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Population Dynamics and Environmental Quality in Africa

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Abstract

The nexus of population dynamics and environmental degradation has been discussed widely in the extant literature. Most related studies have utilized carbon emission as a proxy of environmental quality. However, carbon emission does not capture the multidimensional nature of environmental degradation. To fill this gap, this study utilized the ecological footprint to capture environmental degradation because it is a more dynamic environmental quality measure. The paper examines the population-environmental degradation hypothesis for five populous African countries (DR Congo, Ethiopia, Nigeria, South Africa and Tanzania) using panel information from 1990-2019. The Cross-sectionally Augmented autoregressive distributed lag (CS-ARDL) was employed to assess the relationship among the data – ecological footprint per capita (ECFP), population growth rate (POPG), population density (POPD), urban population growth rate (URBN), age structure of the population (AGES), per capita GDP growth rate (PGDP), energy consumption (ENEC), and trade openness (TRAD). The findings of the study revealed that POPG, POPD, AGES, PGDP, ENEC and TRAD increase environmental degradation. Urbanization (URBN) has no significant influence on environmental degradation in the selected African countries. The study concludes with policy prescriptions geared towards addressing population expansion and improving environmental quality.

Keywords : Population dynamics, Environmental degradation, Africa

JEL Classification **:** C40 ; J11 ; O10 ; Q50

1. Introduction

Environmental quality is deterred by carbon emissions and one of the recognized carbon emission drivers in the literature is population dynamics, which encompasses urbanization, age structure, population growth, among others (Wang et al., 2013; Abdelfattah et al., 2018; Li et al., 2019; Chekouri et al., 2020). Urbanization is a global phenomenon and aside developed nations, it is gradually increasing in developing nations as well (Sadorsky, 2014). It is projected that 65% of urbanization will happen in developing nations by 2050 (Shahbaz et al, 2016). Also, the highest urbanization rate is projected in the African and Asian continents (Ali et al., 2019). It is therefore unsurprising, that urbanization in Africa is intensifying at a very rapid tempo even though it remains the least urbanized (roughly 40%) relative to the most urbanized region (North America) at 82% (Adams and Klobodu, 2017). However, Freire et al. (2015) project the figure will increase to 56% by 2050, propelled by an annual growth rate of 1.1%, to be exceeded only by that of the Asian continent of 1.5% (Adams and Klobodu, 2017).

With over 6 billion people (from a projected 9.8 billion) expected to reside in urban areas around the world by 2050, environmental issues linked with urbanization are gradually becoming a huge concern in recent time (United Nations 2014; United Nations, 2017). For instance, in 2014, urban areas accounted for over 70% of world CO2 emissions (UN-Habitat, 2016).As documented by the 2018 Sustainable Development Report, 91% of urban dwellers in 2016 inhaled air that failed to meet the air quality guidelines of the World Health Organization. Similarly, roughly 50% were subjected to about 2.5 times air pollution levels which are excessive relative to the safety standards, while over 4.2million deaths were linked to air pollution (Madlener and Sunak, 2011, Asongu et al., 2020).

Furthermore, the age structure of a population could have a nontrivial implication on social, economic and environmental outcomes (Fan et al., 2006; Liddle and Lung, 2010; Liddle, 2011, Hassan and Salim, 2015). The age structure equally has a direct or indirect effect on carbon emission. The direct connection between age and emission stems from the pattern of consumption of the various age groups. For instance, Tarazkar et al. (2020) contend that by having more production activity, the working-age population utilizes more energy and resources and hence emits more. On the other hand, Liddle and Lung (2010) and Liddle (2011) argue that, although the older population spends considerable time at home, they are quite not active relative to other age units and most times the size of their household is small. Hence, they utilize less energy and resources and are likely to emit less. The indirect impact of age structure on emission operates via the labour market dynamics (Hassan and Salim, 2015). The older population is connected with less participation in the labour market which hampers economic growth and decreases emission (O'Neill et al., 2010).

As the world continues to witness changes in population size and age distribution, Africa is not left out. In the last three decades, Africa experienced an average annual population growth rate of 2.6% relative to the global average rate of 1.5% (ECA, 2016). The rapid population growth in Africa is expected to continue regardless of the decline in fertility rates in the region from 4.7 births per woman to 3.1 births per woman between 2010 and 2015 and between 2045 and 2050, respectively (United Nations, 2017). The population growth notwithstanding the fall in fertility rates is attributed to the changing population age structure as Africa houses the world's youngest population. In 2017, children under age 15 and young people aged 15 to 24 explained 41% and 19% of the population in Africa, respectively. Similarly, prime working-age (25-59) as well the aged population (People aged 60 and above) accounted for 35% and 5% of the population, respectively (United Nations, 2017). Beyond 2050, it is projected that Africa is likely to be the only continent with prospects for significant population growth (United Nations, 2017)

Consequently, this study makes a modest contribution to the literature on population dynamics and environmental quality in Africa in several ways. First, this paper adopts a multifaceted approach to evaluate the impact of population dynamics (population growth, population density, urbanization, age structure) on environmental quality in place of a one-dimensional population proxy popular with preceding studies. Second, it beams the spotlight on African nations that have not relatively enjoyed considerable attention in this area of research.According to Wang and Dong (2018), future upsurge in energy use and carbon emission will arise from poor developing nations due to their pro-poor growth policies. Although Africa's contribution to global carbon emission is low compared to other regions like Asia and North America, carbon emission in the continent is increasing and likely to reach alarming levels in the next decades. This is feasible given the current institutional and economic reforms targeted at enhancing economic growth, boosting economic diversification, improving industrialization, enhancing transportation systems as well as addressing the energy crisis (Wang and Dong, 2018, Aluko and Obalade, 2020; Avom et al., 2020).

This study analyses panel data of five African nations (Nigeria, Ethiopia, Democratic Republic (DR) of Congo, Tanzania and South Africa). These countries were selected for four salient motives. First, they represent some of the most populous countries of Africa (United Nations, 2019). Second, population and human activities are the major reasons for environmental pollution (Rahman, 2017). Third, according to the United Nations (2019), four out of the five countries (Nigeria, the Democratic Republic of the Congo, Ethiopia and Tanzania) selected are projected to be amongst the nine countries that will drive the expected world population change by 2050. Fourth, South Africa is the highest carbon emitter in Africa and the 14th largest in global rankings (Ndoricimpa, 2017, Salahuddin et al, 2019). Thus this further justifies the country's inclusion in the study.

Another possible influence of this study on existing literature is that as far as we know, most related studies have utilized CO2 emission as a measure of environmental quality. However, recent studies (Wang and Dong, 2018, Nathaniel and Khan, 2020) have favoured a broader proxy of environmental quality (which includes land and water quality) over CO2 emission which they labelled weak and inefficient since man-made pollution does not exclusively affect air quality. A preferred measure is an Ecological footprint (EFP) which encapsulates the threats posed by goods and services production activities on the environment (Rashid et al., 2018). It serves as the lone indicator that relates household, firm and government demand for resources in comparison with the earth's ability to replenish them (Nathaniel, 2020). Additionally, the EFP is widely adopted in the preparation of environmental policy documents by international environmental organisations like the World Wildlife Fund (WWF) and the United Nations Environment Programme (UNEP) (Nathaniel and Khan, 2020) and a very popular environmental metric in the social and ecology research. Lastly, this study applies contemporary panel estimation techniques to examine cross-sectional dependence and produce relevant results. The study findings are essential to assist in repositioning Africa's policy framework to simultaneously manage the region's population while guaranteeing a sustainable environment.

The rest of the study is sectioned thus: Section two presents the literature review, section three describes the data and methodology the study employed. Section four contains the empirical result whereas section five covers the conclusion and recommendations.

2. Literature Review

This section presents related studies on the subject matter. For instance, Adusah-Poku (2016) utilized the pooled mean group (PMG) estimator and found that population and urbanization significantly drive emission in sub-Saharan Africa (SSA) nations. Based on the Autoregressive Distributed Lag(ARDL) model, Aiyetan and Olomola (2017) investigated the nexus between population growth, economic growth, energy use and emission in Nigeria from 1980 to 2012. The study established that population growth and energy use exert a positive and significant effect on emissions. Mansoor and Sultana (2018) examined the connection between population growth, energy use economic growth and carbon emission in Pakistan over the period 1975 to 2016. Employing the ARDL method, the study found that population growth and energy use drive emission while economic growth has a negative effect. Abdelfattah et al. (2018) found that population boosts emission in the Arab regions, while for the case of 128 nations during the period 1990 to 2014, Dong et al. (2018) reported that population size has a positive and significant effect on emission level. By utilizing the stochastic impacts by regression on population, affluence and technology (STIRPAT) model as well as ARDL and Error Correction Model (ECM) technique, Anser (2019) confirmed that population growth contributes significantly to emissions in Pakistan. Li et al. (2019) reported that population growth intensified environmental pollution in China between 2001 and 2016. Rahman (2020) discovered that population density significantly influenced emission in India; while in 28 European nations, Pham et al. (2020) found that population size boosts environmental degradation in the long run.

Dong et al. (2020) adopted the Logarithmic Mean Divisia Index (LMDI) in a panel of 130 countries from diverse income brackets and uncovered that population growth stimulates emissions mostly in low-income nations. Ali et al. (2020) studied the impact of population density, fossil fuel and economic development on CO2 emission in Pakistan, India and Bangladesh from 1971 to 2014. Applying the ARDL, the study reported that in the long run, population density exerts a positive impact on emission. Khan et al. (2020) incorporated the role of population growth and natural resources in exploring the association between electricity access, financial development and carbon emission in Pakistan. Utilizing data from 1990 to 2015 and the ARDL method, the paper reported among other things, that population growth accounts for the rising carbon emission in Pakistan.

On the other hand, several studies reported contrasting results on the impact of population issues on emission. For example, Begum et al. (2015) posit that population growth has no significant effect on emission in Malaysia. For the 11most populous Asian nations, Rahman (2017) discovered that population density negatively influences environmental quality in the long run. Sulaiman and Abdul-Rahim (2018) found that population growth does not stimulate emissions in Nigeria using the ARDL technique.

Also, some studies have documented the implication of different age structures in the environment. For instance, Liddle and Lung (2010) examined the effect of population age-structure on emissions in 17 developed nations during the period 1960 to 2005. The study decomposed the population into three age clusters: 20-34, 35-49, and 50-64, and showed that young adults (20-34) exerted a positive impact on emission while other age groups had a negative connection with emission. In a subsequent study of Organization for Economic Co-operation and Development (OECD) countries, Liddle (2011) confirmed that young adults (20-34) have a positive impact on transport emission while other age units (35-49, 50-69, and 70 and above) are negatively related with transport emission. The study argues that these diverse effects could be explained by the disparity between the economic activities level of the various age groups. For a selection of OECD nations, Menz and Welsch (2012) reported that the age group 15-29 exerts a positive influence on emission, while other age groups (30-44, 45-59, 60-74, and 75 and above) negatively relate to emission. In a panel of 25 OECD nations, Hassan and Salim (2015) highlighted that an increase of 1% in the aged population decreases emission by 1.55%. Zhou and Liu (2016) documented that the working-age population (16-64 years old) has a positive link with emissions in China. Zhang and Tan (2016) confirmed that the effect of population ageing on emissions displays regional differences in China as well.

Wang et al. (2017) used the STIRPAT model for 1997 to 2012 data and found that the ageing population boosts emission in the Chinese Eastern region while reducing emission in the Western and Central regions. In another study, Yu et al. (2018) revealed that population ageing (ratio of population aged over 60 years to total population) has a positive effect on emission in China. Zhang et al. (2018) employed the Generalized method of moments (GMM) method and reported that for the active working group (age 15-64), their indirect effect on emission is contingent on the GDP per capita specific level in China, while the direct effect share on emission is positive. In a more recent study for China, Li et al (2018) reported similar outcomes using the STIRPAT model and data from 1999 to 2014. Kim et al (2020) studied the impact of population ageing in Korea using the Fully Modified Ordinary Least Squares (FMOLS) technique based on 1998 to 2016 data. The study reported that emission is increased by the younger population while the elderly population activities reduce emission. Tarazkar et al. (2020) studied the impact of age structure on environmental degradation in 10 countries in the Middle East region. The study decomposed the age structure into three age groups (less than 15 years, 15-64 and 65 and above) and posits that age structure has a significant association with environmental pollution. The authors further noted that the working-age population has the greatest explanatory power on emission.

In a similar vein, the interconnection between urbanization and the environment have been explored in the literature as follows: Ali et al. (2019) assessed the implication of urbanization on emissions in Pakistan and discovered that urbanization drives emission. Furthermore, there isa multitude of single-country studies that document the linkages between urbanization and the environment which includes Hossain (2012) for Japan, Shahbaz et al. (2014) for the United Arab Emirates, Shahbaz et al. (2016) and Bekhet and Othman (2017) for Malaysia, Ali et al. (2016) for Singapore, Pata (2018) for Turkey, Kwakwa and Alhassan (2018) for Ghana, Salahuddin et al. (2019) for South Africa and Mahmood et al (2020) for Saudi Arabiaamong others, with these studies arriving at various conclusions.

Switching to multi-country studies, utilizing the dynamic ordinary least squares (OLS) in the Middle East and North Africa (MENA) nations, Al-Mulaliet al. (2013) highlighted the existence of a bi-directional positive association between urbanization, energy use and emission.For emerging economies, Sadorsky (2014) and Rafiq et al. (2016) conclude that the association between urbanization and emission is insignificant. Similarly, Al-Mulali and Ozturk (2015) utilized the FMOLS for the MENA data to conclude that urbanization boosts environmental damage whereas political stability reduces it in the long term. Li and Lin (2015) utilized1971 to 2010 data and the STIRPAT method to evaluate the connection between urbanization and emission in 73 nations. Their findings suggest that urbanization increases emission in low-income nations whereas for middle- and high-income economies, urbanization exhibits a trivial effect on energy use and hampers emission. Kasman and Duman (2015) employed panel cointegration and Granger causality tests for selected European Union (EU) nations and found a short-run unidirectional causality from urbanization to emission. Wang et al. (2015) reported that a 1% increase in the urban population enhances emission by 0.2%. The study also finds a short-run unidirectional causality from urbanization to energy consumption and emissions using FMOLS for the Association of Southeast Asian Nations (ASEAN) countries.

For BRICS (Brazil, Russia, India, China, and South Africa) economies, Wang et al. (2016) reported that urbanization induces emission over the period 1985 to 2014. Adams and Klobodu (2017) applied the dynamic OLS estimator and causality methods to assess the implication of urbanization on environment degradation in 38 SSA nations using data spanning from 1970 to 2011. The study reported bidirectional causality between both variables. Khan et al (2019a) confirmed that urbanization exerts a significant effect on emission in 7 out of 10 newly industrialized nations.

Sarwar and Alsaggaf (2019) assessed the implication of urbanization and urban income on emission in 30 Chinese provinces. The estimation outcome shows that urbanization influences environmental degradation while urban income is negatively related to emission. Using Panel Pooled Mean Group-Autoregressive distributive lag methodology (ARDL-PMG), Asongu et al. (2020) estimated the impact of urbanization, fossil fuel consumption, electricity consumption, natural resources rent and economic growth on emission in 13 SSA nations from 1980 to 2014. Their findings show, among other things, that a positive significant association exists between urbanization and emission. Mignamissi and Djeufack (2021) obtained similar outcome for 48 African nations. Mosikari and Eita (2020) found that urban population is negatively correlated with emission in 29 African economies using the panel smooth transition regression method (PSTR).

3. Methodology

3.1 Model

The model of this study follows the highly celebrated STIRPAT model. As the name implies, STIRPAT is an acronym used to refer to a statistical and conceptual model that explains the human impact on the environment. The acronym stands for Stochastic Impacts by Regression on Population, Affluence and Technology. STIRPAT model links human activities to the environment and stresses that environmental degradation is driven by both demographic and economic factors. Demographic factors include population size, population density, urbanization and age structure of the population, while economic factors include the depth of economic activities in the form of economic growth, energy consumption, and perhaps trade (Nathaniel and Khan, 2020). Algebraically, the STIRPAT model is specified as follows:

$$I = \lambda_0 P^{\alpha_1} A^{\alpha_2} T^{\alpha_3} \mu \qquad (1)$$

Where *I*is an indicator of environmental degradation, *P*, *A*, and *T* stand for population, affluence, and technology respectively; $\alpha_1 - \alpha_3$ and μ are the parameter estimates and the error term, respectively. As pointed out by Bello et al. (2018), Anser (2019), and Nathaniel and Khan (2020), *T* can be disintegrated into various other variables based on the research problem. However, following Nathaniel and Khan (2020), this study replaces *I* with an ecological footprint (ECFP), *P* with the elements of population dynamics such as population growth, population density, urbanization and age structure of the population. Underpinned by the theoretical propositions of the STIRPAT model, this study adopts, with modifications, the model used by Nathaniel and Khan (2020) which also resembles that of Wang and Dong (2018). Hence, the model of this study is specified as follows:

$$ECFP_{it} = \beta_0 POPG_{it}^{\beta_1} POPD_{it}^{\beta_2} URBN_{it}^{\beta_3} AGES_{it}^{\beta_4} PGDP_{it}^{\beta_5} ENEC_{it}^{\beta_6} TRAD_{it}^{\beta_7} \mu_{it} \quad 2$$

Where ECFP stands for ecological footprint; POPG is the population growth rate; POPD denotes population density; URBN stands for urban population growth rate; AGES is the age structure of the population; PGDP denotes per capita gross domestic product (GDP); ENEC stands for energy consumption; TRAD is trade openness; $\beta_1 - \beta_7$ and μ are the parameter estimates and the error term, respectively; and subscripts *i* and *t* are cross-section and time dimensions of the panel, respectively. Adopting a log-linear transformation of Equation 2, the following equation is obtained:

$$LECFP_{it} = \beta_0 + \beta_1 LPOPG_{it} + \beta_2 LPOPD_{it} + \beta_3 LURBN_{it} + \beta_4 LAGES_{it} + \beta_5 LPGDP_{it} + \beta_6 LENEC_{it}$$

$$+\beta_7 LTRAD_{it} + \mu_{it} \quad 3$$

Where L is the natural logarithm notation.

3.2 Data

This study is based on panel data covering five African countries namely: Democratic Republicof Congo, Ethiopia, Nigeria, South Africa and Tanzania for 30 years from 1990 to 2019, resulting in the panel structure, N = 5 and T = 30. The chosen variables are drawn from the literature, especially those linking environment to demographic and economic factors (see Nathaniel & Khan, 2020). The dependent variable is environmental quality and has been proxied by ecological footprint which is a measure of environmental degradation. Ecological footprint refers to the amount of biologically productive area needed to sustain all the competing demands of people (Global Footprint Network [GFN]). These demands cover the land space for growing food, production of fibre, regeneration of timber, absorption of CO_2 emission from burning fossil fuel, and accommodation of built infrastructure. For this study, we use data on ecological footprint per capita (ECFP) obtained from the website of the GFN. Other variables such as population growth rate (POPG), population density (POPD), urban population growth rate (URBN), age structure of the population (AGES), per capita GDP growth rate (PGDP), energy consumption (ENEC), and trade openness (TRAD) are as defined and obtained from the World Bank Development Indicators database. The description, measurement and sources of variables are summarized in Table 1.

Table 1: Summary of Variable Definition, and Sources of Data

Variables' Names	Descriptions	Measurements	Sources
ECFP	Ecological footprint per person	A nation's total ecological footprint (in global hectares) divided by the total population of the nation.	GFN database
POPG	Population growth rate	Annual percentage growth in population size.	World Bank database
POPD	Population density	Measures the number people per square kilometre of land area.	World Bank database
URBN	Urbanization	Annual percentage growth in urban population.	World Bank database
AGES	Age structure of the population	Age dependency ratio, measure in terms of the percentage of working-age (median-age) population.	World Bank database
PGDP	Per capita GDP growth	Percentage growth rate of the gross domestic product per capita, measured as the annual percentage change in the ratio of GDP to population.	World Bank database.
ENEC	Energy consumption (per capita kg of oil equivalent)	Energy consumption is the use of primary energy before transformation to other end-use fuels (such as electricity and refined petroleum products). World Bank population estimates are used to calculate per capita data.	World Bank database.
TRAD	Trade openness	The ratio of the sum of exports and imports to GDP	World Bank database.

NB: Global Footprint Network (GFN) database: https://data.footprintnetwork.org; World Bank database (World Development Indicators): https://www.databank.worldbank.org.

Source: Computed by the Authors

3.3. Estimation Technique

This study is based on a panel-autoregressive distributed lag (ARDL) model framework to examine the influence of population dynamics on environmental quality in selected five African countries. The choice of the panel-ARDL model framework is premised on the fact that it allows one to generate both the shortrun and longrun dynamic parameter estimates through an unconstrained error correction model (ECM) obtained from the said ARDL structure. However, the consistency of the Panel-ARDL estimates depends upon errors being cross-sectionally independent irrespective of whether all the regressors are purely exogenous or not, as well as whether all the variables are either I(0) or I(1) or a combination of both (Pesaran and Smith, 1995; Pesaran, et al., 1999). Cross-sectional dependence is a phenomenon that is prevalent in most panel data regressions due to the interdependencies among countries especially those that are found within a particular region. Thus, to overcome the likelihood of biased estimates that characterise cross-sectional dependence in errors, this study opted for the Cross-sectionally Augmented ARDL (CS-ARDL) model based on the Pesaran's (2006) Common Correlated Effect (CCE) approach for panel ARDL as rightly suggested by Chudik and Pesaran (2015). According to Pesaran (2006), cross-sectional means of both the dependent and regressors can be used to capture the unobserved common factors which can be inserted into the original model under the assumption of uncorrelated regressors and parameters. Also, the CS-ARDL assumes that the idiosyncratic error term is identically and independently distributed across country and time dimensions and that the cross-sectional average reverts to zero in root average square error as N, meaning that the linear combination of the cross-sectional averages of both dependent and explanatory variables can help account for the cross-sectional dependence in the errors (Ahmed, 2020). Thus, in line with the CS-ARDL specification, Equation 3 takes the general reduced form as follows:

$$Y_{it} = \emptyset_i + \sum_{k=1}^{p} \Omega_{ik} Y_{it-k} + \sum_{k=0}^{q} \beta_{ik}' X_{it-k} + \sum_{k=0}^{\eta} \delta_{ik}' \bar{W}_{t-k} + \mu_{it} \quad 4$$

where Y is the dependent variable (i.e., ECFP); X is the vector of regressors (i.e., POPG, POPD, URBN, AGES, PGDP, ENEC, and TRAD) as earlier defined; $\overline{W}$ is the vector of cross-sectional averages of both the dependent variable and regressors [i.e., $(\bar{W} = \bar{Y}, \bar{X})$], and η is the number of lagged cross-sectional averages. The ECM version of the CS-ARDL model is represented as follows:

$$\Delta Y_{it} = \emptyset_i + \partial_i (Y_{it-1} - \bar{\gamma}_i' X_{it-1}) + \sum_{k=1}^{p-1} \Omega_{ik}^{*} \Delta Y_{it-k} + \sum_{k=0}^{q-1} \beta_{it}'^{*} \Delta X_{it-k} + \sum_{k=0}^{\eta} \lambda_{ik}' W_{t-k} + \sum_{k=1}^{p-1} \partial_k \Delta \bar{Y}_{t-k} + \sum_{k=0}^{q-1} \varphi_k \overline{\Delta X_{t-k}} + u_{it} \quad 5$$

Like Ahmed (2020), we adopt the rule-of-thumb provided by Chudik and Pesaran (2015) whereby $\eta = T^{1/3}$ in chosen the appropriate number of cross-sectional means which addresses the imminent residual cross-sectional dependence that characterises panel ARDL model. Lastly, the reliability of the estimated CS-ARDL model was verified by performing an additional cross-sectional dependence test following Pesaran’s (2004) pairwise correlation coefficient which is robust to coefficient heterogeneity, non-stationarity, and single or multiple structural breaks (Ahmed, 2020).

The CS-ARDL model estimation begins with determining the existence of residual cross-sectional dependence as this is also particularly important for choosing the appropriate procedure for panel unit root testing. As pointed out by Aluko and Obalade (2020), when cross-section dependence prevails, the second-generation panel unit root tests are considered appropriate. Hence, this study employs the cross-sectionally Augmented Im, Pesaran, and Shin (CIPS) panel unit root test of Pesaran (2007), which explicitly accounts for the possibility of cross-sectional dependence in panel unit root test. Other relevant pre-estimation analyses include descriptive analysis of data using the relevant statistics, correlation analyses of regressors to ensure that multicollinearity does not constitute a serious problem, the Pesaran's CIPS panel unit root test, and panel cointegration test, which was done using the Kao residual-based test. For the cross-sectional dependency, the study examines the degree of association between the residuals in panel cross-sections. The null hypothesis underlying this test is that countries in the panel are cross-sectionally independent, while the alternative is that they are cross-sectionally dependent. Thus, the null hypothesis is rejected if the probability of the Breusch-Pagan statistic is less than 0.05.

4. Results and Discussion

4.1. Summary of Descriptive Statistics

This subsection is to describe the variables with the view of unveiling the spread of the relevant data points across countries under study. This analysis is important as it provides a clearer picture of the data and it has trended overtime across the selected countries. According to Table 2, the mean value of ecological footprint per person across the selected countries is 1.51 per person. With a standard deviation of 0.94 per person, there is a high disparity in ecological footprint per person across the selected countries, meaning that some countries have a relatively high ecological footprint than others. The maximum and minimum values of ecological footprint per person across the selected countries are 3.82 per person and 0.06 per person, which were observed from South Africa and Ethiopia, respectively. The average growth rate in the population of the selected countries is 2.61% with a standard deviation of 0.54, suggesting a similar growth pattern in the population of selected countries. The highest and lowest growth rate in the population is 3.66% and 1.22%, coming from Ethiopia and South Africa, respectively. The mean value of population density across the selected countries is 64.9 people per square kilometre of land area. With a standard deviation of 52.7 people per square kilometre of land area, there is evidence of wide variation in population density across the selected countries. The maximum and minimum values of population density across the selected countries are 209.1 people per square kilometre of land area and 6.99 people per square kilometre of land area respectively observed from Nigeria and the Democratic Republic of Congo. Also, urbanization, which is measured using the urban population growth rate, has a mean value of 4.10% and a standard deviation of 1.07%. This shows that the selected countries share a similar pattern of growth in urban population. The maximum and minimum values of urban population growth rates are 5.79% and 1.93%, coming respectively from Tanzania and South Africa.

Furthermore, the mean value of age structure of the population (measured using age dependency ratio) shows that 83.0% of the total population of selected countries belongs to the median age (working age). With a standard deviation of 13.2%, there is a similar pattern of age structure across the selected countries. The maximum and minimum values of the age structure of the population are 99.1 and 52.2, coming respectively from Ethiopia and South Africa. Interestingly, there is an obvious case of poor per capita GDP growth across the selected countries given the average growth rate of 2.20%. With a standard deviation of 9.06%, there is a considerably high disparity in per capita GDP growth across the countries under study. This is evident as the maximum and minimum values of per capita GDP growth are 80.5% and -53.8% respectively, both observed in Ethiopia. Also, energy consumption has a mean value of 930.2 kg of oil equivalent per capita and a standard deviation of 890.2 kg of oil equivalent per capita across the selected countries, suggesting a wide variation in energy consumption across the countries. The maximum and minimum values of energy consumption are 2979.1 kg of oil equivalent per capita and 225.9 kg of oil equivalent per capita respectively observed from South Africa and the Democratic Republic of Congo. Trade openness (ratio of exports plus imports to GDP) has a mean value of 71.1 and a standard deviation of 36.0, suggesting that the selected countries have a similar pattern of trade openness. The maximum and minimum values of trade openness are 168.6 and 26.5 respectively, coming from the Democratic Republic of Congo and Ethiopia. In passing, it should be noted that due to the spread of relevant data across the selected countries in this study, the natural logarithm transformation of variables is necessary for further econometric analyses.

Table 2: Summary of Descriptive Statistics

Variables	Mean	Std. Dev.	Minimum	Maximum
ECFP	1.51	0.94	0.06	3.82
POPG	2.61	0.58	1.22	3.66
POPD	64.9	52.7	6.99	209.1
URBN	4.10	1.07	1.93	5.79
AGES	83.0	13.2	52.2	99.1
PGDP	2.20	9.06	-53.8	80.5
ENEC	930.2	890.2	225.9	2979.1
TRAD	71.1	36.0	26.5	168.6
Obs.	**150**	**150**	**150**	**150**

Source: Computed by the Authors

N.B: Ecological footprint per person (ECFP) population growth rate (POPG), population density (POPD), urbanization (URBN), age structure of the population (AGES), per capita GDP growth rate (PGDP), energy consumption (ENEC) and trade openness (TRAD)

4.2. Correlation Test Results

Table 3 presents the results of the correlation matrix particularly carried out to ensure that the multicollinearity problem is not severe. Expectedly, no two explanatory variables are correlated to a higher degree, meaning that the specified model is not plagued by multicollinearity issues.

Table 3: Correlation Matrix (listwise missing value deletion)

Correlation Probability Observation	LECFP	LPOPG	LPOPD	LURBN	LAGES	LPGDP	LENEC	LTRAD
LECFP	1.0000							
LPOPG	0.8409	1.0000						
LPOPD	0.0687	-0.0383	1.0000					
LURBN	0.7239	0.6728	0.3377	1.0000				
LAGES	0.8127	0.4896	0.1875	0.5943	1.0000			
LPGDP	0.0069	-0.0754	0.1119	0.0055	-0.0342	1.0000		
LENEC	0.9231	-0.3861	0.2290	-0.5275	-0.6806	0.0198	1.0000	
LTRAD	0.3725	0.1717	-0.6294	-0.1892	-0.0154	-0.1677	-0.3166	1.0000

Source: Computed by the Authors

N.B: Log ecological footprint per person (LECFP) log population growth rate (LPOPG), log population density (LPOPD), log urbanization (LURBN), log age structure of the population (LAGES), log per capita GDP growth rate (LPGDP), log energy consumption (LENEC) and log trade openness (LTRAD)

4.3 Cross-Section Dependence Test Results

Cross-section dependence arises when an individual country's errors are correlated. This is born out of the fact that countries, especially those within the same region or continent are highly interdependent due to globalization and trade, such that the experience of one country may likely affect another country. This study employed the Breusch-Pagan LM test statistic for the test of cross-section dependence given that the time dimension is more than the dimension of the cross-section (i.e. T=30 > N=5) and the results are reported in Table 4. Given that the probability of the Breusch-Pagan LM test statistic is less than 0.05, we reject the null hypothesis of cross-section independence and conclude that there is cross-section dependence in our panel.

Table 4: Residual Cross-Section Dependence Test

Test	Statistic	df	Prob.
Breusch-Pagan LM	59.91	10	0.0000
Pesaran Scaled LM	11.16		0.0000
Pesaran CD	0.117		0.9068

Source: Authors' Calculation

4.4 Panel Unit Root Test Results

Following the rejection of the null hypothesis of cross-section independence, the study employed the second-generation panel unit root test based on the CIPS panel unit root test of Pesaran (2007). The choice of Pesaran's CIPS panel unit root test is that it performs the test of a unit root in the presence of cross-section dependence. The results of the CIPS panel unit root tests are reported in Table 5. Interestingly, four variables (LPOPG, LURBN, LAGES, and LPGDP) out of eight are stationary in the level series or I(0) while the remaining four variables (LECFP, LPOPD, LENEC, and LTRAD) are stationary in the first difference series or I(1). These results imply that the use of CS-ARDL for short run and long run analyses is justified on all fronts.

Table 5: Panel Unit Root Test

Variable	Method	Level	First Diff.	I(d)
	CIPS	Stat. (Prob.)	Stat. (Prob.)	
LECFP		-0.03721 (0.4852)	-5.14611**(0.0000)	I(1)
LPOPG		-11.2821** (0.0000)		I(0)
LPOPD		-1.04851 (0.1472)	-2.29562* (0.0108)	I(1)
LURBN		-2.21909* (0.0132)		I(0)
LAGES		-3.34009** (0.0004)		I(0)
LPGDP		-3.50802** (0.0002)		I(0)
LENEC		1.94719 (0.9742)	-5.40528** (0.0000)	I(1)
LTRAD		3.38091 (0.9996)	-5.65412** (0.0000)	I(1)

**(*) denotes significant at the 1%(5%) level.

Source: Authors' Calculation

N.B: Log ecological footprint per person (LECFP) log population growth rate (LPOPG), log population density (LPOPD), log urbanization (LURBN), log age structure of the population (LAGES), log per capita GDP growth rate (LPGDP), log energy consumption (LENEC) and log trade openness (LTRAD)

4.5. Panel Cointegration Test

While cointegration is confirmed by the negative sign and significance of the error correction term (COINTEQ01) in the CS-ARDL procedure as reported in Table 8, this study also carried out the Kao residual-based cointegration test, and the result is shown in Table 6. Expectedly, the result of the ADF test of the residual rejects the null hypothesis of no cointegration at the 1%

level. Thus, we reject the null hypothesis of no cointegration and posit that a long run relationship exists among the chosen variables.

Table 6: Kao Residual-Based Cointegration Test Result

	t-Statistic	Prob.
ADF	-4.207373	0.0000
Residual variance	0.001703	
HAC variance	0.001454	

Source: Authors' Calculation

4.6. Panel Model Estimation Results

The estimated long-run coefficients of the CS-ARDL model are reported in Table 7. These results are robust to coefficient heterogeneity and residual cross-sectional dependence given that the probability value of the estimated Pesaran Cross-sectional Dependence (CDS) is greater than 0.05, meaning that the null hypothesis of residual cross-sectional independence cannot be rejected. The dependent variable is ecological footprint (LECFP) which is used to capture environmental degradation, while the independent variables include population growth rate (LPOPG), population density (LPOPD), urban population growth rate (LURBN), age dependency ratio (LAGES), per capita GDP growth rate (LPGDP), energy consumption (LENEC) and trade openness (LTRAD) all in natural logarithm form. The results show that, in the long-run, all regressors significantly affect the regresand (LECFP) at either 1% or 5% except the urban population growth (LURBN). This implies that not much inference can be made regarding the influence of urbanization on environmental quality in the selected countries.

It is evident from Table 7 that population growth has a significant positive long run influence on ecological footprint such that a percentage increase in the size of the population is expected to bring about a 0.38 percent increase in ecological footprint. This conclusion cannot be said to be the case in the short run as the short run effect of population growth on ecological footprint is not statistically significant at both current and after a period lag (see Table 8). This implies that population growth leads to environmental degradation only especially during the long run, meaning that a spontaneous rise in population, either in the form of movement from one country to another or moving from one city (within a country) to another, may not generate much impact on the environment, but a long-term rise in the size of the population when all factors (birth and death rates) are considered will have much significant impact on the quality of the environment. The influence of population growth on environmental quality as revealed by this study implies that population growth increases environmental degradation. This finding is not surprising considering that human activities are primarily responsible for increasing environmental deterioration. Similarly, increased population leads to increased energy consumption, urbanization, and deforestation, all of which contribute to increased pollution and carbon emissions. Likewise, population growth causes considerably faster depletion of natural resources and deforestation. Interestingly, this finding is consistent with Abdelfattah et al. (2018) for Arab regions, Chontanawat (2018) for Association of Southeast Asian Nations (ASEAN) region, Pham et al. (2020) for European nations, Solarin (2020) for developing and emerging nations and a host of others. However, this outcome is in contrast to many prior studies like Rahman (2017) for 11 most populous Asian nations, Begum et al. (2015) for Malaysia, among others.

However, it was found that urbanization (urban population growth) has a positive but not significant influence on the ecological footprint in the long run and short run, meaning that urbanization is not a serious contributor to environmental degradation in the selected African countries. This outcome agrees with several studies such as Sadorsky (2014) for 16 emerging nations, Asane-Otoo (2015) for 45 African countries, Xu and Lin (2015) for China, Lin et al.

(2016) for 5 African nations, Rafiq et al. (2016) for 22 urbanized emerging nations, Lin et al. (2017) for 53 countries and Tarazkar et al. (2020) for Middle East regions. This result contradicts the earlier findings of Wang and Dong (2018), Adams and Klobodu (2018), Sarwar and Alsaggaf (2019) and Asongu et al. (2020). The finding that urbanization is not a serious contributor to environmental degradation for the selected African nations is predicated on the fact that several African nations lack access to energy and this may account for why the urbanization estimate is not significant for the selected countries

From the results in Tables 7 and 8, it was found that population density has a significant positive influence on ecological footprint across the selected countries both in the long run and in the short run. In the long run, it is to be expected that a percentage increase in population density will bring about 0.26 percent increase in ecological footprint. This implies that population density has both short run and long run positive effects on environmental quality with a larger effect in the short run (see Table 8). In other words, population density increases environmental degradation across the selected African countries with a larger impact in the short run. This finding is supported by Rahman (2020) for India and Ali et al. (2020) for selected Asian nations and Rahman (2017) for 11 Asian populous countries. This finding is explained by the fact that increased population puts additional strain on natural resource extraction contributing to environmental degradation.

Also, the results show that the age structure of the population (age dependency ratio) has a significant positive influence on the ecological footprint in the long run and short run. In terms of magnitude, a percentage increase in the percentage of the working-age population (median-age) is expected to bring about 0.50 percent increase in ecological footprint in the long-run. This means that countries with a larger percentage of the working-age population (more working-age structure) have more environmental degradation problems. This finding affirms the finding reported by Liddle and Lung (2010) for OECD nations, Zhou and Liu (2016) for China. Analogously this finding aligns with the outcomes of recent studies like Kim et al. (2020) for Korea and Tarazkaret al. (2020) for Middle East Regions. Howbeit, this finding is contrary to the outcomes of Yu et al. (2018) who found that the aged population drives carbon emission in China. The major reason supporting the outcome of working-age population driving emission in Africa is because the working-age population consumes more energy than the elderly population and children and they produce more greenhouse gasses. Additionally, the working population is more productive, and their carbon impact is bigger.

The results also show that growth in per capita GDP exerts a significant positive influence on the ecological footprint in the long run such that a percentage increase in per capita GDP will bring about 0.27 percent increase in ecological footprint across the selected countries. This implies that as countries experience economic growth, the environment loses its quality in the long-run. In other words, economic growth (affluence) increases environmental degradation in the selected African counties. This finding stands in support with the finding reported by Shuai et al. (2017) for 125 nations, Adams and Klobodu (2018) for 26 African nations, Hashmi and Alam (2019) for OECD nations, Solarin (2020) for 35 emerging and developing nations and a host of others. This finding can be explained by the premise that increasing energy inputs are required to expand economic activity. The incremental effect of economic growth on the environment is also contingent on the fact that inefficient production processes and methods predominate African nations. The region’s growth efforts are not pro-environment and the critical challenge facing the region is to find ways to grow their economies without damaging the environment (Adams and Klobodu, 2018).

Energy consumption (in terms of kg of oil equivalent) has a significantly positive effect on ecological footprint across the selected countries in the long run and short run. In the long run, it was found that a percentage increase in energy consumption is expected to result in 1.09 percent increase in ecological footprint. This shows that energy consumption contributes significantly to environmental degradation across the selected countries. Overreliance and inefficient utilization of fossil fuels in Africa could explain the outcome of a positive correlation between energy consumption and environmental degradation. Energy poverty is prevalent in Africa and the majority of energy consumed is from non-renewable sources. This finding is consistent with the finding reported by Sarkodie (2018) for 17 African nations, Khan et al. (2019b)for Pakistan, Gorus and Aslan (2019) for MENA nations and Chekouri et al. (2020) for Algeria

The study also found that trade openness has both short run and long run significant positive influence on the ecological footprint to the extent that a percentage rise in trade openness will result in about 0.21 percent rise in ecological footprint in the long run. This implies that trade openness leads to environmental degradation across the selected countries. This outcome is unsurprising, given that many developing nations have lax environmental trade restrictions, resulting in environmental degradation in these countries. Although trade openness provides various advantages for developing economies, poor restrictions appear to have resulted in an influx of inferior and high-energy-consumption items, resulting in increased carbon emissions in these countries. Previous studies such as Acheampong et al. (2019) for sub-Saharan African nations, Kwakwa (2020) for Tunisia, Coskuner et al (2020) for Organization of Petroleum Exporting Countries (OPEC) countries, have found the incremental effect of trade openness on environmental degradation in many developing nations.

Table 7: Estimated Long run Coefficients Based on Panel CS-ARDL Model
Dependent Variable: LECFP

Variable	Coefficient	Prob.*
	Long Run Equation	
LPOPG	0.382019**	0.0021
LPOPD	0.260215**	0.0083
LURBN	0.091365	0.2915
LAGES	0.501022*	0.0373
LPGDP	0.268744**	0.0024
LENEC	1.088311**	0.0055
LTRAD	0.205199**	0.0050
CSD-test		
Pesaran CD	0.012	0.9224

**(*) denotes rejection of the null hypothesis at the 1%(5%) level.
Source: Authors' Calculation
N.B: Log ecological footprint per person (LECFP) log population growth rate (LPOPG), log population density (LPOPD), log urbanization (LURBN), log age structure of the population (LAGES), log per capita GDP growth rate (LPGDP), log energy consumption (LENEC) and log trade openness (LTRAD)

Furthermore, Table 8 presents the short-run version of the estimated CS-ARDL model which reveals the speed of adjustment from one period error to another. Thus, the emphasis of Table 8 is on the error correction term (COINTEQ01). Going by the negative sign of the error parameter and its significance, the cointegration relationship among the variables as shown by the Kao residual-based test is not in doubt. The size of the error parameter (-0.56) shows that about 56 percent of short-run shocks that usually disrupt the equilibrium will be corrected in each period, meaning that it will take barely two periods for the equilibrium to be fully restored. This revelation implies that the environmental quality may experience shocks whether positive or negative (anticipated or not), but such shocks are temporary as equilibrium holds in the long-run.

Table 8: Estimated Short run Model

Dependent Variable: D(LECFP)
Short Run Equation

Variable	Coefficient	Prob.*
COINTEQ01	-0.560210**	0.0010
D(LECFP(-1))	0.103912**	0.0000
D(LPOPG)	0.024301	0.2189
D(LPOPG(-1))	0.105321	0.2201
D(LPOPD)	0.321153*	0.0291
D(LPOPD(-1))	-0.579144	0.3988
D(LURBN)	0.071254	0.6025
D(LURBN(-1))	0.150032	0.1203
D(LAGES)	0.822163**	0.0021
D(LAGES(-1))	0.510531	0.3426
D(LPGDP)	0.282911	0.2944
D(LPGDP(-1))	-0.084320*	0.0383
D(LENEC)	0.096821	0.2915
D(LENEC(-1))	-0.201516	0.5872
D(LTRAD)	0.335104**	0.0066
D(LTRAD(-1))	-0.420112	0.3416
C	-1.077698*	0.0360

**(*) denotes rejection of the null hypothesis at the 1%(5%) level.

Source: Authors' Calculation

NB:COINTEQ is the cointegrating equation which is the error correction term, D is the difference operator

5. Conclusion

Enhancing environmental quality holds a major place in the quest to achieve the Sustainable Development Agenda initiated in 2015 by the United Nations. To actualise the SDGs, most countries are making concerted efforts to improve environmental quality within their locality. In traditional and contemporary literature, population dynamics has been identified as a key determinant of environmental quality. The debate in the African perspective is relatively growing with room for extensions in theory and methods, using contemporaneous information from the most populous countries in the region. The paper assesses the nexus between population dynamics and environmental quality in five African countries namely: The Democratic Republic of Congo, Ethiopia, Nigeria, South Africa and Tanzania. In this quest, panel information from 1990 – 2019 is analysed using the CS-ARDL framework. The following variables identified from the literature were utilised – ecological footprint per capita (ECFP), population growth rate (POPG), population density (POPD), urban population growth rate (URBN), age structure of the population (AGES), per capita GDP growth rate (PGDP), energy consumption (ENEC), and trade openness (TRAD). The rundown of the main study findings reveals as follows: population growth leads to environmental degradation especially during the long-run, population density increases environmental degradation across the selected African countries with larger impact in the short run, urban population growth has a positive but not significant influence on the ecological footprint in the long run and short run, age structure of the population result points that countries with a larger percentage of the working-age population have more environmental degradation problems, per capita GDP growth rate findings show that countries which experience economic growth loose environment quality in the long run, energy consumption contributes significantly to environmental degradation across the selected countries and trade openness leads to environmental degradation across the selected countries.

The key outcomes of this study provide insightful options to address the population situation in the understudied countries to accelerate environmental quality, proxied by ecological footprint per capita. In line with the study findings, the ensuing recommendations are put forward: rapid expansion in population poses a threat to the environment via the damages to natural habitats and its concomitants. Concerned policymakers need to intensify the propagation of population control measures geared towards sensitisation and education of the populace. Specifically, the countries should embrace complementary population control intervention programmes like enhancing the education of women and girls, promoting birth control and family planning initiatives, gender equality and empowerment as well as socioeconomic policies to discourage early marriage, boost education, living standards and overall welfare outcomes.

Population density and age structure of the population are intricately linked in the population dynamics discourse while exerting dire implications on environmental quality. Population density fuels CO2 emissions and worsens the ecological footprint, paving the way for demographic stress on the environment. Natural resources are depleted more quickly and pollution worsened. Environmental preservation efforts in the face of rising population density should encourage greater acceptance of the sustainable way of life through water savings and conservation, renewable energy and energy efficiency adoption, green consumables and beverages among others. Also, rising population density raises the number of persons beneath the poverty line who patronise cheaper and dirty natural resources. This eventually will contribute to environmental degradation in the following forms – land dilapidation, soil destruction, deforestation, water pollution and worsening land per capita. The age structure of the population points at the demographic features of the country and the impact on environmental quality. Our study highlights that countries with a larger percentage of the working-age population (more working-age structure) have more environmental degradation problems. Therefore, socio-economic development plans should recognise the trends and patterns of consumption of the dominant population age-group, to make products to meet their demand in a holistic and sustainable. In general, the message of environmental security should be better communicated across all age classifications to share the responsibility of minimising environmental challenges.

As confirmed by study findings, urbanisation is not a serious contributor to environmental degradation ecological footprint in the region; however, efforts should be made to preclude the possibility of a future urbanisation challenge. Given the expected increase in urbanisation, the main task for policymakers should dwell around exploiting the gains of urbanisation while dealing with expected rural-urban migration, provision of social services, housing and sanitation, infrastructure, transport networks and manufacturing among others. For improved socio-economic advancement in the region, creative and committed urban governance by urban planners should inculcate environmental concerns in urban and regional planning. Continued carbon emission to the detriment of the environment is traceable to a rise in population and economic endeavour. Our finding is, therefore, not surprising that energy consumption significantly contributes to environmental degradation in the selected African countries. This is evident in the predominant usage of dirty fossil fuels and other inefficient energy sources. Apart from emitting dangerous environmental pollutants, it is becoming a worrying source of rising cases of cancer, respiratory ailments and other medical issues. Another major challenge looks at how to promote economic growth in the region devoid of negative environmental impact. Energy policy within the continent should focus on deepening energy efficiency practice and transition to renewable energy through the deployment of resources to provide requisite infrastructure to boost the production of clean energy.

As for trade openness, it was discovered that it leads to environmental degradation across the selected countries. This result provides greater insight concerning the nexus between environmental quality and trade liberalisation. The study recommends policymakers consider environmental quality when discussing international, regional and local agreements with regards to trade and carbon tariffs. Thus, the synchronisation of environmental and trade policies will help minimise carbon emission to reduce the ecological footprint and boost cleaner production and trade. Lastly, since economic growth increases environmental degradation in the selected African counties, policymakers in the region should prioritise green growth as a sustainable alternative. Hence, the growth process should be energized using green and sustainable energy sources. These innovations will usher in improved energy efficiency practices that lower CO2 emissions.

Growing population figures in the world have been linked with environmental pollution with adverse impacts on natural resources and quality of life. The motivation of this study sought to unearth the relationship between population dynamics and environmental quality for selected African countries. Findings reveal that population growth exacerbates environmental degradation among others. This presents a clarion call to take population policy seriously and preserve the environment for present satisfaction and the betterment of generations to come. While the findings of this study offer significant policy relevance for decision-makers, it is not devoid of limitations that can be treated by future studies, especially with the rolesof artificial intelligence, culture, remittances, corruption and financial development in the region.

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