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Greenhouse gasses emission and economic growth nexus of sub-Saharan Africa

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ABSTRACT

Notwithstanding the lesser contribution to global warming, sub-Saharan Africa (SSA) remained one of the most vulnerable to climate change due to low economic development, high dependence on natural resources for agricultural production and low technological advancement. There is also limited information on the nexus between economic growth and greenhouse gas emissions (GHG) in the region. Therefore, this study applied the Environmental Kuznets hypothesis to test the relationship between economic growth and GHG emissions in SSA and also test the effect of global GHG emission on economic growth of SSA. Using an aggregated panel data for the period of 1970 to 2012, a Vector Autoregressive and an Ordinary Least Square regression were estimated. From the result, although the relationship between economic growth and environmental quality was established in the short run, there are no clear turning points for the greenhouse gasses. Generally, there is a monotonic decreasing relationship between economic growth and environmental quality in the long-run. Interestingly, this study showed that global GHG emission levels have a long-run effect on the economic growth of SSA. We concluded that to ensure that economic growth leads to an improvement in environmental quality, there must be a global effort to introduce innovations and technologies that can lead to increase production with little GHG emissions. The study recommended that, SSA should consider carbon tax policies other than stringent GHG emission reduction initiatives or climate stabilization policies that would negatively affect production in the region.

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Introduction

Over decades, sub-Saharan Africa (SSA) remained one of the regions with low economic performance, battling with high developmental challenges such as food insecurity and poverty. Although the region has made progress over the years, one of every four person is undernourished [1]. Similarly, progress in reducing poverty has been slow in SSA than other regions as two-third of the world population living on below $1.25 a day lives in SSA [2] and the majority come from the rural areas.

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Generally, economic growth has slowed from 5% in 2014 to 3.4% in 2015 [3]. These macroeconomic statistics and indicators portray no good economic position of the region and predispose the region to many external shocks. Unfortunately, there is high dependence on natural resource in SSA. While agriculture is a major employer of the economically active group, 97% of the cultivated land is rain fed. Coupled with other challenges, the high dependence on rainfall for crop production is a cause for lower yields in the region [4]. Nonetheless, agriculture remained the main source of livelihood to many, especially those in rural areas. Addressing the developmental challenges of the region requires that detailed and periodic information, especially, on the bottlenecks are provided to help policy orientation. Unfortunately, climate change has become a major obstacle to addressing the many developmental challenge of the region. A further threat to a turn-over for the region.

Climate change due to global warming is a major discussion among scientists and policy makers at the international and local levels. The signs of climate change are becoming more evident. Climate change could be natural or human induced and since the latter is unavoidable, climate change definition have been centered on human induced causes [5–7]. Carbon dioxide (CO_2) emission is the main source of climate change. CO_2 is a major factor for both production and consumption (for example, fossil fuel consumption) that drives economic progress [8,9]. As stated by Alagidede et al., [8], 'the environment is man, and man is the environment' because man obtains natural resources in the form of inputs for the production of goods and services from the environment and also use the environment as a sink for all its wastes. From the basic requirement of life to the most complex need for sustenance of life, the role of the environment is indispensable for the protection of all living things.

Climate change is expected to negatively affect developmental and economic growth policies already been implemented. Although these effects are global, SSA is one of the regions that would experience worse impacts due to the already poor economic base and high dependence on natural resources. As reckoned by IPCC [5], climate change impacts will vary within space and time depending on a number of factors. SSA is expected to experience warming trend, sea level rise and negative consequences on agriculture. The negative effect of climate change on agriculture has negative forward linkages such as leading to an increasing rural-urban migration that would worsen current urban challenges such as, increase in food prices, arguing that extreme events can cause concurrent effects between sectorsnts can cause concurrent effects between sectors [33]. Through simulation, Elshennawy et al. [10], observed a decline in real gross domestic product (GDP) without 'policy-led adaptation investment'. Alagidede et al. [8] also found that an increase of temperature above 24.9°C would significantly lead to economic decline in SSA. [33]. Through simulation, Elshennawy et al. [10], observed a decline in real gross domestic product (GDP) without 'policy-led adaptation investment'. Alagidede et al. [8] also found that an increase of temperature above 24.9°C would significantly lead to economic decline in SSA.

Unfortunately, the high developmental challenges such as poverty levels reduce the adaptive capacity of the region to climate change. Amjath-Babu et al. [11], indicated that climate change could deteriorate human and social development potentials in the sub-region. Simply put, climate risks interact with biophysical and social challenges [5] and worsen their occurrences and impacts. These make climate change discussions complex and the need for thorough examination of local context to enhance the appropriateness of policies and interventions.

Two available strategies to climate response are mitigation and adaptation. Adaptation leads to a reduction of damage from climate impacts that are unavoidable while mitigation aimed to reduce the occurrence of climate change [5]. Beginning from the third Conference of parties (COP3) at Kyoto, efforts are continuously sought to keep increases in global warning to a threshold. This protocol requires that the Annex1 countries reduce CO_2 emissions [12]. However, responsibility bearing is one major challenge hindering progress in reducing greenhouse gasses (GHG) emissions. Mitigation and adaptation require the commitment of resources, and this will limit the developing effort of the developing economies. Recent literature is therefore keen on issues of ethics, justice and responsibility (see [5]).

The body of existing literature established GHG emission level and economic growth, arguing that as economies grow initially, their emissions rise to a point and begins to fall; on per capita basis. In other words, at early stages of economic growth, environmental degradation would rise but at a certain level of economic growth, environmental degradation drops. This has being demonstrated using the Environmental Kuznets Curve (EKC); an inverted U-shaped. Taylor et al. [13], noted that at a certain emission intensity, higher output leads to higher GHG emissions and that to prevent rising GHG concentration, stable per capita consumption is required. However, from Abid [14], the EKC depend less on the level of per capita income, instead on the positive outcomes from increasing incomes such as institutional, demographic reforms and the demand for quality environment as a result of higher incomes. Recognizing the vital role of CO_2 in both economic growth and global warming, Mladenovi et al. [9], noted that these inseparable linkages serve as a barrier between economic and environmental policies. The presence of EKC may be a sign for lower warming. In other words, assuming that there exists a downward turn in the EKC for every economy would imply that the level of GHG emitted into the atmosphere would be reducing. This could also mean an effectiveness of growth policies [15].

Two schools of thought have been identified in economic growth and environmental quality discussion; the pessimistic and the optimistic [8]. For the pessimistic school, the best approach to attain environmental sustainability is to pause economic growth since economic growth requires environment as a source of energy and raw materials as well as a sink for economic wastes; deteriorating environmental quality. On the other hand, the optimistic argues that technological change should eliminate this incompatibility as held by the pessimistic. Thus, economic growth and environmental sustainability can be simultaneously achieved through technologies such as green technologies that do not hinder economic growth but also foster environmental sustainability [8].

Environmental degradation can be measured using a number of indicators, but largely, the emission level of GHG such as CO_2, sulphur oxide (SO_2) and methane (NH_4). Depending on the availability of data and the objective of the study, different studies [8,12,14,15,16,17,18,19,20] have used single or a combination of indicators to measure environmental degradation. Using CO_2, Abid [14] found that EKC hypothesis was not fulfilled in SSA economies since there is a 'monotonically increasing' effect of GDP on CO_2 emission. However, the general conclusion from these studies is that there exist a positive, negative or non-significant relationship between economic growth and environmental degradation. For instance, Kumar et al. [12] found a short-term stationarity of per capita CO_2 emission from energy sector and argued that this leaves the opportunity for future forecasts on the dynamics of CO_2 emission. Similarly, Abid [14] observed that the relationship between environmental degradation and economic growth vary within space, which means that every economy has its inflexion point. Therefore, six possible shapes of the EKC that could be observed for any set of observations are monotonic increasing relationship, monotonic decreasing relationship, U-shaped relationship, inverted U-shaped relationship, N-shaped relationship or inverted N-shaped relation (see [14] for diagrams).

Lessons from these previous studies suggest further examination of the environmental economic growth nexus. This is very important especially for developing countries where hypotheses are generally inconclusive that considering the low per capita incomes, the EKC may depict monotonic. Thus, there would be a monotonicity in the relationship between environmental degradation and per capita income. Understanding this phenomenon in developing countries would enhance the understanding of the state of the art to identify policy measures needed to achieve both objectives, reducing environmental degradation and maintaining economic growth simultaneously. With recent promotion for the adoption of green technologies, it is important to improve knowledge on the baseline information, on which progress on the adoption of these technologies can be measured.

Sub-Saharan Africa and climate change

The literature on SSA and climate change provided that the sub-region remained one of the most vulnerable to climate change [5]. This is due to the region's economic characteristics including high reliance on natural resources and rainfed agriculture, high poverty, weak infrastructure and technological development. These characteristics lead to a minimal adaptive capacity of the region. Although the region contributes minimal to global GHGs emissions, projections showed that temperatures are rising and will rise further into the future. For instance, temperatures in West Africa are projected to rise by 3–6°C above the 20th century figure by the end of the 21st century, although projections showed a slight increase in precipitations [32]. Notwithstanding the fact that agriculture supports a large share of the labor force, the region is the most deprived in terms of food even without climate change while yields, particularly, cereals are projected to reduce by 3.2 percent as a result of climate change [21]. However, a sensitivity analysis showed that a 3% increase in agriculture productivity (both rainfed and irrigated) is sufficient to offset the negative effects of climate change on GDP in the region [4].

Data sources and analysis

The data used for this study was obtained from World Bank Indicators website (http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators). The data is the aggregated panel data for SSA and the global data for the period of 1970 to 2012. The variables used in this analysis include the GDP and GHGs.

The data was analyzed using the Vector Autoregressive (VAR) model. VAR is an important tool used by econometricians for time series analysis [22] and a dynamic simultaneous equations model.

$$y_t = \alpha_0 + \sum_{l=1}^{m} \alpha_l y_{t-1} + \sum_{l=1}^{m} \delta_l x_{t-1} + u_t \tag{1}$$

where α_0 and δ_l are parameter estimates, m is lag length, y_t and x_t are time series endogenous and exogenous variables, respectively. Estimating this equation is challenging as it requires more time series information, and this is often missing in panel data sets. To allow individual effects and non-stationarity across time, Holt-Eakin et al. [22] proposed that, Eq. (1) should be redefined as;

$$y_t = \alpha_{0t} + \sum_{l=1}^{m} \alpha_{lt} y_{it-1} + \sum_{l=1}^{m} \delta_{lt} x_{it-1} + \psi_t f_t + u_{it} \tag{2}$$

where f_t is an unobserved individual effect. From Eq. (2), u_{it} satisfied the orthogonal condition of;

$$E(y_{is}u_{it}) = E(x_{is}u_{it}) = E(f_{it}u_{it}) = 0, \quad s < t \tag{3}$$

Thus, the lagged values of x and y qualifies as instruments for Eq. (2). Empirically, this study estimated;

$$GHG = \alpha_{0t} + \alpha_1 GDP_t + \alpha_2 GDP_t^2 + u_t \tag{4}$$

where GDP is the log of GDP per capita (constant 2010 US$) while GHG includes the logs of CO_2 (metric tonnes per capita), NH_4 (per capita kt on CO_2 equivalence) and NO_2 (thousand metric tons of CO2 equivalent per capita). To provide empirical evidence of the effects of global GHGs emission on the economic growth of SSA, a cross effect of global GHGs emission

Table 1
Descriptive statistics and normality test of variables.

Variable	Descriptive statistic				Normality test		
	Mean	Std. dev.	Min	Max	Pr(skewness)	Pr(kurtosis)	Adjchi^2(2)
GDP percapital	662.4938	363.762	202.324	1740.42	0.0001	0.0166	15.62***
CO_2 percapital	0.00091	8.18E-05	0.000775	0.001083	0.0338	0.5488	4.83*
NH_4 percapital	0.001155	0.00021	0.000895	0.00181	0.0214	0.3563	5.8*
NO_2 percapital	0.00077	0.000199	0.000503	0.001419	0.0155	0.169	6.96**

* 10%
** 5%
*** 1%

Table 2
Results of unit root tests.

Variable	Augmented Dic key–Fuller		Phillips–Perron	
	Level	1st difference	Level	1st difference
InGDP	−0.743	−4.162***	−0.710	−4.291***
InGDP squared	−1.436	−3.993***	−0.820	−3.993***
$InCO_2$	−2.025	−6.601***	−2.291	−6.604***
$InNH_4$	−3.114**	−9.672***	−3.073**	−11.501***
$InNO_2$	−3.102**	−9.406***	−3.069**	−10.353***

See Green 7th edition pg 989 on tests formula.
** 5%
*** 1%

Table 3
Lag selection of the model.

Lag	LR	AIC	HQIC	SBIC
1	349.20	−16.21	−15.75	−14.91
2	49.48	−16.20	−15.35	−13.80
3	35.92	−15.82	−14.59	−12.34
4	51.26	−15.85	−14.24	−11.28
5	140.87	−18.31	−16.31	−12.65
6	204.37*	−22.48*	−20.10*	−15.73*

* 10%

levels were estimated with the GDP of SSA. This cross analysis is important because, although SSA emits less GHGs, it is the most vulnerable sub-region to climate change since the impacts from climate change does not necessarily affect only the emitting locality.

Table 1 shows the descriptive statistics and normality test of the GHGs and GDP. The mean values of GDP, CO_2, NH_4 and NO_2 are respectively 662.4938, 0.00091, 0.001155 and 0.00077. Thus, the per capita emission of NH_4 is higher than the other GHGs.

Results and discussions

Test for stationarity

Table 2 shows the unit root tests of the variables since the objective of the study is to estimate the relationship between economic growth and greenhouse gas emissions. This involved a Vector Auto Regression (VAR) model. The advantage of the VAR model is that it considers all the variables as endogenous, thereby, examining the interactions among the variables [23, 24]. Xiumei et al. [24] also indicated that the VAR model is simpler than traditional simultaneous models and can also explain the dynamics of time series data better. Since the VAR model requires a stationarity of the variables, we first examine the stationarity of the variables. Two test approaches, the Augmented Dickey–Fuller and Phillips–Perron tests, were used to test the stationarity of the variables. The result shows that GDP and CO_2 were non-stationary at their levels while NH_4 and NO_2 were stationary even at levels. However, the first difference of all the variables shows stationarity. This means that the mean, the variance and the auto-covariance remain unchanged irrespective of the time of measurement. The stationarity of the variables allows to proceed with the estimation of the Johnson cointegration. Apergis [25] and Kasman and Selman [26] also found the presence of unit root among variables.

Lag selection

Table 3 shows the lag length selection results. Four methods were used in the lag selection.

Table 4
Johansen cointegration tests.

R	Trace statistics	Critical value	Max statistics	Critical value
$R = 0$	75.50	68.52	29.13*	33.46
$R \leq 1$	46.37*	47.21	19.40	27.07
$R \leq 2$	26.97	29.68	16.32	20.97
$R \leq 3$	10.65	15.41	9.02	14.07
$R \leq 4$	1.63	3.76	1.63	3.76

* 10%

Table 5
Long run cointegration among variables.

Variable	Coefficient	Standard error	*P* value
GDP	−0.336***	0.058	0.000
GDP sq.	−0.708	1.192	0.553
CO_2	−0.439***	0.166	0.008
NO_2	0.828	0.755	0.273
NH_4	0.503	0.544	0.355

*** 1%

Table 6
Long run relationship between global GHGs emission and GDP of SSA.

Variable	Coef.	Std. err.	*P* value
Global CO_2	−0.141***	0.024	0.000
SSA GDP	−0.122***	0.029	0.000
SSA GDP squared	−0.782***	0.263	0.003
Global NO_2	0.001	0.058	0.987
Global NH_4	−0.051	0.044	0.252

*** 1%

These are the Akaike Information Criterions (AIC), Hanna–Quinn Information criterions (HQIC) and Schwarz Information Criterions (SBIS). The tests result in all four methods confirmed the use of lag six in the analysis.

Johansen cointegration tests

In Johansen cointegration, both trace statistics and max statistics are used to determine whether or not there is cointegration among variables (or equations) of interest. The Johansen cointegration test result shows a mixed finding. While the trace statistics result shows that the variables are cointegrated at 1, the max statistics result shows that the variables are not cointegrated. Thus, from the trace statistics, there is a long-run relationship between the variables and therefore tend to move together in the long-run. However, since the stationarity test shows that our interest variables, CO_2 and GDP are stationary at first difference or cointegrating at same order, we proceeded with the VEC model in this study (Tables 4–7).

Long run (cointegration) coefficients

Generally, if a variable is significant and negative, it implies that there is a long-run causality running from the independent variables in that equation to the dependent variable of the equation. Table 5 shows the speed-adjustment coefficients, which actually measure the long-run relationship existing among variables. For instance, the negative significance of GDP means that there is a long run causality between the other variables (CO_2, NO_2 and NH_4) and GDP. The negative significance of CO_2 indicates that there is a long run causality running from GDP to the CO_2. This is an indication that the EKC can be observed in the SSA context in the long run. The negative significance of GDP and insignificance of the square of GDP means that the shape of the EKC depicts a monotonic decreasing relationship in the long-run. Also, found in Özokcu & Özdemir [27] and Kang et al. [28] an inverted N shape relationship between CO_2 emission and per capita GDP and therefore concluded that EKC hypothesis is not supported by their data. Özokcu and Özdemir [27] argued that in addition to income, other factors such as awareness, trade openness and environmental regulations influences the environmental quality. According to Özokcu and Özdemir [27], it would still be problematic if the EKC hypothesis is supported since the negative effects of environmental degradation is irreversible, hence, environmental degradation should not be allowed for economic growth to reach its turning point. Wang et al. [29] and Kasman and Selman [26] found an inverted U shape between environment and income. Also, the result of [30] reveals an inverted U shape and also concluded that improving trade and use of renewable energy are vital strategies to curb global warming.

The literature provided evidence that although the contribution by SSA to global GHGs emission is low, it is highly impacted by climate change. In this section, this study presents the effect of global GHGs emission on the economic growth of

Table 7
Short run relationship among variables.

Equation	GDP		GDP squared	
	Chi square	*P* value	Chi square	*P* value
CO_2	13.3***	0.0207	15.59***	0.0081
NO_2	5.31	0.3797	2.66	0.752
NH_4	4.94	0.4234	1.86	0.868

*** 1%

Table 8
OLS results of GDP effects on GHG (CO_2, NH_4 and NO_2) emissions.

Independent variables	CO_2		NH_4		NO_2	
	Quadratic	Cubic	Quadratic	Cubic	Quadratic	Cubic
GDP	1.76**(0.77)	22.74(15.24)	−0.57(0.66)	−34.001***(12.38)	−1.72**(0.70)	−35.72**(13.31)
GDP sq.	−0.09(0.06)	−3.79(2.41)	0.08(0.05)	5.36***(1.96)	0.16***(0.06)	5.54**(2.10)
GDP cubed	NA	−0.20(0.13)	NA	−0.28***(0.10)	NA	−0.28**(0.11)
Constant	5.58(2.47)	56.83(31.93)	13.90 (2.12)	83.82(25.95)	17.30 (2.26)	88.41(27.89)
R sq.	0.800	0.826	0.719	0.755	0.644	0.695
Adj. R sq.	0.790	0.802	0.690	0.736	0.626	0.670
F statistics	82.1***	57.8***	48.8***	40.09***	36.2***	29.7***

Note: Standard errors are in parenthesis. *** and ** indicates significance at 1% and 5%, respectively. NA means Not Applicable.

SSA. From the result, it was evident that there is a significant and reverse long run causality between global CO_2 emissions and economic growth of SSA. Both GDP per capita and its squared were both negative. These together with the negative significance of CO_2 implies that as the total CO_2 emission by the world increases, the economic growth of SSA would continue declining. Juxtaposing this result with Table 5 suggests that irrespective of the source of the CO_2 emission, the impacts on the economic growth are negative. In other words, if SSA reduces its CO_2 emission but the global emission continues to increase, SSA would continue to witness deteriorating economic growth. Already, studies such as [33] found that a continued climate change world increase food insecurity, trigger outbreak of diseases and increase extreme events such as floods that would have severe consequences on tourism, transportation and health infrastructure in SSA. Abidoye and Odusola [31] also estimated that a 1°C increase in temperature could reduce the GDP growth of SSA by 0.67 percentage points.

Short run tests

The short run relationship between the environmental variables and economic growth, GDP, is provided in Table 7. This involved a chi square analysis using the estimated results of all six lags of the environmental variables. A lagrangian multiplier test of serial correlation indicates that at the lag order of six, there is no auto or serial correlation in the system of equations. Similarly, a Jarque–Bera test shows that the residuals of all the system equations are normally distributed. From the result, there is a significant relationship between CO_2 and GDP. All other environmental variables show no significant short run relationship. The positive significance of GDP and its square indicates that there is a monotonic increasing relationship between economic growth and environmental degradation, in the short run. However, it is important to recall that the study established a monotonic decreasing relationship in the long run. Abid [14] also found that economic growth has major implications on the environment due to the low technological advancement that forces the use of more natural resources, ultimately leading to more emissions.

Specification of the EKC in SSA

Table 8 shows the results of a multiple regression showing the relationship between economic growth and emission level of various GHGs. The result shows that there is an inverted U-shape and an N-shape of the relationship between carbon dioxide emission and economic growth under quadratic and cubic functions, respectively. Thus, an increase in GDP leads to an initial increase in carbon dioxide emission, a later decline in carbon emission rate but a final increase in the emission level with a higher GDP. This effect is only significant for GDP in the quadratic function. For methane and nitrous oxide emissions, the results show a U-shape and an inverted N-shape relationship with GDP, using quadratic and cubic functions, respectively. This implies that an increase in GDP would lead to an initial reduction in the emission level of methane and nitrous oxide, a later increase in GDP leads to an increase in the emission level of these gases, but finally, there would be a later reduction if GDP continuous to increase. From a two-stage least square, Zaman et al. [15] also estimated a positive and negative effect of GDP and GDP squared on CO_2, respectively. There is a significant effect of GDP and its square on NH_4 emission while GDP, its square and cube all had significant effect on NO_2 emission.

Fig. 1 also shows that except CO_2 that shows an increasing but a decreasing rate with respect to GDP growth, the other GHGs shows a sharp increasing trend. This explains that under business as usual where economic growth should naturally

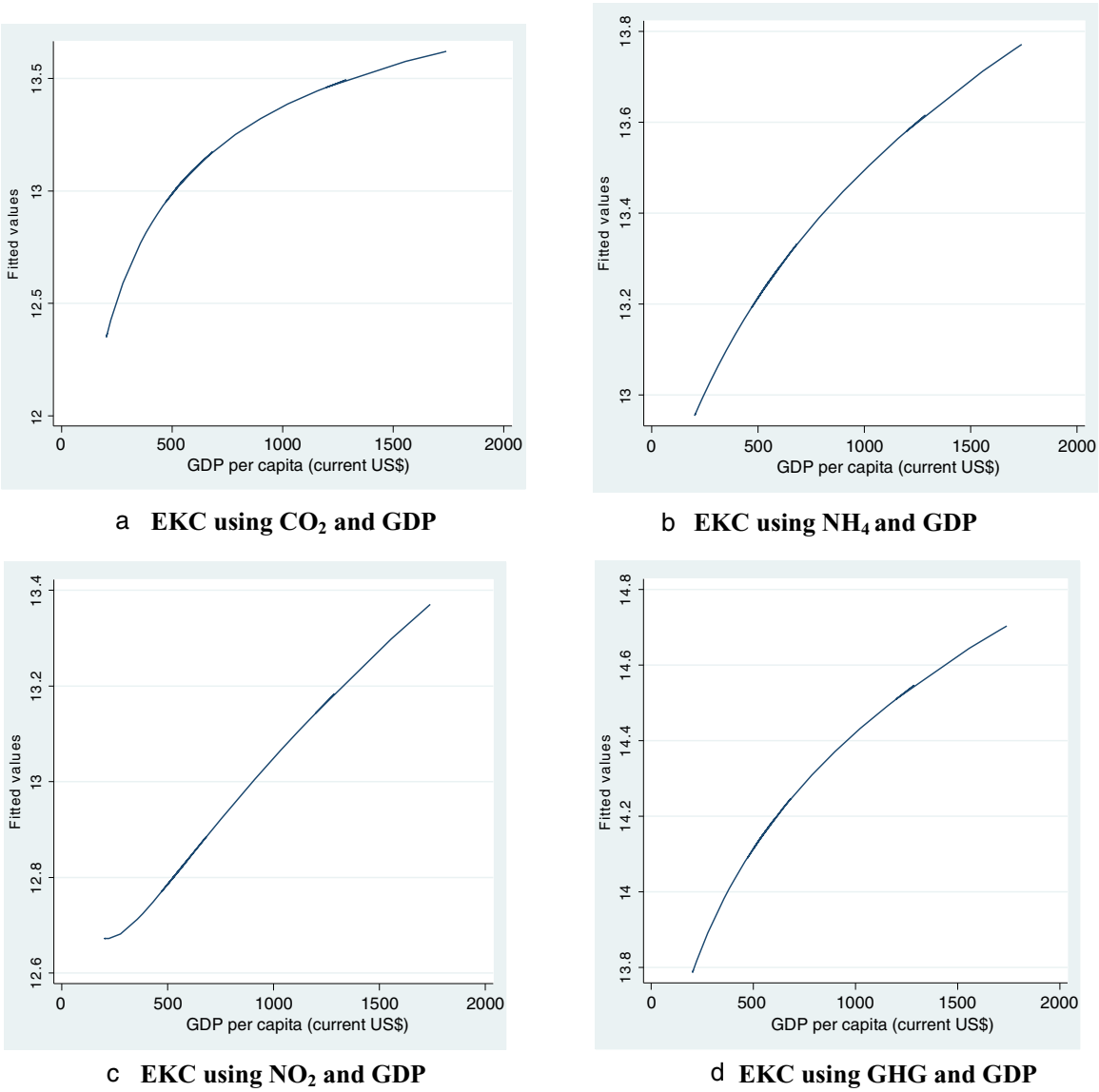

Fig. 1. EKC of GDP and GHGs using the quadratic functions in Table 5.

lead to an improved environmental quality, the SSA has not reached such growth stage. However, considering the negative consequences on societies, including shrinking economic growth itself, it is important that technological advances that would flatten the relationship be explored and adopted.

Conclusion and recommendations

This study examined the effect of economic growth on environmental quality in SSA. This research aimed to contribute knowledge on the path of sustainable development in the subregion. The study established a significant relationship between GDP and GHGs. The relationship between GDP and CO_2 in particular exhibited a classical shape of the EKC. This was evident in the OLS and VAR models. The OLS provide an N-shape relationship between GDP and CO_2 while an inverted N-shape between NO_2 and NH_4. Generally, there is a monotonic decreasing relationship between economic growth and environmental quality in the long-run. Therefore, our results suggest that the level of CO_2 emissions will significantly reduce in the future amidst an increasing GDP. For such observations to be manifested, the role of technology becomes crucial. Governments and developmental organizations in the region should seek best technological options in quest for achieving higher economic growth. It is important to emphasize the need for increased and sustained technological transfer from developed countries to countries within the SSA region as contained in the Paris Agreement. This is probably the most ap-

propriate way to keep growth up, while addressing environmental quality issues. However, the result also provided enough grounds to recommend carbon tax policies other than stringent emission reduction or climate stabilization policies in SSA.

Declaration of conflict of interest

We the authors of this manuscript have declared no conflict of interest.

Supplementary material

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.sciaf.2019.e00065.

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