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To what Extent Does Globalization Influence Climate Change Sensitivity in Sub-Saharan Africa Countries: Evidence from DCCE-MG Approach

Sahar Aghazadeh

Faculty of Economics, Administrative and Social Sciences

Cyprus West University, Cyprus

Jamiu Adetola Odugbesan (Corresponding author)

Faculty of Economics, Administrative and Social Sciences

Cyprus West University, Cyprus

Aliakbar Saei

Faculty of Business and Economics, Eastern Mediterranean University

North Cyprus, Mersin 10, Turkey

E-mail: odugbesanadetola@gmail.com

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Abstract

Though, the issue of climate change is a global challenge that has attracted the attention of various stakeholders, but the understanding of various contributing factors to address the challenge still remains a moot topic. Thus, this study investigates the sensitivity of climate change in Sub-Saharan Africa (SSA) countries to overall globalization, dejure and defacto globalization, population, urbanization and economic growth using a panel data covering the period from 1990-2018. The estimations were performed using the novel Westerlund and Erdgerton panel cointegration approach to estimate the co-movement of the variables in the long run, while the long-run relationship was estimated using the "Dynamic Common Correlated Effect-Mean Group" (DCCE-MG) techniques and used the "Dynamic OLS" and "Fully Modified OLS" for robustness check. Empirical findings reveal the long-run relationship between the variables of interest. In addition, our study shows a significant and positive influence of overall globalization, dejure and defacto globalization, economic growth and urbanization on climate change in SSA countries in the long-run, while population was found to have a negative and significant long-run relationship with climate change. Finally, the findings implications and suggestions for policy makers in SSA countries were presented.

Keywords: Globalization, Environmental quality, Climate change, Greenhouse Gas Emissions, DCCE-MG, Sub-Saharan Africa

1. Introduction

Climate change has been a major issue that has dominated scientific discourse globally and regionally. According to Xiaoman et al. (2021) this issue is the most important challenge that the humanity is facing. Author of the study is also mentioning that the one of the main reasons of the climate change is "green gas emissions (GHGs). There are two major questions that the stakeholders of the issue regarding the subject; first one is "what are the factors that are contributing to climate change?" and the second one is "how fall out of it?" (Ahmed et al., 2019; Xiaoman et al., 2021). All of the countries share the same earth and this gives all of them the responsibility to investigate and detect and reasons of the growing GHGs and mitigate them with the most appropriate strategies. This is even more crucial for the Sub-Saharan Africa (SSA) countries because of their unique nature. Literature suggests that "climate change is indisputably caused by human activities, and it is already affecting every region, as well as making extreme weather events to be worse" (CBS News, 2021). CBS News (2021) opined that "it is unequivocal that human influence has warmed the atmosphere, ocean and land,". Many of the changes inflicted on the planet — especially our oceans — will be "irreversible for centuries to millennia," and continued warming will lead to an acceleration of "extreme events unprecedented in the observational record". The report stressed further that "the alarm bells are deafening, and the evidence is irrefutable: greenhouse gas emissions from fossil fuel burning and deforestation are choking our planet and putting billions of people at immediate risk,". Meanwhile, the U.N. Secretary General submitted in the latest report that that there is still time to take actions on the climate crisis, because every increment of temperature rises matters, so less warming will assist in reducing the disaster (UN, 2021).

The variations in environmental quality leads to some forms of climate change like glaciers melting, increasing air and ocean temperatures, rising sea levels, reduced output of agricultural produces, destruction of wildlife, as well as deterioration of workforce productivity (Wang, 2019; Xu et al., 2018). Owing to the increasing adversity in climate change, Suki et al. (2020) observed that the evidence of environmental concerns is many and apparent in several official policy instruments like pollution taxes, eco-regulations, as well as rapt attention for enduring significant role in the survival of mankind in the long-run and sustainability of economic. Though, every economy desires a growth in their economy, but some certain externalities exist that can appear from the process of growth and constitute hindrance for economic conditions. This view has resulted to the numerous studies that focus on the existing relationship between economic development and environmental externalities using mostly from the theoretical domain of "environmental Kuznets curve (EKC)" (Acheampong et al., 2019; Adebayo et al., 2021; Rafindadi & Usman, 2019; Suki et al., 2020). However, Shahbaz et al. (2016) observed that there is an aspect of EKC model that have not been exhaustively investigated, and this include the vastly ignored globalization.

It is no doubt that the country's exposure to some level of globalization has its positive attributes which are in form of transfer of skills, foreign investment, technological advancement, trade liberalization, as well as encouragement of people, goods and expertise mobility that have brought numerous societal and economic advantages to the course of a nation development (Sharif et al., 2019). Meanwhile, Shahbaz et al. (2015) observed that all these activities also brought some undesirable outcomes like environmental degradation which was as a result of the over-utilization of resource and energy footprint of major industrial and production processes. In addition, Kan et al. (2019) observed that in the course of globalization, some products that impose detrimental effect on the environmental as well as putting pressure on the environment are being imported. Sharif et al. (2020) stressed that while globalization has a direct impact on the production process, it also exerts influence on environmental quality. Meanwhile, the study of Christmann & Taylor (2001) observed that some advocate of globalization opined that some reduction in the level of environmental degradation occur as a result of high levels of globalization, because it promotes stringent environmental regulations on firms. However, the globalization critics are of the opinion that globalization degrade the environment, because it exerts rapid depletion of resources on the environment (Aluko, Opoku, & Ibrahim, 2021). This was believed by the authors to be as a result of expansion of production activities which most times accompanies additional globalization with the attendant effect on the environment.

Empirically, some studies like Destek (2020), Phong (2019), Suki et al. (2020), and Xu et al. (2018) have examined the environmental impact of overall globalization (social, economic, and political). But these studies failed to distinguish between the "defacto" and "dejure" aspect of globalization which is imperative owing to the possible differential effect they could have (Sharif et al., 2020). Gygli et al. (2019) stated that while "dejure" globalization assess the policies and conditions that, in principle, allows, promote and encourage flows and activities, the "defacto" globalization indicate the actual international flows and activities. In other words, while intent to globalize can be measured by 'dejure", the "defacto" can be considered as the resultant variable that measures the actual extent of globalization. Sharif et al. (2020) opined that this position enable researcher to determine the differential impact of these two aspects of globalization on environmental quality. The distinction of these two dimensions of globalization corroborates the significant support observed in the study of Martens et al. (2015). In view of this, these two dimensions will be used in this present study, as this will contribute novel evidence to the existing body of literature.

In addition to the investigation of globalization on environmental quality, some studies observed that the rapid development of urban areas lead to excessive demand for energy in cities and as such leads to the increase of the challenges associated with environmental sustainability as evident in the study of Wang et al. (2016) and Hashimi et al. (2021). This position is consistent other studies who observed a significant structural change of the labor force from rural to urban centers owing to the major economic and industrial growth in some years back (Ahmed et al., 2019; Henderson, 2002). This was corroborated with the statistics from the United Nations that as at 2019, the global urban population is around 58% and it is expected to increase to about 68% by 2050. Extant literature revealed that as the size of a society increases and get urbanized, so also the higher energy consumed than the rural areas (York, 2007), which is owing to the ever-increasing demand for urban infrastructures according to Shahbaz et al. (2017) and Hashimi et al. (2021). The ascending energy demand is believed to have raised the GHG emissions which are believed to be among the main factors that triggers global warming (Ali et al. 2017), as well as the anthropogenic climate changes around the globe (Hashimi et al., 2021; Wang et al., 2018). According to Cities (2020), cities around the globe is estimated to consume about 66% of the world energy consumption resulting in about 70% of the carbon emissions around the world. Several studies have examined the link between urbanization and environmental quality (Cui et al., 2020; Hashimi et al., 2021; Ben Jebli et al., 2016; Liang & Yang, 2019; Liu, Sun, & Feng, 2020; Majeed & Tauqir, 2020; Odugbesan & Rjoub, 2020a; Pata, 2018; Usman et al., 2019; Wang et al., 2020; Wei & Zhang, 2017; Xu et al., 2020), and the result have been mixed. While some of these studies argued for the positive effect of urbanization, some proved that urbanization is a significant driver of pollution. It is in view of this that this present study considers the inclusion of urbanization as one of the possible determinants of climate change sensitivity.

Similarly, as part of the human activities identify by the U.N that affects the current state of global climate change is the human population (UN, 2020). Dovers & Butlers (2019) observed that the world population has been rapidly increasing in the last 100 years, especially in the later years. It has been estimated that presently, there is annual increase of the global population by 80 million (Van Dao & Van, 2020) with the present population forecasted to reach 8.6 billion, 9.8 billion and 11.2 billion by 2030, 2050, and 2100 respectively. Meanwhile, the boom of the current world population is taking place mainly in developing countries. These countries account for about 80% of the world population and 95% of the global growing population. Extant literature revealed that population explosion not only exerts pressure on resources, but in addition is an avenue that gives room for exploitation processes that depletes resource quickly (Alkaher & Carmi, 2019; Van Dao & Van, 2020; Weber & Sciubba, 2019). This position is evident in some studies who suggested that population growth trigger carbon emissions (Liddle, 2013; O'Neil et al., 2012; Weber & Sciubba, 2019). Meanwhile, Satterthwaite (2009) pointed out that the bivariate correlation between population growth and emissions growth is zero or sometimes negative. The study submitted that some countries that are characterized with sudden population growth often experienced reduced levels in emissions and its growth and low growth rates in emissions, and vice versa. Nevertheless, extant literature suggests a relationship between population growth and environment (either direct or indirect) and as such it worth including in this study to investigate the possible relationship with climate change in SSA countries where most of the countries are developing countries characterized with high population growth.

In view of the aforementioned and the current damming report by the U.N. on the climate change (UN, 2021), it becomes imperative to explore empirically possible determinant factors that could contribute significantly to the climate change with the view of guiding the policy makers to make an informed policy that will be anchored on empirical grounded research. Hence, the aim of this present study to explore the implication of globalization, urbanization, population growth and economic growth on the sensitivity of climate change within the context of SSA countries. The choice of SSA countries is based on the current report that shows African temperature in recent decades to be warming, and thus somewhat faster than the global mean surface temperature (WMO, 2020). The report shows further that across mainland Africa, the temperature was between 0.56^0C to 0.63^0C in the year 1981 to 2010, while the third warmest year on record after 2010 and 2010 was 2019. In order to accomplish the aim of this study, this present study will utilize the total GHG emissions value as against the carbon emissions which is just a part of GHG emissions that is commonly used in the literature. This is because the climate change goes beyond carbon emissions and it involves other emissions like CH_4 (methane emissions from solid waste, livestock, mining of hard coal and lignite, rice paddies, agriculture and leaks from natural gas pipelines), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), Sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3). In addition, the novel index of globalization (that is, dejure and defacto) will be used and this constitute part of the study novelty, while economic growth, urbanization and population growth will be additional variables in the model. In order to ensure the validity of our estimates, the novel "Dynamic Common Correlated Effect - Mean Group (DCCE-MG)" panel data estimator will be used to avoid any cross-sectional dependency issue that could make the estimates to be prone to bias. This present study has some significant environmental implications, as it will enhance results of the nexus between the globalization and climate change sensitivity which is crucial to environmental sustainability. Secondly, the study will be helpful to the policymakers in SSA countries to understand the kind of relationship that exist between the two dimensions of globalization which has not been previously investigated in the context of SSA to the best knowledge of the authors. In addition to policy implication, this study demonstrates the implication of urbanization and population growth to the climate change, as well as contributing to the literature on the validity of EKC hypothesis in the context of SSA countries.

The rest of the paper is structured as follows: the next section reviews the previous related studies: the data and methodology were presented in the following section; while the results interpretation, discussions, conclusions and policy recommendations complete the remaining sections.

1.1 Literature REVIEW

A visible insight into the dynamism of environmental quality could be observed in some existing empirical studies, however, a general consensus is still far from being reached. In the studies of Grossman & Krueger (1991, 1995) who are known to have pioneered the discourse on the nexus between environmental pollution and economic growth through "Environmental Kuznets curve (EKC)". Owing to this development, efforts to enhance economic development have kept the preservation of environmental quality as a secondary goal in policy making. This has led to many nations started the implementation of environmental policies that is aimed at reducing the implications of any forms of pollution (Shahbaz et al., 2018). According to Agenor (2004), a greater integration of economies and societies is possible through globalization, and Shahbaz et al. (2018) opined that a higher economic integration and trade openness are the main sources of economic development. It was postulated in the literature that environmental quality is influenced by trade openness in both negative and positive ways (Grossman & Krueger, 1991, 1995; Shahbaz et al., 2018; Copeland & Taylor, 2004). For instance, it was argued by Grossman & Krueger (1991) that "the environmental effects of international trade depend on policies implemented in domestic economies, irrespective of their size and development levels". While some studies opined that the carbon emissions are being lowered by trade openness through the use of standard and cleaner technologies in production and consumption activities (Shahbaz et al., 2018; Runge, 1994), some observed that economic development could be enhanced through trade and that "trade-derived income" has the potential of funding the improved environmental management, as well as distribution of environmentally-inclined technology (Jayadeappa & Chhatre, 2000).

The potential influence of globalization has attracted the attention of scholars in recent times which resulted in the exploration of the nexus between this phenomenon and several environmental indicators for either a country-specific or panel study. Meanwhile, literature suggest that most of the studies are basically on the understanding of the effect of conventional and contemporary globalization indicators on environmental quality (Chang, 2012; Ling et al., 2015; Saboori et al., 2012; Shahbaz et al., 2012; Shahbaz et al., 2015a, b; Solarin, 2014; Tiwari et al., 2013; Yameogo, Omojolaibi, & Dauda, 2020). For instance, Saboori et al., (2012) submitted in their study that even though trade openness is a contributing factor to the Malaysia environmental quality, but not a major factor. In contrast, Solarin (2014) found a positive and significant correlation between the export from Malaysia to Singapore with carbon emissions in the country. From another perspective, Ling et al. (2015) submitted that the environmental quality in Malaysia is reduced by trade openness through the reduction of carbon emissions. An ambiguous result was demonstrated in the study of Chang (2012) who demonstrated an inconclusive result from investigating the impacts of trade openness and FDI on China environmental quality. The study submitted that the impact depends on the types of pollutants. Moreover, in the context of Pakistan, Shahbaz et al. (2012) revealed a negative influence of trade openness on carbon emissions in the country, while in contrast, the study of Tiwari et al. (2013) explored the dynamic causal nexus between trade openness and carbon emissions in the context of India and found that carbon emissions are triggered by trade openness.

Different from the use of conventional indicator of globalization, the use of contemporary globalization index was evident in the study of Shahbaz et al. (2015a) who explored the influence of globalization on environmental quality in India and found that globalization trigger carbon emissions, which is an indication that environmental quality is weakened by globalization. The study of Australian economy revealed a contrast position when investigated by Shahbaz et al (2015b) where it was found that the reduction in the carbon emission was a result of globalization, indicating that environmental quality in the country is achieved with the presence of globalization. In addition, some recent studies like Yameogo, Omojolaibi, & Dauda (2020) who investigate the nexus between economic globalization and environmental quality in SSA countries and found that economic globalization degrades the environmental quality in SSA. This finding was similar to the position of Ahmed, Zhang, & Cary (2021) who demonstrated that in the context of Japan, economic globalization triggers ecological footprint, also study of Wen et al. (2021) stated that globalization and carbon emissions exibits a positive relationship. In contrast to the position of Ahmed et al. (2021), Yang et al. (2021) that explored the implications of globalization and aging population on environmental degradation of OECD countries revealed that overall globalization lowers the ecological footprint in the long-run, while financial and political globalization trigger environmental degradation.

In addition to the human factors that affects the environmental quality, population has been identified in the literature as one of the contributory factors (Alkaher & Carmi, 2019; Van Dao & Van, 2020; Weber & Sciubba, 2019). Studies shows that population explosion not only puts pressure on resources, but as well as a link that result to the process of exploitation that depletes such resource quickly (UNICEF, 2017). Meanwhile, a contradictory position was put forward in the report of UNEP (2019). It was stated in the report that while the overall increase in raw material extraction and utilization requires population as a major driver, the resources utilization and population may in fact actually be negatively correlated. This corroborate the position of Kenneth Small (2016) who observed that despite the debacle of decoupling the population from sustainability concerns, it has gained the attention of policy makers. Empirically, the study of Weber & Sciubba (2019) argued that regional population growth in the European countries significantly impact the environmental quality of the region. This finding corroborates the position of some studies who demonstrated in their studies the positive relationship between population growth and carbon emissions (Alkaher & Cami, 2019; O’Neill et al., 2012; Liddle, 2013). Meanwhile, the study of Satterthwaite (2009) pointed out that the bivariate association between population growth and the emissions growth on country-specific is zero or even negative. This position was in view of the fact that although some nations that exhibits rapid growth in population, have low levels and low growth rates in emissions and vice versa. Thus, Weber & Sciubba (2019) opined that “the differences in consumption levels caused by economic inequality, rather than population sizes or growth, are responsible for carbon emissions increase” (pp. 383). In sum, the extant literature revealed mixed positions. While some studies demonstrated a direct effect of population size and growth on environmental quality, holding all other factors constant, some argued for an indirect effect. The latter group highlighted that the interaction and feedback processes with income and technology provides compensation or even reverse the direct implication from population in the long-run. Though, this present study is not aim at resolving the controversy, but to contribute to literature by understanding what would happen to the climate change in SSA if the region population increases or decreases.

In reference to the urbanization and environment, the theory underpinning the two can be referenced to urban environmental transition theory, the compact city theory, and theory of ecological urbanization. According to Majeed & Tauqir (2020), urban transition theory propound that cities live through several ecological issues when the city is undergoing industrialization and development. As for the compact city theory, Majeed & Mazhar (2019) highlights that “higher urbanization improves the environmental quality by increasing the productivity, efficiency and economies of scale in public infrastructure”. Moreover, it was postulated in the “theory of ecological urbanization” that a way forward for sustainability is achievable through the enhancement of overall income level which admonish individual to utilize green services; the enhancement of environmental awareness via the provision of interactive and social services; and lastly, the promotion of green research and development (R&D) activities and innovations, therefore achieving environmental quality conservation. The deductions from the urbanization theories indicates several medium through which urbanization exerts impact on environment. In reference to Sadorsky (2013), the demand for basic infrastructure is increased through urbanization; fuel consumption is increased through transportation and other anthropogenic activities that creates pollution (Li et al., 2019); the increase of industrial production as suggested by Samreen & Majeed (2020), Liu & Bae (2018), which they opined that it increases air pollutant in the atmosphere; the distortion of equilibrium of natural environment as new habitats were created for some species, while habitat for other were eradicated (Uttara et al., 2012); and lastly, some eco-environmental challenges were thrown-up, like traffic congestion, contamination dispersal, industrial dumps, development of slums, and municipal wastes. Different from the downside of urbanization, Majeed & Tauqir (2020) observed that there are some positive sides of urbanization on environment. For instance, the development of urban cultures which give support to an optimal use of energy sources; the improvement of productivity; promotion of service sector; promotion of innovations which assist in conservation of the environment; promotion of energy efficiency and clean energies (Majeed & Luni, 2019); and lastly, Tao et al. (2016) believes cities are economically developed, owing to their increase of production efficiency and reducing pollution discharge. Empirically, some studies advocate the downside impact of urbanization on the environment (Al-Mulali & Ozturk, 2015; Bekhet & Othman, 2017; Liu, Sun, & Feng, 2020; Majeed & Tauqir, 2020; Odugbesan & Rjoub, 2020a; Wei & Zhang, 2017), while some suggests the environmental conserving impact of urbanization (Barla et al., 2011; Hashimi et al., 2021; Martinez et al., 2018). In addition, some studies suggest an inverted U-shaped impact of urbanization on environmental quality (Abdouli et al., 2018; Xu & Lin, 2017; Xu et al., 2016).

In addition, Grossman and Krueger (1995) has developed the “Environment Kuznet Curve” (EKC) hypothesis that investigates the nexus between environmental and income. In reference to the studies of Xie & Liu (2019), Chen et al. (2019), and Ardakani & Seyedaliakbar (2019), EKC has inverted-U shape, and states that environmental degradation will increase with income, after a turning point environmental quality starts to improve. Several studies have investigated the environment and income nexus and provides empirical evidences that proves the existence of EKC hypothesis for both with time series and panel estimations. According to Wang (2011), who examined the effect of income on CO_2 emissions by analyzing 138 countries’ data set from 1971 to 2007, there are empirical evidences that support the EKC hypothesis. Likewise, a bidirectional causality between economic development and CO_2 emissions in the context of 25 OECD countries using a data from 1980 to 2010 was demonstrated in the study of Jebli et al. (2016). Studies like

Odugbesan et al. (2020), Adebayo et al. (2021), Pata (2018), Cai et al. (2018), Odugbesan et al. (2021), and Shahbaz et al. (2013) demonstrated the evidence of worsen effect of economic growth on the environmental quality in their respective studies. On the other hand, Alam & Kabir, (2013) and Rahman et al. (2020) demonstrated economic growth enhances the environmental quality by controlling for the emission levels. Wang et al. (2019) proved in the context of US demonstrated a significant effect of economic growth and investments on environmental quality. Moreover, economic growth was found in another study to have a significant impact on sustainable environment in the context of Azerbaijan (Mikayilov et al., 2018), which also corroborates the study of Chang and Hao (2017) who found the similar result in the context of OECD and non-OECD countries. On the other hand, studies on the green growth received less attention. However, Tawiah et al. (2021) examined recently the determinant factors of green growth using a panel study consisting of developed and developing countries, and the study demonstrated the existence of a valid impact of economic growth on green growth.

In view of the reviewed literature, it is evident that most studies investigate the nexus between globalization and environmental quality using trade openness as narrow defined indicator of globalization, even the contemporary globalization index of social, economic and political index with few studies utilized the newly defined globalization index (dejure and defacto). This has resulted in the mixed and inconclusive findings. Similarly, the CO_2 is often used in some of these studies as indicator for environmental quality, whereas, carbon emission even though constitute larger percentage in the GHGs, might not account for the total environmental quality and possibly results to some bias findings. Hence, we utilize the total GHGs in this study as an indicator for measuring climate change, as well as using the newly developed dejure and defacto globalization as a measure of globalization.

2. Data and Methods

2.1 Data

This study employed an annual data from 1990 to 2018 in Sub-Sahara African Countries. Meanwhile, 43 countries were considered, the rest were dropped owing to the data unavailability, as well as missing values for some variables that is more than 3 years. This study utilized total greenhouse gas (GHG) emissions which consists of data for total emissions of CO_2 (emissions from energy use and industrial processes, e.g. cement production), CH_4 (methane emissions from solid waste, livestock, mining of hard coal and lignite, rice paddies, agriculture and leaks from natural gas pipelines), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3), including LUCF (CAIT, 2021). This variable is employed in this study as the proxy for climate change and serve as the dependent variable in our model. The independent variables utilized in the present study are: globalization with the use of globalization index as a proxy. In reference to Gygli et al. (2019) and Potrafke (2015), the globalization index measure globalization along the political, economic, and social dimension and the value range between 0-100. In addition, we utilized the revised globalization index which allows for disaggregation of different dimensions and traits of globalization and the new index distinguishes between dejure and defacto globalization (Gyli et al., 2019). While the latter measures actual international flows and activities, the former assess policies and conditions that, in principle, allows, facilitates and foster flows and activities. (Gyli et al., 2019). In order to measure the effect of economic development on climate change sensitivity, this study is using GDP per capita as a determinant factor and a proxy as well as the inclusion of the square of the GDP to explore the validity of EKC hypothesis in SSA countries. Moreover, urbanization was used to determine the impact of rural-urban migration on the climate change, while the total population was included to examine the effect of population growth and human activities on the sensitivity of climate change. The inclusion of population is in reference to the position of Aller et al., (2015) who stated that large population exerts significant impact on the environment. The data for total GHG emissions was sourced from Climate watch database (CAIT, 2021), globalization data was sourced from KOF Swiss Economic Institute data base, while the data for GDP per capita, urban population and total population were sourced from World Development Indicators.

Table 1. Descriptive statistic

Variable	Mean	Max.	Min.	Std. Dev.	Obs
Greenhouse Gas Emissions (MtCO_2e)	64.98	686.17	-0.27	105.65	1247
Globalization Index	43.50	72.35	22.36	9.50	1247
Defacto Globalization	42.18	72.05	18.69	10.20	1247
Dejure Globalization	44.85	81.29	19.98	10.28	1247
GDP per capita	2146.78	20532.98	164.34	2977.49	1247
Total Population	17,099,476	195,874,685	69507	25,631,606	1247
Urban Population	5,871,935	98,611,151	34246	10,378,029	1247

Table 1 presents the group statistics of the variables of the interest. Descriptive statistics provides the mean, minimum, and maximum values in addition to the standard deviation. Wide dispersion can be illustrated for all the variables. Absence of the variation in observations reveals the balances nature of the sample.

2.2 Model Specification

This study attempts to investigate the effect of globalization, dejure and defacto globalization, population, urbanization and economic growth on climate change in Sub-Saharan Africa (SSA) countries for the period 1990-2018. Functional relationship that examines the aforementioned nexus is presented in Equation (1a) and Equation (1b):

$$GHG_{it} = f(KOFGI_{it}^{\beta_1}, GDPpc_{it}^{\beta_2}, Pop_{tot}{}_{it}^{\beta_3}, URB_{pop}{}_{it}^{\beta_4}) \quad (1a)$$

$$GHG_{it} = f(KOFGIdf_{it}^{\beta_1}, KOFGIdj_{it}^{\beta_2}, GDPpc_{it}^{\beta_3}, Pop_{tot}{}_{it}^{\beta_4}, URB_{pop}{}_{it}^{\beta_5}) \quad (1b)$$

Where GHG is greenhouse gas emissions stands for a proxy for climate change; *GDPpc* stands for gross domestic product per capita; *KOFGI* stands for overall globalization index; *KOFGIDF* stands for defacto globalization index; *KOFGIDJ* stands for dejure globalization index; *TP* stands for total population; finally, URB_pop stands for urban population. Equation (1a) and Equation (1b) will be expressed in logarithmic form for long-run regression equation. Thus, Equation (2) and (3) are expressed as:

$Model$ 1:

$$lghg = \alpha_0 + \beta_1 KOFGI_{it} + \beta_2 lGDPpc_{it} + \beta_3 lPop\_tot_{it} + \beta_4 lUrb\_pop_{it} + \varepsilon_{it} \quad (2)$$

Model 2:

$$lghg = \alpha_0 + \beta_1 KOFGIdf_{it} + \beta_2 KOFGIdj_{it} + \beta_3 lGDPpc_{it} + \beta_4 lPop\_tot_{it} + \beta_5 lUrb\_pop_{it} + \varepsilon_{it} \quad (3)$$

Where, α stands for intercept; l stands for natural logarithm; the cross-sections and time-dimension in the Eq. 2 and Eq. 3 were denoted with i and t. Finally, error term is denoting with ε.

2.3 Estimation Procedures

In order to ensure the consistency of the estimates, this study follows the studies of Pala (2020) and Rahman (2020), to examine the aforementioned relationships between the variables as specified in Equation (2) and (3).

First of all, Pesaran (2004, 2007) test for CSD was employed to investigate the presence of cross-sectional dependence (CSD). Thus, it will lead the light for the rest of the study, so that right methodology will be chosen to employed for the rest of the study. Second, slope homogeneity test was examined with a recent technique (Pesaran & Yamagata, 2008) to decide between homogenous or heterogenous panel techniques to be carried out with the analyses. Third step was to examine the stationarity nature of the series; hence, panel unit root tests was carried out. In doing this, the "cross-sectional augmented Im, Pesaran, and Shin (CIPS)" (Im et al., 2003) and "cross-sectional augmented Dickey_Fuller (CADF)" (Pesaran, 2007) were applied, as a result of the presence of "cross-sectional dependence". Within the next step, panel cointegration test was employed to estimate the co-movement of the variables in the long-run. In this present study, Westerlund & Edgerton (2008) panel cointegration which allows cross-sectional dependence, serially correlated errors, and structural breaks in both intercept and slope, was employed. As argued by Ditzen (2016, 208) that in the presence of the cointegration vector, "Dynamic Common Correlated Effects-Mean Group (DCCE-MG)" seems to be effective, hence DCCE-MG was employed to test for the long-run relationship among the variables in this study. Ditze (2016, 208) argued further on the advantages of DCCE-MG among which are: accounting for both heterogeneous and homogeneous coefficients; supporting instrumental variable regressions; controlling for cross-sectional dependence are just some of them. Finally, Dynamic OLS and Fully Modified OLS techniques will be employed to test for the robustness of our estimates.

3. Results and Discussions

3.1 CSD Test Result

Table 2 provides the cross-sectional dependency test results. The carbon productivity, foreign direct investment, renewable energy, GDP per capita, and total population rejects the null hypothesis of no cross-sectional dependency (CD) at 1% significance level. On the other hand, the institutional quality index rejects the H_0 of no cross-sectional dependency at 10% significance level. The existence of CD suggests any shock to one of the cross-sections may be transmitted to other countries in the panel.

Table 2. CD Test

Variable	CD-test	*p*-value
Greenhouse Gas Emissions (log)	31.79	.0000
Overall Globalization	18.33	.0000
Defacto Globalization	7.07	.0000
Dejure Globalization	1.85	.064
GDP per capita (log)	14.17	.0000
Total Population (log)	47.89	.0000
Urban Population (log)	17.35	0.001

3.2 Slope Homogeneity Analysis Result

The result of the slope homogeneity test is presented in Table 3. Test results indicates the existence of heterogeneity across the sample, since it rejects the null hypothesis of homogeneity slope at 1% of significance. In this case employing a heterogeneous panel technique will be appropriate. In this present paper, DCCE-MG will be employed.

Table 3. Slope Homogeneity test

	Delta	*p*-value
$\tilde{\Delta}$	8.72*	0.0000
$\tilde{\Delta}_{adj}$	11.81*	0.0000

3.3 Panel Unit Root Tests Results

CADF and CIPS panel unit root results are presented in Table 4. Almost all the variables are rejected the null hypothesis of unit root in first difference within both CADF and CIPS test statistics, except GDP_PC that is failed to reject the H_0 of unit root for CADF. Bottom line, all the variables of interest are integrated after first difference I(1).

Table 4. Panel Unit Root test

	Level		1st Difference	
Variables	CADF	CIPS	CADF	CIPS
lghg	0.450	-1.409	-4.323**	-6.962**
KOFGI	1.421	-1.605	-2.410*	-8.303**
KOFGIdj	1..210	-1.350	-3.260**	-7.906**
KOFGIdf	0.210	-0.903	-4.308**	-7.109**
lGDP_pc	-3.210**	-1.768	-	-4.321**
lPop_tot	2.001	-1.382	-3.337*	-8.021**
lUrb_pop	1.110	-1.712	-3.012*	-7.309*

Note: lghg = log of greenhouse gas emissions, KOFGI = overall globalization index, KOFGIdj = dejure globalization, KOFGIdf = defacto globalization, lGDP_pc = log of gross domestic product per capita, lnPop_tot = log of total population. *, ** denotes 10% and 5% significance level.

3.4 Panel Cointegration Result

The estimates from the panel cointegration test statistics as presented in Table 5. Suggest the rejection of the H_0 of no cointegration at 5% of significance level which is for almost all the cases, except $Z_t(N)$ statistic for level shift. Empirical findings suggest the presence of the long-run relationship between the variables of interest.

Table 5. Panel Cointegration Test

Model	$Z_\varphi (N)$	$Z_\tau (N)$
No Break	-4.520**	-10.112**
Level Shift	-3.048**	-0.789
Regime Shift	-3.522**	-3.445**

Note: ** denote 5% significance level

3.5 DCCE-MG Result

The long-run estimates based on the DCCE-MG approach is presented in Table 6. The tables show the results from the estimated three models. In the first model, the overall globalization (*GOFGI*), economic growth (*lgdp_pc*), population size (*lPop_tot*) and urbanization (*lUrb_pop*) were considered as determinant factors for climate change. The result from the analysis shows that overall globalization, population, and urbanization have a positive and significant long-run relationship with climate in SSA, while population shows a negative coefficient and significant, which is an indication of a significant negative relationship with greenhouse gas emissions in SSA in the long-run. These findings are an indication that overall globalization, population and urbanization trigger greenhouse gas emissions in SSA countries in the long-run. The positive coefficient for globalization found in this present study is congruent with some studies who demonstrated that the presence of globalization in a country cause a devastating effect on the environmental quality (Ahmed et al., 2021; Destek, 2020; Shahbaz et al., 2015a; Suki et al., 2020; Yameogo et al., 2020). Meanwhile, the finding contradicts the position of Shahbaz et al. (2015b) and Yang et al. (2021) who found globalization as a determinant factor for reducing carbon emissions in the context of Australia and OECD countries respectively. In addition, the positive and significant coefficient of economic growth found in this study as a determinant of greenhouse gas emission (Model 1) is consistent with the studies of Odugbesan et al. (2020a, 2021), Adebayo et al. (2021), Shahbaz et al., 2013, Pata, 2018, Peng et al., 2016, Adedoyin et al., 2021, and Cai et al., 2018 who had earlier demonstrated in their various studies the positive influence of economic growth on environmental degradation. Meanwhile, the finding contradicts the Rahman et al. (2020) and Alam & Kabir (2013) who argued in their respective studies that increase in economic growth sustain the environment through the decrease of carbon emissions).

As for the negative and significant influence of population found in this study (Model 1) which is an indication of a negative influence of population on the greenhouse gas emissions in SSA in the long-run. The estimates from our study is congruent with the position of some studies who opined that association between population and the emissions growth could be zero or even negative (Satterthwaite, 2009; UNEP, 2019). These studies opined that some countries that are characterized with rapid population growth have low levels and low growth rates in emissions, and vice versa. Meanwhile, the finding contradicts the submission of some studies who suggests that population explosion not only exerts pressure on resources, but in addition is an avenue that gives room for exploitation process that depletes resources quickly and degrade the environment (Alkaher & Carmi, 2019; O'Neill et al., 2012; Liddle, 2013; Van Dao & Van, 2020; Weber & Sciubba, 2019). Moreover, our estimate on the relationship between urbanization and greenhouse gas emissions as presented in Table 6 indicate a positive and significant relationship in the long-run. This implies that in the context of SSA countries, urbanization trigger greenhouse gas emissions which is an indication of devastating effect on the environment. This finding is consistent with urban transition theory (Majeed & Tauqir, 2020) and suggest that the SSA countries are prone to several ecological issues in the long-run, owing to the ongoing industrialization and development taken place in the region (Al-Mulali & Ozturk, 2015; Bekhet & Othman, 2017; Liu & Bae, 2018; Liu, Sun, & Feng, 2020; Li et al., 2019; Odugbesan & Rjoub, 2020a; Samreen & Majeed, 2020). Meanwhile, the finding contradicts some studies who opined that urbanziation has some poistive influence on the environment (Majeed & Luni, 2019; Tao et al., 2016).

The estimates from Model 2 as presented in Table 6 where the overall globalization was substituted with defacto and dejure globalization. The result reveal that the defacto and dejure globalization have a positive and significant long-run relationship with greenhouse gas emission in SSA. This implies that the actual flow of international activities, as well as the policies and conditions that allows these flows as put in place in SSA countries have a detrimental effect on the environmental quality of the region in the long-run, and do not conform with the position of Sharif et al. (2020) who posited a possible differential effect of defacto and dejure globalization on environmental quality. İn addition, the estimates from Model 2 as presented in Table 6 for other variables (economic growth, population, and urbanization) shows the consistency of the coefficients with Model 1, which implies that when the overall globalization was substituted with defacto and dejure globalization, the coefficient of other variables remain unchanged.

In order to validate the EKC hypothesis in the context of SSA, we control for the square of economic growth as suggested in the literature in Model 3. The estimates from Model 3 are presented in Table 6, and it shows that while the defacto globalization remains positive and significant, the dejure globalization becomes insignificant. However, the economic growth, population and urbanization coefficients remains unchanged and significant. Meanwhile, the result of the square of GDP added to the model as presented in the table shows a negative and significant coefficient. This indicates that in the context of SSA, when the curve gets to a plateau of the income threshold, the greenhouse gas emission starts decreasing. Thus, this finding validates the EKC hypothesis which is consistent with the studies of Xie & Liu (2019), Grossman & Kruger (1995), Ardakani & Seyedaliakbar (2019), and Chen et al., (2019), hence, we argue that in the context of SSA the increase of greenhouse gas emissions is proportional to income.

Table 6. DCCE-MG Results

	Model 1			Model 2			Model 3		
Variables	Coefficient	t-stat	P-value	Coefficient	t-stat	P-value	Coefficient	t-stat	P-value
GOFGI	0.942	5.135	.0000						
GOFGIdf				0.540	11.37	.0000	0.522	12.409	.0000
GOFGIdj				0.245	2.825	.0049	0.128	1.645	0.101
lgdp_pc	22.439	5.203	.0000	20.35	7.732	.0000	235.69	6.786	.0000
$Lgdp\_pc^2$							-1301.15	-6.941	.0000
lPop_tot	-21.987	-1.345	.179	-68.59	-5.66	.0000	-61.06	-5.38	.0000
lUrb_pop	34.53	2.810	.005	47.71	6.233	.0000	45.09	5.818	.0000

In order to ensure the robustness of this study findings, the DOLS and FMOLS were employed for the estimation of long-run relationship between the dependent variable and independent variables in this study. The result as presented in Table 7 shows a slight difference in the variables coefficients for all the models, but the signs and p-values are consistent with both FMOLS and DOLS in comparison to the estimates presented in Table 6. This indicates the robustness of our findings and suggest possibility of non-bias estimates.

Table 7. FMOLS and DOLS Estimates

	FMOLS			DOLS		
Variables	(1)	(2)	(3)	(1)	(2)	(3)
GOFGI	0.56***			-.23**		
GOFGIdf		0.11***	0.431**		0.15**	0.22***
GOFGIdj		0.40***	0.23***		0.15*	0.20**
lgdp_pc	8.38***	8.31***	7.01**	4.50**	9.49***	6.79**
$lgdp\_pc^2$			-98.15***			-97.57**
lPop_tot	-58.42***	-56.97***	-63.22**	-106.96***	-25.77***	-66.12*
lUrb_pop	24.48***	24.02***	18.98***	37.88***	4.66	7.42***

Note: GOFGI = globalization index, GOFGIdf = defacto globalization index, GOFGIdj = dejure globalization, lgdp_pc = log of GDP per capita, $lgdp^2$ = square of log of GDP per capita, lPop_tot = log of total population, lUrb_pop = log of urban population. *, **, *** denotes 10%, 5%, and 1% significance level respectively.

4. Conclusions and Policy Implications

The effects of dejure and defacto globalization on greenhouse gas (GHG) emissions including economic growth, population size, and urbanization for a panel data of 43 SSA countries over the period from 1990 - 2018 were analyzed in this study. In addition, the analysis is disaggregated into three models. The stationarity properties of the variables were analyzed using a second-generation unit root tests (CADF and CIPS) that address the cross-sectional dependence issue in the panel data. Moreover, a novel panel cointegration technique by Westerlund & Edgerton (2008) was used to analyze the cointegration of the variables. This technique allows for CD, serially correlated errors, and structural breaks in both intercept and slope. Finally, the long-run estimates are obtained using the DCCE-MG technique, while the robustness of the estimates was established using FMOLS and DOLS.

The main findings from this present study suggest that overall globalization, dejure and defacto globalization trigger GHGs emissions in SSA countries. The result validates the position in the literature that activities from globalization also brought some undesirable outcomes like environmental degradation as argued by Sharif et al. (2020), Shahbaz et al. (2015), and Kan et al. (2019). In addition, finding from this study indicate that population size is significantly negative in all model. But, the urbanization shows to have a positive and significant long-run relationship with GHG emissions, which validate the theory of urban transition. It implies that the structural changes in terms of movement of people from rural to urban in SSA region is contributing to the GHGs emissions in the region and the implication is evident on the degradation of environmental quality which would leads to climate change. In addition, the positive influence of economic growth and negative influence of the GDP square for all the models validate EKC theory.

The findings from this study have some implications which are discussed as follows. Though, some studies have explored the relationship between globalization, economic growth, urbanization and population on environmental quality, but most of them utilized conventional globalization index, overlooked the influence of urbanization on the sensitivity of climate change, especially in the context of SSA countries, and none of them have analyzed dejure and defacto globalization, population, economic growth and urbanization side by side. These drawbacks produced misleading conclusions and has been addressed in this study. In view of this, this study contributes in several folds to the existing literature. First, the findings from this study suggest the environmental deteriorating effects of globalization in SSA countries. This implies that in the course of foreign investment inflow to the region, transfer of skills, technological advancement, trade liberalization, they all come to SSA with detrimental effect on the environment which leads to some forms of climate change. Second, the possible differential effect of defacto and dejure globalization on environmental quality was addressed. Third, to the best of authors knowledge, the possible influence of human factors (population and urbanization) as opined in the literature (UN, 2021) on the climate change which has not been previously investigated side by side has been empirically addressed in the context of SSA. Fourth, this study improves methodological part of the paper by employing some novel techniques that addresses the cross-sectional dependence issue that is plaguing panel data.

In view of these, this study suggests that the policy makers in SSA countries should aim at conquering the drawbacks of the dejure and defacto globalization as it affects the GHGs emissions by putting in place some policies that will ensure more flow of globalization activities and ensure that the activities are not at the detriment of the country. Specially to ensure that the technology, good, services and skills being transferred are more of eco-friendly, so that it will be more beneficial to the environment and result to achievement of sustainable development. In addition, the countries should adopt green and sustainable urbanization with the aim of conserving the global environment. This is achievable through the diversion of internal migration away from big cities to small and medium cities by providing planned and resources control. In addition, the pressure of urbanization can be decreased through a balanced development in both urban and rural areas. Finally, in SSA countries, the green economy should be given more priority so as to achieve sustainable development. Finally, economic growth shows in our finding to aggravate global warming by increasing the GHGs emissions, its downside effect on the environment could be partly mitigated by green economy. Though, this study makes significant contributions to the literature, but not devoid of limitation. The main limitation lies in the consideration of only SSA countries, whereas the issue of climate change is global in nature. Thus, in the future, a broader sample will be covered which not only include developing countries, but also developed countries.

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