Journal of Advanced Research in Economics and Administrative Sciences
ISSN 2708-9320 (Print) and 2709-0965 (Online)
Volume 3, Issue 2 Article 5
DOI: https://doi.org/10.47631/jareas.v3i2.479

SUSTAINABLE ECONOMIC DEVELOPMENT ROUTES IN SUB-SAHARA AFRICA: A DYNAMIC LONG-RUN RELATIONSHIP ANALYSIS OF FISCAL POLICY, ENERGY CONSUMPTION AND CARBON DIOXIDE EMISSIONS

Stephen Ansah[1], Zheng Xungang[1]*, Emmanuel Agyapong Wiafe[2], Gideon Ntim-Amo[1]

[1]Sichuan Agricultural University, College of Management 611130, 211 Huimin Road, Chengdu, China
[2]Ghana Institute of Management and Public Administration, Takoradi, Ghana

ARTICLE INFO

Recieved: 30 March 2022
Revised: 20 May 2022
Accepted: 24 May 2022

Keywords:
Fiscal Policy
Energy Consumption
CO2 Emissions
Cross-Sectional Augmented Autoregressive Distributed Lag
Common Correlated Effect Mean Group

JEL: G32, H21, C33, O54, G30

Corresponding Author:
Zheng Xungang

Email: zxg9@sicau.edu.cn
Copyright © 2021 by author(s).

This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).
http://creativecommons.org/licenses/by/4.0/

OPEN ACCESS

ABSTRACT

Purpose*: This study investigates the relationship between fiscal policy, energy consumption, and carbon dioxide emissions in the sub-Saharan African region.*
Approach/Methodology/Design*: The cross-sectional autoregressive distributed lag, common correlated effect means group, and the augmented mean group were used to analyze the long-run effect of fiscal policy, and energy consumption on carbon dioxide emissions for the period 1990–2018.*
Findings*: The findings of this study indicate that expansionary fiscal policy drives carbon dioxide emissions, while contractionary fiscal policy mitigates carbon dioxide emissions for the sub-Sahara African region. The study's findings also indicate that an increase in renewable energy consumption help reduce carbon dioxide emissions, while non-renewable energy consumption causes carbon emissions to rise. Similar results were obtained for the various income-based economies except upper-middle-income economies that recorded insignificant long-run effect of fiscal policy, renewable energy and non-renewable energy consumption on carbon emissions.*
Practical Implications*: The significant role of expansionary and contractionary fiscal policies established from this study's results indicate the possibility of economic managers of various nations to promote sustainable development through fiscal policy implementations. Thus, governments of various economies could use fiscal policy especially expenditure as a tool to ensure sustainable development.*
Originality/value*: This study innovates by employing econometric tools that deal with the problem of cross-sectional dependence that may exist among the study variables. This study innovatively considers the income levels of the selected countries to ascertain the role of income levels in the dynamic relationships between fiscal policy and carbon emissions, which is novel in this area of study within the Sub-Saharan African region.*

INTRODUCTION

One of the biggest challenges that continue to confront countries across the globe in their effort to achieve economic growth and development is the issue of global warming, resulting from the emission of undesirable output into the environment (World Meteorological Organization, 2019). The past decade has been reported as the warmest decade, with 2017 recording the highest temperature (World Meteorological Organization, 2019). This situation has shifted the focus of countries from the conventional development agenda to a sustainable development plan, prioritizing sustainable long-term growth over short-term growth by considering the safety and quality of the environment to achieve economic growth. According to a 2010 report of the World Bank, one of the elements identified as a critical contributor to climate change is the increased concentration of Greenhouse Gases (GHG), of which carbon dioxide (CO2) emissions account for more than 75%.

Driven by higher energy demand in 2018, global energy-related CO2 emissions rose from 1.7% to a historic high of 33.1 Gt CO2. While emissions from all fossil fuels increased, the power sector accounted for nearly two-thirds of emissions growth. Coal use in power alone surpassed 10 Gt CO2, mostly in Asia, and the United States accounted for 85% of the net increase in emissions, while emissions declined for Germany, Japan, Mexico, France, and the United Kingdom. Academically, carbon dioxide, among other determinants, has been theoretically and empirically proven to threaten environmental quality (Adedoyin et al., 2020). Existing literature reveals that energy consumption and economic growth are the most significant contributors to increased GHG emissions. Economic growth is critical for poverty alleviation and improvement in Africa's quality of life and cannot be compromised for any other thing. The continent has, in recent years, experienced improving macro-economic trends. Over the past decade, Africa has recorded some of the fastest-growing economies globally, which has seen the sub-Saharan African region recording an average growth of more than 3 percent until the emergence of the COVD-19 Pandemic (O'Neill, 2021). Considering the discoveries of existing literature, economic growth and development in the sub-Saharan African region have the potential to increase the emissions of GHG, particularly carbon dioxide emissions. According to the 2016 report of the World Health Organization, countries such as Ghana, South Africa, Nigeria, Cameroon, Uganda, Mauritius, and Madagascar within the sub-Saharan Africa region have been identified as the developing countries with high carbon dioxide emissions, as well as other pollutants, which are responsible for severe biological damage. The World Health Organization also reports that close to half a million sub-Saharan Africans die due to air pollution every year.

The use of fossil fuels (coal, gas, and oil) by emerging economies within the Sub-Saharan Africa region to attain economic growth continues to increase despite several challenges emanating from its massive use (Hanif, 2018). Even though economic growth has been accelerated by the consumption of energy, at the same time, the environment has been adversely affected by the generated residues from the combustion of fossil fuels across the whole sub-Saharan African region (Halicioglu, 2011). According to Bekhet and Harun (2012), Poverty eradication, food insecurity, and economic growth are the most desirable relative to environmental quality among emerging economies hence their reluctance to halt the consumption of cheap energy resources, which has dire consequences on the environment.

Recent literature (Katircioglu & Katircioglu, 2018; Chishti et al., 2021) has identified governments' fiscal policy implementation as a possible significant contributor to the increased environmental pollution through expansionary fiscal policy. Fiscal policy implementation involves the use of government expenditure and taxes to control inflation, and the amount of money within an economy has the potential to increase and decrease production and subsequently increase or reduce the emission of dangerous gases into the environment. Empirical evidence to theoretical assertions on specific subjects is key to the planning and implementing policies within every economy. Several empirical studies (Ahmad et al., 2020; Ahmad et al., 2018; Álvarez-Herránz et al., 2017; Arminen & Menegaki, 2019; Chishti et al., 2020; Khan et al., 2020; Khattak et al., 2020; Rauf et al., 2020; Rehman et al., 2019; Ullah et al., 2020; Yuelan et al., 2019; Zambrano-Monserrate et al., 2018; Zoundi, 2017) to validate the various theoretical arguments on the causal relationships among economic growth, energy consumption, and carbon dioxide emissions across the globe have been conducted. However, very few of these studies (Katircioglu & Katircioglu, 2018; Yuelan et al., 2019; Zhang et al., 2017) have considered the role of fiscal policy in the emissions of carbon dioxide into the environment of which none has been carried out in the context of the sub-Saharan African region. Thus, this current study is the first of its kind in the context of the sub-Saharan African region.

Furthermore, most of the studies employed techniques such as panel cointegration, panel causality, Panel vector autoregressive, Granger causality, Autoregressive distributed lags (ARDL), among others, which cannot deal with the problem of cross-sectional dependence that is likely to exist in a panel data. Using econometric methods that do not consider cross-sectional dependence among variables could result in misleading findings (Breitung & Das, 2005). This study assesses the robust long-run relationship between fiscal policy, energy consumption, and carbon dioxide emissions by applying the cross-sectional augmented autoregressive distributed (CS-ARDL), the common correlated effect means group (CCEMG), and the augmented mean group (AMG). These econometric techniques deal with the problem of cross-sectional dependence for 17 sub-Saharan African countries from 1990 to 2018. Also, none of the studies on fiscal policy, energy consumption, and carbon dioxide emission considered the contributory role of income level differences in the dynamic relationships among the variables. The present study innovatively considers the income levels of the selected countries to ascertain the role of income levels in the dynamic relationships between the variables, which is novel in this area of study within the Sub-Saharan African region. This study is expected to provide scholars and policy makers a multidimensional view of the direction of causal relationships and the long-run impact of the variables, which will inform policy and enhance general economic management practice.

Sustainable Economic Development Situation in Sub-Sahara Africa

The development of Sub-Saharan African (SSA) countries is at a crucial stage, considering the rapid population growth being experienced, especially in urban areas, and the youthful growing workforce. Furthermore, several Sub-Saharan African countries are also experiencing high levels of economic growth, whose benefits are distributed disproportionately among most citizens. In addition to these challenges, the food production system of the region is faced with threats of global climate change and the intense frequency of droughts, floods, and fires, capable of reversing the gains made in development and poverty reduction by the region or is expected to achieve in the coming years (Hogarth et al., 2015). Though the contribution of the sub-Saharan African region to per capita levels of greenhouse gas (GHG) emissions is comparatively low, the increasing danger of disastrous climate change across the globe provides the basis for an urgent paradigm shift from high-emission models of economic growth by all countries. Thus, as the sub-region continues to tackle its array of related developmental challenges, countries also need to consider the sustainability of the environment in which the developmental activities occur.

The sub-Saharan African region experienced an average Gross Domestic Product per capita growth of 3.5% between 2010 and 2021, excluding 2020, which recorded an economic recession due to the global pandemic (COVID-19) (World Bank, 2022). Notwithstanding this growth, the economies of the sub-Saharan African region remain relatively small. As of the year 2019 (pre-COVID-19 era), the gross domestic product (GDP) of the whole sub-region stood at $4.3 trillion, four times less than that of the United States (20.6 trillion), whose population is three times less than that of SSA (World Bank, 2022). According to the Intergovernmental Panel on Climate Change (2013), It is almost generally agreed that the way forward to reducing global warming to 2ºC, an attempt to avert catastrophic climate change is to ensure that the atmospheric concentration of GHG does not surpass 450 ppm CO2e5. The attainment of this objective, subject to a world projected to support 9.2 billion people by 2050, requires an annual average per capita emissions convergence of 2.1 to 2.6 tonnes of CO2e by mid-century. Despite sub-Saharan Africa's per capita emission level being the lowest globally, it is a little above the desired level, standing at 2.7 or 3.9 tonnes of CO2e, depending on whether land-use change and forestry are taken into account.

As much as industrialized economies are obliged to lead the mitigation process of reducing GHG emissions considering their historic heavy contributions to global warming, a drastic reduction of emissions by emerging economies will be enough to achieve the target set. Thus the need for regions such as sub-Sahara Africa to ensure a decline in their GHG emissions in the long-term cannot be overemphasized (Hogarth et al., 2015). This climatological constraint does not support the conventional trend of doing things, which contributes to the rapid increase in the GHG emissions of the region due to population growth, increased fossil fuel consumption and production, growth in cattle production, and deforestation (FAO, 2015; IEA, 2014). Mostly, greenhouse gas emissions in sub-Sahara Africa are not linked to fossil fuel due to limited industrialization in the region; instead, emissions in the region are associated with agriculture and increased land-use change. However, GHG emissions in the region are expected to increase rapidly due to the projected population and economic growth, which is expected to cause the use of fossil fuel and extraction (IEA, 2019).

Hogarth et al. (2015) explained that sub-Sahara Africa faces the risk of being locked into a path of increased fossil fuel supply through cheap fossil fuel supply from domestic production, development of fossil fuel-intensive infrastructure, such as coal-fired power plants, and heavy manufacturing industries. According to Hogarth et al. (2015), the region would experience high carbon energy use and significant future GHG emissions, especially for electricity generation and transport, due to this “lock-in.” Oil demand in sub-Sahara Africa is projected by the New Policy Scenario of IEA to increase from 147 to 251 Mtoe and contribute 19% of total energy demand in 2040.

The Construction Industry Council asserts that GHG emissions from the production of construction materials can account for close to 25% of a building's lifetime carbon footprint. The use of low-carbon construction materials thus plays a significant role in reducing GHG emissions in the construction sector. In sub-Sahara Africa, the primary source of GHG emissions from the construction sector is the energy required to operate buildings, lighting, and heating. The manufacturing sector of most sub-Sahara African countries is small and stagnant (Hogarth et al., 2015). Sub-Sahara Africa’s share of manufacturing value-added in the total GDP has declined for nearly four decades from 18% in 1975 and 15% in 1981 to 10.94% in 2019 (albeit with variation in experiences across African countries. Nonetheless, the manufacturing production of sub-Sahara Africa has over tripled, increasing from nearly $54.17 billion in 2000 to approximately $194.03 billion in 2019 (in constant 2010 prices). Despite the sparse data on emissions for Sub-Sahara Africa, A climate analysis indicator from World Resource Institute (WRI) shows that GHG emissions from industrial processes and energy use by the manufacturing sector contribute only 1% of global GHG emissions(WRI, 2014). Projections from IPCC indicate that contribution from sub-Sahara Africa to global manufacturing GHG emissions will increase but remain dwarfed by emissions from developing Asia.

The majority of the population in sub-Saharan Africa survive by employment in agriculture. About 80% of the farmers in the sub-region are smallholder farmers, thus most farmers in the sub-region cultivate less than two hectares in area (Livingston, Schonberger & Delaney, 2011). 70% of the African continent's food supply is provided by small farms provide (IAASTD, 2016). In the sub-Saharan African region, agriculture is the largest contributor to GHG emissions. Among the largest sources of emissions in the sub-region are encroachments of pasture and cropland into forested areas, livestock manure and digestive processes, burning of savannah; and cropland management and cultivation practices. A projection by the Food and Agriculture Organization (2015), indicates that direct agricultural emissions in sub-Saharan Africa will rise by a third between 2012 and 2050, from 600 million to 800 million tCO2e, which is twice that of the European Union's agricultural emissions in 2012 (407 million tCO2e) and almost as high as those of China (832 million tCO2e), which in 2012 had the highest level of agricultural emissions of any country (WRI, 2015).

LITERATURE REVIEW

Income and Carbon Dioxide Emissions Nexus

The Environmental Kuznets Curve hypothesis (EKC) has been employed by a significant number of studies (Acaravci & Ozturk, 2010; Gorus & Aydin, 2019; Grossman & Krueger, 1991; Hassan et al., 2020) to examine the income and environmental pollution nexus for economies across the globe. As explained in previous sections of this chapter, the EKC hypothesis states that environmental pollution rises to a particular threshold as income (per-capita) rises and finally assumes a downward movement. Thus, excessive demand emanates due to increased income and puts pressure on firms to expand production. The situation results in the acquisition and use of large amounts of fossil fuels, which subsequently causes carbon emissions to rise. Several prior studies (Apergis & Payne, 2017; Neequaye & Oladi, 2015; Rehman et al., 2019; Sapkota & Bastola, 2017; Sinha & Shahbaz, 2018; Zambrano-Monserrate et al., 2018) have confirmed the EKC for several economies. Nonetheless, some other studies did not confirm the EKC hypothesis for selected middle-income economies (Arminen & Menegaki, 2019), selected African economies (Zoundi, 2017), 22 Latin America and Caribbean economies (Pablo-Romero & De Jesús, 2016), and OECD & Non-OECD economies (Özokcu & Özdemir, 2017). Income is mostly proxied with the gross domestic product per capita, signifying its critical role in sustainable development studies. Thus, including gross domestic product per capita in this study's model cannot be overemphasized.

Energy Consumption and Carbon Dioxide Emissions Nexus

Several studies have warned of the dire consequences of the production and combustion of energy on the environment, notwithstanding its substantial contribution to economic growth (Rehman & Rashid, 2017). This has been validated by several empirical studies (Ahmad & Zhao, 2018; Álvarez-Herránz et al., 2017; Arminen & Menegaki, 2019; Bhuiyan et al., 2018; Khattak et al., 2020; Mirza & Kanwal, 2017; Rehman & Rashid, 2017; Zaman & Abd-el Moemen, 2017). However, the inclusion of energy consumption as a single variable in the EKC model may yield biased results (Jaforullah & King, 2017), considering that the energy consumption consists of non-renewable (fossil fuel) and renewable energy sources. According to Arminen and Menegaki (2019), fossil fuel consumption as a regressor in a model yields robust findings. A significant number of studies have expressly confirmed the negative effect of non-renewable energy (fossil fuel consumption) on the environment (Bhattacharya et al., 2017; Chishti et al., 2021; Ikram et al., 2020; Waheed et al., 2018). Several studies have also validated the significant influence of renewable energy consumption in mitigating dangerous gas emissions into the environment. The energy consumption variable in this study disintegrated into non-renewable (fossil fuel consumption) and renewable energy consumption in the model to obtain more robust results.

Industrialization and Carbon Dioxide Emissions Nexus

The term industrialization refers to the growth in industrial activities. Most researchers assume that industrialization causes increased energy consumption due to higher value-added manufacturing consumption of more energy than conventional agriculture or basic manufacturing (Sadorsky, 2014). An investigation into the impact of the industrialization-led economy on environmental sustainability in developing countries by Li and Lin (2015) using the Kaya Identity framework for the period 1980–2011 revealed that industrial value-added of an economy adversely and significantly affects the relationship with CO2 emissions. Another study by Raheem and Ogebe (2017) on the effect of urbanization and industrial value on carbon dioxide emissions in 20 African states from 1980-to 2013 also confirmed the significant contribution of industrialization and urbanization on carbon dioxide emissions. The study further revealed that at a certain point indirect effect of industrialization would swarm the direct negative impact of industrialization and urbanization, leading to a reduction of environmental degradation

Fiscal Policy and Carbon Dioxide Emissions Nexus

The contributions of specific sectors of an economy in the traditional EKC remain relevant and require further attention. Though several studies have investigated the financial sector's contribution to the EKC, researchers mostly use financial aggregates such as money supply, one of the monetary policy tools. Those finance-EKC nexus studies argue that economic growth and energy consumption are likely to be influenced by monetary policy and consequently spur climate change proxy by carbon dioxide emissions (Jalil & Feridun, 2011; Kaushal & Pathak, 2015). Fiscal policy is also one of the macroeconomic policy tools used by managers of economies; thus, a similar argument could be made for the role of fiscal policy in environmental issues, considering its significant contribution to economic growth and energy consumption.

In a more concise explanation, it would be interesting to investigate the role of fiscal policy and fiscal aggregates to the EKC in the energy economics literature. Fiscal policy uses government spending and taxation as its major instruments or tools, which are likely to play a role in economic growth, current account balances, energy policy, and energy consumption, therefore, in the EKC (Bolat et al., 2014). Considering that fiscal policy is a significant determinant of income growth, the interaction between fiscal policy and economic growth is highly expected to influence energy consumption; thus, not only will energy demand increase, but also environmental issues will be heightened in the economy. According to Balcilar et al. (2016), the rate of capital accumulation is likely to increase following a decrease in fiscal deficits through increased revenue generation, leading to a higher rate of economic growth. Based on the argument of Balcilar et al. (2016), it could also be argued that increased fiscal deficit through increased government expenditure which spurs economic activity, could cause energy demand and consumption and thus lead to the emission of dangerous gases into the environment. Some scholars (Dongyan, 2009; Liu et al., 2017) argue that fiscal incentives support energy efficiency and hence play a significant role in reducing carbon emissions.

According to Fischer and Fox (2012), countries' climate policies need to be well balanced with the aggregate fiscal policies of governments. Fischer and Fox (2012) also explained that public sector revenues play an important role in climate policy-making. Quite a number of studies have been carried out on the effect of general, and carbon taxation and conclusions are of mixed findings; nonetheless, generally, it is found that taxation is effective for environmental policies (Vera & Sauma, 2015). A study by Ryan et al. (2009) revealed that taxes significantly impact energy consumption and CO2 emissions. Thus, the scanty literature on fiscal policy indicates that fiscal policy plays a significant role in energy consumption and, consequently, environmental quality. A review of the available literature shows that none of the empirical studies conducted in the fiscal policy-emissions nexus considered the government expenditure tool of fiscal policy. This current study thus proxies government expenditure as the fiscal policy to assess the mechanism through which it exacerbates or ameliorates carbon dioxide emissions within the Saharan African context.

Conceptual Framework

As explained in earlier sections, one of the fiscal policy tools used to control the money in an economy is government expenditure. Variations in government expenditures cause significant changes in several economic activities (aggregate consumption, aggregate production, financial development, foreign direct investment, international trade, and economic growth). Considering that these activities contribute significantly to the emission of dangerous gases such as carbon dioxide (CO2e), fiscal policy is thus a key tool for the mitigation and promotion of CO2e. The government's expenditure level could be used to achieve two main objectives (i.e., expansionary and contractionary objectives).

For the expansionary fiscal policy, the government seeks to use its expenditure or tax to increase the amount of money in an economy. The government does this by increasing its expenditure and cutting down on taxes, which increases the disposable income of consumers, hence increasing purchasing power of consumers. A rise in the purchasing power of consumers leads to an increased aggregate domestic consumption spending per capita. This serves as an incentive to producers to increase production, which involves using more fossil fuels, increasing CO2e. On another hand the increased expenditure of the government directly causes an increase in production and construction activities such as roads and other huge public infrastructures which also involves the burning of fossil fuels due to reliance on cheaper and dirty technologies, thus increasing the emission of dangerous gases into the environment. In summary, an increased government expenditure through expansionary fiscal policy increases carbon dioxide emissions.

The contractionary fiscal policy, on the other hand, refers to the situation where the government seeks to reduce the amount of money in an economy. The government pursues this policy through the reduction of its expenditure and increased taxes, which in effect serves as a disincentive for producers to produce due to a reduction in aggregate domestic consumption spending per capita. Thus the disposable income of consumers falls as a result of the reduction in government expenditure. Production and construction of public infrastructure directly fall as government reduces its expenditure, thus causing the combustion of fossil fuels from cheap technologies used by producers and contractors to rreduce. This subsequently causes the emission of dangerous gases such as carbon dioxide to fall as well. Thus, the contractionary fiscal policy reduces CO2e.

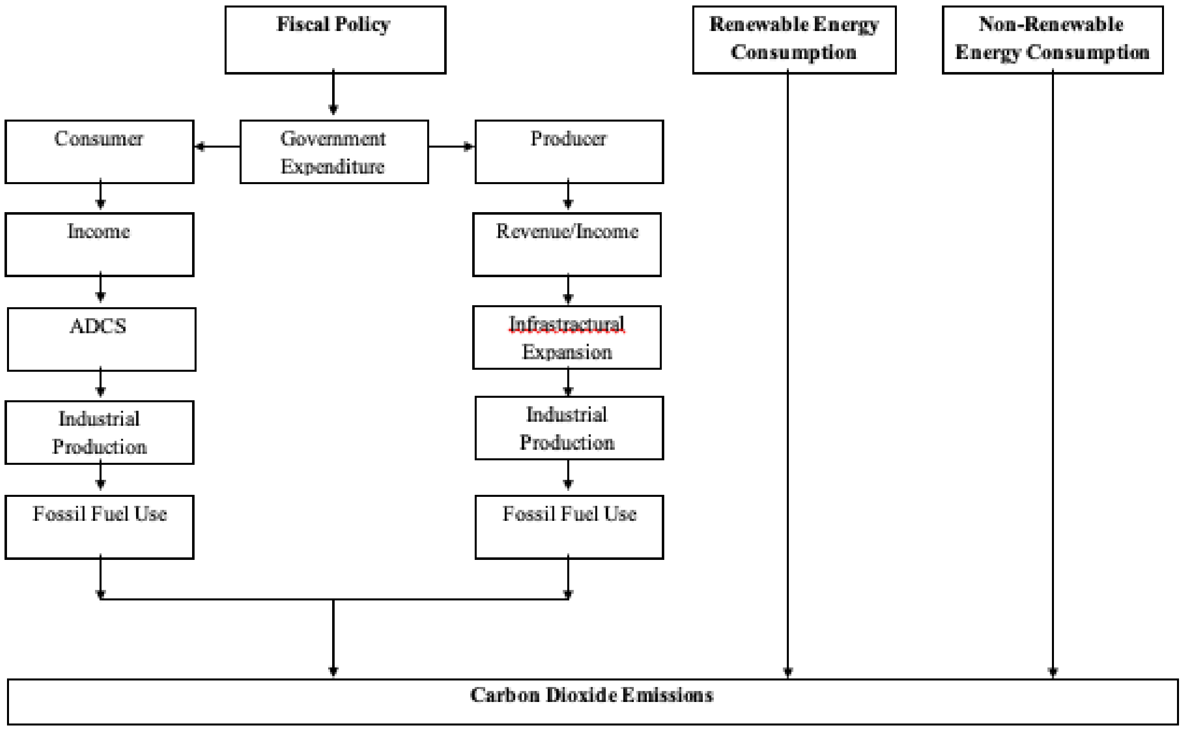


Figure 1. Conceptual Framework

Table 1. Summary of Recent Empirical Studies

Author(s)	Context	Data Period	Econometric Approach	Findings
		Income and Carbon Dioxide Emissions Nexus		
Khattak et al. (2020)	BRICS	1986–2016	CCEMG and FM-LS	EKC confirmed
Rauf et al. (2020)	BRI countries	1981–2016	FMOLS and DOLS	EKC confirmed
Ahmad et al. (2020)	China	1995–2014	NARDL	EKC confirmed
Arminen and Menegaki (2019)	Middle-income countries	1985-2011	SEM	EKC not confirmed
Ahmad et al. (2019)	Developing countries	1995 -2014	FMOLS	EKC confirmed
Rehman et al. (2019)	Pakistan	1990 –2017	VECM	EKC confirmed
Zambrano-Monserrate et al. (2018)	Peru	1980-2011	ARDL	EKC confirmed
Sapkota and Bastola (2017)	Latin American economies	1980-2010	Random and Fixed effects	EKC confirmed
Zoundi (2017)	Selected African economies	1980-2012	Panel ARDL	EKC not confirmed

Non-Renewable Energy Consumption (Fossil Fuel Consumption) and Carbon Dioxide Emissions Nexus				
Ahmad and Khattak (2020)	South Africa	1980-2014	NARDL	Positive Relationship
Arminen and Menegaki (2019)	67 high & upper-middle-income economies	1985-2011	SEM	Positive Relationship
Ahmad et al. (2018)	China	1980-2014	NARDL	Positive Relationship
Álvarez-Herránz et al. (2017)	OECD countries	1990-2014	FMOLS	Positive Relationship
Zhang et al. (2019)	Developing & developed countries	1990 -2015	FMOLS and DOLS	Positive Relationship

ARDL - Autoregressive Distributed Lag; BRICS - Brazil, Russia, India, China, & South Africa; BRI - belt and road initiative; CCE - Common Correlated Effects; CCEMG, correlated effects mean group; DOLS, dynamic ordinary least squares; AGM - Average mean group; GMM - General Method of Moment; VECM - Vector error correction model; SEM - Simultaneous equation model; NARDL - Non-linear ARDL; FMOLS - Fully-modified ordinary least-square; DOLS - Dynamic OLS.

Table 2. Summary of Recent Empirical Studies

Author(s)	Context	Year	Econometric Approach	Findings
Renewable Energy Consumption and Carbon Dioxide Emissions Nexus				
Ullah et al. (2020)	Pakistan	1980-2018	NARDL	Negative Relationship
Chishti et al. (2020)	South Asian region	1980-2018	NARDL	Negative Relationship
Ikram et al. (2020)	SAARC	2000-2014	G-TOPSIS	Negative Relationship
Ben Jebli and Ben Youssef (2017)	Tunisia	1980-2011	ARDL	Negative Relationship
Industrialization and Carbon Dioxide Emissions Nexus				
Li and Lin (2015)	73 countries	1971–2010	DPTRM	Positive Relationship
Raheem and Ogebe (2017)	20 African countries	1980–2013	PMG	Positive Relationship
Sadorsky (2014)	MSCI countries	1971–2008	ARDL	Positive Relationship
Fiscal Policy and Carbon Dioxide Emissions Nexus				
Katircioglu and Katircioglu (2018)	Turkey	1960-2013	ARDL	Negative Relationship
Chishti et al. (2021)	BRICS Economies	1985-2014	ARDL, FMOLS, DOLS	Positive Relationship (EFP &

	CO2e Negative Relationship (CFP & CO2e

Note: ARDL - Autoregressive Distributed Lag; BRI - belt and road initiative; BRICS - Brazil, Russia, India, China, & South Africa; CCEMG, correlated effects mean group; DOLS, dynamic ordinary least squares; CCE - Common Correlated Effects; SEM - Simultaneous equation model; NARDL - Non-linear ARDL; FMOLS - Fully-modified ordinary least-square; DOLS - Dynamic OLS; DPTRM- Dynamic Panel Threshold Regression Model; MENA, Middle East and North Africa; OECD, Organization for Economic Co-operation and Development; OLS, ordinary least squares; PMG, pooled mean group.

METHODOLOGY AND PROCEDURES

Data Sources and Variables

This study used a panel dataset of 17 countries from the sub-Saharan African region for the period of 1990-2018, providing a total of 493 observations. Considerably, the sample is relatively larger in terms of countries and the length of period for similar studies conducted in the sub-region. The 17 countries were classified into three different income groups in line with the World Bank's Atlas method, which uses the per capita gross national income (GNI). These groups serves as sub-panels for detailed analysis. According to the method, countries whose GNI are less than $1045, are considered to be low income countries, while countries whose GNI range between $1046-$4125, $4126–12736, and more than $12,736 are considered to be lower-middle, upper-middle and high-income countries respectively. This study considers the first three groups only because no country within the sub-Saharan African region falls in the high-income group. The low-income sub-panel consists of 5 countries, while the lower-middle and upper-middle-income sub-panels consist of 8 countries and 4 countries respectively. The geographic distribution of the income-based country groups that form the subpanels is shown in Figure 3.

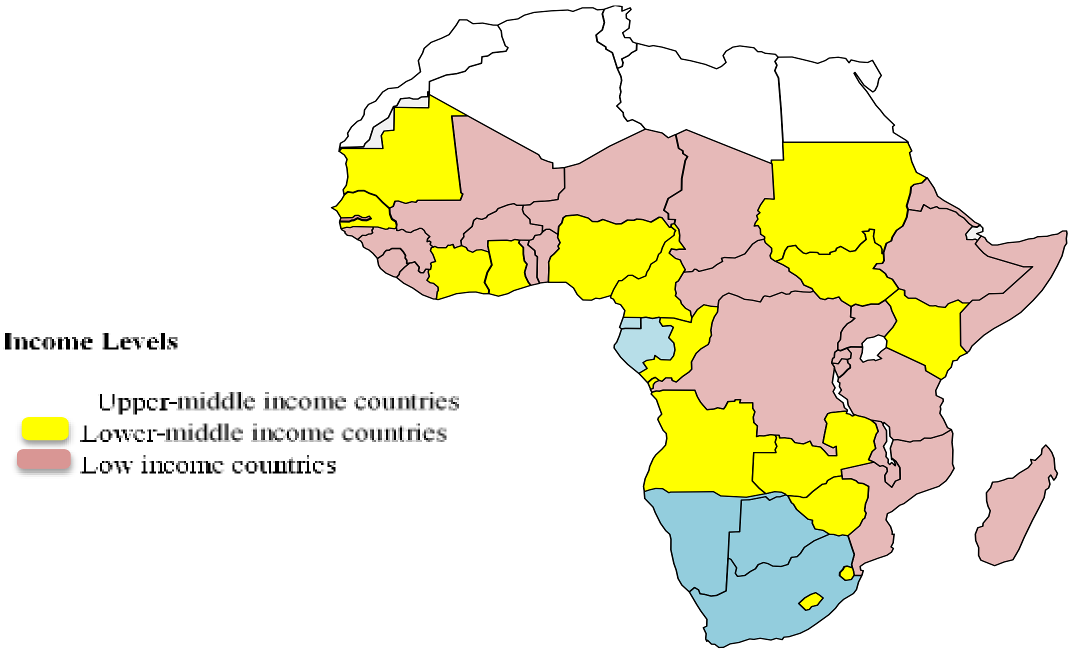


Figure 2. Distribution of the income-based country groups included in the analysis

Data on the various variables which include fiscal policy (measured by the total government expenditure of a country), non-renewable energy consumption (measured by per capita fossil fuels i.e. oil, coal, gas consumption in kilograms of oil equivalent), renewable energy consumption (measured by the annual consumption of per capita renewable energy i.e. water, wind, sun in kilograms of oil equivalent), income (measured by the per capita GDP of a country), industrialization (measured by value-added of industry of a country)and CO2 emissions (measured by per capita CO2 emissions) were collected from the World Development Indicators published by the World Bank, the U.S. Energy Information Administration (EIA), and the International Energy Agency (IEA). Information on the variables used in this study are summarised in the table below.

Table 4. Summary of Study Variables

	Variable	Measurement	Source
Independent Variables	Fiscal Policy (FPL)	Government expenditure	World Development Indicators.
	Non-Renewable Energy Consumption (NRE)	Per capita fossil fuels i.e. oil, coal, gas consumption in kilograms of oil equivalent	International Energy Agency (IEA).
	Renewable Energy Consumption (REC)	Per capita renewable energy i.e. water, wind, sun in kilograms of oil equivalent	International Energy Agency (IEA).
Control Variables	Income (GDP)	per capita GDP	World Development Indicators
	Industrialization (IND)	Value added of Industry	World Development Indicators
Independent Variable	Carbon Dioxide Emissions (CO2)	Measured by per capita CO2 emissions	World Development Indicators

Source: Author's Compilation, 2022

Model Specification

The model specification of this present study is hinged on the Cobb-Douglas production function used in the work of Benchimol (2015). The Cobb-Douglas production function employed by Benchimol (2015) in his study expresses the relationship between capital, labour inputs, real cash balance, and output. The function is presented as

$$Y_t = AK_t^{\alpha} L_t^{\alpha} [RCB_t]^{\gamma} \ldots\ldots \quad \ldots\ldots\ldots\ldots (1)$$

In the above function, the final output is represented by Y_t, A is Solow's residuals, K_t is the capital inputs, L_t is the labor inputs, while RCB_t is the real cash balance. Firms are expected to keep money for capital purchases induced by production activities hence the introduction of real cash balance into the production function (Fischer, 1974). The elasticity of the final output of the production process in response to changes in capital, labour, and the real cash balance is given as α, β, and γ. The changes in, β, and γ g can be shown with laws of returns to scale (LRS). Multiplying the inputs in equation (1) above by a factor z will yield the equation below

$$hY_t = A(zK)^{\alpha} (zL)^{\beta} (zRCB)^{\gamma} \ldots\ldots\ldots\ldots\ldots \quad (2)$$

$$hY_t = Az^{\alpha+\beta+\gamma}K^{\alpha}L^{\beta}RCB^{\gamma}\ldots\ldots\ldots\ldots\ldots \quad (3)$$

$$hY_t = z^{\alpha+\beta+\gamma}(AK^{\alpha}L^{\beta}RCB^{\gamma})\ldots\ldots\ldots\ldots\ldots \quad (4)$$

The coefficient h in equations (2), (3), and 4 represent the h-times rise in the final output (Y_t). The laws of return to scale rules are provided by the equations above. Following that $Y_t = AK^{\alpha}L^{\beta}RCB^{\gamma}$, $h = z^{\alpha+\beta+\gamma}$. From this association, the rules for LRS can be obtained.

From equation (1), we obtain the per capita output by dividing through the equation by labour (L_t). Thus, we obtain

$$y_t = Ak_t^{\alpha}[rcb_t]^{\gamma}\ldots\ldots\ldots\ldots\ldots \quad (5)$$

From equation 4.5, $y_t = {}^{Y_t}/_{L_t}$, $k_t = {}^{K_t}/_{L_t}$, $rcb_t = {}^{RCB_t}/_{L_t}$

An economy's supply and demand for money can be controlled with fiscal policy tools such as government spending and taxes. The implementation of fiscal policies thus affects the quantity of money supply within an economy. This subsequently influences real cash balances. Hence following the study of Chishti et al. (2021), fiscal policy is integrated into the aggregate Cobb-Douglas production function:

$$y_t = Ak_t^{\alpha}[FPL_t]^{\gamma}\ldots\ldots\ldots\ldots\ldots \quad (6)$$

The emission of dangerous gases such as carbon dioxide (CO_2) into the environment is primarily related to the economic activities within an economy. Thus, following the study of Ahmad et al. (2019), carbon dioxide (CO_2e) is equated to output, as shown below

$$CO_{2e} = Y_t\ldots\ldots\ldots\ldots\ldots \quad (7)$$

$$CO_{2e} = Ak_t^{\alpha}[FPL_t]^{\gamma}\ldots\ldots\ldots\ldots\ldots \quad (8)$$

Following the study of Chishti et al. (2021), the capital inputs in the function are replaced with renewable and non-renewable resources (fossil fuel). According to Chishti et al. (2021), not all capital resources such as renewables contribute to environmental pollution. It is, therefore, appropriate to represent capital inputs in the function with both renewable and non-renewable energy resources. Thus, capital inputs in the function are presented as

$$k_t = k_{REC} + k_{NRE}\ldots\ldots\ldots\ldots\ldots \quad (9)$$

Where k_t is total capital inputs, k_{REC} is renewable energy resources, and k_{NRE} is non-renewable resources. Thus, the function becomes

$$CO_{2e} = A[REC_t]^{\partial}[NRE_t]^{\partial}[FPL_t]^{\gamma}\ldots\ldots\ldots\ldots\ldots \quad (10)$$

To satisfy the environmental Kuznets curve (EKC) hypotheses for this study, the gross domestic product per capita (GDP) was integrated to represent income, while industrialization is included as a control variable. However, to solve the issue of collinearity between EFPL and CFPL, this present study combined the two variables and used FPL to represent both expansionary and contractionary fiscal policy. Thus an increase and decrease in FPL represent expansionary and contractionary fiscal policy respectively.

Hence, the final model is shown as:

$$CO2_{eijt} = \alpha_0 + \alpha_1 REC_{ijt} + \alpha_{2ij}NRE_{ijt} + \alpha_3 FPL_{ijt} + \alpha_4 GDP_{ijt} + \alpha_5 IND_{ijt} \quad (11)$$

Econometric Techniques

Cross-Sectional Dependence

None of the studies on fiscal policy, energy consumption, and carbon dioxide emissions has paid significant attention to the issue of cross-sectional dependence. As explained in previous sections, the presence of cross-sectional dependence among variables could lead to spurious regression results if not addressed appropriately. This current study employed the Pesaran CD and standardized Lagrange Multiplier (LM) cross-sectional dependence tests proposed by Pesaran (2004) and the Breusch-Pagan LM proposed by Breusch and Pagan (1980) to detect the presence of cross-sectional dependence among the dataset used for this study.

Persaran CIPS Panel Unit Root Test

To ensure that the problem of cross-sectional dependence is dealt with while performing unit root test, this study used the Persaran CIPS panel unit root test to assess the stationarity of the dataset. Persaran CIPS panel unit root test considers each unit's average lagged levels and differences, allowing cross-sectional dependence. The Persaran CIPS panel unit root test is estimated as follows:

Westerlund Error Correction Panel Cointegration

Among the various conintegration tests employed by academics for their studies over the years include Engle-Granger, the Johansen Test, and the Phillips-Ouliaris test. Nonetheless none of these approaches to cointegration test is able to deal with the problem of the possible existences of cross-sectional dependence among panel dataset. This study thus employed the Westerlund error correction panel cointegration test, which is able to detect cointegration in the cross-sectional panel data in this study. This analytical technique efficiently addresses the issue of cross-sectional dependence by using the error correction term.

Long-Run Relationship Estimation Techniques (CS-ARDL, CCEMG, and AMG)

The Panel Cross-Section Augmented ARDL (CS-ARDL) advanced by Chudik and Pesaran (2013), Common Correlated Effect Means Group (CCEMG) proposed by Pesaran (2006) and extended by Chudik and Pesaran (2015), and the augmented mean group (AMG) were used to estimate the coefficient of the variables of the study. These analytical techniques were employed to deal with the issue of cross-sectional dependence, which is highly probable to be present in panel data. The cross-sectional augmented autoregressive distributed lag (CS-ARDL) modelling approach, considers time dynamics, cross-sectional heterogeneity, and cross-sectional dependence in it estimation. common Correlated Effect Means Group (CCEMG) on the other hand accounts for heterogeneous unobserved common factors by introducing cross-section averages for the dependent and independent variables into the model. The augmented mean group (AMG) considers the common factors in the series and is also used in the presence of the problem of internalisability, which indicates that there is a correlation between explanatory variables and error terms

Causality Test

In an effort to establish the directional causal relationship among the variables of this study, the Dumitrescu and Hurlin (2012) approach to causality was employed to carry out the causality test. The causality test provides three different directional causality results. The three possible results from the causality test include bi-causal relationships running from two variables to each other; the uni-directional causation running from one variable to the other, and the neutral-causal relationship where there are is causal linkages between the variables

RESULTS AND DISCUSSION

Empirical Analysis

Descriptive Statistics

All the study variables were logged to ensure that the distribution of the transformed variables are more symmetric. Table 5 below presents the summary statistics of the variables used for the study. The statistics for the study variables shown on Table 5 include the means, median maximum, minimum, standard deviations, skewness, and kurtoses of the study variables.

Table 5. Descriptive Statistics

Panel (1990–2015)	**Statistics**	**$lnCO_2$**	**lnFPL**	**lnREC**	**lnNRE**	**LnGDP**	**lnIND**
Sub-Saharan region	Mean	8.3257	23.8866	4.1508	3.0571	11.8066	21.5792
	Median	8.2762	23.4458	4.3328	3.0405	12.3349	21.5228
	Maximum	11.7882	48.4747	4.5885	4.4490	15.0526	25.5588
	Minimum	3.6973	21.3414	2.3640	0.4945	5.7801	18.7810
	Std Dev	1.0567	2.4162	0.4489	0.8309	2.2467	1.1836
	Skewness	0.7209	5.7434	-1.6939	0.5352	0.9611	0.4805
	Kurtosis	5.4662	49.4870	5.7416	3.0409	3.3037	3.8619
	Observations	493	493	493	493	493	493
Low-income Economics	Mean	7.6843	23.9582	4.4310	2.2058	12.1706	20.8358
	Median	7.6546	23.0702	4.5201	2.1139	12.3927	20.6965
	Maximum	9.4676	48.4747	4.5885	3.7270	14.4509	23.4165
	Minimum	6.5621	21.3414	3.8736	0.4945	8.9336	18.7809
	Std Dev	0.6615	3.9680	0.1803	0.7655	1.5938	1.1772
	Skewness	0.5399	4.2927	-1.5623	0.1123	0.6446	0.3521
	Kurtosis	2.6855	22.9367	4.4901	2.5217	2.3844	2.2351
	Observations	145	145	145	145	145	145
Lower-middle Economies	Mean	8.8747	24.3350	4.2499	3.1324	11.4977	22.0911
	Median	8.7930	24.1474	4.3292	3.0480	12.9396	21.8179
	Maximum	11.7882	29.5319	4.4867	3.9635	13.9878	25.5588
	Minimum	4.6316	21.6208	3.7004	2.4084	5.7801	20.2661
	Std Dev	1.1511	1.3588	0.2071	0.3627	2.7089	1.1314
	Skewness	0.4137	0.7924	-1.0914	0.3773	0.9857	1.0033
	Kurtosis	4.2684	4.1469	3.1681	2.1311	2.4232	3.7725
	Observatios	232	232	232	232	232	232
Upper-middle Economies	Mean	8.0294	22.904	3.6023	3.977	11.9695	21.4847
	Median	8.2161	22.991	3.5334	4.151	11.2890	21.5285
	Maximum	8.8331	23.814	4.4784	4.440	15.0526	23.0614
	Minimum	3.6973	21.975	2.3640	2.801	10.0004	20.3508
	Std Dev	0.5945	0.4143	0.5596	0.433	1.8157	0.6738
	Skewness	-3.8966	0.4368	-0.1846	1.3016	0.7551	0.2460
	Kurtosis	28.1733	2.4433	2.4656	3.423	1.9722	2.5653
	Observatios	116	116	116	116	116	116

Source: Author's Compilation, 2022

Cross-Sectional Dependence Test

Presented on Table 5.2 are the results for cross-sectional dependence tests based on Breusch and Pagan (1980) and Pesaran (2004). It can be observed from the results presented on Table 6 that cross-sectional dependence exist for all the panel series used except for non-renewable energy (lnNRE), renewable energy (lnREC), income (lnGDP) (at the upper-middle income level by the Pesaran CD statistic). The results thus indicates the presence of cross-sectional dependence at various income levels of economies within the sub-Saharan African region. The presence of the cross-sectional dependence among the panel series thus justifies the need for the application of recent econometric techniques that are able to deal with the problem of cross-sectional dependence. Thus, the Pesaran CIPS panel unit root test, cross-sectional augmented autoregressive distributed lag (CS-ARDL), common correlated effect means group (CCEMG), and the augmented mean group (AMG) were used to estimate the dynamic panel regression since they provide consistent and robust results in the presence of cross-sectional dependence challenges in estimation

Table 6. Cross-Sectional Dependency Results

Region	**Variable**	**Test**			
		Breusch-Pagan LM	Pesaran scaled LM	Bias-corrected scaled LM	Pesaran CD
Sub-Saharan region					
	$lnCO_2$	1622.9980***	90.1625***	89.8225***	36.2647***
	lnFPL	1301.8390***	70.6894***	70.3494***	22.7489***
	lnREC	986.2860***	51.5562***	51.2162***	17.3225***
	lnNRE	1083.1700***	57.4306***	57.0906***	12.7817***
	lnGDP	1880.5780***	105.7806***	105.4406***	23.6932***
	lnIND	2667.430***	153.4905***	153.1505***	50.99930***
Low-income Economies					
	$lnCO_2$	134.7535***	27.8957***	27.7957***	10.0001***
	lnFPL	88.9490***	17.6535***	17.5535***	4.4672***
	lnREC	78.4789***	15.3124***	15.2124***	7.5193***
	lnNRE	70.1058***	13.4401***	13.3401***	3.8637***
	lnGDP	90.6977***	18.0446***	17.9446***	4.0096***
	lnIND	188.6526***	39.94793***	39.84793***	13.59434***
Lower Middle-Income Economies	$lnCO_2$	334.1360***	40.9091***	40.7491***	17.5228***
	lnFPL	228.6654***	26.8150***	26.6550***	10.4707***
	lnREC	334.1360***	16.9561***	16.7961***	6.7811***
	lnNRE	238.1793***	28.0864***	27.9264***	5.2694***

	lnGDP	380.3045***	47.0787***	46.9187***	14.0311***
	lnIND	529.0087***	66.95010***	66.79010***	22.36093***
Upper-Middle Income Economies					
	$lnCO_2$	46.0675***	11.5665***	11.4865***	5.8330***
	lnFPL	49.1383***	12.4530***	12.3729***	4.0637***
	lnREC	90.1427***	24.2899***	24.2099***	1.2879
	lnNRE	49.3057***	12.5013***	12.4213***	0.2072
	lnGDP	128.2624***	35.2941***	35.2141***	0.9020
	lnIND	136.6819***	37.72463***	37.64463***	11.68664

*Indicates significance at 10% level. **Indicates significance at 5% level. ***Indicates significance at 1% level

Unit Root Test

The results of the CIPS Persaran panel unit root test are shown in Table 5.3. From the results presented in Table 7, it could be observed that while some of the panel series (variables) are stationary at various significance levels across the various income sub-panels at levels, others are not. However, all the panel series are stationary at first difference. The null hypothesis of the unit root is therefore rejected for all the variables (panel series) employed in this study at first difference. Thus, the variables are integrated in order one I (1). The results obtained for the unit root analysis is indicative of a possible long-run relationship between the variables (fiscal policy, renewable energy, non-renewable energy, and carbon dioxide emissions).

Table 7. CIPS Persaran Panel Unit Root Test Results for Different Income-Based Countries in Sub-Saharan Africa.

Region	**Variable**	**Test**	
		Level	First Difference
Sub-Saharan region	$lnCO_{2e}$	-2.386***	-4.986***
	lnFPL	-2.396***	-4.216***
	lnREC	-2.222**	-4.799***
	lnNRE	-2.001	-4.869***
	lnGDP	-1.346	-4.125***
	lnIND	-2.293 ***	-4.983***
Low-income Economies	$lnCO_{2e}$	-1.585	-4.232***
	lnFPL	-2.391**	-4.076***
	lnREC	-1.945	-4.200***
	lnNRE	-1.757	-4.279***
	lnGDP	-1.046	-3.998***
	lnIND	-2.862***	-4.810***
Lower Middle-Income	$lnCO_{2e}$	-2.354***	-5.337***
	lnFPL	-2.228*	-4.069***
	lnREC	-1.767	-4.885***
	lnNRE	-2.631	-5.159***

Economies	lnGDP	-1.496	-3.422***
	lnIND	-2.583***	-4.952***
	$lnCO_{2e}$	-3.808***	-5.569***
	lnFPL	-1.685	-4.629***
	lnREC	-3.904***	-5.426***
Upper-Middle-Income	lnNRE	-1.496	-4.850***
Economies	lnGDP	-1.927	-5.381***
	lnIND	-3.100***	-5.002***

"Note: *Indicates significance at 10% level. **Indicates significance at 5% level. ***Indicates significance at 1% level"

Westurland ECM Cointegration

The use of the Westurland ECM panel cointegration test in this study was aimed at establishing a long-run cointegration relationship among the study variables in the presence of cross-sectional dependence. As presented in Table 8 below, the test results indicate the presence of a long-run cointegration relationship among the study variables. Thus, the null hypothesis of no cointegration is rejected. The results imply a long-run relationship exist between fiscal policy, energy consumption and carbon dioxide emissions. Hence, the results provide the basis for estimating the impact of fiscal policy, renewable energy, and non-renewable energy on carbon dioxide emissions.

Table 8. Westurland ECM Cointegration Test Results

	G_t	G_a	P_t	P_a
Sub-Saharan Africa	-2.658**	-7.186	-12.755***	-11.600***
Low-Income Economies	-2.023*	-3.839	-4.205*	-6.031*
Lower-Middle Income Economies	-3.084***	-7.690	-10.585***	-12.164***
Upper-Middle Income Economies	-2.963*	-28.499***	-3.892	-30.754***

*Indicates significance at 10% level., **Indicates significance at 5% level., ***Indicates significance at 1% level

CS-ARDL, CCEMG, AMG Long-Run Estimation Results

Long-Run Estimation Results For Sub-Sahara Africa and Low-Income Economies

The study's results show a significant impact of all the study variables across the three estimation methods (CS-ARDL, CCEMG, and AMG) used at different significance levels. As shown in Table 5.5, a 1% increase or decrease in the fiscal policy which represents expansionary or contractionary respectively causes carbon dioxide emissions to rise or decrease by 0.14%, 0.29%, and 0.21% for the sub-Saharan African region, respectively as estimated with CS-ARDL, CCEMG, and AMG. The results indicates that fiscal policy has significant long-run effect on carbon dioxide emissions in the sub-Saharan African region. Thus the pursuit of expansionary fiscal policy by governments of sub-Saharan Africa is expected to cause carbon dioxide emissions to rise. On the other hand the implementation of contractionary fiscal policy in sub-Saharan Africa is expected to cause carbon emissions to fall. This could be attributed to the fact that most of the production within the sub-Saharan region is dependent on fossil fuel; thus, an increase or decrease in fiscal policy (expansionary or contractionary fiscal policy), which is expected to increase or decrease production respectively, will cause carbon dioxide emissions into the environment to increase or decrease respectively. These findings are consistent with the findings of Chishti et al. (2021) and Katircioglu and Katircioglu (2018), who found a significant positive relationship between fiscal policy and carbon dioxide emission.

The study's result, as expected, revealed a significant negative long-run effect of renewable energy consumption on carbon dioxide emissions. The study's results as presented in Table 5.5 shows that 1% increase in renewable energy consumption in the sub-Saharan African region will decrease carbon dioxide emissions by 0.56%, 1.03%, and 0.93%, as estimated by CS-ARDL, CCEMG, and AMG respectively. These findings are supported by the findings of Ullah et al. (2020), Chishti et al. (2020), and Ikram et al. (2020), who also found a long-run negative effect of renewable energy consumption on carbon dioxide emissions. This finding is suggestive that as more of renewable energy resources are consumed, the lesser the emission of dangerous gases such as carbon dioxide into the environment in the sub-Saharan African region. Non-renewable energy consumption was however found to positively affect carbon dioxide emissions significantly in the long-run. This study's results specifically show that carbon dioxide emissions rises by 0.41%, 0.53%, and 0.38% as estimated by CS-ARDL, CCEMG, and AMG respectively when the use of non-renewable energy sources such as fossil-fuel increases by 1%. These results are consistent with the findings of Ahmad and Khattak (2020), Arminen and Menegaki (2019), and Zhang et al. (2019), who also a significant positive effect of non-renewable energy consumption on carbon dioxide emissions.

As shown in Table 5.5, the coefficients of the estimations indicates that a percentage increase in income causes carbon dioxide emissions to increase by 0.02%, 0.31%, and 0.25%, respectively. These results indicate that as income increases, economic activities increases and subsequently causes the pollution of the environment to increase. The findings of Khattak et al. (2020), Arminen and Menegaki (2019), and Ahmad et al. (2020), which validated the EKC model, support the findings of this current study. Thus, the EKC model is also validated in this study. Finally, the results of only CCEMG in this study as shown in Table 5.5 shows that industrialization in sub-Saharan Africa has a significant positive effect on carbon dioxide emissions. Though the results of the CCEMG estimator revealed a significant effect of industrialization on carbon emissions, the significance is at 10% significance level indicating a weak relationship. The results obtained for industrialization is a testament to the fact that industrialization in sub-Saharan Africa has not experienced the necessary growth over the years to influence carbon emissions. Specifically, the results of the CCEMG estimator revealed that carbon dioxide emissions increases by 0.13%, , as industrialization increases by 1%. This finding support the findings of Li and Lin (2015), Raheem and Ogebe (2017), and Sadorsky (2014), which also revealed a significant positive effect of industrialization on carbon dioxide emissions.

Regarding low-income economies in the sub-Saharan African region, the study's results from the three estimators (CS-ARDL, CCEMG, and AMG) as presented in Table 8 revealed that fiscal policy has a significant positive effect on carbon dioxide emissions. Thus, the implementation of expansionary and contractionary fiscal policies will lead to the increase and decrease in carbon dioxide emissions respectively in low-income economies. The results specifically indicates that implementation of expansionary and contractionary fiscal policies in low-income economies in sub-Saharan Africa will lead to an increase and decrease respectively in carbon dioxide emissions by 0.20%, 0.42%, and 0.45% as estimated by CS-

ARDL, CCEMG, and AMG. Similar to the estimated the results for whole sub-Saharan African region, the estimated results for renewable and non-renewable energy consumption in low-income economies have significant negative and positive effects on carbon dioxide emissions respectively. Thus, an increase in the use of renewable and non-renewable energy will lead to a decrease (4.2%, 2.27%, and 2.711%) and increase (1.26%, 0.11%, and 0.29%) in carbon dioxide emissions respectively. The results estimated also revealed that income is a significant contributor to the variations in carbon dioxide emissions in lower-income economies. As shown in Table 5.5, a percentage increase in income will lead to 0.12%, 0.97%, and 0.29% increase in carbon dioxide emissions in low-income economies. The long-run effect of industrialization on carbon emissions in low-income economies, similar to the results of the entire sub-Saharan Africa had only two estimators' (CCEMG and AMG) results being significant but weak (at 10% significance level).

Table 8. CS-ARDL, CCEMG, and AMG Estimation Results for Sub-Saharan Africa and Low-Income Economies

	Sub-Sahara Africa			Low-Income Economies		
Variable	CS-ARDL	CCEMG	AMG	CS-ARDL	CCEMG	AMG
lnFPL	0.1436**	0.2940**	0.2088*	0.2036*	0.4184**	0.4455*
lnREN	-0.5639*	-1.0330**	-0.9321	-4.2624*	-2.2740***	-2.7078***
lnNRE	0.4136*	0.5275*	0.3807**	1.2622**	0.1133**	0.2921**
lnGDP	0.0234*	0.3061**	0.2517*	0.1209*	0.9656*	0.2942**
lnIND	1.0023	0.1287*	0.0210	1.0023	0.1518*	0.1312*
R-Squared	0.88			0.86		
Adj. R-Squared	0.77			0.73		
F-Statistics	7.85 (0.00)			6.74 (0.00)		
CD Statistic	-1.72 (0.09)			-1.07 (0.28)		
Root MSE	0.11	0.11	0.09	0.07	0.05	0.05
Wald chi2		9.40(0.05)	7.93(0.16)		9.21(0.05)	10.78(0.0)

*Indicates significance at 10% level. **Indicates significance at 5% level. ***Indicates significance at 1% level

Long-Run Estimation Results For Lower- and Upper-Middle-Income Economies

The estimated results for the lower-middle-income economies, though similar to that of the entire sub-Saharan African region and low-income economies show a comparatively weaker (majority of coefficients are significant at 10%) long-run effect of the study variables on carbon dioxide emissions. As presented in Table 5.6, fiscal policies (expansionary and contractionary) have a significant effect on carbon dioxide emissions in lower-middle-income economies of the sub-Saharan African region. The results indicate that a percentage change in fiscal policy will lead to a 0.17%, 0.48%, and 0.36% change in carbon emissions as estimated by CS-ARDL, CCEMG, and AMG respectively, depending on the kind of fiscal policy being pursued by the government. As shown in Table 5.7, renewable and non-renewable energy consumption are significant determinants of carbon emissions in lower-middle-income economies. The estimated results of this study show that a percentage increase in renewable energy consumption will cause carbon emissions to decrease by 2.24%, 1.29%, and 0.18% as estimated by CS-ARDL, CCEMG, and AMG respectively. Non-renewable energy, on the other hand, is expected to increase carbon emissions by 1.23%, 0.67%, and 0.18% as estimated by CS-ARDL, CCEMG, and AMG respectively, when its consumption is increased by 1%. Regarding income and industrialization, the results for lower-middle-income economies within the sub-Saharan African region revealed that carbon emissions into the environment increase as income and industrialization increases.

Contrary to the results for the entire sub-Saharan African region, low-income economies, and lower-middle-income economies, the CS-ARDL and AMG estimations for the upper-middle-income economies shows an insignificant long-run effect of fiscal policy on carbon dioxide emissions. Thus, the pursuit of either expansionary or contractionary fiscal policies by governments of upper-middle-income economies has no bearing or influence on carbon emissions. These results validate the EKC hypothesis, which indicates that activities geared towards economic growth at the initial stages ignore the sustainability of the environment until development reaches a stage where income is high enough to employ technologies that ensure a clean environment while still pursuing growth. The results obtained from the estimation also reveal an insignificant long-run effect of renewable and non-renewable energy consumption on carbon dioxide emissions for higher-middle-income economies. Thus, a variation in the use of renewable and non-renewable energy consumption has no significant influence on carbon dioxide emissions variations for higher-middle income economies. Though the results of CCEMG and AMG estimators indicate a significant long-run positive effect of income on carbon dioxide emissions in higher-middle-income economies, these effects are weak (at 10% significance level).

Table 9. CS-ARDL, CCEMG, and AMG Estimation Results for Lower- and Upper-Middle Income Economies

	Lower-Middle Income Economies			Upper-Middle-Income Economies		
Variable	CS-ARDL	CCEMG	AMG	CS-ARDL	CCEMG	AMG
lnFPL	0.1745*	0.4825***	0.3588*	0.0525	0.0969*	0.1110
lnREN	-2.2438*	-1.2905*	-1.7612*	-0.0324	-0.0957	-0.1897
lnNRE	1.2326***	0.6652**	0.1776*	0.0172	0.0661	0.5827
lnGDP	2.3714*	0.2766*	0.3801*	0.1612	0.6428*	0.4845*
lnIND	0.3551*	0.2840*	0.1631	0.2509	0.0314	0.0706*
R-Squared	0.83			0.98		
Adj. R-Squared	0.67			0.95		
F-Statistics	7.74 (0.00)			42.55 (0.00)		
CD Statistic	-2.68 (0.00)			-2.21 (0.02)		
Root MSE	0.08	0.11	0.16	0.06	0.04	0.06
Wald chi2		22.43 (0.00)	11.39(0.04)		193.95(0.00)	3.01(0.69)

*Indicates significance at 10% level. **Indicates significance at 5% level. ***Indicates significance at 1% level

Granger Causality Results

The three estimators (CS-ARDL, CCEMG, and AMG), used to estimate the long-run effects of the study variables on carbon dioxide emissions do not provide a direction of causation of the impact of the variables used in the model. Hence a causality test that provides the direction of causality between two different variables was carried out to ascertain the direction of causality between the study variables (fiscal policy, renewable energy consumption, non-renewable energy consumption, income, and industrialization). This current study employed the Dumitrescu and Hurlin (2012) approach to granger causality to test the causal relationships between the variables. The causality test for the entire sub-Saharan African region in Table 5.7 shows a uni-directional causal relationship between fiscal policy and carbon dioxide emissions, which runs from fiscal policy to carbon dioxide emissions. This result is consistent with the findings ofChishti et al. (2021), who also found a uni-directional causal relationship between fiscal policy and carbon dioxide emissions, running from fiscal policy to carbon dioxide emissions. The results for the entire sub-Saharan African region also revealed a uni-directional causal relationship between renewable energy consumption and carbon dioxide emissions, and between non-renewable energy consumption and carbon dioxide emissions, which are all consistent with the findings of Chishti et al. (2021). A uni-directional causal relationship is also observed in the causal relationship between income and carbon dioxide emissions, and industrialization and carbon emissions for the whole sub-Sahara Africa.

Regarding the low-income, and lower-middle-income economies within the sub-Saharan African, the study's results in Table 5.7 revealed a uni-directional causal relationship between fiscal policy and carbon dioxide emissions, running from fiscal policy to carbon dioxide emissions. These results confirm the results obtained for the entire sub-Sahara Africa. The results for the various income-based sub-panels, with the exception of upper-middle also revealed a uni-directional causal relationship between renewable energy consumption and carbon dioxide emissions, and between non-renewable energy consumption and carbon dioxide

Table 10. Causality Test Results

	Test				
	Variable	**W-Stat.**	**Zbar-Stat.**	**Zbar tilde.**	**Hypothesis**
Sub-Saharan Africa	lnFPL → lnCO2e	8.2790	19.9343***	16.5473***	Uni-directional
	lnCO2e → lnFPL	2.8561	5.0832	4.0478	
	lnREN → lnCO2e	3.7937	7.6509***	6.2089***	Uni-
	lnC02e → lnREN	10.7604	26.7299	22.2669	directional
	lnNRE → lnCO2e	2.8118	4.9620***	3.9458***	Uni-
	lnCO2e → lnNRE	3.8562	7.8221	6.3530	directional
	lnGDP → lnCO2e	9.2785	22.6715***	18.8511***	Uni-directional
	lnCO2e → lnGDP	4.6956	10.1207***	8.2876***	
	lnIND → lnCO2e	7.1774	16.9176	14.0083	Uni-
	lnCO2e → lnIND	1.5091	1.3941	0.9429	directional
Low-Income Economies	lnFPL → lnCO2e	3.5820	4.0825***	3.3030***	Uni-directional
	lnCO2e → lnFPL	3.2695	3.5884	2.8871	
	lnREN → lnCO2e	4.1870	5.0391***	4.1081***	Uni-

					directional
	lnC02e → lnREN	1.0679	-0.1074	-0.0427	
	lnNRE → lnCO2e	6.2013	8.2239***	6.7886***	Uni-directional
	lnCO2e → lnNRE	1.6475	1.0238	0.7286	
	lnGDP → lnCO2e	2.5033	2.3769**	1.8675*	Uni-directional
	lnCO2e → lnGDP	4.8102	6.0244	4.9374	
	lnIND → lnCO2e	3.2241	3.5167***	2.8267***	Uni-directional
	lnCO2e → lnIND	0.7388	0.4130	0.4807	
Lower-Middle Income Economies	lnFPL → lnCO2e	2.5834	2.7425***	2.1624**	Uni-directional
	lnCO2e → lnFPL	3.0583	3.5652***	2.8549***	
	lnREN → lnCO2e	2.2066	-2.0898**	-1.6131*	Uni-directional
	lnC02e → lnREN	0.8219	-0.3085	-0.4055	
	lnNRE → lnCO2e	2.8832	3.2617***	2.5995***	Uni-directional
	lnCO2e → lnNRE	1.0273	0.0473	0.1060	
	lnGDP → lnCO2e	2.5591	2.7004***	2.1270**	Uni-directional
	lnCO2e → lnGDP	7.4643	11.1965	9.2778	
	lnIND → lnCO2e	2.1504	1.9925**	1.5312*	Uni-directional
	lnCO2e → lnIND	2.0651	1.8449	1.4070	
Upper-Middle Income Economies	lnFPL → lnCO2e	22.6935	30.6793	25.7024	No Causality
	lnCO2e → lnFPL	2.0361	1.4653	1.1142	
	lnREN → lnCO2e	11.6587	15.0737***	12.5678***	Uni-directional
	lnC02e → lnREN	31.8079	43.5689	36.5509	
	lnNRE → lnCO2e	4.1603	4.4694	3.6426	No Causality
	lnCO2e → lnNRE	5.1683	5.8948	4.8424	
	lnGDP → lnCO2e	27.8265	37.9384**	31.8120**	Uni-directional
	lnCO2e → lnGDP	0.3992	0.8496	0.8341	
	lnIND → lnCO2e	19.6597	26.3888	22.0912	No Causality
	lnCO2e → lnIND	1.6378	0.9020	0.6401	

*Indicates significance at 10% level., **Indicates significance at 5% level., ***Indicates significance at 1% level

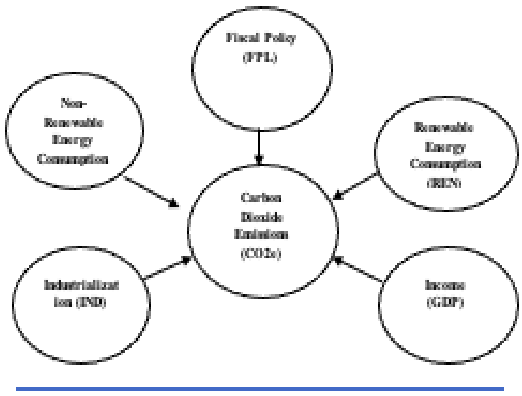


Figure 5: Summary of Causal Relationships between Variables for Sub-Saharan Africa

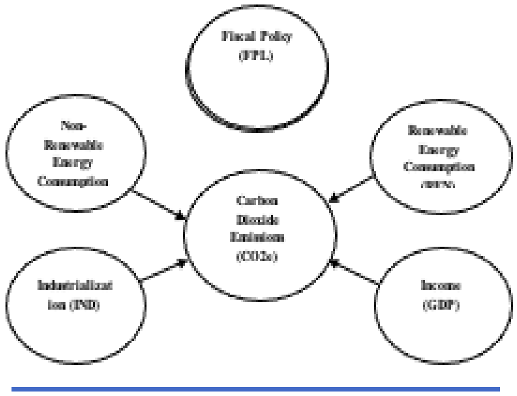
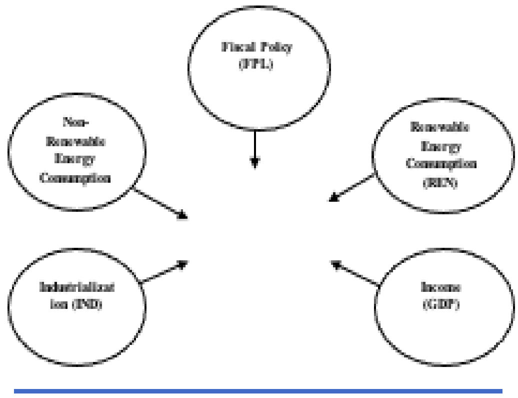


Figure 6: Summary of Causal Relationships between Variables for Low-Income Group



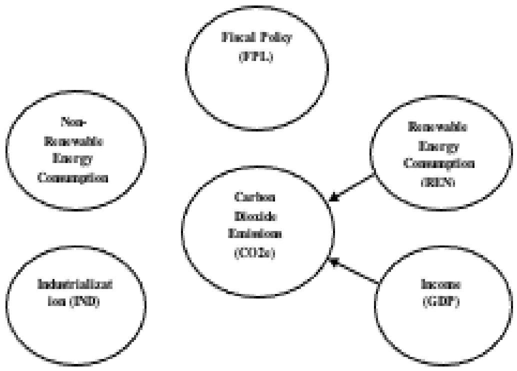


Figure 7: Summary of Causal Relationships between Variables for Lower-Middle-Income Group

CONCLUSION AND SUGGESTION

This study investigated the role of fiscal policy and energy consumption in the emission of carbon dioxide within the sub-Saharan African region. The study specifically examined the long-run effect of fiscal policy on carbon dioxide emissions across 17 sub-Saharan African countries. Among the variables used in the analysis of this study were fiscal policy, renewable energy consumption, non-renewable energy consumption, income, and industrialization. While GDP per capita representing income was introduced in the study model to satisfy the EKC hypothesis, industrialization was introduced as a control variable. Considering the possibility of the existence of cross-sectional dependence among the panel dataset, the study initially analysed the data to establish the presence or otherwise of cross-sectional dependence to ensure robust analysis. Following the confirmation of cross-sectional dependence among the study variables at a 1% significance level across the study variables, the null hypothesis of no cross-sectional dependence was rejected. To further ensure robust analysis following the detection of cross-sectional dependence, the CIPS Persaran panel unit root test, which considers the presence of cross-sectional dependence for the stationarity check was employed. The Westurland ECM cointegration, which also deals with the issue of cross-sectional dependence, was employed to reject the null hypothesis of no cointegration. Using the CS-ARDL, CCEMG, and AMG analytical tools to estimate the results provide robust analysis, which offers similar conclusions despite the difference in the degree of effect in terms of coefficients.

This study established the significant role of fiscal policy in the escalation and amelioration of carbon dioxide emissions within the sub-Saharan African region from the estimations of

CS-ARDL, CCEMG, and AMG. Specifically, the results of the study for entire sub-Saharan Africa indicate that expansionary fiscal policy contributes to carbon dioxide emissions increase, while contractionary fiscal policy mitigates the emissions of carbon dioxide into the environment. Similar results were found for the low- and lower-middle-income economies of the sub-region. The study found an insignificant effect/relationship between fiscal policy and carbon emissions for upper-middle-income economies. This study also revealed significant role of renewable and non-renewable energy consumption in reducing and increasing carbon dioxide emissions into the environment respectively for the entire region as well as the low- and lower-middle-income economies. The study's analysis also established a significant positive effect/relationship between income and carbon dioxide emissions and industrialization and carbon dioxide emissions. Thus, income and industrialization contribute to the rise in carbon dioxide emissions.

The results of the long-run estimations from CS-ARDL, CCEMG, and AMG were confirmed by the causality test.

The findings of this study bring into focus both theoretical and practical implications. These implications provide necessary causes for actions toward the inducement of low-carbon transition in the sub-Saharan African region and the world at large. Theoretically, this study offers a broader understanding of the issues regarding the situation of sustainable development in the sub-Saharan African region and the world at large and the possible determinants or factors associated to it. The empirical analysis of the role of fiscal policy, and energy consumption in the emission of carbon dioxide into the environment in this study has uncovered the significant role of both fiscal policy and the various sources of energy consumption in the escalation and mitigation of carbon emissions. This current study also having dealt with the problem of cross-sectional dependence among the dataset confirms or validates the long-run negative and positive effects of renewable energy consumption and non-renewable energy consumption respectively.

The significant role of expansionary and contractionary fiscal policies established from this study's results indicates the possibility of economic managers of various nations to promote sustainable development through fiscal policy implementations. As revealed by this study, the implementation of fiscal policy through increased government expenditure, increases environmental pollution (carbon dioxide emissions), as production from cheaper technology adoption by producers increases. In contrast, contractionary fiscal policy through reduced government expenditure mitigates the emissions of carbon dioxide. Thus, governments of various economies could use fiscal policy especially expenditure as a tool to ensure sustainable development (manage the emissions of dangerous gases into the environment). Considering that governments need to spend in an economy to promote economic growth, which is also expected to increase economic activities and spur environmental pollution, governments could implement green fiscal policy. This could be implemented by ensuring that agencies, firms and individuals involved in the execution of government projects provide "low-carbon transition" proposal as part of their bid for government projects. Governments could also target only firms and agencies that employ technologies that mitigate carbon emissions and award them with government projects.

As postulated by the EKC model, at the early stages of development, cheap technologies and dirty fuels are mostly used which pollutes the environment and later cleaned up as income increases. The findings of this current study revealed that non-renewable energy consumption significantly contributes significantly to the escalation of carbon emissions. Considering climate change and the urgent need for Africa especially sub-Saharan Africa to close the development gap, a school of thought argues that sub-Sahara Africa should pursue the path of development rooted in fossil fuel and cheap technologies similar to that which was pursued by today's industrialized countries and clean up later. Nonetheless, such path of development as revealed by this current study will create highly carbon-intensive economies and lock the continent into rising uncompetitive socio-economic and technical systems. This will subsequently limit the the region's growth potential and make it the "market of last resort". Governments of various sub-Sharan African economies should therefore avoid pursuing unsustainable development paths of the past centuries and invest in vast renewable energy sources that are available in the region.

Established that fiscal policies contribute significantly to the escalation and mitigation of carbon emissions, governments could impose special taxes called "green tax" on firms whose activities release dangerous gases such as carbon dioxide into the environment. These taxes could be invested into building large renewable energy resources for consumption as it has been established that renewable energy consumption mitigates carbon emissions. The negative effect of renewable energy consumption on the emission of carbon dioxide shows the urgent need to shift from non-renewable energy consumption to ensure sustainable development, hence the need for managers of Sub-Saharan Africa economies to innovatively shift the growth of their economies from fossil fuel-driven ones to more sustainable growth.

Funding

The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

Competing Interests

The authors have no relevant financial or non-financial interests to disclose

REFERENCES

Acaravci, A., & Ozturk, I. (2010). On the relationship between energy consumption, CO2 emissions and economic growth in Europe. *Energy*, *35*(12), 5412-5420.

Adedoyin, F. F., Gumede, M. I., Bekun, F. V., Etokakpan, M. U., & Balsalobre-Lorente, D. (2020). Modelling coal rent, economic growth and CO2 emissions: does regulatory quality matter in BRICS economies? *Science of The Total Environment*, *710*, 136284.

Ahmad, F., Draz, M. U., Ozturk, I., Su, L., & Rauf, A. (2020). Looking for asymmetries and nonlinearities: the nexus between renewable energy and environmental degradation in the Northwestern provinces of China. *Journal of Cleaner Production*, *266*, 121714.

Ahmad, F., Draz, M. U., Su, L., & Rauf, A. (2019). Taking the bad with the good: The nexus between tourism and environmental degradation in the lower middle-income Southeast Asian economies. *Journal of Cleaner Production*, *233*, 1240-1249.

Ahmad, M., Khan, Z., Ur Rahman, Z., & Khan, S. (2018). Does financial development asymmetrically affect CO2 emissions in China? An application of the nonlinear autoregressive distributed lag (NARDL) model. *Carbon Management*, *9*(6), 631-644.

Ahmad, M., & Khattak, S. I. (2020). Is aggregate domestic consumption spending (ADCS) per capita determining CO2 emissions in South Africa? A New Perspective. *Environmental and Resource Economics*, *75*(3), 529-552.

Ahmad, M., & Zhao, Z.-Y. (2018). Empirics on linkages among industrialization, urbanization, energy consumption, CO2 emissions and economic growth: a heterogeneous panel study of China. *Environmental Science and Pollution Research*, *25*(30), 30617-30632.

Álvarez-Herránz, A., Balsalobre, D., Cantos, J. M., & Shahbaz, M. (2017). Energy innovations-GHG emissions nexus: fresh empirical evidence from OECD countries. *Energy policy*, *101*, 90-100.

Anderson, D., & Cavendish, W. (2001). Dynamic simulation and environmental policy analysis: beyond comparative statics and the environmental Kuznets curve. *Oxford Economic Papers*, *53*(4), 721-746.

Andreoni, J., & Levinson, A. (1998). Simple Anal Environmental Kuznets Curve. In: NBER Work.

Andreoni, J., & Levinson, A. (2001). The simple analytics of the environmental Kuznets curve. *Journal of public economics*, *80*(2), 269-286.

Apergis, N., & Payne, J. E. (2017). Per capita carbon dioxide emissions across US states by sector and fossil fuel source: evidence from club convergence tests. *Energy economics*, *63*, 365-372.

Arminen, H., & Menegaki, A. N. (2019). Corruption, climate and the energy-environment-growth nexus. *Energy economics*, *80*, 621-634.

Balcilar, M., Gupta, R., & Segnon, M. (2016). The role of economic policy uncertainty in predicting US recessions: A mixed-frequency Markov-switching vector autoregressive approach. *Economics*, *10*(1).

Banerjee, S. G., Romo, Z., McMahon, G., Toledano, P., Robinson, P., & Arroyo, I. P. (2014). *The power of the mine: A transformative opportunity for sub-Saharan Africa*. World Bank Publications.

Bast, E., Makhijani, S., Pickard, S., & Whitley, S. (2014). The fossil fuel bailout.

Bekhet, H. A., & Harun, N. H. B. (2012). Energy essential in the industrial manufacturing in Malaysia. *International Journal of Economics and Finance*, *4*(1), 129-137.

Ben Jebli, M., & Ben Youssef, S. (2017). Renewable energy consumption and agriculture: evidence for cointegration and Granger causality for Tunisian economy. *International Journal of Sustainable Development & World Ecology*, *24*(2), 149-158.

Benchimol, J. (2015). Money in the production function: A new K eynesian DSGE perspective. *Southern Economic Journal*, *82*(1), 152-184.

Bhattacharya, M., Churchill, S. A., & Paramati, S. R. (2017). The dynamic impact of renewable energy and institutions on economic output and CO2 emissions across regions. *Renewable Energy*, *111*, 157-167.

Bhuiyan, M. A., Jabeen, M., Zaman, K., Khan, A., Ahmad, J., & Hishan, S. S. (2018). The impact of climate change and energy resources on biodiversity loss: Evidence from a panel of selected Asian countries. *Renewable Energy*, *117*, 324-340.

Bolat, S., Hunady, J., & Orviska, M. (2014). The Effects of Fiscal Policy on Economic Growth Nexus in OECD Countries: A Boostrap Panel Granger Causality Analysis. *Finance and Risk 2014 vol.*, *1*, 25.

Carabine, E., Lemma, A., Dupar, M., Jones, L., Mulugetta, Y., Ranger, N., & Van Aalst, M. (2014). The IPCC's fifth assessment report: What's in it for Africa. *Climate & Development Knowledge Network (CDKN)*, 1-33.

Carrington, D. (2015). Norway fund could trigger wave of large fossil fuel divestments, say experts. *The Guardian*, *28*.

Carson, R. T. (2020). The environmental Kuznets curve: seeking empirical regularity and theoretical structure. *Review of environmental Economics and Policy*.

Chishti, M. Z., Ahmad, M., Rehman, A., & Khan, M. K. (2021). Mitigations pathways towards sustainable development: assessing the influence of fiscal and monetary policies on carbon emissions in BRICS economies. *Journal of Cleaner Production*, *292*, 126035.

Chishti, M. Z., Ullah, S., Ozturk, I., & Usman, A. (2020). Examining the asymmetric effects of globalization and tourism on pollution emissions in South Asia. *Environmental Science & Pollution Research*, *27*(22).

Dongyan, L. (2009). Fiscal and tax policy support for energy efficiency retrofit for existing residential buildings in China's northern heating region. *Energy policy*, *37*(6), 2113-2118.

Ekins, P. (1997). The Kuznets curve for the environment and economic growth: examining the evidence. *Environment and planning a*, *29*(5), 805-830.

Ellis, K., Lemma, A., Mutimba, S., & Wanyoike, R. (2013). Low carbon competitiveness in Kenya. *Policy brief for Overseas Development Institute*.

Explorer, C. C. D. (2017). Country greenhouse gas emissions. *World Resources Institute: Washington, DC, USA*, *2020*.

Fischer, C., & Fox, A. K. (2012). Climate policy and fiscal constraints: Do tax interactions outweigh carbon leakage? *Energy economics*, *34*, S218-S227.

Fischer, S. (1974). Money and the production function. *Economic Inquiry*, *12*(4), 517.

Gill, A. R., Viswanathan, K. K., & Hassan, S. (2018). The Environmental Kuznets Curve (EKC) and the environmental problem of the day. *Renewable and Sustainable Energy Reviews*, *81*, 1636-1642.

Gorus, M. S., & Aydin, M. (2019). The relationship between energy consumption, economic growth, and CO2 emission in MENA countries: Causality analysis in the frequency domain. *Energy*, *168*, 815-822.

Grossman, G. M., & Krueger, A. B. (1991). Environmental impacts of a North American free trade agreement. In: National Bureau of economic research Cambridge, Mass., USA.

Halicioglu, F. (2011). A dynamic econometric study of income, energy and exports in Turkey. *Energy*, *36*(5), 3348-3354.

Hanif, I. (2018). Impact of fossil fuels energy consumption, energy policies, and urban sprawl on carbon emissions in East Asia and the Pacific: A panel investigation. *Energy strategy reviews*, *21*, 16-24.

Hassan, S. T., Baloch, M. A., & Tarar, Z. H. (2020). Is nuclear energy a better alternative for mitigating CO2 emissions in BRICS countries? An empirical analysis. *Nuclear Engineering and Technology*, *52*(12), 2969-2974.

Hogarth, J., Haywood, C., & Whitley, S. (2015). Low-carbon development in sub-Saharan Africa: 20 cross-sector transitions. *Overseas Dev. Institute, London*.

Ikram, M., Zhang, Q., Sroufe, R., & Shah, S. Z. A. (2020). Towards a sustainable environment: The nexus between ISO 14001, renewable energy consumption, access to electricity, agriculture and CO2 emissions in SAARC countries. *Sustainable Production and Consumption*, *22*, 218-230.

Jaeger, W. (1998). A Theoretical Basis for the Environmental Inverted-U and Implications for International Trade. *Department of Economics, Williams College*.

Jaeger, W. (1998). A theoretical basis for the environmental inverted-U curve and implications for international trade. *Williams College*, 57-78.

Jaforullah, M., & King, A. (2017). The econometric consequences of an energy consumption variable in a model of CO2 emissions. *Energy economics*, *63*, 84-91.

Jalil, A., & Feridun, M. (2011). The impact of growth, energy and financial development on the environment in China: a cointegration analysis. *Energy economics*, *33*(2), 284-291.

John, A., & Pecchenino, R. (1994). An overlapping generations model of growth and the environment. *The economic journal*, *104*(427), 1393-1410.

Jones, L. E., & Manuelli, R. (1995). A positive model of growth and pollution controls. In: National Bureau of Economic Research Cambridge, Mass., USA.

Katircioglu, S., & Katircioglu, S. (2018). Testing the role of fiscal policy in the environmental degradation: the case of Turkey. *Environmental Science and Pollution Research*, *25*(6), 5616-5630.

Kaushal, L. A., & Pathak, N. (2015). The causal relationship among economic growth, financial development and trade openness in Indian economy. *International Journal of Economic Perspectives*, *9*(2), 5-22.

Kelly, D. L., & Kolstad, C. D. (1999). Integrated assessment models for climate change control. *International yearbook of environmental and resource economics*, *2000*, 171-197.

Khan, M. K., Khan, M. I., & Rehan, M. (2020). The relationship between energy consumption, economic growth and carbon dioxide emissions in Pakistan. *Financial Innovation*, *6*(1), 1-13.

Khattak, S. I., Ahmad, M., Khan, Z. U., & Khan, A. (2020). Exploring the impact of innovation, renewable energy consumption, and income on CO2 emissions: new evidence from the BRICS economies. *Environmental Science and Pollution Research*, *27*(12), 13866-13881.

Li, K., & Lin, B. (2015). Impacts of urbanization and industrialization on energy consumption/CO2 emissions: does the level of development matter? *Renewable and Sustainable Energy Reviews*, *52*, 1107-1122.

Liu, Y., Han, L., Yin, Z., & Luo, K. (2017). A competitive carbon emissions scheme with hybrid fiscal incentives: the evidence from a taxi industry. *Energy policy*, *102*, 414-422.

Lopez, R. (1994). The environment as a factor of production: the effects of economic growth and trade liberalization. *Journal of Environmental Economics and management*, *27*(2), 163-184.

McMillan, M. S., & Rodrik, D. (2011). *Globalization, structural change and productivity growth*.

Mirza, F. M., & Kanwal, A. (2017). Energy consumption, carbon emissions and economic growth in Pakistan: Dynamic causality analysis. *Renewable and Sustainable Energy Reviews*, *72*, 1233-1240.

Neequaye, N. A., & Oladi, R. (2015). Environment, growth, and FDI revisited. *International Review of Economics & Finance*, *39*, 47-56.

Özokcu, S., & Özdemir, Ö. (2017). Economic growth, energy, and environmental Kuznets curve. *Renewable and Sustainable Energy Reviews*, *72*, 639-647.

Pablo-Romero, M. d. P., & De Jesús, J. (2016). Economic growth and energy consumption: The energy-environmental Kuznets curve for Latin America and the Caribbean. *Renewable and Sustainable Energy Reviews*, *60*, 1343-1350.

Perspectives, G. C., & Economics, O. (2013). Global Construction 2025. A global forecast for the construction industry to 2025. *London: Global Construction Perspectives and Oxford Economics*.

Raheem, I. D., & Ogebe, J. O. (2017). CO2 emissions, urbanization and industrialization: evidence from a direct and indirect heterogeneous panel analysis. *Management of Environmental Quality: An International Journal*.

Rauf, A., Liu, X., Amin, W., Rehman, O. U., Li, J., Ahmad, F., & Bekun, F. V. (2020). Does sustainable growth, energy consumption and environment challenges matter for Belt and Road Initiative feat? A novel empirical investigation. *Journal of Cleaner Production*, *262*, 121344.

Rehman, A., Rauf, A., Ahmad, M., Chandio, A. A., & Deyuan, Z. (2019). The effect of carbon dioxide emission and the consumption of electrical energy, fossil fuel energy, and renewable energy, on economic performance: evidence from Pakistan. *Environmental Science and Pollution Research*, *26*(21), 21760-21773.

Rehman, M. U., & Rashid, M. (2017). Energy consumption to environmental degradation, the growth appetite in SAARC nations. *Renewable Energy*, *111*, 284-294.

Rogelj, J., Nabel, J., Chen, C., Hare, W., Markmann, K., Meinshausen, M., . . . Höhne, N. (2010). Copenhagen Accord pledges are paltry. *Nature*, *464*(7292), 1126-1128.

Ryan, L., Ferreira, S., & Convery, F. (2009). The impact of fiscal and other measures on new passenger car sales and CO2 emissions intensity: Evidence from Europe. *Energy economics*, *31*(3), 365-374.

Sadorsky, P. (2014). The effect of urbanization and industrialization on energy use in emerging economies: implications for sustainable development. *American Journal of Economics and Sociology*, *73*(2), 392-409.

Sapkota, P., & Bastola, U. (2017). Foreign direct investment, income, and environmental pollution in developing countries: Panel data analysis of Latin America. *Energy economics*, *64*, 206-212.

Sarkodie, S. A., & Strezov, V. (2019). A review on environmental Kuznets curve hypothesis using bibliometric and meta-analysis. *Science of The Total Environment*, *649*, 128-145.

Selden, T. M., & Song, D. (1994). Environmental quality and development: is there a Kuznets curve for air pollution emissions? *Journal of Environmental Economics and management*, *27*(2), 147-162.

Selden, T. M., & Song, D. (1995). Neoclassical growth, the J curve for abatement, and the inverted U curve for pollution. *Journal of Environmental Economics and management*, *29*(2), 162-168.

Sinha, A., & Shahbaz, M. (2018). Estimation of environmental Kuznets curve for CO2 emission: role of renewable energy generation in India. *Renewable Energy*, *119*, 703-711.

Stern, D. I. (2004). The rise and fall of the environmental Kuznets curve. *World development*, *32*(8), 1419-1439.

Stokey, N. L. (1998). Are there limits to growth? *International economic review*, 1-31.

Ullah, S., Ozturk, I., Usman, A., Majeed, M. T., & Akhtar, P. (2020). On the asymmetric effects of premature deindustrialization on CO2 emissions: evidence from Pakistan. *Environmental Science and Pollution Research*, *27*(12), 13692-13702.

Vera, S., & Sauma, E. (2015). Does a carbon tax make sense in countries with still a high potential for energy efficiency? Comparison between the reducing-emissions effects of carbon tax and energy efficiency measures in the Chilean case. *Energy*, *88*, 478-488.

Waheed, R., Chang, D., Sarwar, S., & Chen, W. (2018). Forest, agriculture, renewable energy, and CO2 emission. *Journal of Cleaner Production*, *172*, 4231-4238.

WRI, C. (2014). Climate analysis indicators tool: WRI's climate data explorer. *World Resources Institute. Published*.

Yuelan, P., Akbar, M. W., Hafeez, M., Ahmad, M., Zia, Z., & Ullah, S. (2019). The nexus of fiscal policy instruments and environmental degradation in China. *Environmental Science and Pollution Research*, *26*(28), 28919-28932.

Zaman, K., & Abd-el Moemen, M. (2017). Energy consumption, carbon dioxide emissions and economic development: evaluating alternative and plausible environmental hypothesis for sustainable growth. *Renewable and Sustainable Energy Reviews*, *74*, 1119-1130.

Zambrano-Monserrate, M. A., Silva-Zambrano, C. A., Davalos-Penafiel, J. L., Zambrano-Monserrate, A., & Ruano, M. A. (2018). Testing environmental Kuznets curve hypothesis in Peru: The role of renewable electricity, petroleum and dry natural gas. *Renewable and Sustainable Energy Reviews*, *82*, 4170-4178.

Zhang, J., Wang, B., & Latif, Z. (2019). Towards cross-regional sustainable development: The nexus between information and communication technology, energy consumption, and CO 2 emissions. *Sustainable Development*, *27*(5), 990-1000.

Zhang, K., Zhang, Z.-Y., & Liang, Q.-M. (2017). An empirical analysis of the green paradox in China: From the perspective of fiscal decentralization. *Energy policy*, *103*, 203-211.

Zhao, W. (2015). *Corporate social responsibility in the energy industry: A content analysis of leading energy companies' websites* The Florida State University].

Zoundi, Z. (2017). CO2 emissions, renewable energy and the Environmental Kuznets Curve, a panel cointegration approach. *Renewable and Sustainable Energy Reviews*, *72*, 1067-1075