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Carbon footprint and economic growth in Nigeria and Ghana

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Abstract

The study investigates the relationship between carbon footprint and economic growth in Nigeria and Ghana over the period between 1990 and 2020 (31 years). The carbon footprint related variables used in the study include greenhouse gas emissions, renewable energy consumption, electricity consumption and trade openness. These variables have been regressed against gross domestic product per capita (a proxy for economic growth). The fully modified least square and panel dynamic least square have been employed for the main analysis of the study. The findings have revealed that greenhouse gas emissions and renewable energy consumption have a significant negative effect on economic growth in Nigeria and Ghana, while electricity consumption and trade openness have insignificant positive and negative relationships with economic growth respectively. The study recommends, among others, that the governments should initiate a carbon pricing law which should be implemented through tax policy specifically on the emissions from burning of biomass which consist of methane (CH_4) and nitrous oxide (N_2O) from the combustion of biomass in forest areas as well as carbon dioxide gas from the combustion of organic soils. High taxes will deter indiscriminate bush burning among others, resulting in lower environmental pollution and degradation. This measure will help reduce adverse greenhouse gas emissions and positively impact economic growth.

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Keywords

- carbon footprint
- greenhouse gas
- renewable energy
- economic growth
- econometric and statistical methods

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Introduction

One of the most crucial issues posing serious threat to human existence which has also attracted serious attention from governments, academia and environmental experts over the past two decades across the globe is the issue of carbon footprint and its attendant effect on the ecosystem and growth process of nations. It is strongly believed that environmental quality, alongside carbon and other greenhouse gases (GHG) emissions, has a direct relationship with economic growth (Grossman & Krueger, 1991). In other words, the higher the growth is, the higher the emissions are. This is true because of the strong desire to increase foreign exchange earnings from crude oil export, which is a major driver of economic growth among African countries. Furthermore, this desire has pushed African countries to open-up their trading activities (trade openness) with other countries of the world. Increased trade increases carbon emissions through environmental goods consumption, which in turn increases the volume of global trade and specific country's output and thus affect economic growth (Mesagan, 2015). The carbon footprint represents the total amount of greenhouse gases (including carbon dioxide and methane) that are generated by human activities through the product life cycle (Gui et al., 2019). The concept derives its name from the ecological footprint traceable to Rees (1992), a Canadian ecologist who was a regional planner at the University of British Columbia. According to Finkbeiner (2009), the idea of ecological footprint is not new, it has even been in existence for the past three decades. Today, the concept is a hybrid serving as strong potential indicator for global warming.

The link between the carbon footprint and economic growth is clearly rooted in the famous Environmental Kuznets Curve Hypothesis advocated by Kuznets (1955) who stated that energy (whether fossil fuels or renewable sources), though very fundamental to economic growth by way of increased production of goods and services, and state of the art technology could have both positive and negative adverse externality effects on aggregate productivity in the long run (Kılavuz & Doğan, 2021). Thus, as countries desire to increase their foreign exchange earnings through imports and exports mechanisms, trading activities across national borders will increase, and for this to happen, the level of production will shoot up leading to high level of carbon emissions because industrial machineries will consume more fuel that will be emitted into the environment as CO_2 (Mesagan, 2015; Olubusoye & Dasauki, 2018). Hence, increases in economic activities mean high rates of carbon emissions. In order to effectively moderate and checkmate the negative effect of the carbon footprint on economic growth, various financing mechanism have been introduced, such that companies are made to compensate for their carbon emissions by either adhering to emission allowances or contributing to sustainable projects (UNHCR, 2012).

Nigeria annual greenhouse gas emissions/carbon (CO_2) emissions for 2019 was 115,280.00, while that of 2018 was 109,890.00, with an increase of 4.9% (Macrotrends, 2022). The CO_2 emissions per capita in Nigeria are equivalent to 0.44 tonnes per person (based on a population of two hundred million), and Ghana is 0.51 tonne per person. While those of the US is about 16 tonnes per person, representing the highest rates in the world; but the global average carbon footprint is approximately 4 tonnes (Worldometer, b.d.). Nigeria is also a signatory to the Paris Agreement, the international deal aimed at tackling climate change, a position it ratified in 2017, and by implication, the country has pledged to reduce its greenhouse gas emissions by 20% by 2030; this percentage has since increased to 45% as a result of the amount of international support it has received in this direction (Macrotrends, 2022).

Several carbon footprint and economic growth nexus studies have been conducted across the globe (Bimanatya & Widodo, 2018; Magazzino, 2016; Li et al., 2019; Sabbaghi et al., 2018). However, apart from those of Amuakwa-Mensah and Adom (2017) in Ghana as well as Aye and Edoja (2017) and Olubusoye and Dasuki (2018, 2020) in Nigeria, to the best of our knowledge, not much has been done in this area in Nigeria and Ghana, hence the need to conduct this study.

Furthermore, given the danger and increasing risk that carbon footprint emissions pose to the world spectrum in terms of environmental degradation, destructive climate change and atmospheric concentration of GHG, Nigeria and Ghana should be more proactive in handling climate change issue. The two countries should not only refrain from high-emission economic growth models but also develop, adopt and implement alternative environmental friendly models that are capable of increasing total economic activities and at the same time reduce total carbon footprint emissions. This is what this study seeks to provide.

Significance of the study

The Nigerian and Ghanaian economies are heavily dependent on fossil fuel energy consumption based on the current level of technological development in their industrial sector, and a shift to renewable energy has serious implications for the two countries both in the short and long run. Thus, the study is significant in that its outcome will enable us to assess and evaluate the impact of these two energy sources as well as the shift from fossil energy to renewables and their attendant impact on economic growth in Nigeria and Ghana over time. Additionally, the outcome of this study will assist foreign investors to carefully identify and take cognisance of carbon sensitive assets in order to effectively minimise the associated investment portfolio risk within the region. It will also be of immense benefit to non-governmental agencies and the UN agencies which are interested in supporting carbon footprint reduction in African countries. Hence, it will enable them to identify the short fall between carbon financing needs and actual invested funds in the region in order to assist countries to improve their environment and achieve the goal of carbon footprint reduction. Finally, it will provide a veritable platform that will serve as a guide to the management of oil firms in oil producing countries (Nigeria and Ghana) on how to effectively mitigate carbon emission issues.

Research questions

The study seeks to provide answers to the following research questions:

1. What is the relationship between greenhouse gas emissions and economic growth (measured by gross domestic product [GDP] per capita) in Nigeria and Ghana?
2. What is the impact of renewable energy consumption on economic growth in Nigeria and Ghana?
3. To what extent does electricity consumption affect economic growth in Nigeria and Ghana?
4. What is the relationship between trade openness and economic growth in Nigeria and Ghana?

Aim of the study

The main aim of the study is to examine the relationship between the carbon footprint and economic growth in Nigeria and Ghana. However, the specific objectives are to:

1. Examine the relationship between greenhouse gas emissions and economic growth (measured by GDP per capita) in Nigeria and Ghana.
2. Investigate the impact of renewable energy consumption on economic growth in Nigeria and Ghana.
3. Determine the extent to which electricity consumption affects economic growth in Nigeria and Ghana.
4. Ascertain the relationship between trade openness and economic growth in Nigeria and Ghana.

Contribution to knowledge

First of all, this study is one of the fewest and most recent studies in this area in the oil producing countries of the West African subregion. Apart from the studies of Amuakwa-Mensah and Adom (2017) in Ghana as well as Aye and Edoja (2017), Olubusoye and Dasuki (2018, 2020) in Nigeria, to the best of our knowledge, not much has been done in this area in Nigeria and Ghana. Secondly, the study highlights the fact that greenhouse gas emissions and renewable energy consumption are critical to growth, and failure to manage them timely and effectively will have serious adverse consequences on the nation's economic growth.

The remaining part of the paper has the following format: section two presents the literature review, section three discusses the methodology adopted for the study, section four shows data analysis and interpretation of results and section five offers conclusions and recommendations.

1. Literature review

1.1. Economic growth

Economic growth is a steady rise in real output in a given country. According to Ivic (2015), economic growth is the overall increase in the productive capacity of a country over a given period of time, usually measured by the monetary value of the total goods and services produced within a specific year. However, the International Monetary Fund (2013) sees economic growth as improvement in the market value of the goods and services produced and adjusted for inflation. Stone (2017) identified two diamensions of growth, the one that relates to size of labour and that of productivitythere are two main sources of economic growth: growth in the size of the workforce and growth in the productivity. Both factors can stimulate economic growth while productivity is attributable to per capita GDP (Stone, 2017, p. 4).

1.2. Carbon footprint

The concept of carbon footprint is strongly connoted with the earlier concept of ecological footprint advocated by Rees (1992), which has gained considerable attention and publicity over the past two decades due to its strong focus on the impact of human activities in terms of carbon emissions (GHG) on global environmental and climate conditions (Ercin & Hoekstra, 2012). According to Rees (1992), later corroborated by Selin (2022), "ecological footprint is the total area of land required to sustain an activity or population which includes environmental impacts, such as water use and the amount of land used for food production; in contrast, a carbon footprint is often expressed as a measure of weight, as in tons of CO_2 or CO_2 equivalent per year" (p. 1). Gui et al. (2019) and Syafrudin et al. (2020) also see the carbon footprint as an estimation of the aggregate CO_2 emissions directly or indirectly caused by an activity or accumulated through the product life cycle, where carbon dioxide is not only one of the greenhouse gases (GHG) but its most vital component (about 30%), followed by CH_4 and N_2O (Chen et al., 2019; Liu, et al., 2019). Muthu (2015) had earlier argued that "the amount of GHG is denoted by carbon dioxide equivalent (CO_2-eq) or Global Warming Potential (GWP), which is a combination of a large GHG impact based on radiation power and the length of GHG time in the atmosphere" (p. 2).

According to Gao, Liu and Wang (2013), "carbon footprints is a standard measure of human demands for natural resources, which causes serious depletion of the natural resources by generating wastes for the earth to absorb in the form of GHG emissions in waters, air and on land" (p. 3). It could also be generated from agricultural activities, energy consumption, transportation, use of water and foods among others.

1.3. Renewable energy consumption (RENGC) and economic growth

Renewable energy is usually generated from natural processes continuously, and it includes sunlight, geothermal heat, wind, tides, water, and various forms of biomass. This type of energy does not produce greenhouse gas emissions like those of fossil fuels and it is constantly renewed. Therefore, diversifying energy supply and reducing dependence on imported fuels increases the level of economic growth by creating more jobs in the manufacturing and installation sectors among others.

According to Timmons et al. (2014), as economies grow, demand for energy. Also increases. For instance, history has it that at a certain point, supplies of firewood and other biomass energy proved insufficient to support growing economies in Europe and the US, which necessitated a shift to hydropower, followed by coal during the nineteenth century, and then to oil and natural gas during the twentieth century. In the 1950s, nuclear power became part of the energy mix such that the different phases of economic development over time were associated by series of energy transitions from one major source to another. Nowadays, fossil fuels – coal, oil and natural gas – are dominant energy sources globally. However, "the twenty-first century is already witnessing the start of the next drastic transition in energy sources – away from fossil fuels towards renewable energy sources. This transition is motivated by many factors, including concerns about environmental impacts (particularly climate change), limits on fossil fuel supplies, prices and technological change. Thus, countries will eventually adopt renewable energy, since they are seen to be cheaper and growth-friendly compared to fossil fuels that are limited in supply and only created over geologic time" (Timmons et al., 2014, p. 3).

1.4. Electricity consumption (ELCON) and economic growth

Regular and stable supply of electricity is indispensable for the economic growth as it affects significantly all sectors of the economy, including households. It was corroborated by Satpathy (2015) that it enhances the quality of education, health services and access to information among others; hence, a strong positive relationship exists between ELCON and growth (Stern et al., 2019). According to Xiao et at. (2012, p. 5), "electricity consumption can promote economic growth by way of enhancing the production of capital, labour and technology, and in turn economic growth can also promote the demand for electricity consumption; and this demonstrates the inherent relationship between them". This clearly aligns with the submission of Paresh and Narayan (2007) that if ELCON can stimulate economic activities, and economic activities are energy dependent, then shortages in electricity supply will have an adverse effect on economic growth. Therefore, the causal link between electricity consumption and economic growth is traceable to the seminar work of Kraft and Kraft (1978), who concluded causality running from GNP to energy consumption in the US; however, subsequent works by Akarca and Long (1980), Yu and Hwang (1984) as well as Xiao et al. (2012) found unidirectional causality running from ELCON to economic growth.

1.5. Environmental Kuznets curve hypothesis

The environmental Kuznets curve hypothesis is predicated on the fact that during the early stages of economic development, a country experiences increased environmental pollution and degradation until a certain level of income growth, otherwise known as the "turning point", where improvement in the environment also occurred. This implies that, in the early stage of the growth process, when agriculture and allied activities dominate the entire economy, the level of environmental pollution and degradation will be generally low; yet, when economic activities begin to tint towards industrialisation, the rate of pollution tends to increase. However, as the economy continues to experience a steady shift to high level of technological advancement and services, the level of observable pollution continues to decline, thus leading to a state of the U-shaped curve (Grossman & Krueger, 1991; Omoto, 2019), a situation that strongly corroborated Kuznets (1955) hypothesis of the relationship between income inequality and average national income (economic growth).

More specifically, the basic tenet of Kuznets (1955) curve hypothesis is the existence of an inverted U-shaped nexus between environmental degradation/pollution (occasioned by carbon footprints/emissions as a result of intermediate stage of industrialisation) and economic growth (see Figure 1). It added that at the early economic growth stages of an economy, improvement in environmental quality occurs until it reaches a peak, and thereafter begins to decline due to an aggregate increase in per capita income of the population. Subsequently, economic development would eventually lead to improvement in the environment such that the U-shaped nexus between the environmental pollution and growth is attained. By implication, the rising rate of aggregate economic activities where less input is required for efficient production, will bring about general reduction in the rate of pollution and environmental degradation, thereby resulting in the U-shaped pattern.

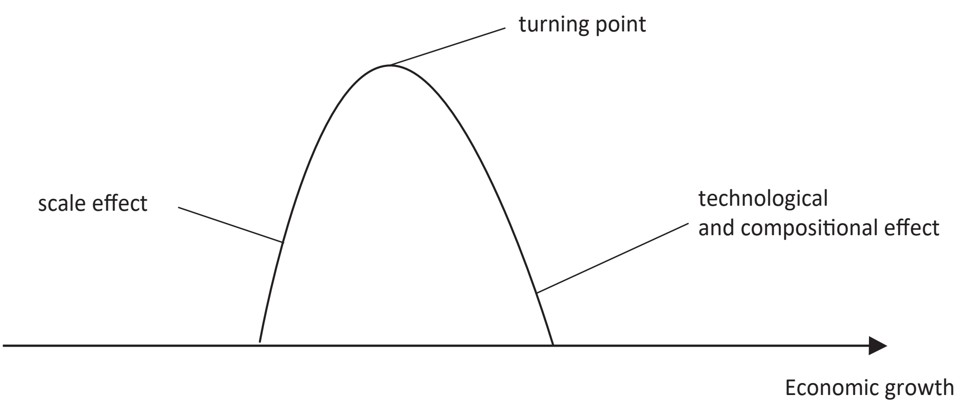

Figure 1. The N-shaped environmental Kuznets curve

Source: based on Stern (2004).

1.6. Theoretical review

1.6.1. Neo-classical theory of economic growth

The neo-classical theory and Harrod-Domar theory best explain modern economic growth behaviour by analyzing different economic aspects. The neo-classical theory of economic growth is based on the collective works of Tobin, Swan, Solow, Meade, Phelps and Johnson. According to the theory, economic growth is determined with the help of certain factors, such as the stock of capital, supply of labour and technological development over time (Solow, 1956). It is usually expressed in the following production function:

$$Y = F\,(K, L, T) \tag{1}$$

where: Y is the national output, K is capital stock; L is labour supply and T is the scale of technological development. According to the assumption of constant return to scale, increase in the national output (ΔY) would be equal to the marginal productivity (MP) times ΔK and ΔL, therefore:

$$\Delta Y = \Delta K \times MP_k + \Delta L \times MP_l \tag{2}$$

where: MP_k is the marginal physical product of capital, MP_l is the marginal physical product of capital. Thus, dividing the national output by Y, we arrive at $\Delta Y/Y =$ $= \Delta K(MP_k/Y) + \Delta L(MP_l/Y)$; the $K \times MP_k$ and $L \times MP$ represent the total stake of capital and labour in the national output, whereas $K/Y \times MP_k$ and $L/Y \times MP_l$ represent the relative stake of capital and labour in the national output; thus:

$$(K \times MP_k/Y) + (L \times MP_l/Y) = 1 \tag{3}$$

The theory further argues that economic growth (at a given level of technology) = elasticity of output with respect to the increase in capital stock + elasticity of output with respect to the increase in labour. However, with respect to technological change, the change in national output is given by:

$$\Delta Y/Y = b\,\Delta K/K + (1 - b)\,\Delta T \tag{4}$$

where b is elasticity of output.

Deducing from the above, it is obvious that a strong positive relationship exists between economic growth and energy consumption as represented by the stock of capital and technological changes in the above model. Thus, as the process of energy consumption (EC) rises, the total output and growth also rise leading to what is called the growth hypothesis. However, the conservative view has it that the quantity of EC in a country depends on the economic growth level. Hence, when energy consumption is embraced, it will not have an adverse effect on growth; yet, from the view of the feedback hypothesis, a bidirectional relationship does exist between economic growth (EG) and the level of energy consumption in a country (Bimanatya & Widodo, 2018).

1.7. Empirical literature

Cole et al. (2011), testing the validity of the U-EKC curve, examine how FDI affects economic growth and carbon footprint emissions in 112 major PRC cities in the period of 2001–2004. The finding indicated an inverted-U EKC-type curve with a turning point between RMB32,4557 and RMB35,098 for wastewater and a turning point between RMB17,233 and RMB23,866 for petroleum-like matter. In a similar study by He and Wang (2012) on how economic growth strategy and environmental laws impact the quality of the environment, the authors, employing the panel data analysis, established a significant positive relationship between environmental quality and economic development, which could vary at different stages of development.

In a related study by Olarinde et al. (2014) on the effect of CO_2 emissions on economic growth in selected West African countries, the authors employed the panel data analysis and found that the N-shaped hypothesis holds between economic growth and CO_2 emissions. Tubiello et al. (2014), employing the panel data methodology, studied greenhouse gas (GHG) emissions and other agricultural and forestry pollutants. The authors found that increases in agricultural emissions reduce deforestation rates and forest sinks. They also observed GHG intensity of products between 1990 and 2010, concluding that if not properly mitigated, future emissions may further rise by 30% by 2050.

The study of Kasman and Duman (2015) on the causality relationship between CO_2 emissions, trade openness, energy consumption, urbanisation and economic growth in new EU members over the period between 1992 and 2010, revealed that energy consumption, CO_2 emissions, GDP and lagged trade openness have a significant positive effect on CO_2 emission.

Halicioglu and Ketenci (2016), in their study on environmental quality and international trade in 15 transition countries, employed the autoregressive distributed lags (ARDL) and generalize method of moment (GMM). The authors found that the EKC hypothesis holds in only Uzbekistan, Turkmenistan and Estonia, while the displacement hypothesis was confirmed in Latvia, Armenia, Kyrgyzstan, Estonia and Russia.

In another related study, Olubusoye and Dasauki (2018) empirically examined the validity of the EKC hypothesis in 20 African countries. The authors employed the income elasticity analysis based on the long and short run and found that an inverted U-shaped curve in the long run income elasticity, which is an indication that as carbon emissions , aggregate income rises considerably. Additionally, Fang et al. (2018) examine the impact of industrial wastewater and sulfur dioxide pollution as well as openness on economic growth in China for the period of 2004–2013. Employing the fully modified least square (OLS), the result showed that the environmental Kuznets curve hypothesis does not hold, and that greater openness tends to favour lower industrial waterways emissions and higher sulfur dioxide emissions.

Iskandar's (2019) empirical investigation of the EKC hypothesis with respect to CO_2 emissions and economic growth (EG) in Indonesia for the period between 1981 and 2016, used the ARDL analysis and found that the EKC hypothesis does not hold in the country. Balcilar et al., (2019) study on the nexus between CO_2 emissions and EG in G-7 countries used the historical decomposition technique and observed a trade off on EC in order to minimize CO_2 emissions in the US, Canada and Italy; while the EKC does not hold in the case of the UK and Germany, EC has a positive effect on the environmental quality.

In an attempt to minimise the impact of the carbon footprint at Diponegoro University, Syafrudin et al. (2020) employed the panel method to analyze the carbon footprint under three stages of the Greenhouse Gas Protocol, such as clean water treatment activities, electricity usage activities as well as transportation, wastewater and solid waste treatment activities. The results showed that the largest contributor to carbon footprints came from the electricity and transportation activities.

Khan et al. (2020) investigated the impact of CO_2 emissions and energy consumption on economic growth in Pakistan for the period of 1965–2015. Using the ARDL econometric technique, the authors found that EC and growth significantly impact CO_2 emissions both in the short and long run. Kılavuz and Doğan (2021) examined the EKC hypothesis in Turkey in the period of 1961–2018. Using the ARDL, the authors' findings confirmed its existence, with CO_2 playing the dominant role, while trade openness had no significant impact.

1.8. Knowledge gap

From the above reviewed empirical literature, it was observed that most of the studies were carried out in other countries, and to the best of the authors' knowledge, not much has been done in this area in Nigeria and Ghana. This created a gap in the literature that needed to be filled, hence the need to conduct this study using the above two countries as they are the leading economies in the West African subregion.

In terms of the methods of analysis, it was also found that, unlike this study, no studies employed the fully modified ordinary least squares and the panel dynamic least squares (PDLS) in their empirical analysis of data. The methods are deemed to be more suitable and appropriate for a work of this nature due to the fact that these two methods are non-parametric analysis that possessed the ability to address small sample bias and endogeneity bias by taking the leads and lags of the first-differenced regressors.

Furthermore, the major energy mix and energy intensity trends in Nigeria and Ghana (coal, petroleum reserves, natural gas, peat, hydroelectricity, solar and wind) have been observed to be on a downward trend for some time now (Knoema, 2020a). For instance, in Nigeria, there is a marked fall from 10 MJ per dollar of GDP in 2000 to 6 MJ per dollar of GDP in 2019; while in Ghana, it fell gradually from 5 MJ per dollar of GDP in 2000 to 3 MJ per dollar of GDP in 2019 (Knoema, 2020b). Given this worrisome scenario, one cannot vividly ascertain what could have been responsible. It is therefore necessary to carry empirical investigation in this direction in order to see the extent to which these downward trends have impacted the two countries' economic growth over time.

2. Methodology

The research design employed for this study is the longitudinal (ex post facto) research design because the data involved have already occurred, and so the researchers cannot alter them. Moreover, in order to effectively analyse the impact of the carbon footprint on economic growth in Nigeria and Ghana, the study employed an augmented Decay-Fuller unit root test, correlation coefficient, fully modified ordinary least squares (FMOLS) and the panel dynamic least squares (PDLS). The augmented Decay-Fuller unit root test is used to ascertain the stationarity property of the data set for the purpose of avoiding spurious regression results, the correlation coefficient is used to assess the background characteristics and the nature of the relationships among the data, while the FMOLS and PDLS have been employed for the main estimation of the study. Both methods are non-parametric and are often preferred to the OLS estimator because they are able to address small sample bias and endogeneity bias by taking the leads and lags of the first-differenced regressors; the methods also impose additional requirements that all variables should be integrated of the same order [i.e. order one of one I(1)] and that the regressors themselves should not be cointegrated (Philips, 1993).

2.1. Model specification

The model for this study hinges on the neo-classical theory and the Harrod-Domar theory of modern economic growth that is determined by the help of certain factors, such as stock of capital, supply of labor, and technological development over time (Solow, 1956).

Thus, Equation 1 above is slightly modified to incorporate carbon footprints and trade openness factors, such that (*Y*) national output (economic growth) is a function of carbon footprint variables which is presented in its functional form as follows:

$$EGRWTH = f\,(GHG, RENGC, ELCON, TOPN) \tag{5}$$

The econometric form of the model is stated in the following order:

$$GDPPC = \alpha_0 + \alpha_1 GHGe_t + \alpha_2 RENGC_t + \alpha_3 ELCON_t + \alpha_4 TOPN_t + u_t \tag{6}$$

where:
$GDPPC$ – GDP per capita income (a proxy for economic growth),
$GHGe$ – greenhouse gas emissions,
$RENGC$ – renewable energy consumption,
$ELCON$ – electricity consumption,
$TOPN$ – trade openness,
u_t – the error term.
The a ppriori expectations are $\alpha_1, \alpha_2, \alpha_3, \alpha_4 > 0$.

2.2. Measurement of variables

The respective measurements of various variables employed in the study are specifically defined in Table 1.

Table 1. Definition of variables

Acronym	Variable	Measurement	Source
GDPPC	gross domestic product per capita	GDP/midyear population	World Bank Development Indicators (n.d.)
GHG	greenhouse gas emissions	Aggregate GHG emissions (inclusive of forest, land use, kilotonne of CO_2 equivalent), etc.	Hu et al. (2019); World Bank Development Indicators (n.d.)

Table 1 continued

Acronym	Variable	Measurement	Source
RENGC	renewable energy consumption	Renewable energy consumption as % of aggregate final energy consumption	Hu et al. (2019); World Bank Development Indicators (n.d.)
ELCON	electricity consumption	Electric power consumption measures the production of power plants and combined heat and power plants less transmission, distribution, and transformation losses and own use by heat and power plants	World Bank Development Indicators (n.d.)
TOPN	trade openness	ratio of trade (imports and exports) to GDP	Navaretti and Venables (2004); Rambeli et al. (2020)

Source: own study.

3. Data analysis and interpretation of results

In this section, we present different analyses of data based on the methodology presented in the previous section. First, we analyse the correlation coefficients for each country (Nigeria and Ghana) as well as their fully modified least square (OLS) results. Next, we proceed to the combined analysis of the results for the two countries with respect to the unit root test, correlation coefficient and panel dynamic least square (PDLS).

3.1. Correlation analysis (for Nigeria and Ghana)

The results of the correlation matrix for the relationship between the carbon footprint and economic growth in Nigeria and Ghana are presented in Table 2. It may be noted that GDP per capita income generally has a weak negative correlation value of –0.35033 and –0.01705 with greenhouse gas emissions (GHG) and electricity consumption (ELCON), and weak positive correlation values of 0.11437 and 0.29583 with renewable energy consumption (RENGC) and trade openness (TOPN). The corresponding result from Ghana shows GDP per capita income with

Table 2. Pairwise correlation matrix

	Nigeria				
	GDPPC	GHG	RENGC	ELCON	TOPN
GDPPC	1				
GHG	–0.35033	1			
RENGC	0.11437	–0.81054	1		
ELCON	–0.01705	0.83055	–0.60036	1	
TOPN	0.29583	–0.19698	–0.09402	–0.01751	1
	Ghana				
	GDPPC	GHG	RENGC	ELCON	TOPN
GDPPC	1				
GHG	0.24425	1			
RENGC	–0.35162	–0.95533	1		
ELCON	–0.17009	0.25351	–0.01787	1	
TOPN	0.09991	–0.00536	–0.03976	–0.20533	1

Source: own study.

the same variables are also very weak; while a weak positive correlation values of 0.24425 and 0.09991 was observed between GDPPC, GHG and TOPN, a weak negative correlation values of –0.35162 and –0.17009 was noticed between GDPPC RENGC and ELCON. In Nigeria, GHG has a strong positive and negative values of 0.83055 and –0.81054 ELCON and RENGC; but those of RENGC and ELCON were strongly and inversely correlated. On the other hands, those of Ghana indicate a strong inverse correlation value of –95533 between GHG and RENGC. In a nutshell, the correlation results simply suggest the absence of multicolinearity among the data set used in the empirical analysis.

3.2. Panel fully modified ordinary least squares (FMOLS) estimates (for each country)

3.2.1. Nigeria's case

The results for each country (Nigeria and Ghana) are presented in Table 3. In the case of Nigeria, the diagnostic indicators are impressive, the R-squared value of 0.62 is high and shows that over 62% of the systematic variations in economic growth are captured by changes in the explanatory variables; even the adjusted

Table 3. Carbon footprint and economic growth

Variables	Nigeria			Ghana		
	Coefficient	*T*-Ratio	Probability	Coefficient	*T*-Ratio	Probability
GHG	–0.000241	–6.794486	0.0000**	–0.000533	–2.673745	0.0133*
RENGC	–1.566044	–5.894024	0.0000**	–0.339228	–2.807638	0.0098**
ELCON	0.183150	6.972458	0.0000**	0.014001	1.264911	0.2180
TOPN	–0.101688	–1.543273	0.1358	0.023664	0.980502	0.3366
Constant	179.5210	5.833728	0.0000	28.59312	2.882490	0.0082
R^2 = 0.62	$\bar{R}^2$ = 0.55	–	–	R^2 = 0.23	$\bar{R}^2$ = 0.06	–

Note: * significant at 5% level; ** significant at 1% level.

Source: own study.

R-squared value of 0.55% is equally good, which it implies that the models have good predictive abilities. With respect to the individual coefficients of the variables in terms of significance and signs, it is seen that GHG emissions, RENGC and ELCON have a significant positive and negative relationship with economic growth in Nigeria; they are significant at the 1% significance level. This means that the growth of the Nigerian economy is highly dependent on GHG, RENGC and electricity consumption. However, the negative signs for greenhouse gas emissions and renewable energy consumption suggest that a unit increase in these variables reduces economic growth in Nigeria by –0.000241% and –1.566044% respectively. The other variable TOPN does not play a significant role in economic growth in Nigeria within the period of analysis.

3.2.2. Ghana's case

On the other hand, the results from Ghana show a weak diagnostic indicator because the *R*-squared value of 0.23 is low, indicating that over about 23% variations in economic growth are captured by changes in the dependent variables; even the low adjusted *R*-squared value of 0.06 indicates a weak predictive ability of Ghana's economic growth-carbon footprint model. However, turning to the results of individual variables, we observe similar results to those of Nigeria, i.e. GHG emissions and RENGC have a significant negative impact on economic growth in Ghana, passing the 5% and 1% levels of significance. It therefore follows that these two variables play a significant role in determining the growth of Ghana's economy over time. However, the variables of ELCON and TOPN failed the 5% significance level, suggesting that they do not play a significant role in Ghana's economic growth.

3.3. Combined analysis of carbon footprint in Nigeria and Ghana

3.3.1. Correlation analysis

In this section, the analysis of the correlation matrix for the relationship between the carbon footprint and economic growth in Nigeria and Ghana (taken together) is presented in Table 4. Generally, the correlation between GDP per capita income,

Table 4. Pairwise correlation matrix (Nigeria and Ghana)

	GDPPC	GHG	RENGC	ELCON	TOPN
GDPPC	1				
GHG	–0.20925	1			
RENGC	–0.22703	0.66642	1		
ELCON	0.11577	–0.87027	–0.71837	1	
TOPN	0.03798	0.46733	0.34760	–0.51552	1

Source: own study.

greenhouse gas (GHG) emissions, renewable energy consumption (RENGC), electricity consumption (ELCON) and trade openness (TOPN) is very weak. However, GHG have strong positive and negative correlation values of 0.66642 and –0.87027 with RENGC and ELCON, and a moderate positive correlation value of 0.46733 with TOPN. Furthermore, while RENGC is inversely correlated with ELCON (–0.71837), ELCON and TOPN are inversely correlated (–0.51552). The conclusion is that the outcome of this result is an indication of the absence of multicolinearity among the data used for the analysis in this study.

3.3.2. Panel unit root tests

The panel unit root tests analysis involving Levin, Lin & Chu (LLC), Fisher Chi-square-ADF and PP-Fisher Chi-square has been performed. Table 5 presents the results for the unit root test at levels and the first difference. It has been observed that at levels the variables were non-stationary but after the first difference they became stationary. Hence, we have technically avoided spurious regression results.

Table 5. Unit root test (Nigeria and Ghana)

Variable	At levels				At first difference			
	LLC	Fisher-ADF	PP-Fisher	Remark	LLC	Fisher-ADF	PP-Fisher	Remark
GDPPC	–0.38865 (0.3488)	6.15101 (0.1882)	14.9717 (0.0048)	stationary	0.29902 (0.6175)	18.9900 (0.0008)	61.1651 (0.0000)	stationary
GHG	1.60876 (1.9462)	0.05794 (0.9996)	0.06416 (0.9995)	non-stationary	–1.56507 (0.0588)	13.1126 (0.0107)	36.3898 (0.0000)	stationary
RENGC	–0.31577 (0.3761)	0.95382 (0.9167)	1.23693 (0.8720)	non-stationary	–3.54038 (0.0002)	28.0943 (0.0000)	56.3945 (0.0000)	stationary
ELCON	0.15126 (1.5601)	1.79691 (0.7730)	3.59326 (0.4638)	non-stationary	–3.47265 (1.0003)	22.9493 (0.0001)	51.7900 (0.0000)	stationary
TOPN	–1.29926 (0.0969)	9.17270 (0.0569)	8.59038 (0.0722)	non-stationary	–5.13273 (0.0000)	23.9275 (0.0001)	36.8992 (0.0000)	stationary

Note: the numbers in parenthesis are *p*-values.

Source: own study.

3.3.3. Cointegration test

The Pedroni Residual Panel Cointegration Test (PRPCT) was employed to test for cointegration. The result in Table 6 shows that there are more than one (1) significant cointegrating vectors among the variable. This implies the existence of a long run relationship among the variables.

Table 6. Pedroni Residual Cointegration Test Results (Nigeria and Ghana)

Variable	Statistic	Probability	Weighted statistic	Probability
Panel *v*-Statistic	0.300825	0.3818	–0.101824	0.5406
Panel rho-Statistic	–1.017157	0.1545	–1.361830	0.0866
Panel PP-Statistic	–6.791202	0.0000**	–7.413860	0.0000**
Panel ADF-Statistic	–1.951504	0.0255*	–2.036511	0.0208*

Note: * significant at 5% level; ** significant at 1% level.

Source: own study.

3.4. The panel dynamic least squares (PDLS) estimates for Nigeria and Ghana (combined)

The relationship between the carbon footprint and economic growth in Nigeria and Ghana has been analysed using the PDLS (see Table 7). The goodness of fit is very high, with the *R*-squared value of 0.84, suggesting that over 84% changes in economic growth in both countries are captured by changes in the dependent variables. However, the adjusted *R*-squared value of 0.21% suggests a weak predictive ability of the model.

Table 7. Carbon footprint and economic growth in Nigeria and Ghana (PDLS)

Variables	Dependent variable = GDPPC		
	Coefficient	*T*-Ratio	Probability
GHG	–0.000143	–2.863323	0.0187*
RENGC	–0.257296	–2.213801	0.0541*
ELCON	0.015043	0.445232	0.6667
TOPN	–0.046706	–0.501861	0.6278
GDPPC(–5)	–0.051284	–0.120824	0.9065
R^2 = 0.84	$\bar{R}^2$ = 0.21	–	–

Note: * sig at 5% level.

Source: own study.

On the basis of the individual relationship between the explanatory variables and the dependent variable, it is seen that greenhouse gas emissions (GHG) have a significant negative relationship with economic growth (proxied by GDP per capita income (GDPPC)) in Nigeria and Ghana. The variable passes the 5% significance level, which may suggest that it plays a significant role in the growth of Nigeria's and Ghana's economies over time. However, the negative sign suggests that as the level of greenhouse gas emissions increases, economic growth in these two countries decreases by approximately –0.000143%. This further suggests that, besides policy initiatives towards reducing GHG, the governments of these two countries need to be very proactive by taking decisive actions towards effectively tackling and reducing the menace of GHG so that the space of economic growth will not only improve but also become equally sustained over the long term. Indeed, this result is corroborated by Cole et al. (2011), Kasman and Duman (2015), Tubiello et al. (2014), as well as Olubusoye and Dasauki (2018) all of whom found a significant inverse relationship between GHG emissions on EG. However, the above research disagrees with that of Fang et al. (2018), He and Wang (2012), Iskandar (2019), Syafrudin et al. (2020), as well as Khan et al. (2020) who observed in their respective studies that GHG emissions significantly and positively impact EG.

The coefficient of renewable energy consumption (RENGC) also has a significant inverse relationship with economic growth, being significant at the 5% level. This simply implies that a unit increase in the level of RENGC reduces EG in Nigeria and Ghana by –0.257296%. Therefore, proper combination, deployment, application and management of all forms of renewable energy alongside other sources of energy is imminent in these two countries in order to positively boost their economic growth. This is true because, given the low level of technological know-how as well as weak infrastructure to effectively engage renewable energy, it will continue to have a negative impact on their economic activities compared to their American, Europen and Asian counterparts. In fact, this result does not corroborate the research of Fang et al. (2018), Iskandar (2019), Kasman and Duman (2015), Syafrudin et al. (2020), as well as Khan et al. (2020) who unanimously confirmed a significant positive relationship between the renewable energy consumption and EG.

On the other hand, the coefficients of ELCON and TOPN failed the 5% significance level, which is an indication that these two variables do not play a significant role in the determination of economic growth in Nigeria and Ghana over the period of analysis. This result is a clear confirmation of the poor, epileptic and disappointing level of electricity supply in these two countries, including a total blackout in major cities and towns lasting for several months and years. The ineffective and corrupt nature of electricity companies in these two countries accounts for the inability of electricity energy to impact positively their economic growth. This result is seen to agree with the findings of Kılavuz and Doğan (2021) who found an insignificant impact of TOPN on EG; however, it contradicts the findings of Iskandar (2019), Syafrudin et al. (2020), as well as Khan et al. (2020) who found that ELCON significantly impacts growth and those of Kasman and Duman (2015) who also found that TOPN significantly impacts economic growth.

3.5. Discussion of results

Within the analysed period (1990–2020), some observed trends/changes in Nigeria and Ghana GDP per capita showed that in 1990, Nigeria's GDP per capital stood at $568, with a growth rate of 11.78%, while that of Ghana was $399 with a growth rate of 3.33%. Between 1993 and 1995, a negative growth rate was observed in Nigeria, and from that period to 2020, the growth rate was not stable; the rate was even decreasing. The average growth rate between 1990 and 2020 stood at about –13.57%. In Ghana, the growth rate was generally positive and seemed to be more stable compared to that of Nigeria; however, the average growth rate between 1990 and 2020 for Ghana was –2.82%. This is a clear confirmation of the results of this study, with greenhouse gas (GHG) emissions and renewable energy consumption (RENGC) having a significant negative impact on economic growth of the two countries. This suggests that the slow pace of economic growth in Nigeria and Ghana over time was influenced primarily by greenhouse gas emissions and renewable energy consumption.

The result from the empirical analysis has shown that trade openness (TOPN) (measured as the ratio of trade (imports and exports) to GDP) has had a weak inverse relationship with economic growth in Nigeria and Ghana. This suggests that over time TOPN has not really impacted positively the countries' economies; in fact, it has rather had the tendency to reduce them. There is further confirmation of the current trends in international trade of the two countries within the period of analysis. For instance, Nigeria's total export was about \$34,900,471.09 (in thousands) and its imports \$55,455,401.89 (thousands) resulting in an inverse trade balance of \$20,554,930.80. The trade growth is –19.12% compared to the global growth of –3.91%. Nigeria's GDP is about \$432,293,776,262.40 and its services export is \$3,993,012,590.25 while the services import stand at \$19,832,514,705.25. However, for the case of Ghana, aggregate export is \$16,768,275.19 (thousands), total import is about \$10,439,795.45 (thousands), leading to a positive trade balance of \$6,328,479.74. Its overall trade growth is –1.94% compared to the global growth of –1.78%. The above scenario was strongly corroborated by Kılavuz and Doğan (2021), who observed that TOPN does not significantly affect economic growth. However, studies by Iskandar (2019), Syafrudin et al. (2020), Khan et al. (2020) concluded otherwise.

Finally, the major energy mix and energy intensity trends in Nigeria include coal, petroleum reserves, natural gas, peat, hydroelectricity, solar and wind. The country remains a top producer of crude oil and natural gas in Africa. According to Knoema (2020b), in 2019, energy intensity for Nigeria was 6 MJ per dollar of GDP. Energy intensity of Nigeria fell gradually from 10 MJ per dollar of GDP in 2000 to 6 MJ per dollar of GDP in 2019. On the other hand, Ghana's major energy mix includes hydropower generation as well as thermal generation fueled by crude oil, natural gas and diesel. Energy intensity for Ghana in 2019 was 3 MJ per dollar of GDP, which fell gradually from 5 MJ per dollar of GDP in 2000 to 3 MJ per dollar of GDP in 2019 (Knoema, 2020a).

4. Conclusions

The main aim of the study was to empirically investigate the relationship between carbon footprint and economic growth in Nigeria and Ghana over the period of 1990–2020 (31 years). The study was to provide answers to 4 specific research questions such as: what is the relationship between greenhouse gas emissions, renewable energy consumption, electricity consumption, trade openness and economic growth (measured by GDP per capita income) in Nigeria and Ghana? The carbon footprint related variables used in the study include greenhouse gas emissions (GHG), renewable energy consumption (RENGC), electricity consumption (ELCON) and trade openness (TOPN), which were regressed against GDP per capita (GDPPC) (a proxy for EG). Preliminary tests such as unit root tests, correlation coefficient and panel cointegration tests were carried out, while the fully modified ordinary least square (FMOLS) and panel dynamic least square (PDLS) were employed for the main analysis of the study. Generally, the results obtained from the analysis of data indicate that greenhouse gas emissions (GHG) and RENGC have a significant negative effect on GDPPC, and thus they were the major factors affecting economic growth in Nigeria and Ghana. ELCON and TOPN have an insignificant positive and negative relationship with economic growth. The conclusion is that in the determination of economic growth in Nigeria and Ghana, GHG and RENGC are the potent factors that must not be undermined by the governments and relevant policy makers in these two countries. Any attempt to ignore or downplay them will spell doom for the two economies.

Recommendations

In view of the findings of this study, the following recommendations for policy action are brought forward:

First, since GHG emissions have a significant inverse impact on economic growth, appropriate mitigation strategy aimed at reducing the adverse effect of all forms of greenhouse emissions should be put in place. For example, the governments of Nigeria and Ghana and their respective environmental policy makers can initiate a carbon pricing law which should be implemented through tax policy specifically on the emissions from burning of biomass which consist of methane (CH_4) and nitrous oxide (N_2O) from the combustion of biomass in forest areas and carbon dioxide gas from the combustion of organic soils. High taxes will deter indiscriminate bush burning among others, resulting in lower environmental pollution and degradation. This measure will not only reduce adverse GHG emissions but will also have the much needed positive effect on economic growth.

Secondly, the current thought towards the near future that should preoccupy the minds of Nigerian and Ghanaian governments is diversifying energy supply to renewable energy and reducing dependence on imported fuels. This will increase the level of economic growth by creating more jobs in the manufacturing and installation sectors among others. The reason being that this form of energy does not generate greenhouse gas emissions and is constantly renewed.

Finally, the poor, epileptic and disappointing level of electricity supply in these two countries, and especially total blackouts in major cities and towns for several months and years, should be properly and effectively tackled. The ineffective and corrupt nature of electricity companies also accounted for the inability of electricity energy to positively impact the economic growth. If the governments are sincere in this direction and vigorously pursue and implement the right policy, electricity energy will have a significant positive impact on economic growth while overall aggregate emissions will be reduced.

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