et al. (2019), Jha and Mani (2006), and Al-Mulali et al. (2015a) for Vietnam.

Since effect does not necessarily mean causation, the D-H Granger non-causality test, in Table 8, presents the direction of

Table 7 AMG estimate result

Dependent variable: *ln*EFP

Variables	Panel	Colombia	Egypt	Indonesia	South Africa	Turkey	Vietnam
lnNREN	0.579** (0.000)	0.505** (0.000)	0.715** (0.002)	0.327 (0.181)	0.558** (0.010)	1.034** (0.000)	0.335** (0.001)
*ln*GDP	− 0.046 (0.538)	− 0.254** (0.000)	0.124 (0.474)	0.066 (0.154)	− 0.054 (0.368)	− 0.281** (0.009)	0.121*** (0.057)
*ln*REN	− 0.048 (0.556)	− 0.001 (0.979)	− 0.125 (0.495)	− 0.118 (0.644)	− 0.201 (0.292)	− 0.048 (0.513)	− 0.385** (0.001)
*ln*TRD	− 0.100** (0.005)	− 0.143 (0.246)	− 0.180** (0.001)	− 0.087* (0.020)	− 0.027 (0.608)	− 0.191** (0.000)	0.029 (0.498)
*ln*URB	0.201** (0.000)	0.133 (0.423)	0.506* (0.020)	0.712** (0.000)	0.566** (0.004)	0.332** (0.002)	0.204* (0.062)
CONS.	15.63** (0.000)	17.40** (0.000)	13.20** (0.000)	16.51** (0.000)	15.42** (0.000)	14.62** (0.000)	16.63** (0.000)

Source: Author's computation

, * Significance at 1% and 5% levels

Table 8 D-H Granger non-causality test

Null hypothesis	W-bar	Z-bar	Probability
GDP ≠> EFP	2.482	0.223	0.823
EFP ≠> GDP	14.26	11.53	0.000
NREN ≠>EFP	1.969	− 0.269	0.787
EFP ≠> NREN	5.474	3.095	0.002
URB ≠>EFP	4.491	2.151	0.031
EFP ≠>URB	3.774	1.464	0.143
TRD ≠>EFP	1.633	− 0.591	0.554
EFP ≠>TRD	4.982	2.623	0.008
REN ≠>EFP	2.561	0.299	0.764
EFP ≠>REN	7.597	5.134	3.E-07
NREN ≠>GDP	9.415	6.879	6.E-12
GDP ≠>NREN	5.054	2.692	0.007
URB ≠>GDP	7.867	5.393	7.E-08
GDP ≠>URB	10.13	7.570	4.E-14
TRD ≠>GDP	10.90	8.309	0.000
GDP ≠>TRD	4.967	2.609	0.009
REN ≠>GDP	2.479	0.219	0.825
GDP ≠>REN	4.634	2.289	0.022
URB ≠>NREN	6.638	4.213	0.105
NREN ≠>URB	4.980	2.621	0.602
REN ≠>NREN	3.344	1.050	0.293
NREN ≠>REN	2.109	− 0.135	0.892
TRD ≠>URB	1.932	− 0.304	0.760
URB ≠>TRD	4.210	1.882	0.059
REN ≠>URB	2.835	0.562	0.573
URB ≠>REN	5.380	3.005	0.002
REN ≠>TRD	1.624	− 0.600	0.548
TRD ≠>REN	3.034	0.753	0.451

Source: Author's computation

Note: Lag order: 2. Probability values are computed using the default 1000 bootstrap replication. The symbol ≠> represents "does not homogeneously cause"

causality among the various variables. From the findings, EFP drives GDP, energy use, and trade, while urbanization drives REN and EFP. This points to the fact that urbanization is really a serious problem in these countries. This is a peculiar problem in emerging economies. At the initial stage of development, social amenities and other facilities that make life meaningful are mostly concentrated in the urban centers.

Interestingly, GDP drives energy use in the CIVETS countries. This result confirmed the growth-led energy consumption hypothesis in these countries. This complements the findings of Chen and Fang (2018), Kirikkaleli et al. (2018), and Nyasha et al. (2018) and calls for caution as regards the energy sources consumed in these countries. For growth to be sustainable, the energy source should be one that does not pollute the environment. A feedback causality was further discovered between trade and economic growth. This is an indication that

Table 9 Check for robustness

Variables	AMG	CCEMG	MG
*ln*NREN	0.579 (0.000)	0.422 (0.005)	0.438 (0.000)
*ln*GDP	− 0.046 (0.538)	− 0.124 (0.654)	− 0.546 (0.551)
*ln*REN	− 0.048 (0.556)	− 0.342 (0.581)	− 0.004 (0.432)
*ln*TRD	− 0.100 (0.005)	− 0.214 (0.049)	− 0.198 (0.031)
*ln*URB	0.201 (0.934)	1.342 (0.876)	0.453 (0.998)

Source: Author's computation. Note: *P* values in parentheses

trade is core among the variables that promote economic growth and advancement in these countries. The MG and the CCEMG estimator tests confirmed the robustness of the results in Table 8. See Table 9.

Controlling for CSD and endogeneity, results from the *MG* and *CCEMG* estimations reveal that NREN and trade exhibit statistically significant relationships at 1% and 5% levels, respectively. The coefficients of all the five variables are similar to those of the *AMG* in sign and magnitude. Hence, a similar interpretation holds.

Conclusion and policy directions

This study investigated the effect of renewable energy, urbanization, economic expansion, and trade on the ecological footprint in CIVETS countries by applying the augmented mean group estimator. With the evidence of CSD, the second generation unit root and cointegration tests were applied. Findings confirmed long run interaction among the variables. REN (though not significant), economic expansion, and trade reduce environmental degradation, while NREN and urbanization deteriorate the quality of the environment. Urbanization arises from discrepancies in development factors. These factors include household income, basic amenities, infrastructural provisions, etc. The inadequate provision of these factors in the rural areas will encourage urbanization. Therefore, to address this issue, the provision of basic infrastructures in the rural areas in the CIVETS countries will help mitigate the upward surge in urbanization and all the anomaly it creates. The consumption of NREN was the major contributor to environmental degradation. Policymakers in these countries should invest and encourage the consumption of REN (like solar, tide, wind, hydropower, geothermal, etc.). These REN sources are different from fossil fuels, because they are clean and low in emissions. An improved investment in environmentally friendly technologies will not only curtail emissions, but also enhance growth.

This study was conducted on a panel of CIVETS countries. The study was limited by data availability which informed the exclusion of some determinants of ecological footprint. The future research should be conducted on the European Union and BRICS countries and compare the findings to obtain more robust inferences which will promote policies that will aid the attainment of the SDGs by 2030.

References

Acaravci A, Ozturk I (2010) On the relationship between energy consumption, CO2 emissions and economic growth in Europe. Energy 35(12):5412–5420. https://doi.org/10.1016/j.energy.2010.07.009

Ahmad M, Zhao ZY, Li H (2019) Revealing stylized empirical interactions among construction sector, urbanization, energy consumption, economic growth and CO2 emissions in China. Sci Total Environ 657:1085–1098. https://doi.org/10.1016/j.scitotenv.2018.12.112

Ahmed Z, Zafar MW, Ali S (2020) Linking urbanization, human capital, and the ecological footprint in G7 countries: an empirical analysis. Sustain Cities Soc 55:102064. https://doi.org/10.1016/j.scs.2020.102064

Alam A, Azam M, Abdullah AB, Malik IA, Khan A, Hamzah TAAT et al (2015) Environmental quality indicators and financial development in Malaysia: unity in diversity. Environ Sci Pollut Res 22(11):8392–8404. https://doi.org/10.1007/s11356-014-3982-5

Alam MM, Murad MW, Noman AHM, Ozturk I (2016) Relationships among carbon emissions, economic growth, energy consumption and population growth: testing environmental Kuznets curve hypothesis for Brazil, China, India and Indonesia. Ecol Indic 70:466–479. https://doi.org/10.1016/j.ecolind.2016.06.043

Aliyu AK, Modu B, Tan CW (2018) A review of renewable energy development in Africa: a focus in South Africa, Egypt and Nigeria. Renew Sust Energ Rev 81:2502–2518. https://doi.org/10.1016/j.rser.2017.06.055

Al-Mulali U, Che Sab CNB (2018) Electricity consumption, CO2 emission, and economic growth in the Middle East. Energy Sources, Part B: Economics, Planning, and Policy 13(5):257–263. https://doi.org/10.1080/15567249.2012.658958

Al-Mulali U, Saboori B, Ozturk I (2015a) Investigating the environmental Kuznets curve hypothesis in Vietnam. Energy Policy 76:123–131. https://doi.org/10.1016/j.enpol.2014.11.019

Al-Mulali U, Weng-Wai C, Sheau-Ting L, Mohammed AH (2015b) Investigating the environmental Kuznets curve (EKC) hypothesis by utilizing the ecological footprint as an indicator of environmental degradation. Ecol Indic 48:315–323. https://doi.org/10.1016/j.ecolind.2014.08.029

Alola AA (2019a) The trilemma of trade, monetary and immigration policies in the United States: accounting for environmental sustainability. Sci Total Environ 658:260–267. https://doi.org/10.1016/j.scitotenv.2018.12.212

Alola AA (2019b) Carbon emissions and the trilemma of trade policy, migration policy and health care in the US. Carbon Manag:1–10. https://doi.org/10.1080/17583004.2019.1577180

Alola AA, Alola UV (2018) Agricultural land usage and tourism impact on renewable energy consumption among Coastline Mediterranean Countries. Energy Environ 29(8):1438–1454

Alola AA, Yalçiner K, Alola UV, Saint Akadiri S (2019) The role of renewable energy, immigration and real income in environmental sustainability target. Evidence from Europe largest states. Sci Total Environ 674:307–315. https://doi.org/10.1016/j.scitotenv.2019.04.163

Alshehry AS, Belloumi M (2015) Energy consumption, carbon dioxide emissions and economic growth: the case of Saudi Arabia. Renew Sustain Energy Rev 41:237–247. https://doi.org/10.1016/j.rser.2014.08.004

Alvarado R, Ponce P, Criollo A, Córdova K, Khan MK (2018) Environmental degradation and real per capita output: new evidence at the global level grouping countries by income levels. J Clean Prod 189:13–20. https://doi.org/10.1016/j.jclepro.2018.04.064

Andrés L, Padilla E (2018) Driving factors of GHG emissions in the EU transport activity. Transp Policy 61:60–74. https://doi.org/10.1016/j.tranpol.2017.10.008

Apergis N, Jebli MB, Youssef SB (2018) Does renewable energy consumption and health expenditures decrease carbon dioxide emissions? Evidence for sub-Saharan Africa countries. Renew Energy 127:1011–1016. https://doi.org/10.1016/j.renene.2018.05.043

Azizalrahman H (2019) A model for urban sector drivers of carbon emissions. Sustain Cities Soc 44:46–55. https://doi.org/10.1016/j.scs.2018.09.035

Balcilar M, Ozdemir ZA, Ozdemir H, Shahbaz M (2018) The renewable energy consumption and growth in the G-7 countries: evidence from historical decomposition method. Renew Energy 126:594–604. https://doi.org/10.1016/j.renene.2018.03.066

Baloch MA, Zhang J, Iqbal K, Iqbal Z (2019a) The effect of financial development on ecological footprint in BRI countries: evidence from panel data estimation. Environ Sci Pollut Res 26(6):6199–6208. https://doi.org/10.1007/s11356-018-3992-9

Baloch MA, Mahmood N, Zhang JW (2019b) Effect of natural resources, renewable energy and economic development on CO2 emissions in BRICS countries. Sci Total Environ 678:632–638. https://doi.org/10.1016/j.scitotenv.2019.05.028

Balsalobre-Lorente D, Shahbaz M, Roubaud D, Farhani S (2018) How economic growth, renewable electricity and natural resources contribute to CO2 emissions? Energy Policy 113:356–367. https://doi.org/10.1016/j.enpol.2017.10.050

Bao C, Xu M (2019) Cause and effect of renewable energy consumption on urbanization and economic growth in China's provinces and regions. J Clean Prod 231:483–493. https://doi.org/10.1016/j.jclepro.2019.05.191

Bekun FV, Alola AA, Sarkodie SA (2019) Toward a sustainable environment: Nexus between CO2 emissions, resource rent, renewable and nonrenewable energy in 16-EU countries. Sci Total Environ 657:1023–1029. https://doi.org/10.1016/j.scitotenv.2018.12.104

Bento JPC, Moutinho V (2016) CO2 emissions, non-renewable and renewable electricity production, economic growth, and international trade in Italy. Renew Sust Energ Rev 55:142–155. https://doi.org/10.1016/j.rser.2015.10.151

Bond S, & Eberhardt M (2013) Accounting for unobserved heterogeneity in panel time series models. Nuffield College, University of Oxford, mimeo

Boutabba MA, Diaw D, Lessoua A (2018) Environment-energy-growth nexus in sub-Saharan Africa: the role of intermediate goods. Int Econ 156:254–267. https://doi.org/10.1016/j.inteco.2018.04.003

Chang T, Gupta R, Inglesi-Lotz R, Simo-Kengne B, Smithers D, Trembling A (2015) Renewable energy and growth: evidence from heterogeneous panel of G7 countries using Granger causality. Renew Sust Energ Rev 52:1405–1412. https://doi.org/10.1016/j.rser.2015.08.022

Chen Y, Fang Z (2018) Industrial electricity consumption, human capital investment and economic growth in Chinese cities. Econ Model 69:205–219. https://doi.org/10.1016/j.econmod.2017.09.021

Chen Y, Wang Z, Zhong Z (2019a) CO2 emissions, economic growth, renewable and non-renewable energy production and foreign trade in China. Renew Energy 131:208–216. https://doi.org/10.1016/j.renene.2018.07.047

Chen Y, Zhao J, Lai Z, Wang Z, Xia H (2019b) Exploring the effects of economic growth, and renewable and non-renewable energy consumption on China's CO2 emissions: evidence from a regional panel analysis. Renew Energy 140:341–353. https://doi.org/10.1016/j.renene.2019.03.058

Danish Z, Wang Z (2019) Does biomass energy consumption help to control environmental pollution? Evidence from BRICS countries. Sci Total Environ 670:1075–1083. https://doi.org/10.1016/j.scitotenv.2019.03.268

de Souza ES, de Souza Freire F, Pires J (2018) Determinants of CO 2 emissions in the MERCOSUR: the role of economic growth, and renewable and non-renewable energy. Environ Sci Pollut Res 25(21):20769–20781. https://doi.org/10.1007/s11356-018-2231-8

Destek MA, Okumus I (2019) Does pollution haven hypothesis hold in newly industrialized countries? Evidence from ecological footprint. Environ Sci Pollut Res:1–7. https://doi.org/10.1007/s11356-019-05614-z

Destek MA, Sarkodie SA (2019) Investigation of environmental Kuznets curve for ecological footprint: the role of energy and financial development. Sci Total Environ 650:2483–2489. https://doi.org/10.1016/j.scitotenv.2018.10.017

Destek MA, Ulucak R, Dogan E (2018) Analyzing the environmental Kuznets curve for the EU countries: the role of ecological footprint. Environ Sci Pollut Res 25(29):29387–29396. https://doi.org/10.1007/s11356-018-2911-4

Dogan E, Ozturk I (2017) The influence of renewable and non-renewable energy consumption and real income on CO2 emissions in the USA: evidence from structural break tests. Environ Sci Pollut Res 24(11):10846–10854. https://doi.org/10.1007/s11356-017-8786-y

Dogan E, Seker F (2016) Determinants of CO2 emissions in the European Union: the role of renewable and non-renewable energy. Renew Energy 94:429–439. https://doi.org/10.1016/j.renene.2016.03.078

Dogan E, Turkekul B (2016) CO 2 emissions, real output, energy consumption, trade, urbanization and financial development: testing the EKC hypothesis for the USA. Environ Sci Pollut Res 23(2):1203–1213. https://doi.org/10.1007/s11356-015-5323-8

Dogan E, Taspinar N, Gokmenoglu KK (2019) Determinants of ecological footprint in MINT countries. Energy Environ: 0958305X19834279. https://doi.org/10.1177/0958305X19834279

Dong K, Sun R, Li H, Liao H (2018) Does natural gas consumption mitigate CO2 emissions: testing the environmental Kuznets curve hypothesis for 14 Asia-Pacific countries. Renew Sust Energ Rev 94:419–429. https://doi.org/10.1016/j.rser.2018.06.026

Dumitrescu EI, Hurlin C (2012) Testing for Granger non-causality in heterogeneous panels. Econ Model 29(4):1450–1460. https://doi.org/10.1016/j.econmod.2012.02.014

Emir F, Bekun FV (2019) Energy intensity, carbon emissions, renewable energy, and economic growth nexus: new insights from Romania. Energy Environ 30(3):427–443. https://doi.org/10.1177/0958305X18793108

Esso LJ, Keho Y (2016) Energy consumption, economic growth and carbon emissions: cointegration and causality evidence from selected African countries. Energy 114:492–497. https://doi.org/10.1016/j.energy.2016.08.010

Fan P, Ouyang Z, Nguyen DD, Nguyen TTH, Park H, Chen J (2019) Urbanization, economic development, environmental and social changes in transitional economies: Vietnam after Doimoi. Landsc Urban Plan 187:145–155. https://doi.org/10.1016/j.landurbplan.2018.10.014

Farhani S, Ozturk I (2015) Causal relationship between CO 2 emissions, real GDP, energy consumption, financial development, trade openness, and urbanization in Tunisia. Environ Sci Pollut Res 22(20):15663–15676. https://doi.org/10.1007/s11356-015-4767-1

Frondel M, Ritter N, Schmidt CM, Vance C (2010) Economic impacts from the promotion of renewable energy technologies: the German experience. Energy Policy 38(8):4048–4056. https://doi.org/10.1016/j.enpol.2010.03.029

Ghazali A, Ali G (2019) Investigation of key contributors of CO2 emissions in extended STIRPAT model for newly industrialized countries: a dynamic common correlated estimator (DCCE) approach. Energy Rep 5:242–252. https://doi.org/10.1016/j.egyr.2019.02.006

Global Footprint Network (2019) Global Footprint Network. https://www.footprintnetwork.org/our-work/ecological-footprint/(2019), Accessed 1st May 2019

Gorus MS, Aslan M (2019) Impacts of economic indicators on environmental degradation: evidence from MENA countries. Renew Sust Energ Rev 103:259–268. https://doi.org/10.1016/j.rser.2018.12.042

Gorus MS, Aydin M (2019) The relationship between energy consumption, economic growth, and CO2 emission in MENA countries: causality analysis in the frequency domain. Energy 168:815–822. https://doi.org/10.1016/j.energy.2018.11.139

Hanif I (2018a) Energy consumption habits and human health nexus in sub-Saharan Africa. Environ Sci Pollut Res 25(22):21701–21712. https://doi.org/10.1007/s11356-018-2336-0

Hanif I (2018b) Impact of economic growth, nonrenewable and renewable energy consumption, and urbanization on carbon emissions in sub-Saharan Africa. Environ Sci Pollut Res 25(15):15057–15067. https://doi.org/10.1007/s11356-018-1753-4

Hanif I (2018c) Impact of fossil fuels energy consumption, energy policies, and urban sprawl on carbon emissions in East Asia and the Pacific: a panel investigation. Energy Strategy Rev 21:16–24. https://doi.org/10.1016/j.esr.2018.04.006

Hanif I, Raza SMF, Gago-de-Santos P, Abbas Q (2019) Fossil fuels, foreign direct investment, and economic growth have triggered CO2 emissions in emerging Asian economies: some empirical evidence. Energy 171:493–501. https://doi.org/10.1016/j.energy.2019.01.011

Hassan ST, Xia E, Khan NH, Shah SMA (2019) Economic growth, natural resources, and ecological footprints: evidence from Pakistan. Environ Sci Pollut Res 26(3):2929–2938. https://doi.org/10.1007/s11356-018-3803-3

Hatzigeorgiou E, Polatidis H, Haralambopoulos D (2011) CO2 emissions, GDP and energy intensity: a multivariate cointegration and causality analysis for Greece, 1977–2007. Appl Energy 88(4):1377–1385. https://doi.org/10.1016/j.apenergy.2010.10.008

Heidari H, Katircioğlu ST, Saeidpour L (2015) Economic growth, CO2 emissions, and energy consumption in the five ASEAN countries. Int J Electr Power Energy Syst 64:785–791. https://doi.org/10.1016/j.ijepes.2014.07.081

Ho SY, Iyke BN (2019) Trade openness and carbon emissions: evidence from central and eastern European countries. Rev Econ 70(1):41–67. https://doi.org/10.1515/roe-2018-0001

Ibrahiem DM (2016) Environmental Kuznets curve: an empirical analysis for carbon dioxide emissions in Egypt. Int J Green Econ 10(2):136–150. https://doi.org/10.1504/IJGE.2016.080554

IEA (2016) Energy policies of IEA countries: Turkey 2016. OECD. https://doi.org/10.1787/9789264266698-en

IEA (2017) World Energy Outlook: Energy Subsidies. https://www.iea.org/weo/energysubsidies. Accessed 14 Sept 2016

Im KS, Pesaran MH, Shin Y (2003) Testing for unit roots in heterogeneous panels. J Econ 115(1):53–74. https://doi.org/10.1016/S0304-4076(03)00092-7

Jha S, & Mani M (2006) Trade liberalization and the environment in Vietnam. The World Bank

Karasoy A (2019) Drivers of carbon emissions in Turkey: considering asymmetric impacts. Environ Sci Pollut Res 26(9):9219–9231. https://doi.org/10.1007/s11356-019-04354-4

Katircioğlu S, Katircioğlu S (2018) Testing the role of urban development in the conventional environmental Kuznets curve: evidence from

Turkey. Appl Econ Lett 25(11):741–746. https://doi.org/10.1080/13504851.2017.1361004
Khan MK, Khan MI, Rehan M (2020) The relationship between energy consumption, economic growth and carbon dioxide emissions in Pakistan. Financial Innov 6(1):1–13. https://doi.org/10.1186/s40854-019-0162-0
Khoshnevis Yazdi S, Ghorchi Beygi E (2018) The dynamic impact of renewable energy consumption and financial development on CO2 emissions: For selected African countries. Energy Sources, Part B: Economics, Planning, and Policy 13(1):13–20
Kirikkaleli D, Sokri A, Candemir M, Ertugrul HM (2018) Panel cointegration: long-run relationship between internet, electricity consumption and economic growth. Evidence from OECD countries. Investig Econ 77(303):161–176
Kraft J, Kraft A (1978) On the relationship between energy and GNP. J Energy Dev:401–403
Kurniawan R, Managi S (2018) Coal consumption, urbanization, and trade openness linkage in Indonesia. Energy Policy 121:576–583. https://doi.org/10.1016/j.enpol.2018.07.023
Kurniawan R, Sugiawan Y, Managi S (2018) Cleaner energy conversion and household emission decomposition analysis in Indonesia. J Clean Prod 201:334–342. https://doi.org/10.1016/j.jclepro.2018.08.051
Lau LS, Yii KJ, Lee CY, Chong YL, Lee EH (2018) Investigating the determinants of renewable energy consumption in Malaysia: an ARDL approach. Int J Business Soc 19(3)
Levin A, Lin CF, Chu CSJ (2002) Unit root tests in panel data: asymptotic and finite sample properties. J Econ 108(1):1–24. https://doi.org/10.1016/S0304-4076(01)00098-7
Li S, Zhou C, Wang S, Hu J (2018) Dose urban landscape pattern affect CO2 emission efficiency? Empirical evidence from megacities in China. J Clean Prod 203:164–178. https://doi.org/10.1016/j.jclepro.2018.08.194
Lin D, Wackernagel M, Galli A, Kelly R (2015) Ecological footprint: informative and evolving–a response to van den Bergh and Grazi (2014). Ecol Indic 58:464–468. https://doi.org/10.1016/j.ecolind.2015.05.001
Liu JL, Ma CQ, Ren YS, Zhao XW (2020a) Do real output and renewable energy consumption affect CO2 emissions? Evidence for selected BRICS countries. Energies 13(4):960. https://doi.org/10.3390/en13040960
Liu M, Ren X, Cheng C, Wang Z (2020b) The role of globalization in CO2 emissions: a semi-parametric panel data analysis for G7. Sci Total Environ 137379. https://doi.org/10.1016/j.scitotenv.2020.137379
Luqman M, Ahmad N, Bakhsh K (2019) Nuclear energy, renewable energy and economic growth in Pakistan: evidence from non-linear autoregressive distributed lag model. Renew Energy 139:1299–1309. https://doi.org/10.1016/j.renene.2019.03.008
Lv Z, Xu T (2019) Trade openness, urbanization and CO2 emissions: dynamic panel data analysis of middle-income countries. J Int Trade Econ Dev 28(3):317–330. https://doi.org/10.1080/09638199.2018.1534878
Ma X, Wang C, Dong B, Gu G, Chen R, Li Y, Zou H, Zhang W, Li Q (2019) Carbon emissions from energy consumption in China: its measurement and driving factors. Sci Total Environ 648:1411–1420. https://doi.org/10.1016/j.scitotenv.2018.08.183
Marques AC, Fuinhas JA (2012) Is renewable energy effective in promoting growth? Energy Policy 46:434–442. https://doi.org/10.1016/j.enpol.2012.04.006
Mohamed H, Jebli MB, Youssef SB (2019) Renewable and fossil energy, terrorism, economic growth, and trade: evidence from France. Renew Energy 139:459–467. https://doi.org/10.1016/j.renene.2019.02.096
Moutinho V, Madaleno M, Inglesi-Lotz R, Dogan E (2018) Factors affecting CO2 emissions in top countries on renewable energies: a LMDI decomposition application. Renew Sust Energ Rev 90:605–622. https://doi.org/10.1016/j.rser.2018.02.009
Muhammad B (2019) Energy consumption, CO2 emissions and economic growth in developed, emerging and Middle East and North Africa countries. Energy. https://doi.org/10.1016/j.energy.2019.03.126
Muhammad S, Qazi Muhammad AH, & Aviral Kumar T (2013) Economic growth, energy consumption, financial development, international trade and CO2 emissions, in Indonesia. https://doi.org/10.1016/j.rser.2013.04.009
Mutascu M (2016) A bootstrap panel Granger causality analysis of energy consumption and economic growth in the G7 countries. Renew Sust Energ Rev 63:166–171. https://doi.org/10.1016/j.rser.2016.05.055
Nathaniel SP (2019) Modelling urbanization, trade flow, economic growth and energy consumption with regards to the environment in Nigeria. Geo J:1–15. https://doi.org/10.1007/s10708-019-10034-0
Nathaniel SP, Iheonu CI (2019) Carbon dioxide abatement in Africa: the role of renewable and non-renewable energy consumption. Sci Total Environ 679:337–345. https://doi.org/10.1016/j.scitotenv.2019.05.011
Nathaniel S, Nwodo O, Adediran A, Sharma G, Shah M, Adeleye N (2019) Ecological footprint, urbanization, and energy consumption in South Africa: including the excluded. Environ Sci Pollut Res 26:1–12. https://doi.org/10.1007/s11356-019-05924-2
Nathaniel S, Anyanwu O, Shah M (2020) Renewable energy, urbanization, and ecological footprint in the Middle East and North Africa region. Environ Sci Pollut Res:1–13. https://doi.org/10.1007/s11356-020-08017-7
Nyasha S, Gwenhure Y, Odhiambo NM (2018) Energy consumption and economic growth in Ethiopia: a dynamic causal linkage. Energy Environ 29(8):1393–1412. https://doi.org/10.1177/0958305X18779574
Oganesyan M (2017) Carbon emissions, energy consumption and economic growth in the BRICS. https:// urn:nbn:se:hj:diva-35891
Ozcan B, Ozturk I (2019) Renewable energy consumption-economic growth nexus in emerging countries: a bootstrap panel causality test. Renew Sust Energ Rev 104:30–37. https://doi.org/10.1016/j.rser.2019.01.020
Ozcan B, Apergis N, Shahbaz M (2018) A revisit of the environmental Kuznets curve hypothesis for Turkey: new evidence from bootstrap rolling window causality. Environ Sci Pollut Res 25(32):32381–32394. https://doi.org/10.1007/s11356-018-3165-x
Ozturk I (2017) The dynamic relationship between agricultural sustainability and food-energy-water poverty in a panel of selected sub-Saharan African countries. Energy Policy 107:289–299. https://doi.org/10.1016/j.enpol.2017.04.048
Ozturk I, Acaravci A (2010) CO2 emissions, energy consumption and economic growth in Turkey. Renew Sust Energ Rev 14(9):3220–3225. https://doi.org/10.1016/j.rser.2010.07.005
Panayotou T (1993) Empirical tests and policy analysis of environmental degradation at different stages of economic development (No. 992927783402676). International Labour Organization
Pata UK (2018a) The effect of urbanization and industrialization on carbon emissions in Turkey: evidence from ARDL bounds testing procedure. Environ Sci Pollut Res 25(8):7740–7747. https://doi.org/10.1007/s11356-017-1088-6
Pata UK (2018b) The influence of coal and noncarbohydrate energy consumption on CO2 emissions: revisiting the environmental Kuznets curve hypothesis for Turkey. Energy 160:1115–1123. https://doi.org/10.1016/j.energy.2018.07.095

Pata UK (2018c) Renewable energy consumption, urbanization, financial development, income and CO2 emissions in Turkey: testing EKC hypothesis with structural breaks. J Clean Prod 187:770–779. https://doi.org/10.1016/j.jclepro.2018.03.236
Payne JE (2010) A survey of the electricity consumption-growth literature. Appl Energy 87(3):723–731. https://doi.org/10.1016/j.apenergy.2009.06.034
Pedroni P (1999) Critical values for cointegration tests in heterogeneous panels with multiple regressors. Oxf Bull Econ Stat 61(S1):653–670. https://doi.org/10.1111/1468-0084.0610s1653
Pesaran MH (2007) A simple panel unit root test in the presence of cross-section dependence. J Appl Econ 22(2):265–312. https://doi.org/10.1002/jae.951
Rafindadi AA, Usman O (2019) Globalization, energy use, and environmental degradation in South Africa: startling empirical evidence from the Maki-cointegration test. J Environ Manag 244:265–275. https://doi.org/10.1016/j.jenvman.2019.05.048
Rashid A, Irum A, Malik IA, Ashraf A, Rongqiong L, Liu G et al (2018) Ecological footprint of Rawalpindi; Pakistan's first footprint analysis from urbanization perspective. J Clean Prod 170:362–368. https://doi.org/10.1016/j.jclepro.2017.09.186
Rasoulinezhad E, Saboori B (2018) Panel estimation for renewable and non-renewable energy consumption, economic growth, CO2 emissions, the composite trade intensity, and financial openness of the commonwealth of independent states. Environ Sci Pollut Res 25(18):17354–17370. https://doi.org/10.1007/s11356-018-1827-3
Rauf A, Zhang J, Li J, Amin W (2018) Structural changes, energy consumption and carbon emissions in China: empirical evidence from ARDL bound testing model. Struct Chang Econ Dyn 47:194–206. https://doi.org/10.1016/j.strueco.2018.08.010
Román R, Cansino JM, Rodas JA (2018) Analysis of the main drivers of CO2 emissions changes in Colombia (1990–2012) and its political implications. Renew Energy 116:402–411. https://doi.org/10.1016/j.renene.2017.09.016
Saboori B, Sulaiman J (2013) CO2 emissions, energy consumption and economic growth in Association of Southeast Asian Nations (ASEAN) countries: A cointegration approach. Energy 55:813–822
Saidi H, El Montasser G, & Ajmi N (2018) Renewable Energy, Quality of Institutions and Economic Growth in MENA Countries: a Panel Cointegration Approach (No. 84055). University Library of Munich, Germany. https://mpra.ub.uni-muenchen.de/id/eprint/84055
Saint Akadiri S, Alkawfi MM, Uğural S, Akadiri AC (2019) Towards achieving environmental sustainability target in Italy. The role of energy, real income and globalization. Sci Total Environ 671:1293–1301. https://doi.org/10.1016/j.scitotenv.2019.03.448
Salahuddin M, Gow J, Ali MI, Hossain MR, Al-Azami KS, Akbar D, Gedikli A (2019) Urbanization-globalization-CO2 emissions nexus revisited: empirical evidence from South Africa. Heliyon 5(6):e01974. https://doi.org/10.1016/j.heliyon.2019.e01974
Sarkodie SA (2018) The invisible hand and EKC hypothesis: what are the drivers of environmental degradation and pollution in Africa? Environ Sci Pollut Res 25(22):21993–22022. https://doi.org/10.1007/s11356-018-2347-x
Sarkodie SA, Adams S (2018) Renewable energy, nuclear energy, and environmental pollution: accounting for political institutional quality in South Africa. Sci Total Environ 643:1590–1601. https://doi.org/10.1016/j.scitotenv.2018.06.320
Sebri M, Ben-Salha O (2014) On the causal dynamics between economic growth, renewable energy consumption, CO2 emissions and trade openness: Fresh evidence from BRICS countries. Renew Sust Energ Rev 39:4–23
Shafiei S, Salim RA (2014) Non-renewable and renewable energy consumption and CO2 emissions in OECD countries: a comparative analysis. Energy Policy 66:547–556. https://doi.org/10.1016/j.enpol.2013.10.064
Shahbaz M, Sinha A (2019) Environmental Kuznets curve for CO2 emissions: a literature survey. J Econ Stud 46(1):106–168. https://doi.org/10.1108/JES-09-2017-0249
Shahbaz M, Haouas I, Van Hoang TH (2019) Economic growth and environmental degradation in Vietnam: is the environmental Kuznets curve a complete picture? Emerg Mark Rev 38:197–218. https://doi.org/10.1016/j.ememar.2018.12.006
Sharif A, Raza SA, Ozturk I, Afshan S (2019) The dynamic relationship of renewable and nonrenewable energy consumption with carbon emission: a global study with the application of heterogeneous panel estimations. Renew Energy 133:685–691. https://doi.org/10.1016/j.renene.2018.10.052
Sinha A, Gupta M, Shahbaz M, Sengupta T (2019) Impact of corruption in public sector on environmental quality: implications for sustainability in BRICS and next 11 countries. J Clean Prod 232:1379–1393. https://doi.org/10.1016/j.jclepro.2019.06.066
Sinha A, Shahbaz M, Balsalobre D (2017) Exploring the relationship between energy usage segregation and environmental degradation in N-11 countries. J Clean Prod 168:1217–1229
Solarin SA, Al-Mulali U (2018) Influence of foreign direct investment on indicators of environmental degradation. Environ Sci Pollut Res 25(25):24845–24859. https://doi.org/10.1007/s11356-018-2562-5
Ssali MW, Du J, Mensah IA, Hongo DO (2019) Investigating the nexus among environmental pollution, economic growth, energy use, and foreign direct investment in 6 selected sub-Saharan African countries. Environ Sci Pollut Res 26(11):11245–11260. https://doi.org/10.1007/s11356-019-04455-0
Tiba S, Omri A (2017) Literature survey on the relationships between energy, environment and economic growth. Renew Sust Energ Rev 69:1129–1146. https://doi.org/10.1016/j.rser.2016.09.113
Turkish Statistical Institute (2018) Greenhouse Gas Emissions Statistics, 2016. Retrieved August 8, 2018, from http://www.turkstat.gov.tr/PreHaberBultenleri.do;jsessionid=6h2ybpyZZPplp0972xt?TsZXg9GBntVP2lSF3zKWTZ8T16hTlDJL1!1771578339?id=27675
Ulucak R, Khan SUD (2020) Determinants of the ecological footprint: role of renewable energy, natural resources, and urbanization. Sustain Cities Soc 54:101996. https://doi.org/10.1016/j.scs.2019.101996
Ulucak R, Khan SUD, Baloch MA, Li N (2020) Mitigation pathways toward sustainable development: is there any trade-off between environmental regulation and carbon emissions reduction? Sustain Dev. https://doi.org/10.1002/sd.2032
UNDP (2017) World population prospects: the 2017 revision, New York
Wang J, Dong K (2019) What drives environmental degradation? Evidence from 14 sub-Saharan African countries. Sci Total Environ 656:165–173. https://doi.org/10.1016/j.scitotenv.2018.11.354
Wang S, Wang J, Li S, Fang C, Feng K (2019) Socioeconomic driving forces and scenario simulation of CO2 emissions for a fast-developing region in China. J Clean Prod 216:217–229. https://doi.org/10.1016/j.jclepro.2019.01.143
Westerlund J (2007) Testing for error correction in panel data. Oxf Bull Econ Stat 69(6):709–748. https://doi.org/10.1111/j.1468-0084.2007.00477.x
World Bank (2017) World Bank Development Indicators database (online) available at https://data.worldbank.org/. Accessed 10 Oct 2016
World Bank (2018) World Bank Development Indicators database (online) available at https://data.worldbank.org/. Accessed 24 Oct 2018

Yang L, Xia H, Zhang X, Yuan S (2018) What matters for carbon emissions in regional sectors? A China study of extended STIRPAT model. J Clean Prod 180:595–602. https://doi.org/10.1016/j.jclepro.2018.01.116

Zafar MW, Shahbaz M, Hou F, Sinha A (2019) From nonrenewable to renewable energy and its impact on economic growth: the role of research & development expenditures in Asia-Pacific Economic Cooperation countries. J Clean Prod 212:1166–1178. https://doi.org/10.1016/j.jclepro.2018.12.081

Zhang Z, Xi L, Bin S, Yuhuan Z, Song W, Ya L et al (2019) Energy, CO2 emissions, and value added flows embodied in the international trade of the BRICS group: a comprehensive assessment. Renew Sust Energ Rev 116:109432. https://doi.org/10.1016/j.rser.2019.109432

Zhou C, Wang S, Feng K (2018) Examining the socioeconomic determinants of CO2 emissions in China: a historical and prospective analysis. Resour Conserv Recycl 130:1–11. https://doi.org/10.1016/j.resconrec.2017.11.007

Zhu H, Xia H, Guo Y, Peng C (2018) The heterogeneous effects of urbanization and income inequality on CO 2 emissions in BRICS economies: evidence from panel quantile regression. Environ Sci Pollut Res 25(17):17176–17193. https://doi.org/10.1007/s11356-018-1900-y