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Modelling urbanization, trade flow, economic growth and energy consumption with regards to the environment in Nigeria

Solomon Prince Nathaniel

Abstract This study tries to model urbanization, trade flow and energy consumption with regards to the environment in Nigeria relying on the STIRPAT model with data spanning 1980Q1–2016Q4. The Zivot and Andrews (J Bus Econ Stat 10(3):251–270, 1992) test affirm that the variables are trended but stationary after first difference. The ARDL bounds test and the Bayer and Hanck (J Time Ser Anal 34(1):83–95, 2013) cointegration tests confirm a long run relationship among the variables. Findings reveal that urbanization and energy consumption are the major drivers of CO_2 emissions in both time periods, while trade performs the opposite. Also, a unidirectional causality exists from urbanization and its square to carbon emissions. This clearly indicates that urbanization causes environmental degradation. Therefore, policies to tackle energy poverty and also make it clean, minimize urban anomalies and enhance sustainable growth were suggested.

Keywords Urbanization · Energy consumption · STIRPAT · ARDL · Nigeria

S. P. Nathaniel (✉)
University of Lagos, Akoka, Nigeria
e-mail: nathaniel_solomon21@yahoo.com

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Introduction

Climate change is like a rain that falls on everyone's roof. Every nation have tasted the bitter fruit in one way or the other. Income, growth and stages of development do not exempt countries from the negative effects of climate change. The world has a big task in hand, that task, is how to minimize the horrendous effects of climate change. It has remained the most significant and potent menace facing humanity right from the turn of the 21st century. Climate change is majorly driven by global warming, and CO_2 is the major contributor to global warming (Lv and Xu 2018; Liu and Xiao 2018; Bong et al. 2017). Sequel to this, a plethora of studies have been dedicated to CO_2 emissions determinants (Gökmenoglu and Taspinar 2016; Green and Stern 2017; Lau et al. 2014; Ouyang and Lin 2015; Sharma 2011; Ahmed and Long 2012; Iwata et al. 2012; Dogan and Seker 2016; Shahbaz et al. 2013; Akbostancı et al. 2011; Andersson and Karpestam 2013; Balogh and Jámbor 2017). Studies have affirmed that factors like energy consumption, economic growth are the chief causes of CO_2 emissions (Ito 2017; Wang et al. 2017a). Worthy of note is that, developing countries (Nigeria inclusive) are not among the highest emitters, yet they are not spared from the aftermath of this emission. China overtook USA in 2005 to become the world's biggest emitter of CO_2 (Liu and Xiao 2018). Meanwhile, as countries become urbanized and more open to trade, it is bound to tell negatively on the environment in terms of increase in emissions. This is the tale of most developing countries. Simply put, trade and urbanization deteriorate the environment as confirmed by Al-Mulali et al. (2015), Ertugrul et al. (2016), Adams and Klobodu (2017), Farhani and Ozturk (2015) and Dogan and Turkekul (2016). Nevertheless, consensus is yet to be reached regarding the magnitude of their impact and actual direction of causality despite the plethora of studies dedicated to this purpose. Many factors could have contributed to this. Development and income level, methodological differences, nature of data, inability to consider the long-and short-term of both variables on CO_2 emissions could be the causes for these discrepancies.

According to the EIA (2013), developing countries emission, by 2040, is expected to be 127% higher compared to that of more advanced economies. If this is anything to go by, then it is germane to explore and also understand the determinants of CO_2 emissions in Nigeria with a view to suggesting possible policy directions to mitigate it and enhance sustainable growth, since Nigeria is among the most populated developing countries of the world. This was the motivation for the study. Urbanization is a serious problem in Nigeria owing to energy and infrastructural poverty in the rural areas. An increase in economic activities and the availability of industries in the urban centres (e.g., Lagos and Port Harcourt) have encouraged rural–urban migration. The urban growth rate in Lagos is 5.8% (Aliyu and Amadu 2017). The resultant increase will necessitate increase in demand for energy and this will make emissions inevitable since the country's energy source(s) is not renewable. The rise in CO_2 emissions directly affect humans and indirectly affect their livelihood (Heil and Selden 2001). Nigeria also have a population of about 187 million people (NPC 2017) which makes her the most populated country in Africa. For a developing country, like Nigeria, to have more than 60% of its population being in the working population, is a good tale in relation to production, labour availability amongst others, but on the flip side, this may not be the same for environmental quality. The country has also be open to trade over the years. As at September, 2018, the country's trade surplus was 805.2 billion Naira compared to 467.7 billion in 2017 as reported by the Central Bank of Nigeria. But, is the country's trade environmentally friendly? Has the country's population impacted negatively on the environment? Is it possible for the country to grow without degrading the environment? These and other germane questions the study tried to provide answers to.

There is a dearth of literature in this area of the study, especially for Nigeria which should be a potential candidate for such study. Only one study by Ali et al. (2016) was discovered in the literature for the case of Nigeria. Ali et al. (2016) depended on the Stochastic Impact by Regression on Population, Affluence and Technology (STIRPAT) model to understudy the relationship among carbon emission, urbanization and economic growth. They rely on ARDL model, neglecting the possibility of a structural breakpoint in the data structure knowing fully well that environmental actions and policies in Nigeria have never been linear. The study also neglected causal test and failed to introduce a quadratic term for the urbanization variable in model.

This study adds to the literature by introducing the Zivot and Andrews (1992) tests which improved upon the more maligned ADF and PP test on account of their low explanatory power and inability to account for breaks in the series. The Bayer and Hanck (2013) combined cointegration and the ARDL bounds tests were used to ascertain the long-run relationship. The square of urbanization was introduced to augment the STIRPAT model, a phenomenon that was hardly considered by many previous studies. This is the first study in Nigeria to incorporate the square of urbanization into the STIRPAT model, as the author is not aware of any study in Nigeria in this regard. The square of urbanization will provide insights on how an increase or decrease in urbanization rate affects carbon emissions (our proxy for environmental quality).

In this study, Second section concentrates on literature review. Third section presents the data description and methodology. Fourth section shows the technique of estimation. Results are presented and discussed in fifth section. Sixth section gives conclusion, policy implication and policy direction.

Literature review

The literature is by no means in shut of studies that relate either energy consumption or urbanization to environmental quality. Most of the studies have achieved this by adopting the STIRPAT framework.

Mikayilov et al. (2018) examined the effect of economic growth on the environment in Azerbaijan from 1992 to 2013. The ARDL results, complemented with the Fully Modified OLS, confirmed that economic growth is one of the major drivers of environmental degradation in Azerbaijan. Nilrit et al. (2017) investigated the role of urbanization and energy use on CO_2 emissions in Thailand relying on time series data spanning 1971–2010. Apart from discovering a weak correlation between urbanization and CO_2 emissions, technology and energy consumption were found to increase CO_2 emissions in both the short and long run periods. Saidi and Mbarek (2017) examined the impact of trade and urbanization of CO_2 emissions in nineteen (19) emerging countries from 1990 to 2013 using the system GMM approach. The study failed to establish the EKC hypothesis for all the models estimated. Findings revealed that income increases emissions. Financial development and urbanization abate CO_2 emissions. Azizalrahman (2019) investigated the link between urbanization and carbon emissions for lower, middle and high-income countries relying mainly on secondary data spanning 1973–2013. The Autoregressive-Distributed Lag technique was utilized for data analysis. The study focused on emissions emanating from residential, industrial and commercial settings. Findings established that energy use and urbanization are positively correlated with carbon emissions for the high-income countries, while growth shows a negative association. The exact opposite was discovered for upper-middle-income and lower-middle-income countries. Trade openness and energy consumption strongly influence emissions coming from residential, industrial and commercial settings.

Li et al. (2019a, b) examined the role of five (5) different types of modernization on environmental quality in China from 1997 to 2016 by utilizing the fixed and random effect models. The study provided evidence to the effect that urbanization, industrial, agricultural and information modernization encourage emissions, thereby degrading the environment. On the other hand, ecological modernization abates CO_2 emissions. The authors argued that the findings from the study will help policymakers in promoting decarbonisation and the need for organic agriculture which will help in erecting low-carbon cities.

Wu et al. (2019) used the STIRPAT framework to examine the effect of industrial structure, economic growth and population on CO_2 emissions in 30 Provinces in China from 2005 to 2014. From their findings, population, industrial structure and per capita GDP are the drivers of emissions.

Wang et al. (2019) examined the role of population, urbanization and industrialization on environmental degradation in China from 1995 to 2014 using a ridge regression in a STIRPAT model framework. The study confirmed that urbanization, population, industrialization, economic growth and fixed asset investment are chief among the drivers of CO_2 emissions in China.

A handful of studies concentrated on oil exporting countries (see, Iwata and Okada 2014; de Mattos and Filippi 2014; Brizga et al. 2013; Kick and Mckinney 2014; Fang and Miller 2013; Lamb et al. 2014; Hasanov et al. 2016) while others either focused on provinces or cities (see also, Liu et al. 2018; Zhang et al. 2018; Xie et al. 2017; Wang et al. 2017a, b; Zhou and Liu 2016; Fu et al. 2015; Liddle 2013; Jia et al. 2009). However, none of the studies reviewed (especially those from Nigeria) inculcated the square of urbanization as one of the explanatory variables which is capable of providing insights on how CO_2 emissions respond to both increase and decrease in urbanization rate. Table 1 below provide a summary of related studies in the literature.

Methodology and data description

The IPAT model was suggested by Ehrlich and Holdren (1971) in an attempt to link the environment and human activities. The implicit form of the model is given as;

$$I = f(P, A, T) \tag{1}$$

I is emission level, P stands for population, A is affluence and T denotes technology. This proposition has been criticised on several grand. It is only an accounting equation aimed at calculating the impact factor of environmental pressure (Xu et al. 2017). Furthermore, the elasticity of each of the parameters are presumed to be the same (Liu and Xiao 2018). According to Xu et al. (2016), it contradicts the EKC. The IPAT approach did not gain much popularity because, it is too conclusive to assume that the impact of all the parameters (Population, Affluence and Technology) on emission level are the same in size and magnitude.

Table 1 Literature summary. *Source*: Authors compilation from literature

References	Period	Country(s)/region	Estimation techniques	Major findings
Ahmad et al. (2019)	2000–2016	China	STIRPAT	Construction sector growth, energy consumption and urbanization contribute to pollution
Li et al. (2019a, b)	2003–2014	China	STIRPAT	An upgrade in the manufacturing sector will help curb emission
Rauf et al. (2018)	1968–2016	China	ARDL	Economic growth and urbanization reduce carbon emission
Kwakwa et al. (2018)	1971–2013	Ghana	STIRPAT	Urbanization does encourage emission
Raggad (2018)	1971–2014	Saudi Arabia	ARDL	Energy use increase emission, urbanization reduces it
Chin et al. (2018)	1997–2014	Malaysia	ARDL; Decomposition-type threshold methods.	Growth in the economy drives emission
Liu and Xiao (2018)	2000–2012	China	STIRPAT	Carbon emission peaks will exist
Yang et al. (2018b)	1995–2014	China	STIRPAT	Growth was discovered as the major cause of CO_2 emissions
Zhu et al. (2018)	1994–2013	BRICS	Panel quartile regression	Urbanization reduces emission
Kwakwa and Alhassan (2018)	1971–2013	Ghana	FMOLS	Urbanization affects the environment negatively
Yang et al. (2018a)	1978–2015	China (Shanghai)	STIRPAT; NSGAII	FDI and per capital GDP are positively correlated with CO_2 emissions
Lv and Xu (2018)	1992–2012	55 middle-income countries	Pooled Mean Group	Urbanization reduces emission. Trade harms the environment in the long run
Andrés and Padilla (2018)	1990–2014	EU	STIRPAT	Population and transport energy intensity among other factors contributes to GHG emissions
Chai et al. (2018)	Scenerio analysis and forecast based on 2016–2025	China	LMDI-STIRPAT-PLSR framework	Urbanization and per capita GDP are less potent determinants of CO_2 emissions
Shahbaz et al. (2017)	1972Q1–2011Q4	Pakistan	STIRPAT	Urbanization promotes energy consumption
Yeh and Liao (2017)	1990–2014	Taiwan	STIRPAT	Population is a significant force that pulls CO_2 emissions
Wang et al. (2017a, b)	2000–2013	China	STIRPAT	Technology and urbanization are not helping the environment
Shuai et al. (2017)	1990–2011	125 countries	STIRPAT	Urbanization and growth cause CO_2 emissions
Abdallh and Abugamos (2017)	1980–2014	MENA	STIRPAT	Economic growth and energy use are significant sources of CO_2 emissions
Balogh and Jámbor (2017)	24 years data (date not specified)	168 countries	GMM	Trade drives emission, not agricultural development

Table 1 continued

References	Period	Country(s)/region	Estimation techniques	Major findings
Ibrahim et al. (2017)	1960–2015	Turkey	STIRPAT	Energy import weakens the country's conservative policy
Yang et al. (2017)	2000–2010	China	STIRPAT	Population and urbanization contribute to CO_2 emissions
Behera and Dash (2017)	1980–2012	Asia	STIRPAT	FDI, energy consumption and urbanization are the major drivers of carbon emission.
Zhang et al. (2017a)	1961–2011	141 countries	STIRPAT	The relationship between urbanization and carbon emission takes the form of an inverted U-shaped
Long et al. (2017)	1980–2008	72 countries	STIRPAT	Ecological elasticity of urbanization is negative
Sbia et al. (2017)	1975–2011	UAE	ARDL	Urbanization drives electricity consumption which in turn pollutes the environment
Saidi and Mbarek (2017)	1990–2013	19 countries	GMM	Urbanization reduces emission while income encourages it
Lin and Benjamin (2017)	1980–2010	China	QRA	GDP, urbanization, carbon intensity, energy intensity add to CO_2 emissions
Mrabet and Alsamara (2017).	1991–2000	Qatar	ARDL	The EKC does not exist in Qatar
Ali et al. (2017)	1970–2015	Singapore	ARDL	Urbanization promotes environmental quality
Zhang et al. (2017b)	2005–2012	China	STIRPAT	Industrial and energy structure, alongside urbanization, add in CO_2 emissions
Lin et al. (2017)	1991–2013	Non-high income countries	STIRPAT	Real economic development and urbanization have infinitesimal impact on CO_2 emissions
Ali et al. (2016)	1971–2011	Nigeria	ARDL	Urbanization does not encourage emissions
Hasanov et al. (2016)	1990–2012	Oil exporting countries of Commonwealth	STIRPAT	Affluence exacts significant impact on energy use
Shahbaz et al. (2016)	1970Q1–2011Q4	Malaysia	STIRPAT	Economic growth is the major factor that drives emissions
Cansino et al. (2016)	1995–2009	Spain	SDA	Energy intensity and structure are key pollutants of the environment
Al-mulali and Ozturk (2015)	1996–2012	14 MENA countries	FMOLS	Urbanization and trade promotes environmental damage
Chen and Yang (2015)	1995–2011	China	IDA	Sector-specific activity and fossil fuel substitution are among factors that reduce the quality of the environment
Farhani and Ozturk (2015)	1971–2012	Tunisia	ARDL	Financial development and urbanization degrade the environment

Table 1 continued

References	Period	Country(s)/region	Estimation techniques	Major findings
Moutinho et al. (2015)	1999–2010	Europe	IDA	Carbon and energy intensity amidst other factors drive CO_2 emissions
Li and Lin (2015)	1971–2010	73 countries	STIRPAT	Urbanization increase CO_2 in low income countries
Wang et al. (2015)	1960–2010	OECD	STIRPAT	Urbanization contributes to CO_2 emissions
Liddle (2015)	1971–2011	OECD and non-OECD	STIRPAT	CO_2 elasticity of population is neither robust for OECD nor non-OECD members

SNA social network analysis. *IDA* index decomposition analysis, *QRA* quantile regression analysis, *PLS* partial least squares regression, *LMDI* logarithmic mean divisia index, *NSGA-II* non-dominated sorting genetic algorithm II

To ameliorate for these problems, Dietz and Rosa (1997) introduced the Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) model building on the IPAT following in its implicit form as $E = f(EC, P, A, T)$. The model is assumed to be nonlinear and hence it is written as shown in Eq. (2).

$$E_t = \varphi EC_t^{\alpha} P_t^{\beta} A_t^{c} T_t^{d} e_t \quad (2)$$

E_t represents pollutant. EC_t, P_t, A_t and T_t represent CO_2 emissions, population, affluence and trade respectively. α, β, c and d are the various elasticities with e_t as the error term. Unlike the EKC, the STIRPAT model incorporates technology, affluence and population as potential determinants on environmental degradation. To empirically estimate the model, we take the logarithm of each of the variables. As such, Eq. (2) becomes:

$$lnE_t = \xi + \alpha * \ln(EC_t) + \beta * \ln(P_t) + c * \ln(A_t) + d * \ln(T_t) + \gamma \quad (3)$$

ln represents natural logarithm. ξ and γ are the logarithm of φ and e_t respectively. φ shows the changes in E_t when other variables remain constant, while e_t captures the influence of other variables not included in the model.

The current study included trade flow to augment the model since openness to trade encourage technological transfer from developed countries to their trading partners. The impact of technology on the economy is hydra-headed. It can reduce pollution, promote economic activities, and also encourage dumping. Therefore, its impact can either be positive or negative. By performing logarithm transformation on the variables, converting all variables into per capita terms by dividing through by population in line with the studies of (Shahbaz and Lean 2012; Lean and Smyth 2010), and incorporating the square of urbanization (quadratic term) into the model, we have;

$$lnE_t = \vartheta_0 + \vartheta_1 lnEC_t + \vartheta_2 lnU_t + \vartheta_3 lnU_t^2 + \vartheta_4 lnY_t + \vartheta_5 lnT_t + \varepsilon_t \quad (4)$$

where $lnE_t, lnEC_t, lnU_t, U_t^2, lnY_t$ and lnT_t are the natural logarithm of per capita CO_2 emissions, energy consumption, urbanization, urbanization square, economic growth (measured by the difference of the log of GDP per capita) and trade openness respectively. Data were obtained from World Bank Development Indicators (2018).

Techniques of estimation

Cointegration test

The study used the Bayer and Hanck (2013) cointegration test. The choice of the test was based on its superiority over others, just as it gives room for the combination of other individual tests (such as; Phillips and Ouliaris 1990; Banerjee et al. 1998; Boswijk 1995; Engle and Granger 1987; Johansen 1991) to arrive at a robust estimate. The Fisher version of the test is presented as:

$$EG - JOH = -2[\ln(\rho_{EG}) + (\rho_{JOH})] \tag{5}$$

$$EG - JOH - BO - BDM = -2[\ln((\rho_{EG}) + (\rho_{JOH}) + (\rho_{BO}) + (\rho_{BDM})] \tag{6}$$

ρ_{BDM}, ρ_{BO}, ρ_{JOH} and ρ_{EG} are the probability values of individual cointegration tests. We reject the null hypothesis when the F-statistic is exceeds the critical value of the test.

Autoregressive distributed lag (ARDL) technique

The study relied on the ARDL model initiated by Pesaran et al. (2001). The techniques has a lot of advantages that places it above other methods of estimation. It is simple and flexible (Apergis and Cooray 2015). It can be applied without the prior knowledge of the variable's order of integration (Granger and Yoon 2002). However, it does not accommodate I(2) variable(s). It provides robust estimates when the sample is small (Ghatak and Siddiki 2001; Panopoulou and Pittis 2004). The general form of the model is given as:

$$\Delta Y = \mu_0 + \mu_1 t + \lambda_1 y_{t-1} + \sum_{i=1}^{N} \theta_1 v_{it-1} + \sum_{j=1}^{p} \gamma_j \Delta Y_{t-j} + \sum_{i=1}^{N} \sum_{j=1}^{P} \omega_{ij} \Delta V_{it-j} + \Psi D_t + \varepsilon_t \tag{7}$$

D_t is an exogenous variable that is used to capture a structural break in the framework. The variable was constructed by coding zero from the initial dates before the date of a break (structural break), then one (1) from the year of a break to the end date. V_t is the cointegrating vector. The null and alternative hypotheses of the test are shown in Eqs. (8) and (9).

$$H_0 : \pi_1 = \pi_2 = \cdots = \pi_{k+2} = 0 \tag{8}$$

$$H_1 : \pi_1 \neq \pi_2 \neq \cdots \neq \pi_{k+2} \neq 0 \tag{9}$$

Causality test

When variables are cointegrated, then the possibility of at least one direction of causality is almost certain. The VECM Granger causality test was used for this purpose and represented as;

$$(1-L)\begin{bmatrix} LnE_t \\ LnU_t \\ LnU_t^2 \\ LnEC_t \\ LnY_t \\ LnTO_t \end{bmatrix} = \begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \\ \beta_5 \\ \beta_6 \end{bmatrix} + \sum_{i=1}^{p} (1-L) \begin{bmatrix} \beta_{11i}\beta_{12i}\beta_{13i}\beta_{14i}\beta_{15i}\beta_{16i} \\ \beta_{21i}\beta_{22i}\beta_{23i}\beta_{24i}\beta_{25i}\beta_{16i} \\ \beta_{31i}\beta_{32i}\beta_{33i}\beta_{34i}\beta_{35i}\beta_{16i} \\ \beta_{41i}\beta_{42i}\beta_{43i}\beta_{44i}\beta_{45i}\beta_{46i} \\ \beta_{51i}\beta_{52i}\beta_{53i}\beta_{54i}\beta_{55i}\beta_{56i} \\ \beta_{61i}\beta_{62i}\beta_{63i}\beta_{64i}\beta_{65i}\beta_{66i} \end{bmatrix} \times \begin{bmatrix} LnE_{t-1} \\ LnU_{t-1} \\ LnU_{t-1}^2 \\ LnEC_{t-1} \\ LnY_{t-1} \\ LnTO_{t-1} \end{bmatrix} + \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \\ \alpha_6 \end{bmatrix} ECT_{t-1} + \begin{bmatrix} \varepsilon_{t1} \\ \varepsilon_{t2} \\ \varepsilon_{t3} \\ \varepsilon_{t4} \\ \varepsilon_{t5} \\ \varepsilon_{t6} \end{bmatrix} \tag{10}$$

where $\varepsilon_{t1} - \varepsilon_{t5}$ are the error terms. ECT_{t-1} is the lag value of the residual derived from the ARDL long run result. The lag operator is represented by $(1-L)$. When the first difference of the variables have a significant F-statistic, short run causality is affirmed. On the flipside, if the t-statistic of ECT_{t-1} is significant, long run causality is affirmed.

Results presentation and discussion

A good knowledge of the properties of a time series data is needed before embarking on its analysis. As a starting point, we first examine the characteristic of each of the variables.

Descriptive statistic

This section of the study examines the properties of each of the variables. From the findings, the median of each of the variables almost equals their mean.

Economic growth has the highest average value of 7.421 US$, while carbon emissions have the lowest over the period of study. Economic growth also has the highest maximum value of 7.855 US$ among the variables considered for the study. The minimum value of − 1.235, which is the lowest, is recorded by carbon emissions (Table 2).

For energy consumption, the average energy use is 6.544 kg. Also, all the variables, apart from economic growth, are negatively skewed. Having a kurtosis value that is less than three in absolute term, suggest that the variables are platykurtic. Evidence of normality exist as the probability values of each of the variables are well above 5%, which is desirable.

Unit root

The unit root tests were carried out to ensure that no I(2) variable(s) exist in the series. To achieve this, we proceeded with the conventional Dickey and Fuller (ADF) (1981, 1979); and the Philip and Perron (PP) (1988) test, complemented with the Zivot and Andrew unit root test (Table 3).

The three tests are in harmony. The variables were found to be 1 $\sim$ I(1). Since the ADF and the PP tests had been criticized for poor explanatory power and inability to consider break(s) in the series, we further subjected the variables to the Zivot and Andrews (1992) test to cater for structural break in the series. The results met the pre-condition for cointegration. With these, we can safely proceed to examine the co integrating relationship among the variables (Table 4).

From the tests results, each of the variables assumed the position of an independent variable.

Since the 5% critical value of 10.419 and 15.701 is less than the Fisher statistic for EG-JOH and EG-JOH-BO-BDM respectively. Therefore, cointegration exist (Table 5).

Since the F-statistic of 7.813816 is greater than 4.77 at 5%, the finding suggests cointegration. This means that our variables (lnE, $lnEC$, lnY, lnT, lnU, lnU^2) have a long-run relationship.

The result was arrived at by comparing the F-statistic to the 5% critical value of the upper bound. The finding is reported in Table 6.

In the short-run, we see a significant positive relationship between energy consumption and CO_2 emissions. That is, high energy consumption which is evident in Nigeria will increase CO_2 emissions with a magnitude of 3.05%. Interestingly, a similar trend was seen in the long-run, though not statistically significant. This is in tandem with the findings of Raggad (2018) and Abdallh and Abugamos (2017). This did not come as a surprise, since the country's source of energy is not renewable. Hence, the country's energy source (which is largely non-renewable) acts as a pollutant to the environment. This calls for clean energy sources to enhance environmental protection (Balsalobre-Lorente et al. 2018; Bekun et al. 2019). While for the Economic growth exacts a positive and inelastic impact on CO_2 emissions in the short-run while an inverse relationship is observed in the long-run. This shows that the economy is growing at the expense of the environment, at least in the short run. However, in the long run, economic growth promotes environmental quality by reducing CO_2 emissions. However, as the country become more aware of the negative impact of growth, it adjust accordingly. This complements the findings of Shahbaz et al. (2016), Chin et al. (2018), Yang et al. (2018a, b) and Shuai

Table 2 Descriptive statistic results. *Source*: Authors computation

	*ln*E	*ln*EC	*ln*Y	*ln*T	*ln*U	*ln*U^2
Mean	− 0.486	6.544	7.421	3.810	2.212	4.907
Median	− 0.413	6.543	7.465	3.859	2.250	5.064
Maximum	0.028	6.684	7.855	4.421	2.351	5.530
Minimum	− 1.235	6.359	7.035	2.997	1.944	3.780
SD	0.316	0.078	0.247	0.364	0.113	0.489
Skewness	− 0.596	− 0.540	0.183	− 0.502	− 0.810	− 0.746
Kurtosis	2.385	2.773	1.630	2.302	2.490	2.378
Probability	0.410	0.124	0.077	0.162	0.453	0.061

Table 3 ADF and PP unit root tests (without break) and ZA unit root test (with break). *Source*: Authors computation

Variables	ADF T-statistic	PP T-statistic	ZA unit root test T-statistic	Break date Time break
Panel A at levels				
At levels				
Ln Y	− 1.2405	− 0.9392	− 3.5127(4)	1985Q2
Ln EC	− 3.0816	− 2.4854	− 2.9004(4)	2009Q2
Ln E	− 2.5981	− 2.1691	− 5.1699(1)	1999Q2
Ln U	− 2.8349	− 2.8368	− 5.0216(1)	1980Q2
Ln U^2	− 2.6533	− 2.2569	− 4.7879(1)	1980Q2
Ln T	− 2.9103	− 2.2569	− 3.5556(1)	1988Q2
Panel B at first difference				
At first difference				
Ln Y	− 6.8708***	− 6.5849***	− 6.1018(1)***	2003Q2
Ln EC	− 6.8758***	− 6.1115***	− 5.1324(1)***	2009Q2
Ln E	− 7.5551***	− 7.6009***	− 6.2031(1)***	1999Q2
Ln U	− 3.9174**	− 3.4703**	− 6.0900(1)***	1983Q2
Ln U^2	− 8.0624***	− 8.9271***	− 6.0007(1)**	1983Q2
Ln T	− 4.7379***	− 7.7423***	− 5.5535(1)**	1986Q2

***,**,*Denotes 1%, 5% and 10% significance rejection level respectively. () indicates lag length of the variables

Table 4 The result of Bayer–Hanck test for cointegration. *Source*: Authors computation

Estimated model	EG-JOH	EG-JOH-BO-BDM	Cointegration
*ln*E = f(*ln*EC, *ln*Y, *ln*T, *ln*U, *ln*U^2)	12.9836**	15.8056	✔
*ln*EC = f(*ln*E, *ln*Y, *ln*T, *ln*U, *ln*U^2)	16.8482***	29.5435**	✔
*ln*Y = f(*ln*E, *ln*EC, *ln*T, *ln*U, *ln*U^2)	13.6011**	17.1095	✔
*ln*T = f(*ln*E, *ln*EC, *ln*Y, *ln*U, *ln*U^2)	13.2903**	18.8835	✔
*ln*U = (*ln*E, *ln*EC, *ln*Y, *ln*T, *ln*U^2)	14.0711**	33.8598***	✔
lnU^2 = f(*ln*E, *ln*EC, *ln*Y, *ln*T, *ln*U)	14.0719**	33.8599***	✔
5% critical value	10.419	15.701	
1% critical value	19.888	29.85	

*,**,***Denotes 10%, 5% and 1% significance rejection level respectively

Table 5 ARDL bounds test. *Source*: Authors computation

Estimated model	Lower bound	Upper bound	Significance levels (%)
$F_c(lnEC, lnY, lnT, lnU, lnU^2)$	3.02	4.26	10
F = 7.813816	3.48	4.77	5
K = 5	3.81	5.22	2.5
	4.50	5.12	1

et al. (2017). Unlike growth, the country's trade promotes environment quality in both time periods. The short run result is consistent with that of the long run, as a 1% increase in trade will amounted to about 0.15% and 0.43% reduction in CO_2 emission both in the short and long-run respectively. This suggests that the Pollution Haven Hypothesis does not hold for Nigeria, as trade does not impact negatively on the environment.

Table 6 ARDL results. *Source*: Authors computation

Independent variables	Coefficients	SE	T-statistic
Dependent variable: *ln*E			
Short-run coefficients			
D*ln*E(−1)	0.4763***	0.0717	6.6430
D*ln*EC	3.0515***	0.7508	4.0643
D*ln*EC(−1)	− 1.1779	0.7836	− 1.5032
D*ln*Y	0.8198***	0.2067	3.9649
D*ln*Y(−1)	− 0.4871**	0.2161	− 2.2535
D*ln*T	− 0.1525***	0.0479	− 3.1781
D*ln*T(−1)	0.0772	0.0489	1.5766
D*ln*U(−1)	30.4146**	14.8001	2.0550
D*ln*U^2	− 3.9338**	1.5504	− 2.5372
D@TREND	0.0039***	0.0015	2.6922
ECM_{t-1}	− 0.0749***	0.0192	− 3.9065
R-square	0.4664		
F-statistic	25.4984***		
Long-run coefficients			
*ln*EC	4.5384	2.8149	1.6122
*Ln*Y	− 1.1490**	0.6209	− 1.8504
*Ln*T	− 0.4318**	0.1838	− 2.3497
*Ln*U	199.3262	72.6053	2.7453
lnU^2	− 52.5321***	18.4756	− 2.8433
Constant	− 207.9660***	69.5980	− 2.9881
@TREND	0.0531***	0.0180	2.9448
R-square	0.9799		
F-statistic	752.58***		

Test	Statistics	*P* value
Diagnostic tests		
Serial correlation	1.9382	0.1473
ARCH	0.0652	0.7988
White	1.4781	0.1084
Ramsey	3.0523	0.0825

*,**,***Denotes 10%, 5% and 1% significance rejection level respectively

We also observe a significant positive and negative effect of urbanization and its square on CO_2 emissions both in both time periods. This outcome gives credence to the N-shape hypothesis well established in the energy economic literature, were urbanization increase industrialization and economic activities up to a certain threshold after that threshold urbanization becomes detrimental by causing environmental degradation with a high emission of CO_2. This is in many ways similar to the findings of Kwakwa et al. (2018) for Ghana, Ahmad et al. (2018) for China, Kwakwa and Alhassan (2018) for Ghana, Yang et al. (2017) for China, Farhani and Ozturk (2015) for Tunisia, but contradicts that of Ali et al. (2017) for Singapore.

This is possible given that in recent times Nigeria has experienced an economic transformation that opens her economy to the rest of the world which is evident in the trade-off between both variables. Therefore, the government and energy administrators should intensify efforts on the implementation of the

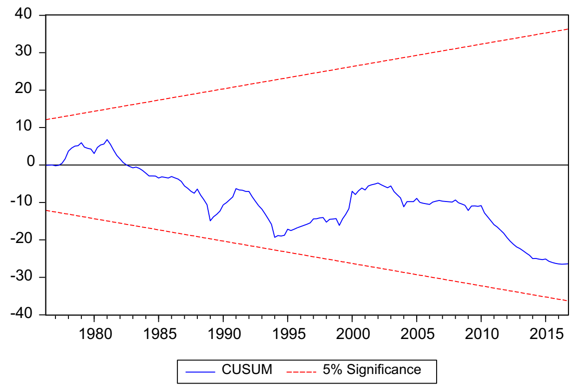

Fig. 1 CUSUM stability test

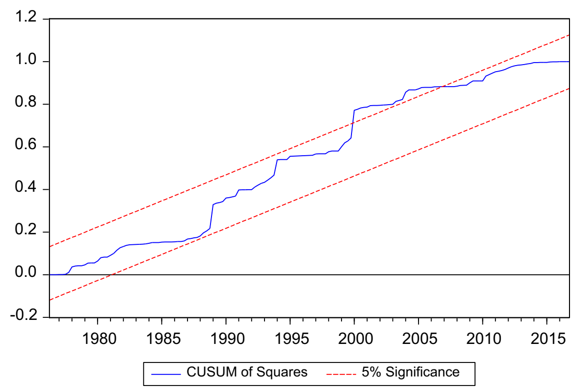

Fig. 2 CUSUM Square stability test

Kyoto Protocol of which Nigeria is a signatory. Since urbanization increase emission in the long-run, policies to curtail urbanization is germane. One way the government can achieve this is to be involve in aggressive infrastructural development, increase rural access to electricity by reducing energy poverty, and create the needed jobs to ameliorate urban anomalies (Figs. 1 and 2).

The graphs show the stability of the model for the sample drawn and indicated that the residuals are within 5% critical bonds. Confirming that all the coefficients in the ARDL model are stable (Table 7).

The result of the VECM Granger causality test shows a unidirectional causality from economic growth to energy consumption in the long run. This confirms that economic growth encourages an increase in energy demand. Similarly, there is unidirectional causality, both in the short and long run, from urbanization and its square to carbon emissions. This clearly indicates that urbanization cause environmental degradation. This is not surprising, because most rural areas in Nigeria are in acute shortage of basic infrastructures and industries. This motivates people in these areas to migrate to fairly industrially rich cities to cater for their livelihood thereby increasing CO_2 emission. This is a clarion call for policymakers to initiate policies to mitigate the negative consequences of urbanization. This is more likely to be

Table 7 Results of VECM causality analysis. *Source*: Authors computation

Dependent variable	Direction of causality						
	Short run						Long run
	$DlnE_{t-i}$	$DlnEC_{t-i}$	$DlnY_{t-i}$	$DlnU_{t-i}$	$DlnU^2_{t-i}$	$DlnT_{t-i}$	ECT_{t-1}
D*ln*E	_	0.6924 (0.0501)	0.2534 (0.0271)	2.7082* (0.0696)	2.7018* (0.6100)	0.7989 (0.0052)	− 0.2712 (0.0251)***
D*ln*EC	0.3655 (0.3506)	_	0.0664 (0.0139)	0.5439 (0.0195)	0.5391 (0.0262)	0.1137 (0.0574)	0.0123 (0.0201)**
D*ln*Y	0.6263 (0.0670)	0.4816 (0.0144)	_	1.3285 (0.0343)	1.3195 (0.0560)	0.1461 (0.0587)	− 109.022 (0.0311)***
D*ln*U	0.0493 (0.3451)	0.0184 (0.0231)	0.0143 (0.0187)	_	0.0820 (0.0329)	0.0054 (0.0511)	− 0 00017 (0.0176)
D*ln*U^2	0.0399 (0.3561)	0.0143 (0.0352)	0.0146 (0.0165)	0.0325 (0.0281)	_	0.0051 (0.0119)	− 0.00071 (0.0516)
D*ln*T	0.0612 (0.0531)	0.8799 (0.0418)	0.8066 (0.0181)	2.3578 (0.0417)	2.2523 (0.0283)	_	0.4083 (0.0021)***

*,**,***Denotes 10%, 5% and 1% significance rejection level respectively, while () are the standard errors

achieved faster than improving urban infrastructure considering the meagre allocation to capital expenditure in the countries budget year-in-year-out.

Conclusion, policy implication and direction

This study tried to model urbanization, trade flow, economic growth and energy consumption with regards to the environment in Nigeria relying on STIRPAT model with data spanning 1980Q1–2016Q4. The unit root properties of the variables were examined relying specifically with the outcome of the Zivot and Andrews (1992) test. The Bayer and Hanck (2013) and the ARDL bounds test confirmed that the variables are cointegrated. Urbanization and energy consumption were the major drivers of CO_2 emissions in both time periods, while trade perform the opposite. Trying to reduce energy consumption with a view to protecting the environment will derail growth since the countries growth is energy dependent. The best policy direction will be for the country to adjust its energy portfolio and give due attention to renewable energy sources like tidal power, geothermal heat, wave power, biofuel, biogas, solar energy, amongst others. These energy sources protects the environment due to their low emission rate (Emir and Bekun 2018).

Nigeria can take a cue from Morocco, a fellow Africa country gradually going green with a solar power plant in Noor-Ouarzazate which is one of the largest solar complexes in the world. The VECM Granger causality test re-affirmed a positive and significant impact of urbanization on CO_2 emissions. As long as rural infrastructures are improved, problems associated with urban health crisis of waste management, risky transport and environmental degradation would be minimized. The error correction term is statistically significance having coefficient − 0.07 suggesting that the disturbance in the system will be adjusted 7% in each quarter. The study is also in harmony with various OLS assumptions making it relevant for policy prescription and forecast.

Acknowledgements I, Nathaniel Solomon Prince, wish to state that, I comply with the journals principles and policies. I wish to state that I am bonded by all the rules of this reputable journal in terms of copyright, publication, information and any other rules. Also, I confirm that all information provided in the study are true, and authors that were cited are all well referenced.

References

Abdallh, A. A., & Abugamos, H. (2017). A semi-parametric panel data analysis on the urbanisation-carbon emissions nexus for the MENA countries. *Renewable and Sustainable Energy Reviews, 78,* 1350–1356.

Adams, S., & Klobodu, E. K. M. (2017). Urbanization, democracy, bureaucratic quality, and environmental degradation. *Journal of Policy Modeling, 39*(6), 1035–1051.

Ahmad, M., Zhao, Z. Y., & Li, H. (2019). Revealing stylized empirical interactions among construction sector, urbanization, energy consumption, economic growth and CO_2 emissions in China. *Science of the Total Environment, 657,* 1085–1098.

Ahmed, K., & Long, W. (2012). Environmental Kuznets curve and Pakistan: An empirical analysis. *Procedia Economics and Finance, 1,* 4–13.

Akbostancı, E., Tunç, Gİ., & Türüt-Aşık, S. (2011). CO_2 emissions of Turkish manufacturing industry: A decomposition analysis. *Applied Energy, 88*(6), 2273–2278.

Ali, H. S., Abdul-Rahim, A. S., & Ribadu, M. B. (2017). Urbanization and carbon dioxide emissions in Singapore: Evidence from the ARDL approach. *Environmental Science and Pollution Research, 24*(2), 1967–1974.

Ali, H. S., Law, S. H., & Zannah, T. I. (2016). Dynamic impact of urbanization, economic growth, energy consumption, and trade openness on CO_2 emissions in Nigeria. *Environmental Science and Pollution Research, 23*(12), 12435–12443.

Aliyu, A. A., & Amadu, L. (2017). Urbanization, cities, and health: The challenges to Nigeria—A review. *Annals of African medicine, 16*(4), 149.

Al-Mulali, U., & Ozturk, I. (2015). The effect of energy consumption, urbanization, trade openness, industrial output, and the political stability on the environmental degradation in the MENA (Middle East and North African) region. *Energy, 84,* 382–389.

Al-Mulali, U., Ozturk, I., & Lean, H. H. (2015). The influence of economic growth, urbanization, trade openness, financial development, and renewable energy on pollution in Europe. *Natural Hazards, 79*(1), 621–644.

Andersson, F. N., & Karpestam, P. (2013). CO_2 emissions and economic activity: Short-and long-run economic determinants of scale, energy intensity and carbon intensity. *Energy Policy, 61,* 1285–1294.

Andrés, L., & Padilla, E. (2018). Driving factors of GHG emissions in the EU transport activity. *Transport Policy, 61,* 60–74.

Apergis, N., & Cooray, A. (2015). Asymmetric interest rate pass-through in the US, the UK and Australia: New evidence from selected individual banks. *Journal of Macroeconomics, 45,* 155–172.

Azizalrahman, H. (2019). A model for urban sector drivers of carbon emissions. *Sustainable Cities and Society, 44,* 46–55.

Balogh, J. M., & Jámbor, A. (2017). Determinants of CO_2 emission: A global evidence. *International Journal of Energy Economics and Policy, 7*(5), 217–226.

Balsalobre-Lorente, D., Shahbaz, M., Roubaud, D., & Farhani, S. (2018). How economic growth, renewable electricity and natural resources contribute to CO_2 emissions? *Energy Policy, 113,* 356–367.

Banerjee, A., Dolado, J., & Mestre, R. (1998). Error-correction mechanism tests for cointegration in a single-equation framework. *Journal of Time Series Analysis, 19*(3), 267–283.

Bayer, C., & Hanck, C. (2013). Combining non-cointegration tests. *Journal of Time Series Analysis, 34*(1), 83–95.

Behera, S. R., & Dash, D. P. (2017). The effect of urbanization, energy consumption, and foreign direct investment on the carbon dioxide emission in the SSEA (South and Southeast Asian) region. *Renewable and Sustainable Energy Reviews, 70,* 96–106.

Bekun, F. V., Emir, F., & Sarkodie, S. A. (2019). Another look at the relationship between energy consumption, carbon dioxide emissions, and economic growth in South Africa. *Science of the Total Environment, 655,* 759–765.

Bong, C. P. C., Lim, L. Y., Ho, W. S., Lim, J. S., Klemeš, J. J., Towprayoon, S., et al. (2017). A review on the global warming potential of cleaner composting and mitigation strategies. *Journal of Cleaner Production, 146,* 149–157.

Boswijk, H. P. (1995). Efficient inference on cointegration parameters in structural error correction models. *Journal of Econometrics, 69*(1), 133–158.

Brizga, J., Feng, K., & Hubacek, K. (2013). Drivers of CO_2 emissions in the former Soviet Union: A country level IPAT analysis from 1990 to 2010. *Energy, 59,* 743–753.

Cansino, J. M., Román, R., & Ordonez, M. (2016). Main drivers of changes in CO_2 emissions in the Spanish economy: A structural decomposition analysis. *Energy Policy, 89,* 150–159.

Chai, J., Liang, T., Lai, K. K., Zhang, Z. G., & Wang, S. (2018). The future natural gas consumption in China: Based on the LMDI-STIRPAT-PLSR framework and scenario analysis. *Energy Policy, 119,* 215–225.

Chen, L., & Yang, Z. (2015). A spatio-temporal decomposition analysis of energy-related CO_2 emission growth in China. *Journal of Cleaner Production, 103,* 49–60.

Chin, M. Y., Puah, C. H., Teo, C. L., & Joseph, J. (2018). The determinants of CO_2 emissions in Malaysia: A new aspect. *International Journal of Energy Economics and Policy, 8*(1), 190–194.

de Mattos, E. J., & Filippi, E. E. (2014). Drivers of environmental impact: A proposal for nonlinear scenario designing. *Environmental Modelling and Software, 62,* 22–32.

Dickey, D. A., & Fuller, W. A. (1979). Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American statistical association, 74*(366a), 427–431.

Dickey, D. A., & Fuller, W. A. (1981). Likelihood ratio statistics for autoregressive time series with a unit root. *Econometrica: Journal of the Econometric Society, 49*(4), 1057–1072.

Dietz, T., & Rosa, E. A. (1997). Environmental impacts of population and consumption. In *Environmentally significant consumption: Research directions* (pp. 92–99).

Dogan, E., & Seker, F. (2016). Determinants of CO_2 emissions in the European Union: The role of renewable and non-renewable energy. *Renewable Energy, 94,* 429–439.

Dogan, E., & Turkekul, B. (2016). CO_2 emissions, real output, energy consumption, trade, urbanization and financial development: testing the EKC hypothesis for the USA. *Environmental Science and Pollution Research, 23*(2), 1203–1213.

Ehrlich, P. R., & Holdren, J. P. (1971). Impact of population growth. *Science, 171*(3977), 1212–1217.

Eia, U. (2013). *Annual energy outlook 2013* (pp. 60–62). Washington, DC: US Energy Information Administration.

Emir, F., & Bekun, F. V. (2018). Energy intensity, carbon emissions, renewable energy, and economic growth nexus: New insights from Romania. *Energy and Environment*. https://doi.org/10.1177/0958305X18793108.

Engle, R. F., & Granger, C. W. (1987). Co-integration and error correction: representation, estimation, and testing. *Econometrica: Journal of the Econometric Society, 55*(2), 251–276.

Ertugrul, H. M., Cetin, M., Seker, F., & Dogan, E. (2016). The impact of trade openness on global carbon dioxide emissions: Evidence from the top ten emitters among developing countries. *Ecological Indicators, 67,* 543–555.

Fang, W., & Miller, S. M. (2013). The effect of ESCO s on carbon dioxide emissions. *Applied Economics, 45*(34), 4796–4804.

Farhani, S., & Ozturk, I. (2015). Causal relationship between CO_2 emissions, real GDP, energy consumption, financial development, trade openness, and urbanization in Tunisia. *Environmental Science and Pollution Research, 22*(20), 15663–15676.

Fu, B., Wu, M., Che, Y., Wang, M., Huang, Y., & Bai, Y. (2015). The strategy of a low-carbon economy based on the STIRPAT and SD models. *Acta Ecologica Sinica, 35*(4), 76–82.

Ghatak, S., & Siddiki, J. U. (2001). The use of the ARDL approach in estimating virtual exchange rates in India. *Journal of Applied Statistics, 28*(5), 573–583.

Gökmenoğlu, K., & Taspinar, N. (2016). The relationship between CO_2 emissions, energy consumption, economic growth and FDI: The case of Turkey. *The Journal of International Trade and Economic Development, 25*(5), 706–723.

Granger, C. W., & Yoon, G. (2002). Hidden Cointegration. In *Royal economic society annual conference 2002* (No. 92). Royal Economic Society.

Green, F., & Stern, N. (2017). China's changing economy: implications for its carbon dioxide emissions. *Climate Policy, 17*(4), 423–442.

Hasanov, F. J., Bulut, C., & Suleymanov, E. (2016). Do population age groups matter in the energy use of the oil-exporting countries? *Economic Modelling, 54,* 82–99.

Heil, M., & Selden, T. (2001). Carbon emissions and economic development: Future trajectories based on historical experience. *Environment and Development Economics, 6,* 63–83.

Ibrahim, S. S., Celebi, A., Ozdeser, H., & Sancar, N. (2017). Modelling the impact of energy consumption and environmental sanity in Turkey: A STIRPAT framework. *Procedia Computer Science, 120,* 229–236.

Ito, K. (2017). CO_2 emissions, renewable and non-renewable energy consumption, and economic growth: Evidence from panel data for developing countries. *International Economics, 151,* 1–6.
Iwata, H., & Okada, K. (2014). Greenhouse gas emissions and the role of the Kyoto Protocol. *Environmental Economics and Policy Studies, 16*(4), 325–342.
Iwata, H., Okada, K., & Samreth, S. (2012). Empirical study on the determinants of CO_2 emissions: Evidence from OECD countries. *Applied Economics, 44*(27), 3513–3519.
Jia, J., Deng, H., Duan, J., & Zhao, J. (2009). Analysis of the major drivers of the ecological footprint using the STIRPAT model and the PLS method—A case study in Henan Province, China. *Ecological Economics, 68*(11), 2818–2824.
Johansen, S. (1991). Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models. *Econometrica: Journal of the Econometric Society, 59*(6), 1551–1580.
Kick, E. L., & McKinney, L. A. (2014). Global context, national interdependencies, and the ecological footprint: A structural equation analysis. *Sociological Perspectives, 57*(2), 256–279.
Kwakwa, P. A., & Alhassan, H. (2018). The effect of energy and urbanisation on carbon dioxide emissions: Evidence from Ghana. *OPEC Energy Review, 42*(4), 301–330.
Lamb, W. F., Steinberger, J. K., Bows-Larkin, A., Peters, G. P., Roberts, J. T., & Wood, F. R. (2014). Transitions in pathways of human development and carbon emissions. *Environmental Research Letters, 9*(1), 014011.
Lau, L. S., Choong, C. K., & Eng, Y. K. (2014). Investigation of the environmental Kuznets curve for carbon emissions in Malaysia: Do foreign direct investment and trade matter? *Energy Policy, 68,* 490–497.
Lean, H. H., & Smyth, R. (2010). On the dynamics of aggregate output, electricity consumption and exports in Malaysia: Evidence from multivariate Granger causality tests. *Applied Energy, 87*(6), 1963–1971.
Li, K., & Lin, B. (2015). Impacts of urbanization and industrialization on energy consumption/CO_2 emissions: Does the level of development matter? *Renewable and Sustainable Energy Reviews, 52,* 1107–1122.
Li, S., Zhou, C., & Wang, S. (2019a). Does modernization affect carbon dioxide emissions? A panel data analysis. *Science of the Total Environment, 663,* 426–435.
Li, Z., Shao, S., Shi, X., Sun, Y., & Zhang, X. (2019b). Structural transformation of manufacturing, natural resource dependence, and carbon emissions reduction: Evidence of a threshold effect from China. *Journal of Cleaner Production, 206,* 920–927.
Liddle, B. (2013). Urban density and climate change: A STIRPAT analysis using city-level data. *Journal of Transport Geography, 28,* 22–29.
Liddle, B. (2015). What are the carbon emissions elasticities for income and population? Bridging STIRPAT and EKC via robust heterogeneous panel estimates. *Global Environmental Change, 31,* 62–73.
Lin, B., & Benjamin, N. I. (2017). Influencing factors on carbon emissions in China transport industry. A new evidence from quantile regression analysis. *Journal of Cleaner Production, 150,* 175–187.
Lin, S., Wang, S., Marinova, D., Zhao, D., & Hong, J. (2017). Impacts of urbanization and real economic development on CO_2 emissions in non-high income countries: Empirical research based on the extended STIRPAT model. *Journal of Cleaner Production, 166,* 952–966.
Liu, D., & Xiao, B. (2018). Can China achieve its carbon emission peaking? A scenario analysis based on STIRPAT and system dynamics model. *Ecological Indicators, 93,* 647–657.
Liu, J. P., Zhang, X. B., & Song, X. H. (2018). Regional carbon emission evolution mechanism and its prediction approach driven by carbon trading—A case study of Beijing. *Journal of Cleaner Production, 172,* 2793–2810.
Long, X., Ji, X., & Ulgiati, S. (2017). Is urbanization eco-friendly? An energy and land use cross-country analysis. *Energy Policy, 100,* 387–396.
Lv, Z., & Xu, T. (2018). Trade openness, urbanization and CO_2 emissions: Dynamic panel data analysis of middle-income countries. *The Journal of International Trade and Economic Development, 28*(3), 1–14.
Mikayilov, J. I., Galeotti, M., & Hasanov, F. J. (2018). The impact of economic growth on CO_2 emissions in Azerbaijan. *Journal of Cleaner Production, 197,* 1558–1572.
Moutinho, V., Moreira, A. C., & Silva, P. M. (2015). The driving forces of change in energy-related CO_2 emissions in Eastern, Western, Northern and Southern Europe: The LMDI approach to decomposition analysis. *Renewable and Sustainable Energy Reviews, 50,* 1485–1499.
Mrabet, Z., & Alsamara, M. (2017). Testing the Kuznets curve hypothesis for Qatar: A comparison between carbon dioxide and ecological footprint. *Renewable and Sustainable Energy Reviews, 70,* 1366–1375.
National Population Commission. (2017). http://population.gov.ng/nigerias-population-now-182-million-npc/. Accessed 17 April 2018.
Nilrit, S., Sampanpanish, P., & Bualert, S. (2017). Comparison of CO_2 emissions from vehicles in Thailand. *Applied Environmental Research, 39*(1), 65–74.
Ouyang, X., & Lin, B. (2015). An analysis of the driving forces of energy-related carbon dioxide emissions in China's industrial sector. *Renewable and Sustainable Energy Reviews, 45,* 838–849.
Panopoulou, E., & Pittis, N. (2004). A comparison of autoregressive distributed lag and dynamic OLS cointegration estimators in the case of a serially correlated cointegration error. *The Econometrics Journal, 7*(2), 585–617.
Pesaran, M. H., Shin, Y., & Smith, J. R. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics, 16*(3), 289–326.
Phillips, P. C., & Ouliaris, S. (1990). Asymptotic properties of residual based tests for cointegration. *Econometrica Journal of the Econometric Society, 58*(1), 165–193.
Phillips, P. C., & Perron, P. (1988). Testing for a unit root in time series regression. *Biometrika, 75*(2), 335–346.
Raggad, B. (2018). Carbon dioxide emissions, economic growth, energy use, and urbanization in Saudi Arabia: Evidence from the ARDL approach and impulse saturation break tests. *Environmental Science and Pollution Research, 25*(15), 14882–14898.
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. *Structural Change and Economic Dynamics, 47,* 194–206.

Saidi, K., & Mbarek, M. B. (2017). The impact of income, trade, urbanization, and financial development on CO_2 emissions in 19 emerging economies. *Environmental Science and Pollution Research, 24*(14), 12748–12757.

Sbia, R., Shahbaz, M., & Ozturk, I. (2017). Economic growth, financial development, urbanisation and electricity consumption nexus in UAE. *Economic Research-Ekonomska Istraživanja, 30*(1), 527–549.

Shahbaz, M., Chaudhary, A. R., & Ozturk, I. (2017). Does urbanization cause increasing energy demand in Pakistan? Empirical evidence from STIRPAT model. *Energy, 122,* 83–93.

Shahbaz, M., Hye, Q. M. A., Tiwari, A. K., & Leitão, N. C. (2013). Economic growth, energy consumption, financial development, international trade and CO_2 emissions in Indonesia. *Renewable and Sustainable Energy Reviews, 25,* 109–121.

Shahbaz, M., Loganathan, N., Muzaffar, A. T., Ahmed, K., & Jabran, M. A. (2016). How urbanization affects CO_2 emissions in Malaysia? The application of STIRPAT model. *Renewable and Sustainable Energy Reviews, 57,* 83–93.

Sharma, S. S. (2011). Determinants of carbon dioxide emissions: Empirical evidence from 69 countries. *Applied Energy, 88*(1), 376–382.

Shuai, C., Shen, L., Jiao, L., Wu, Y., & Tan, Y. (2017). Identifying key impact factors on carbon emission: Evidences from panel and time-series data of 125 countries from 1990 to 2011. *Applied Energy, 187,* 310–325.

Wang, C., Wang, F., Zhang, X., Yang, Y., Su, Y., Ye, Y., et al. (2017a). Examining the driving factors of energy related carbon emissions using the extended STIRPAT model based on IPAT identity in Xinjiang. *Renewable and Sustainable Energy Reviews, 67,* 51–61.

Wang, S., Wang, J., Li, S., Fang, C., & Feng, K. (2019). Socioeconomic driving forces and scenario simulation of CO_2 emissions for a fast-developing region in China. *Journal of Cleaner Production, 216,* 217–229.

Wang, Y., Zhang, C., Lu, A., Li, L., He, Y., ToJo, J., et al. (2017b). A disaggregated analysis of the environmental Kuznets curve for industrial CO_2 emissions in China. *Applied Energy, 190,* 172–180.

Wang, Y., Zhang, X., Kubota, J., Zhu, X., & Lu, G. (2015). A semi-parametric panel data analysis on the urbanization-carbon emissions nexus for OECD countries. *Renewable and Sustainable Energy Reviews, 48,* 704–709.

Wu, Y., Shen, L., Zhang, Y., Shuai, C., Yan, H., Lou, Y., et al. (2019). A new panel for analyzing the impact factors on carbon emission: A regional perspective in China. *Ecological Indicators, 97,* 260–268.

Xie, R., Fang, J., & Liu, C. (2017). The effects of transportation infrastructure on urban carbon emissions. *Applied Energy, 196,* 199–207.

Xu, B., Luo, L., & Lin, B. (2016). A dynamic analysis of air pollution emissions in China: Evidence from nonparametric additive regression models. *Ecological Indicators, 63,* 346–358.

Xu, L., Chen, N., & Chen, Z. (2017). Will China make a difference in its carbon intensity reduction targets by 2020 and 2030? *Applied Energy, 203,* 874–882.

Yang, L., Xia, H., Zhang, X., & Yuan, S. (2018a). What matters for carbon emissions in regional sectors? A China study of extended STIRPAT model. *Journal of Cleaner Production, 180,* 595–602.

Yang, S., Cao, D., & Lo, K. (2018b). Analyzing and optimizing the impact of economic restructuring on Shanghai's carbon emissions using STIRPAT and NSGA-II. *Sustainable Cities and Society, 40,* 44–53.

Yang, Y., Liu, J., & Zhang, Y. (2017). An analysis of the implications of China's urbanization policy for economic growth and energy consumption. *Journal of Cleaner Production, 161,* 1251–1262.

Yeh, J. C., & Liao, C. H. (2017). Impact of population and economic growth on carbon emissions in Taiwan using an analytic tool STIRPAT. *Sustainable Environment Research, 27*(1), 41–48.

Zhang, N., Yu, K., & Chen, Z. (2017a). How does urbanization affect carbon dioxide emissions? A cross-country panel data analysis. *Energy Policy, 107,* 678–687.

Zhang, G., Zhang, N., & Liao, W. (2018). How do population and land urbanization affect CO_2 emissions under gravity center change? A spatial econometric analysis. *Journal of Cleaner Production, 202,* 510–523.

Zhang, Q., Yang, J., Sun, Z., & Wu, F. (2017b). Analyzing the impact factors of energy-related CO_2 emissions in China: What can spatial panel regressions tell us? *Journal of Cleaner Production, 161,* 1085–1093.

Zhou, Y., & Liu, Y. (2016). Does population have a larger impact on carbon dioxide emissions than income? Evidence from a cross-regional panel analysis in China. *Applied Energy, 180,* 800–809.

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. *Environmental Science and Pollution Research, 25*(17), 1–18.

Zivot, E., & Andrews, D. W. K. (1992). Further evidence on the great crash, the oil price shock, and the unit root hypothesis. *Journal of Business and Economic Statistics, 10*(3), 251–270.