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The Impact of Carbon Emission (co2) on Economic Growth: Evidence from Sub-Saharan Africa

Salum Bakari Khamis & Fuzhong Chen

Abstract

The main aim of this paper is to investigate the impact of carbon dioxide (CO2) emissions on the economic growth of sub-Saharan Africa (SSA). The paper employed Generalized Method of Moments (GMM) to examine the relationships between CO2 and economic growth of sub-Saharan Africa. The study used panel data from 1981 to 2020 that was extracted from World Bank database for 45 countries in SSA. The study findings indicate that CO2 significantly impacts the economic growth of sub-Saharan Africa. Furthermore, the study shows that foreign direct investment (FDI), Gross Fixed Capital Formulation (GFCF), Unemployment (UMP), and Official development assistance (ODA) have a significant impact on economic growth of SSA. Based on the findings, it is suggested that despite the fact CO2 have mixed findings in previous literature, this study adds new insight into that CO2 was found to positively influence economic growth of SSA.

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About Author (s)

Salum Bakar Khamis (corresponding author), PhD student at School of International Trade and Economics, University of International Business and Economics (UIBE), Beijing, China.

Prof. Fuzhong Chen, School of International Trade and Economics, University of International Business and Economics (UIBE), Beijing, China.

1.0 Introduction

Sub-Saharan Africa (SSA) is one of the continents which have experienced enormous economic growth over the past couple of decades. According to the World Economic Development, the SSA experienced a tremendous growth in gross domestic product (GDP) where the countries observed growth of 5% for eight years (Anyanwu, 2014). The economic development has also increased the region's energy consumption level, which rose from 6% in 2000 to 20% in 2008. The increased energy consumption level led to detrimental environmental effects, including emission of greenhouse gas (Sarkodie & Strezov, 2019; Yusuf et al., 2020). The gas emission has brought a continent into persistent global warming and climate change problems. SSA is considered the least continent contributing greenhouse emission compared to other continents (Jebli & Youssef, 2017; Solarin, 2014), but it cannot be excluded that it has risen global warming and attention from diverse angles, including researchers, policymakers, and environmental activist (Baloch et al., 2020; Maji, 2019; Mentel et al., 2022; Salahuddin et al., 2019). The increasing population and industrial development in SSA probably increase the level of human activities and greenhouse gas emissions (Espoir & Sunge, 2021; Namahoro et al., 2021). According to the previous literature, there is a causal link between economic development, energy consumption, and increased greenhouse gas emissions (Charfeddine & Kahia, 2019; Hamit-Haggar, 2012; Sarkodie & Strezov, 2019; Zhang & Cheng, 2009). The ongoing debate is about implementing different international United Nations Framework Convention on Climate Change in SSA. For instance, the Kyoto Protocol released a binding agreement regarding reducing greenhouse gas emissions for developed and developing countries. The 8th session of the conference of parties (COP) was held in Qatar, COP 15 held in China, COP26 held in Scotland, and recently COP 27, which took place in Egypt, all focused on agreements, strategies, and initiatives for the reduction of greenhouse gas emission including CO_2, nitrous oxide (N_2O) and methane (CH_4). The relationship between greenhouse gas emissions and economic growth is still a vital topic because there is an increase in industrial activities across the globe that lead to the emission of different gas that harms the environment and sustainable economic growth. Therefore, this has motivated us to examine the impact of CO_2 emission on economic growth using the SSA as the growing greenhouse gas emission area. As the world emphasizes sustainable economic growth and development so that the future generation will be safe, the need for environmental sustainability is indispensable. Thus, the prime focus of this study is to explore the side of sub-Saharan Africa and examine the influence of CO_2 on economic growth using the panel data from 1981-2020. The design of this study is devised as follows: First, the literature related to CO2 emission and economic growth is provided; second, the methodology and description of variables are provided, followed by the presentation of the results based on the GGM method. Finally, the study interprets the results, summarize the results, and provides a general conclusion.

2.0 Review of literature

Although a spate of empirical literature exists that investigate the relationships between CO_2 and economic growth, but still some contraction exists on the impact of CO_2 on GDP as some studies focus on the positive impact (Abbasi et al., 2021; Al-Mulali & Sab, 2012) while some studies focus on the negative impact of CO_2 on GDP (Azam et al., 2016; Ozturk & Acaravci, 2010). This section provides an in-depth review of literature on both sides of CO_2 on GDP. Starting with the positive relationship between CO_2 and Economic Growth. A plethora of studies focuses on this side. For example, Mata et al. (2021) conducted a study examining the relationships between CO2 emission and GDP using secondary data for 48 years from 1970 to 2018 in Thailand. Using the ARDL and the frequency domain causality (FDC) techniques, the study finds a positive influence between CO_2 and economic growth in Thailand. In this case, the study concludes that the emission of CO_2 improves the country's GDP in Thailand. Karedla et al.

(2021), using the world development indicators, conducted a study to examine the relationships between CO_2 and economic growth using the secondary from 1971 to 2016 and (ARDL) bounds test approach. The study found a positive relationship between CO2 and GDP. Wu et al. (2021) examine the influence of CO_2 on economic growth using the data collected from Eastern, Southern Africa, West African States, and the Community of Sahel-Saharan States. The study indicates that an increase in CO_2 emissions has a major material influence on economic growth. Furthermore, Cederborg and Snöbohm (2016) used a cross-sectional data set and found a link between per capita GDP and carbon dioxide emissions. Muftau et al. (2014) use a data set from 1970 to 2011 to determine the influence of greenhouse gas emissions on economic growth. Using the estimated regression mode, the study found a positive link between greenhouse gas emissions and GDP in West Africa. Fan and Hossain (2018) use China and India as a case study to examine the relationships between trade openness and CO_2 on economic growth. Using the secondary data from 1974-2016 found a long-term beneficial positive influence on economic growth. In the bottom line, carbon emissions from gas flaring or gas fuels, as well as solid fuels, have a major impact on economic growth (Chen & Huang, 2013; Saidi & Hammami, 2015). The other side is the negative relationship between CO_2 and economic growth. Nawaz et al. (2021) use panel data from 1980 to 2016 to examine the relationship between CO_2 emission and GDP. Using the quantile autoregressive distributed lag (QARDL) on the data BRICS and OECD economies, the study found a negative relationship between carbon emission and GDP. A study by Mesagan (2015) conducted in Nigeria using the data from 1970 to 2013 saw a negative link between carbon emission and economic growth in Nigeria. Fan and Hossain (2018) used a data set from 1974-2016 to examine the relationships between CO_2 and economic growth in China and India and found a negative influence between CO_2 and economic growth. Islam et al. (2021) conducted a study in Saudi Arabia to examine the relationships between CO2 and economic growth from 1990–2019. The study found that there is a negative result between CO_2 and GDP. Furthermore, Azam et al. (2016) revealed a negative impact between CO2 emission and economic growth. The study adopted the Fully Modified Ordinary Lease Squares Method using the data from 1971 to 2013 and found that the more emission of CO_2, the more economic growth decreases. Nevertheless, Ejuvbekpokpo (2014) revealed a negative relationship between CO2 and GDP using the study data collection between 1980 and 2010. The study further indicates that CO_2 emission decreases productivity activities and reduces the country's economic growth. According to Sebri and Ben-Salha (2014), a survey of BRICS countries, including Brazil, Russia, India, China, and South Africa, using the data from 1971 to 2010, found that when there is an increase in CO_2 emissions, the economic growth of the countries are affected.

3.0 Methodology

3.1 Model Specification

The paper investigated the relationships between carbon emission and growth development in sub-Saharan Africa. Based on analytical structure, the proposed model in this study is described as follows:

$$lnGDP = \beta_0 + \beta_1 lnCO_{2it} + \beta_2 lnEDS + \beta_3 lnFDI_{it} + \beta_4 lnGFCF_{it} + \beta_5 lnGGCF_{it} + \beta_6 lnINF_{it} + \beta_7 lnLF_{it} + \beta_8 lnNODA_{it} + \beta_9 lnOER_{it} + \beta_{10} lnPOP_{it} + \beta_{11} lnTRD_{it} + \beta_{12} lnUMP_{it} + \varepsilon_{it} \quad \ldots\ldots 1$$

GDP = Gross Domestic Product
CO_2 = Carbon dioxide emission
EDS = External debt
FDI = Foreign Direct Investment
GFCF = Gross Fixed Capital Formulation
INF = Inflation
LF = Labour force

GGCF = General Government consumption formulation
OER = official exchange rate
POP = Population
TRD = Trade openness
UM = Unemployment
t = Country
i = time period
ε = error term.
β_0 = constant terms,
Ln = Logarithm
$\beta_1 - \beta_{11}$ = coefficient estimator

3.2 Data and variables

The study focused on the following counties from sub-Saharan Africa, including Angola, Benin, Botswana, Burkina Faso, Burundi, Central African Republic, Cabo Verde, Chad, Comoros, Congo, Democratic Republic, Congo Republic, Cote d'Ivoire, Djibouti, Egypt, Equatorial Guinea, Swaziland, Ethiopia, Gabon, Gambia, Ghana, Kenya, Lesotho, Madagascar, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, South Africa, Sudan, Tanzania, Togo, Tunisia, Uganda, Zimbabwe. The study used secondary data extracted from the World Bank database accessed in early 2022. The variables used in this study were derived from the theoretical justification and available secondary data from the primary source. The study examines the relationship between CO2 and economic growth for 41 years from 1981 to 2020. The description of the variables is presented in Table 1. The variables include the foreign direct investment, population growth, official exchange rate, gross fixed capital formation, Net official development assistance, inflation, trade openness, employment, and General government final consumption expenditure. Some variables were dropped in, including education and health. Table 1 present the description of data sources, a measurement of variables, and predicted sign of the results.

Table 1. Data source, description of variables, and predicted sign

Main variable	Descriptions of variables	Predicted sign
GDP per capita	GDP per capita is gross domestic product divided by midyear population.	
CO_2 emission	CO2 emissions are expressed by per capita emissions of CO2 in tons.	Negative
Foreign Direct Investment	The measure of foreign direct investment is taken as a net. The more FDI inflow in the country, the more CO2 emission is expected.	Positive
Inflation	Inflation is measured in terms of a price index that reflects the annual percentage change in the cost of purchasing goods and services.	Negative
Trade openness	The indicator shows how the countries comply with international trade policies measured in terms of trade (import plus export) share to total GDP.	Positive
Population Growth	The increasing number of people in the country. It is viewed that the increase in population is directly proportional to economic growth.	Positive
Unemployment	The rate of laborers without work in the country: the more unemployment, the less purchasing power, and economic growth.	Negative
Official exchange rate	The amount of money paid in exchange for the use of borrowed money and interest of the principal loan per year.	Negative
Official development assistance	Foreign aid is provided to sub-Saharan Africa from donor countries.	Positive
Labour force	The labor force includes the workforce used in production over some time.	Zero
General government consumption	It includes the government's current expenditures for purchases of goods and services.	Positive
External debt stocks	Total external debt is the sum of foreign institutions' short- and long-term debt.	Negative

3.3 Empirical Methodology

The main purpose of this study is to investigate the relationship between CO_2 and economic growth. The study focuses on the generalized method of moments (GMM), which is the centerpiece of semiparametric estimation. The GGM two steps approach is used to examine the relationships between exogenous and endogenous variables. It is widely acknowledged that a two-step GMM estimator is the best approach when the resulting estimator does not have the higher-order asymptotic bias arising from the choice of a preliminary weighting matrix (Kim, 2020). Furthermore, the robustness check is performed using various techniques to validate the results provided in this study.

4.0 Empirical Results and Discussion

This section provides the empirical results and discussion based on the data collected from sub-Saharan Africa. This study sought to investigate the relationships between CO2 emission and economic growth.

4.1 Descriptive statistics

Table 3.2 stipulates the descriptive statistics of the main model in terms of mean, standard deviation, min, and maximum. For example, the mean value of GDP (M = 7.289, S.D = 2.1408, Min = 3.559, Max = 21.878), the mean value of CO_2 (M = 3.050, S.D = 2.7602, Min = -1.609, Max = 11.902), the mean value EDS (M = 19.03, S. D = 2.572, Max = 24.85, Min = 10.30). FDI (M= 4.88, S.D = 7.28, MAX = 22.928, Min = -3.08). GGFM (M= 19.86, S.D = 1.85, Max = 24.35, Min= 0.56). INF (M = 1.77, S.D = 1.64, Max = 14.56, Min = -8.33), LBF (M =14.75, S.D = 2.33, Max = 22.38, Min = 0.49). The NODA (M = 21.23, S.D =1.91, Min = 25.85, Max = 13.88). The OER (M= 17.81, S.D = 4.09, Min =25.269, Max = -17.324), TRD (M= -1.237, Max = 3.035, Min = -5.106, S.D = 0.85), UMP (M = 1.441, the max = 21.867, min = -2.395, S.D = 1.719).

Table 2. Descriptive statistics

Variables	Observations	Mean	S.D	Max	Min
LRGDP	329	7.2895	2.1408	21.878	3.5598
LCO2	329	3.0508	2.7602	11.902	-1.6094
LEDS	329	19.034	2.5727	24.856	10.308
LFDI	329	4.8869	7.2842	22.928	-3.0848
LGFCF	329	21.716	9.8168	110.41	-25.114
LGGFC	329	19.861	1.8575	24.356	0.5672
LINF	329	1.7787	1.6432	14.561	-8.3319
LLF	329	14.751	2.3361	22.381	0.4973
LNODA	329	21.239	1.9111	25.858	13.880
LOER	329	17.811	7.5932	25.269	-17.324
LPOP	329	4.0900	6.2199	17.839	-1.1210
LTRD	329	-1.2372	0.8538	3.0354	-5.1063
LUMP	329	1.4412	1.7197	21.867	-2.3955

4.2 Correlation matrix

Table 4 present the correlation matrix for assessing the relationship between CO_2 and economic growth. The matrix provides a preliminary result on the relationships between the endogenous and exogenous variables. The correlation matrix between economic growth measured in terms of GDP and CO_2 indicate a positive linear relationship. This implies a positive influence between the CO_2 and GDP in sub-Saharan Africa. In another way, someone can say that when the CO_2 increase in sub-Saharan Africa, it increases the economic growth (GDP). The matrix also presents the relationships between different variables, including FDI, EDS, GFCF, GGFC, INF, LF, NODA, OER, POP, TRD, UMP, and GDP.

Table 2. Correlation matrix

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13
1. LRGDP	1												
2. LCO2	.07												
3.LEDS	).07	.51											
4.LFDI	).04	.89	.57										
5.LGFCF	).36	.27	.38	.29									
6.LGGFC	).04	.33	.49	.28	.32								
7.LINF	).38	.07	.12	.12	.42	).15							
8.LLF	).75	.01	.48	.08	.47	.33	.40						
9.LNODA	).12	).46	.16	).49	.05	.23	.06	.51					
10.LOER	.09	).65	).38	).34	).38	).22	).19	).03	.56				
11.LPOP	).07	.58	.51	.16	.23	.36	.05	.08	).49	).22			
12.LTRD	).14	.14	.14	.19	.08	).06	).02	.07	).20	).06	.08		
13.LUMP	).07	.01	).01	.03	.014	.11	.18	.09	).003	).03	.03	).02	1

4.3 Regression results

The Generalized Method of Moments (GMM) is used in this paper to examine the relationships between CO2 and economic growth of sub-Saharan Africa. The researcher included other variables (UMP, GFCF, NODA, and FDI). These variables were controlled in order to prevent their influence on the relationships between dependent (GDP) and independent variable (CO_2). A one-step and two-step approach was applied under the GMM in order to estimate the relationships between variables. The Sargan *p-value* and the AR (2) *p-value* were adopted to determine if the instruments employed are genuine and whether the residuals are auto-correlated. Because the second order autocorrelation does not exist and legitimate instruments are used in the estimated model, the null hypothesis of proper instruments and lack of higher order autocorrelation cannot be rejected. Based on the two-stage approach of GGM, the results indicate that CO2 emission have significant influence on the economic growth of sub-Saharan Africa. When other factors kept constant, the increase by 1% of CO2 indicate a 6.5% increase in economic growth measured in GDP. The UMP and FDI indicates a negative relationship on economic growth in sub-Saharan Africa. A 0.03897-unit decrease in CO2 emissions is linked to 1%-unit increase in UMP and 0.146328-unit decrease in GDP result to increase 1% increase in FDI. Furthermore, the results indicate that 1% increase in GFCF, the GDP is going to increase to 0.005878 percentage points.

Table 4. Regression results

ONE STEP				**TWO STEP**		
Variable	**β**	**SE**	***t*-Statistic**	**β**	**SE**	***t*-Statistic**
LRGDP(-1)	0.588954	0.104623	5.629314	0.609751*	0.037667	16.18807
LCO2	0.123725	0.058627	2.110377	0.064943*	0.028896	2.247444
LUMP	-0.038972	0.022733	-1.714332	-0.041573**	0.018606	-2.23435
LGFCF	0.005878	0.008719	0.674215	0.006806*	0.00381	1.786419
LNODA	0.156737	0.048641	3.22231	0.126099*	0.018996	6.638161
LFDI	-0.146328	0.062084	-2.356944	-0.072592*	0.026796	-2.709008
AR (1) *p –value*	0.09			0.002		
AR (2) *p –value*	0.890			0.422		
Sagan *p – value*	0.181			0.213		

Notes: ***, **, and * denote significant at $p<0.001$, $p<0.05$, $p<0.1$ respectively

These findings are consistence with several past studies. For example, Al-Mulali and Sab (2012) studied the impact of energy consumption and CO_2 emission on economic growth and financial development in sub-Saharan African countries using a study period from 1980 to 2008. They found that CO_2 emissions increase sub-Saharan Africa's economic growth and financial development. This study insists that when countries increase their energy emission, it increases the country's GDP growth. Abbasi et al. (2021), using the autoregressive distributed

lag, determine how energy consumption, industrial growth, urbanization, and CO_2 emissions affect economic growth in Pakistan. The study uses panel data from 1972 to 2018 to show that electricity consumption and industrial value-added activities have short- and long-term impacts on the country's economic growth. Still, the CO_2 emission positively affects economic growth in the short run. The study concludes that energy consumption, CO_2 emission, industrial growth activities, and urbanization positively impact Pakistan's economic growth. Furthermore, Chaabouni et al. (2016) examine the causal dynamics between CO_2 emissions, health expenditures, and economic growth using the dynamic simultaneous-equations models. The study uses a global panel of 51 countries from 1995 to 2013. The empirical findings indicate casual relationships between CO_2 emission, health expenditure, and economic growth. Nevertheless, using the MENA countries, Al-Mulali (2011) examines the impact of oil consumption on economic growth. Using the panel data from 1980 to 2009 and the cointergration approach, the study found that CO_2 emission and oil consumption has a long-term relationship with the economic growth in MENA countries. However, the findings of this study contradict some past literature, such as Azam et al. (2016). They conducted a study using panel data from India, China, USA, and Japan using data from 1971 and 2013. Based on the panel of fully modified ordinary least squares the study found that there is a negative relationship between the CO_2 emission and economic growth.

5.0 Conclusion

CO_2 accounts for 76% of greenhouse gas emissions that trigger severe global warming and acute climate conditions in sub-Saharan Africa and other regions. Sub-Saharan Africa is one of the continents that are conscious of the environmental problems and their adverse effects on the region's economic development. The findings of this study pave new insight and empirical evidence that support the ongoing debate about the relationships between CO_2 and economic growth in sub-Saharan Africa. However, various studies have examined the relationships between CO_2 and African economic growth. The findings of previous studies with this one in terms of the approach applied and a number of the countries involved. The study investigates the relationships between CO_2 and economic growth in sub-Saharan Africa from 1981-2020. The panel data approach based on GGM was applied to validate the relationships between the CO_2 and economic growth measured in Gross Domestic Product. The paper suggests that CO_2, as one of the primary sources of greenhouse emissions, affects the African countries' economic growth positively. This study contributes to the existing contemporary literature in economics and fiancé about the influence of greenhouse gas emissions on economic growth using the new data set of sub-Saharan Africa. It is well known that very few studies exist in sub-Saharan Africa to explore the relationship. Based on the results of this study, we recommend that more studies be conducted to examine the relationships between the CO2 and economic growth as more mixed findings are observed in the literature compared to this study. Similarly, future research should be conducted to compare this study's results.

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