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Article Review

The Interconnection of Economic Growth, Carbon Dioxide Emission, Foreign Direct Investment and Energy Consumption: Evidence from Sub-Saharan Africa.

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Abstract:

This study examines how economic growth, carbon dioxide (CO_2) emissions, foreign direct investment (FDI), and energy consumption relate to each other in Sub-Saharan African (SSA) region by employing the quantile regression model to guesstimate the point coefficients of the explanatory variables on the response variables for a range of quantiles from 0.01 to 0.99. The researchers make use of data from 17 SSA countries, with the years ranging from 1975 to 2018. The study reveals a dynamic result for the estimated regression parameters of the quantile regression models for all the respective explanatory variables at varied quantiles. The effect of FDI inflow on economic growth is statistically significant at quantiles 0.1, 0.4 to 0.8 but not statistically significant at quantiles 0.2, 0.3, and 0.9 at 1% and 5% significance levels. Also, the effects of energy consumption on economic growth and the effect of CO_2 emissions on economic growth are statistically significant at quantiles of 0.1, 0.2, and 0.7 at 1% and 5% significance levels. Furthermore, the result established that the coefficients for FDI inflow, energy consumption, and CO_2 emissions are positive across all the specified quantiles except for quantile 0.1 for FDI inflow, which is negative. Evidently, there exists an asymmetric relationship between economic growth and its explanatory variables (FDI inflow, energy consumption, and CO_2 emissions) at diverse quantile levels in its restrictive distribution. The study recommends that governments in the various regions should authorize the environmental agencies to act within the power given to them by the constitution. Also, less polluting foreign production techniques such as greener energy should also be sought after.

Keywords: FDI, CO_2 Emission, Economic Growth, Energy Consumption

1- Introduction

The world is in search of investors, from developing to developed countries but the problem is the adverse effect of this downpour of resources on the production of goods and services. For example, according to Muhammad and Khan (2021), increased energy use, social globalization, FDI, and economic expansion have all increased carbon dioxide emissions globally in 170 nations.

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The research was conducted by means of GMM and a fixed effect model relying on data from 1990 to 2018. Economic growth, electricity consumption, and FDI are also believed to stimulate CO2 emissions in both the short and long run (Salahuddin et al., 2018). Studies on environmental pollution indicate that, the global emissions of greenhouse gases have been rising, notably in SSA. For instance, the yearly carbon dioxide emissions from burning fossil fuels were 11.5%. Additionally, carbon dioxide emissions from African nations like Libya, South Africa, the Seychelles, and Equatorial Guinea exceeded the global average of 1.3 metric tons of carbon per year (Andres et al., 2011)

This proves that economic growth played a substantial role in driving greenhouse gas emissions in SSA countries (Liousse et al., 2014). Likewise, OPEC nations in Africa have demonstrated that, over time, economic expansion contributed to carbon dioxide and methane emissions (Yusuf et al., 2020). The Kaya theoretical research also verified that factors such as population growth, economic expansion, and energy consumption intensity affected carbon dioxide emissions (Kaya and Yokobori, 1997). In recent times, industrialization has become necessary because it leads to economic growth (Udi et al., 2020) and also because there is a need to produce more to meet world demand for goods and services (Zhou, 2009); this could be blamed on population density in the last two decades (Berger 2019; Atack et al. 2022). Atack et al. (2022) stress that an increase in the total population positively influences urbanization, which directly influences industrialization. They further document that with industrialization comes FDI and the consumption of energy. Further, Munir & Ameer (2019) spell out that the ever-increasing consumption of energy is due to the growing demand for goods and services in the world, which is as a result of the increase in industrialization and FDI. This attests to the fact that there appears to exist a certain relationship amid FDI and energy consumption, carbon emissions and economic growth. Most researchers have tried this line of analysis and have documented diverse findings. For example, Munir & Ameer Research into the interconnections between FDI, economic growth, industrialization. For example, the author specifies in the long run that, FDI has a significant and positive effect on CO_2, but not in the short run as there are other similar findings in line with these arguments, although a lot less has been done in Africa, specifically in the Sub-Saharan Region. In this light, we are prompted to research and add our voice to the ongoing argument.

To this extent, this study examines how these variables, namely, economic growth, CO_2 emissions, FDI, and energy consumption relate to each other in the SSA region. The following questions arise: How do FDI, carbon emissions, and energy consumption affect economic growth in SSA? Again, how does FDI, economic growth, and carbon emissions affect SSA energy consumption? Finally, how do FDI, economic growth, and energy consumption affect carbon emissions in the Sub-Saharan region? These relationships will allow further studies on the topic.

1.1 Economic Development, Energy Consumption, and CO_2 Emissions

The factors influencing economic growth are enormous and they continue to increase as economists day in and day out come up with new modules with variables that were previously neglected because of their ambiguity or unreliability. For instance, in developing and developed countries, researchers have documented that education and human capital as a whole influence economic growth (Pelinescu 2015; Hanushek & Woessmann 2021). Hanushek & Woessmann employ data from the international math and science skills and state that the linking between cumulative reasoning skills, commonly known as the knowledge capital of an economy, is astonishingly strong. They added that although it is unlikely to provide convincing proof of interconnection between knowledge and growth, the existing facts make a strong case that modifying the skill-sets of the working class will lead to a greater rate of growth. Others have also created a link between industrialization and economic growth (Udi et al. 2020; Ahmed et al. 2021). With industrialization comes energy-related carbon emissions.

It's been documented that the growth of industries leads to the major dilapidation of the environment (Udemba et al., 2021). This has led to stricter rules and laws around the globe to curb or reduce the negative effects of industrialization on the environment.

The relationship between CO_2, energy consumption and economic growth has been established by most scholars in recent times (Mirza & Kanwal 2017; Nawaz et al. 2021; Nguyen et al. 2020). There have been diverse findings with respect to the relationships between these variables. Previously, researchers stated that there is no link between economic growth and carbon emissions or energy consumption. For instance, X.-P. Zhang & Cheng (2009) document that economic growth in China has no bearing on carbon emissions and energy consumption. With data from 1960 to 2007, X.-P. Zhang and Cheng investigate the existence and direction of Granger causality between energy consumption, carbon emissions, and economic growth in China. They conclude that neither energy consumption nor carbon emissions led to economic growth using Granger causality and the generalized impulse response function, but they urge the Chinese government to enact laws to reduce energy consumption and carbon emissions in the long run because it will not impede economic growth. Perhaps the researchers were looking at a greener way of production because other recent findings (Long et al. 2015; Yao et al. 2019) indicate that there is a link between energy consumption, carbon emissions and economic growth, where the rising levels of carbon emissions and energy consumption have been attributed to an increase in economic growth. In this line of argument, Yao et al. (2019) state categorically that rising carbon levels are a result of economic growth. The researchers investigated renewable energy, carbon emissions, and economic growth using two panel data sets from seventeen major developed and developing countries, as well as six global geoeconomic regions. Data for the research spans from 1990–2014. They established that there exists a long-term relationship between economic growth and carbon emissions.

To that end, it goes without saying that higher levels of economic growth necessitate a significant increase in energy consumption, which has the potential to increase carbon dioxide emissions in the atmosphere.

1.2 FDI, energy consumption, CO_2 emissions, and economic growth.

There is no argument that FDI inflows can augment the economic growth of a nation (Muhammad & Khan, 2019), but an increase in FDI has a positive and significant effect on CO_2 emissions in the long run (Muhammad & Khan, 2021; Bakhsh et al. 2017; Ben Jebli et al. 2019). Research on the relationship between economic growth, CO_2 emissions, renewable waste, and FDI in Pakistan and concludes that FDI is positively related to pollution. They added that a rise in economic growth also leads to more pollution. They concluded, however, that economic growth begins to decline as pollution crosses a certain threshold. Bakhsh et al. used data from 1980 to 2014 and employed technique and composition effects of simultaneous equations to guesstimate the relationship between the research variables. This work differs from this study in that, firstly, they add a variable (environmental pollution) that's omitted in this research. Their study area differs from this research as while they focus on Pakistan, this work concentrates on Sub-Saharan Africa.

It is now becoming increasingly clear as to how FDI can have uncertain effects on the environmental class of the host country. Adding their voice, Chishti et al.'s (2021) research on the asymmetric associations between FDI inflows, terrorism, CO_2 emissions, and economic growth. The paper investigates the linear and nonlinear weights of terrorism and FDI inflows on carbon dioxide emissions, controlling for energy consumption and economic growth using the linear and nonlinear autoregressive distributed lag methods. Data for the study spans from 1973 to 2016. Chishti et al. (2021) confirm that a shock to FDI significantly deteriorates the environment with a dominating effect. They, however, added that economic growth and energy consumption were also recorded to aggravate the carbon dioxide emission levels in all selected countries. The researchers ended by recommending an inflexible environmental set of laws on FDI inflows to lessen the unsympathetic environmental effects of such sources of foreign finance and that the government should offer tax benefits and other financial incentives so that the MNCs will be buoyant to invest in cleaner technologies. In this same line of argument, Mujtaba & Jena (2021) analyse the asymmetric impact of economic growth, energy use, FDI inflows, and oil prices on CO_2 emissions in India. Data for the study lapsed from 1986 to 2014, and a nonlinear autoregressive distributed lag (NARDL) model and asymmetric causality test were employed. Their research supports the notion that FDI inflows support pollution, although they realized a undesirable relationship between economic growth and carbon emissions.

1. MATERIAL AND METHODS

The model for fixed-effect panel quantile regression is used to assess the interconnectedness of the variables and their relevance to previous studies. This is in reference to earlier research done (Zhu et al. 2016; Ma et al. 2019; and Albulescu et al. 2019) to ascertain the interconnectedness between variables like carbon emission, FDI, economic growth, etc and how they influence each other.

2.1 Model Specification

In order to assess the relationship between carbon emission, FDI inflow, energy consumption, and economic growth and how they impact each other on the SSA, the fixed effect panel quantile regression model is employed, proposed by Ma et al. (2019) and Albulescu et al. (2019) for fixed panel data models, and has been applied to economic models in recent years. In the same line, we adopt the fixed effect panel quantile regression model to scrutinize the influence of carbon emissions, FDI inflow, and energy consumption on economic growth and vice versa. Specifically, the panel quantile regression can help explore the determining factor of economic growth throughout the conditional distribution, particularly in the countries with the highest and smallest economic growth rates. Nevertheless, Binder & Coad (2011) specified that the ordinary least square regression method emphasizes the mean effects, which may result in under-or-over estimating the relevant coefficient or even failing to distinguish significant associations. The quantile regression method, which is the simplification of the median regression analysis to other quantiles, was proposed by R. W. Koenker & Bassett (1978).
We therefore consider the following conditional quantile of y_t, given $x_{t,i}$;

$$Qyt(\tau|xt) = xtT\beta\tau \qquad (1)$$

Where $Q_{y\,t}(\tau|x_t)$ represents the τ^{th} conditional quantile of y_t, x_t^T denotes a vector of the explanatory variables, and the β_τ represent the estimated coefficient effect of quantile τ and $0 < \tau < 1$. From Eq (1), the fixed effect panel quantile regression model which makes it likely to estimate the conditional mixed effects for the response variable by controlling for unobserved individual heterogeneity is given by;

$$Qyit\ (\tau|\alpha it,\ xit) = \alpha i + xitT\beta\tau \qquad (2)$$

Where $Q_{yit}\ (\tau|\alpha_{it},\ x_{it})$ represents the τ^{th} conditional quantile of $y_{i,t}$ for the individual (i) in the time t and the α_i denotes the unobserved effect at quantile τ.The model also has its own flaws, for example, Zhu et al. (2016); Bui et al. (2021) H. Khan et al. (2020) and Usman & Jahanger (2021) stated that, the main problem per fixed effect panel quantile regression is that, the addition of a considerable amount of α_i(fixed effect) is equivalent to the incidental parameters problem. Thus, the estimator will vary when the number of individuals goes to infinity but the number of observations for each cross-sectional unit is fixed. This problem is addressed by R. Koenker (2004) by calculating the parameter estimates as follows:

$$min\Sigma_{k=1}^{K}\Sigma_{t=1}^{T}\Sigma_{t=1}^{N}W_k\rho_{\tau k}(y_{it} - \alpha_i - x_{it}^{T}\beta(\tau_k)) + \lambda\Sigma_i^N|\alpha_i| \qquad (3)$$

where (x) denotes the matrix of the independent variables, (i) denotes the index for countries (N), (T) denotes the index for the number of observations per countries, (K) denotes the index for the quantiles, $\rho_{\tau k}$ denotes the quantile loss function and the W_k denotes the relative weight given the k^{th} quantile controlling the contribution of the k^{th} quantile on the estimation of the fixed effect. We therefore transformed the model in Eq (2) into a panel quantile regression given the following models;

$$Q_{EGit}(\tau|\alpha x,tx_i,t) = \alpha i(\tau)+\beta 1(\tau)FDI_i,t +\beta 2(\tau)CE_i,t +\beta 3(\tau)EC_i,t \qquad (4)$$

The effect of FDI inflow, carbon emission (CE) and energy consumption (EC) on economic growth (EG) is displayed in Eq (4).

$$Q_{EGit}(\tau|\alpha x,tx_i,t) = \alpha i(\tau)+\beta 1(\tau)FDI_i,t +\beta 2(\tau)CE_i,t +\beta 3(\tau)EG_i,t \quad (5)$$

The effect of FDI inflow, carbon emission (CE) and economic growth (EG) on energy consumption (EC) is displayed in Eq (5).

$$Q_{EGit}(\tau|\alpha x,tx_i,t) = \alpha i(\tau)+\beta 1(\tau)FDI_i,t +\beta 2(\tau)EC_i,t +\beta 3(\tau)EG_i,t \quad (6)$$

The effect of FDI inflow, energy consumption (EC) and economic growth (EG) oncarbon emission (CE) is displayed in Eq (6). Where (i) represents the country index at time (t). EG_{it}, $EC_{i,t}$ and $CE_{i,t}$ are the indicator for economic growth, energy consumption and carbon emission indexed by countries (i) at time (t).

2.2 Data Source and Descriptive Statistics Summary

Scanty and unavailability of data with respect to the selected variables caused the number of countries that qualify for this study to shrink. To estimate the relationship between the variables selected, 17 SSA countries based on complete data availability were considered. The time span for the study was from 1975 to 2018. Four main variables, namely; Economic Growth, Energy Consumption, FDI and CO_2 emission were selected for this paper. Primarily, data was sourced from the World Banks WIR and WDI and compared with country information agencies. Data is

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collected on a yearly basis and the sampled number of countries as well as the variables were dictated by data availability. All the variables are in the natural logarithm. The summary of the data set is reported in Table 1. It must be however emphasized that the economic growth rate was computed by the researchers using Gross domestic products of the selected countries.

Table 1 Descriptive Statistics of the Variables Under Study.

Variables	FDI Inflow	Energy Consumption	CO_2 Emissions	Economic Growth Rate
Mean	2.150	27.110	27775.882	0.079
Median	1.184	18.827	4080.686	0.066
Maximum	42.440	90.506	447980.000	3.052
Minimum	-10.775	0.000	187.017	-0.610
Standard Deviation	3.871	23.747	78452.973	0.210
Skewness	4.844	1.090	3.784	5.838
Kurtosis	39.524	0.389	13.848	75.376
JB	51906.62*	153.593*	7808.255*	182329.1*

Note: *p-value < 0.01, JB = Jarque-Bera test

2.3 Empirical Estimation

The descriptive statistics for the variables under study is shown in Table 2. From the result, we found that, the mean values for FDI inflow, energy consumption, CO_2 emissions and economic growth rate were 2.150, 27.110, 27775.882, and 0.079 respectively. Thus, the positive sign for the mean values of all the economic variables indicates an increasing trend in these variables over the study period. Again, the standard deviation values for all the variables are positive and above one except for the economic growth rate which is less than one. The most volatile variable is CO_2 emissions, followed by energy consumption, FDI inflow and lastly economic growth rate. Again, we found a positive skewness for all the variables while the kurtosis and the Jarque-Bera test for all the variables proved to follow a normal distribution at 1% significance level for the study period.

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2.4 ADF Root and Stationarity Test

The study employed the standard stationarity and unit root tests for instance the Augmented Dickey-Fuller (ADF) and the Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) test to evaluate the stationarity and unit root of the panel time series variables for accurate prediction in forecasting the quantile effects of the explanatory variables on the response variables. We found from Table 3 that, the null hypothesis of unit root was rejected at levels since all the values of the ADF test statistic for each variable were higher than the absolute values of the critical values at all levels of significance (1%, 5%, 10%) except for CO_2 emissions whose value is less than the critical values at 1% significance level. However, we fail to reject the null hypothesis of stationary in all cases for the KPSS test for all levels of significance at level except for CO_2 emissions which become stationary after first differencing. This demonstrates that, at the 1% levels of significance at level, the panel time series variables are fixed and unity, and as a result, the panel time series variables are integrated of order zero, except for CO_2 emissions variable which is integrated of order one.

Table 3 Augmented Dickey-Fuller (ADF) Unit Root and Stationarity Tests (Level and first difference).

Variables	Unit root test at Levels		Unit root test at first difference	
	ADF	KPSS	ADF	KPSS
FDI Inflow	-16.439	0.251		
Energy Consumption	-5.044	0.404		
CO_2 Emission	-3.304	1.087	-27.006	0.024
Economic Growth Rate	-26.306	0.104		

Note: Critical Values (1%, 5%, 10%): ADF (intercept) (-3.43, -2.86, -2.57) and KPSS (intercept) (0.74, 0.46, 0.35).

2.5 Estimation of the Panel Quantile Regression

Estimation of the Panel Quantile Regression models for Economic Growth Rate, Energy Consumption and CO_2 Emission. The study measures the parameters of the quantile regression estimates and check the plots of the point coefficients estimates for the various quantile as per each model. We employed the quantile regression models to estimate the point coefficients of the explanatory variables on the response variables for a range of quantiles from 0.01 to 0.99 as shown in Fig. 1, Fig. 2 and Fig. 3. We obtained the plots after estimating the quantile regression models in equations (1), (2) and (3). The plots display the quantile regression (QR) coefficients and ordinary least square (OLS) estimates for economic growth rate, energy consumption and CO_2 emissions. The range of quantiles are shown on the horizontal axis and the degree of the estimated coefficients shown on the vertical axis. The red solid and sprint lines respectively specify the estimated and regression coefficients of the OLS slope with their 95% levels of confidence. The shaded parts represent the estimated intercept and the regression coefficients of the quantile regression models along with their 95% levels of confidence. Alpha0(tau), alpha1(tau), alpha2(tau) and alpha3(tau) denote the coefficient estimates for the constant and the explanatory variables per each model respectively across quantiles. The advantage of the quantile regression (QR) model over the ordinary least squares (OLS) model is evident from the plots. The results for the estimated quantile coefficients for each model are shown in Table 4, Table 5 and Table 6.

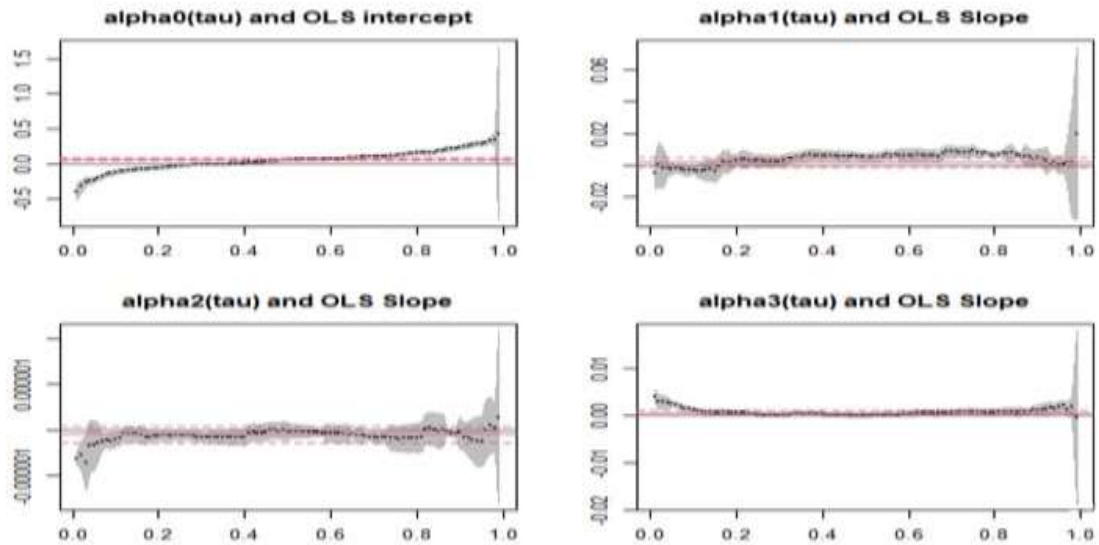

Figure 1. Model 1

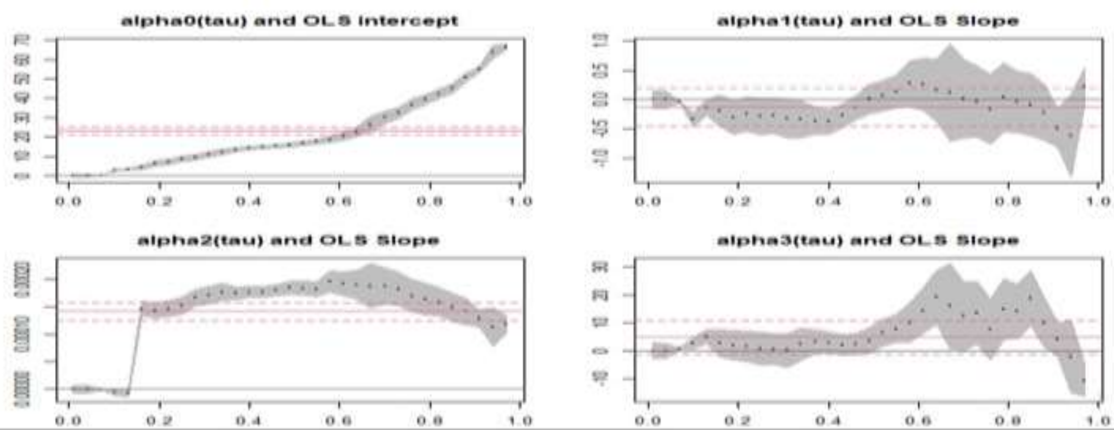

Figure 2. Model 2

The study found a dynamic result for the estimated regression parameters of the quantile regression models for all the respective explanatory variables at varied quantiles. From Table 4, we found that the effect of FDI inflow on economic growth is statistically significant at quantiles 0.1, 0.4 to 0.8 but not statistically significant at quantiles 0.2, 0.3 and 0.9 at 1% and 5% significance level. Again, the result suggests that, the effect of energy consumption on economic growth is statistically significant at quantiles 0.1, 0.2 and 0.7 at 1% and 5% significance level. Similarly, the effect of CO_2 emissions on economic growth is statistically significant at quantiles 0.1, to 0.3, and 0.7 at 5% and 10% significance level. Furthermore, the result established that, the coefficients for FDI inflow, energy consumption and CO_2 emissions are positive across all the specified quantiles except for quantile 0.1 for FDI inflow which is negative. Evidently, there exist an asymmetric relationship between economic growth and its explanatory variables (FDI inflow, energy consumption and CO_2 emissions) at diverse quantile levels in its restrictive distribution.

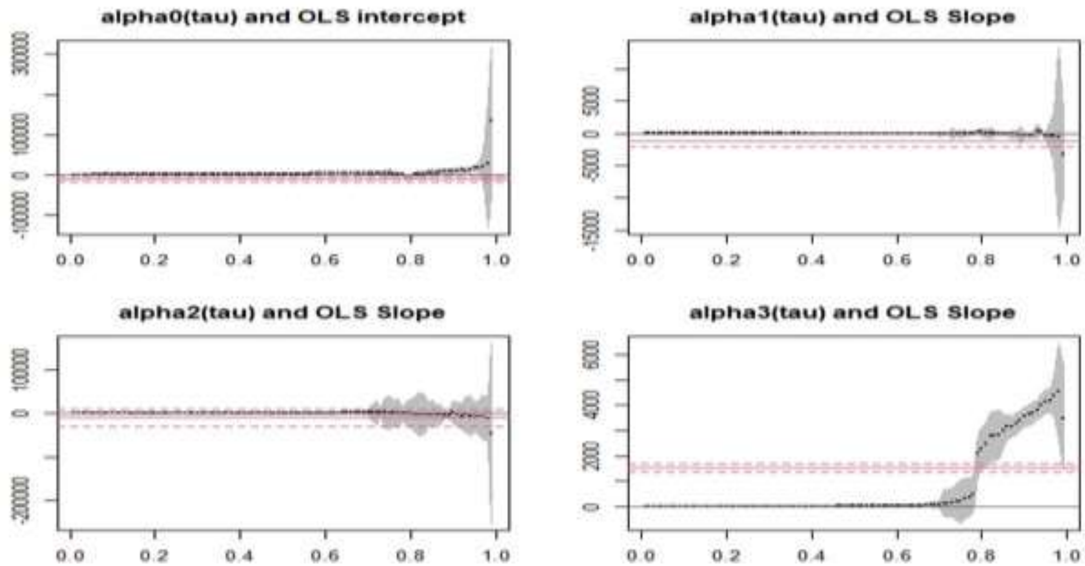

Figure 3. Model 3

Table 4: Quantile Regression Coefficient Estimation of Economic Growth Rate (Model 1)

Quantile (τ)	$\hat{\alpha}_0(\tau)$	FDI Inflow	Energy Consumption	CO_2 Emission
		$\hat{\alpha}_1(\tau)$	$\hat{\alpha}_2(\tau)$	$\hat{\alpha}_3(\tau)$
0.1	-0125*** (-6.654)	-0.004*** (-3.579)	0.001*** (4.505)	0.0001** (-2.122)
0.2	-0.057*** (-5.272)	0.003 (1.396)	0.001** (2.000)	0.0001** (-2.181)
0.3	-0.001 (-0.151)	0.002 (0.959)	0.0002 (0.804)	0.0001** (-2.588)
0.4	0.014 (1.526)	0.006** (2.877)	0.0003 (1.156)	0.0001 (-1.417)
0.5	0.055*** (5.457)	0.005*** (3.208)	0.0001 (0.071)	0.0001 (-0.168)
0.6	0.075*** (7.545)	0.006** (2.404)	0.0001 (1.099)	0.0001 (-0.597)
0.7	0.106*** (9.114)	0.008*** (3.559)	0.001** (2.063)	0.0001* (-1.897)
0.8	0.159*** (9.30)	0.006*** (4.954)	0.001 (1.390)	0.0001 (-0.910)
0.9	0.231*** (11.824)	0.005 (1.390)	0.001 (1.405)	0.0001 (-0.255)

Table 5 shows the quantile regression coefficients estimation for the effect of FDI inflow, economic growth and CO_2 emissions on energy consumption. The result revealed that, the effect of FDI inflow on energy consumption is statistically significant at quantiles 0.1 to 0.3 at 1% significance level. Also, the effect of economic growth on energy consumption is statistically significant at quantiles 0.7 and 0.8 at 10% significance level. However, the effect of CO_2 emissions on energy consumption is statically significant across all levels of quantiles at 1% significance level except for quantile 0.1 where it is statistically not significant. In addition, the estimated coefficients for both CO_2 emissions and economic growth are positive across all specified quantiles except for quantile 0.1 for CO_2 emissions. In the case of FDI inflow, only quantiles 0.5 to 0.7 were positive. The result evidently suggests that, there is an asymmetric relationship among energy consumption and the explanatory variables (FDI inflow, economic growth and CO_2 emissions) at diverse quantile levels in its restrictive distribution.

Table 5: Quantile Regression Coefficient Estimation of Energy Consumption (Model 2)

Quantile (τ)	$\hat{\alpha}_0(\tau)$	FDI Inflow	Economic Growth Rate	CO_2 Emission
		$\hat{\alpha}_1(\tau)$	$\hat{\alpha}_2(\tau)$	$\hat{\alpha}_3(\tau)$
0.1	2.846*** (3.611)	-0.340** (-2.409)	2.679 (0.652)	-0.0001 (-0.076)
0.2	6.668*** (7.505)	-0.328*** (-5.325)	1.847 (0.365)	0.0001*** (5.547)
0.3	10.552*** (12.596)	-0.307*** (-4.114)	0.480 (0.121)	0.0002*** (9.214)
0.4	14.281*** (20.404)	-0.383 (-1.593)	2.892 (0.710)	0.0002*** (15.654)
0.5	16.323*** (21.461)	0.042 (0.126)	4.493 (1.124)	0.0002*** (14.013)
0.6	19.801*** (12.543)	0.264 (0.874)	13.653 (1.636)	0.0002*** (10.792)
0.7	30.154*** (13.928)	0.014 (0.045)	12.482* (1.725)	0.0002*** (16.735)
0.8	40.439*** (20.677)	-0.029 (-0.089)	14.994* (1.866)	0.0002*** (29.882)
0.9	53.125*** (20.824)	-0.313 (-1.181)	5.965 (0.625)	0.0001*** (26.165)

The results for the quantile regression coefficients estimation for the effect of FDI inflow, economic growth and energy consumption on CO_2 emissions is displayed in Table 6. The result showed that, the effect of FDI inflow on CO_2 emissions is statistically significant at quantiles 0.1 to 0.3 at 1% and 5% significance level. Correspondingly, the effect of economic growth on CO_2 emissions is statistically not significant across all range of quantiles. However, the effect of energy consumption on CO_2 emissions is statically significant at quantiles 0.2 to 0.6, 0.8 and 0.9 at 1% and 5% significance level except for quantile 0.1 and 0.7 where it is statistically not significant. Moreover, the estimated coefficients for FDI inflow are positive at quantiles 0.1 to 0.5, and 0.8 but negative at 0.6, 0.7 and 0.9. The estimated coefficients for economic growth are negative at quantiles 0.1 to 0.5, and 0.8 but positive at quantiles 0.6, 0.7, and 0.9. In the case of energy consumption, all the estimated coefficients are positive across the range of quantiles except for quantile 0.1 which was negative. The result evidently suggests that, there is an asymmetric relationship among CO_2 emission and the explanatory variables (FDI inflow, economic growth and energy consumption) at diverse quantile levels in its restrictive distribution.

Table 6 Quantile Regression Coefficient Estimation of CO_2 Emissions (Model 3)

Quantile (τ)	$\hat{\alpha}_0(\tau)$	FDI Inflow	Economic Growth Rate	Energy Consumption
		$\hat{\alpha}_1(\tau)$	$\hat{\alpha}_2(\tau)$	$\hat{\alpha}_3(\tau)$
0.1	1285.247*** (9.562)	45.552*** (3.499)	-123.278 (-0.234)	-5.627 (-1.215)
0.2	1821.206*** (12.149)	23.418** (1.970)	-308.719 (-0.605)	14.463** (2.258)
0.3	2285.570*** (14.857)	24.676** (2.215)	-462.199 (-1.023)	16.150*** (3.635)
0.4	2875.858*** (15.003)	12.154 (0.506)	-396.784 (-0.564)	17.891** (2.364)
0.5	3271.961*** (14.710)	16.141 (0.817)	-140.261 (-0.147)	37.360*** (4.161)
0.6	4011.039*** (15.898)	-12.483 (-0.330)	378.849 (0.391)	44.729*** (3.046)
0.7	4279.746*** (3.867)	-0.0005 (0.0001)	2560.142 (0.939)	99.857 (1.157)
0.8	-3425.697 (-1.293)	190.623 (0.620)	-132.032 (-0.007)	2285.067*** (4.509)
0.9	9664.215** (2.510)	-145.914 (-0.535)	3054.720 (0.207)	3550.088*** (15.330)

Note: ***p-values<0.01, **p-values<0.05, *p-values<0.1. The t-values are in parenthesis ().

2. RESULTS AND DISCUSSION

From the results, it is evident that, there exist an asymmetric relationship between FDI, economic growth, energy consumption and carbon emission in the Sub-Saharan region. These findings on the interconnectedness of the variables according to the data gathered, are similar to early research done by Odugbesan & Adebayo (2020); Sreenu (2022) and Ghazouani (2021), whose work highlights on the asymmetrical relations that exist between the variables under study in developing countries. Based on the findings of this study we produce the following diagram to explain the interconnectedness of the research variables in SSA for the period of study.

3.1 The impact of Energy Consumption, CO_2 Emissions, and FDI on Economic Growth in SSA

This model was developed to measure how energy consumption, carbon emissions, and FDI impact economic growth in Sub-Saharan Africa and the individual relationships between the dependent and independent variables. We first measure whether FDI influences economic growth in SSA, then how energy consumption influences economic growth in SSA, and finally how carbon emissions influence economic growth in SSA. We found a strong relationship between the variables. In addition, in SSA, FDI influences economic growth, meaning an increase in FDI inflow will positively influence economic growth and vice versa. This finding is in line with research done by (Raza et al. 2021; Baiashvili & Gattini 2020; Adedoyin et al. 2020; Rao et al.

2020; Sirag et al. 2018; Asamoah et al. 2019). FDI has an impact on economic growth in OECD countries; data for the study ranges from 1996 to 2013.

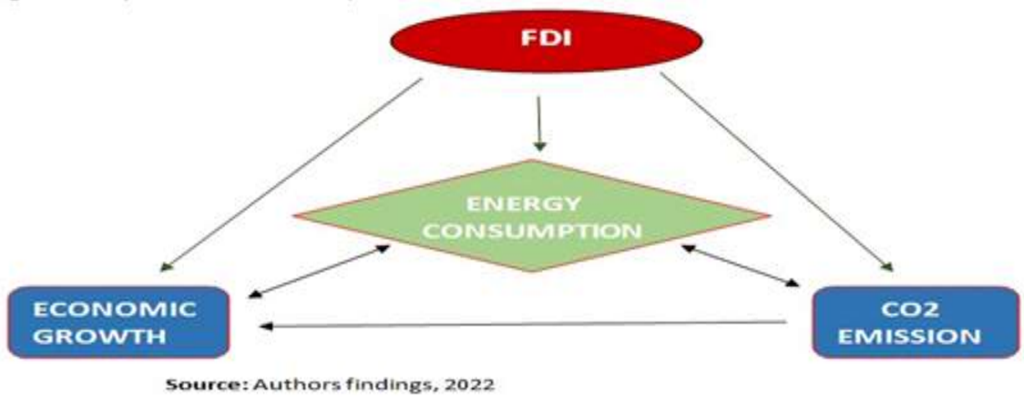

Figure 4. The asymmetric relationship between FDI, CE, EG and CO_2 Emission in SSA

There exists a strong relationship between energy consumption and economic growth in Sub-Saharan Africa. Seemingly, as energy consumption increases, economic growth also increases, and as it reduces, economic activity becomes stagnant. Although worrying, a lot of factors could account for this happening. It could be a rise in the standard of living, causing the populist to use more electronic devices. But this variable focused more on industrial energy consumption than domestic, which makes that point, although true, somewhat invalid. So far as this research is concerned, energy consumption by producers influences economic growth in Sub-Saharan Africa, and therefore, the more they consume, the greater the economic growth. Although Mutumba et al., 2021) found the relationship between energy consumption and economic growth to be inconclusive, these findings are in line with research done by researchers in this area (Siddique & Majeed 2015; Omri 2014; Gozgor et al. 2018; Waheed et al. 2019; Rao et al. 2020; and Rahman & Velayutham 2020) and therefore confirm the data from this study.

Finally, data analysis shows that in the Sub-Saharan Region, carbon emissions are linked with economic growth. This literally means that as carbon emissions increase, economic growth in the region also increases. Therefore, it implies that more carbon is emitted in the quest to increase economic growth. This finding brings to light that there are probably no strict laws in the region to put producers in line to use environmentally friendly forms of energy in the production of goods and services. This is because the region wants to attract as much FDI as possible, and therefore stricter laws may deter investors. This finding, although contrary to that of Sreenu, who contends that in India, increased economic growth would result in lower CO_2 emissions and decreased economic growth would result in higher CO_2 emissions, is in line with previous literature which argues that economies in their quest to increase production of goods and services increase carbon emissions (Y. Chen et al. 2019).

3.2 The impact of Energy Consumption, FDI, and Economic Growth on CO_2 Emissions in SSA

This model was developed to measure how energy consumption, economic growth, and FDI impact carbon emissions in SSA and the individual relationships between them. Firstly, we measure the relationship between carbon dioxide emissions and FDI in SSA and, secondly, how energy consumption influences carbon emissions in Sub-Saharan Africa. Findings indicate that FDI, to a large extent, contributes to the emissions of carbon in the SSA. Any attempt to increase the inflow of FDI augments the emissions of carbon of the region. This again brings to light that either laws are not adequate to check the operations of these MNCs or they are not being enforced in the region. The region is eager to alleviate poverty and create jobs and other opportunities for its citizens, and that might be causing them to compromise on environmental laws to protect the region from pollution and the degrading of the environment. Contrary to this finding, Blanco et al. (2013) and He et al. (2010) found no robust relationship between FDI and CO_2 emissions. However, He et al.'s research was done on the BRICS countries, and Blanco et al.'s work was also on Latin American countries. These research areas with their economic characteristics are different from those of Sub-Saharan Africa. Their finding, however disheartening, is in line with research done by (Bukhari et al. 2014; Omri et al. 2014; Blanco et al. 2013; and Odugbesan & Adebayo 2020). Odugbesan & Adebayo (2020) used yearly data spanning from 1981 to 2016 and by applying linear ARDL and non-linear ARDL approaches. The results of the estimations of Odugbesan and Adebayo indicate that in Nigeria, FDI and energy consumption have a long-run linear connection with CO_2.What, then, is the relationship between energy consumption and carbon emissions in the region? Data gathered and analysed shows that energy consumption impacts carbon emissions in Sub-Saharan Africa. Unabated, the energy sources in the region are not environmentally friendly and/or outmoded. This finding also throws light on the fact that Sub-Saharan economies are not using greener sources of energy. The energy sources available in these regions may be outmoded or the governments have simply not put measures and educational programs on the ground to educate the public on the adoption and usage of green energy. This finding is in line with research done by a lot of researchers in this area (P.-Y. Chen et al. 2016; Wang et al. 2018; and M. K. Khan et al. 2019) and therefore re-affirms the data gathered from SSA.

3.3 The effects of CO_2 Emissions, FDI, and Economic Growth on Energy Consumption in Sub-Saharan Africa

The final model for this paper was developed to measure how economic growth, carbon emissions, and FDI impact energy consumption in Sub-Saharan Africa and the individual relationships between the dependent and independent variables. We first measure whether FDI influences energy consumption in SSA, then how economic growth influences energy consumption in SSA, and finally how carbon emissions influence energy consumption in SSA. Although asymmetric, we found a strong relationship between the variables. We conclude from the data analysis that in Sub-Saharan Africa, FDI influences energy consumption. There is a need for governments in the region to build and enforce stricter rules to keep FDI operations in check. This finding indicates that the production processes of the MNC's in the region are not environmentally friendly. This could be "dumping" of old production processes and mechanisms that are being disallowed in developed countries or countries with stricter environmental laws. There are no doubt most developing countries need the revenue and the jobs that FDI creates, but in the quest to ensure their citizens have their "daily bread", keen interest should also be paid to processes that harm the environment. To this end, the findings of this study are in line with (Rafindadi et al. 2018; Halliru et al. 2020; Muhammad & Khan 2019; and Amoako & Insaidoo 2021).

Similarly, economic growth affects the energy consumption of the region. The growth of an economy is like a two-edged sword in that it exerts both negative and positive effects. While improving the standard of living of the residents, the environment is sometimes affected. Data from SSA shows that energy consumption in the region is increasing during the study period due to factors like economic growth. The regions need to start looking into cleaner forms of energy production and also use energy-saving gadgets. It is known that old air-conditioners and fridges are dumped on the African market day in and day out, and these appliances are part of our daily lives. If they are not energy-saving, then obviously they could contribute to the relationship between these two variables, but, again, this data has very little to do with domestic energy consumption. It is more likely that governments are not doing enough in the region to protect the environment. The government should put laws and related policies in place to keep energy consumption at its barest minimum and in areas where laws have already been enacted should be enforced. This finding is, however, similar to work done by (Aqeel & Butt, 2001; Chiou-Wei et al., 2008; Saidi & Hammami, 2015; Tang et al., 2016; Shahbaz et al., 2018; and Kahouli 2019).

Finally, carbon emissions influence energy consumption in Sub-Saharan Africa. The results of the data analysis are worrying when looking at the effect on the environment in the region. This finding also amplifies the fact that most of the energy production methods used in the region contaminate the environment. There is more to be done by rulers in this region if the future is of any importance. The fact is, the more these pollutants, the worse the quality of air, and this directly affects the mortality rates of its residents. This finding is in line with literature (Fei et al. 2011; Alshehry & Belloumi 2015) and adds to the fact that governments in developing countries have very few environmental laws in place or they are not being enforced. Fei et al. note that the economic growth in east China to a great extent is energy-dependent, and the income elasticity of energy consumption in east China is greater than in west China.

3. CONCLUSION

There is some literature pertaining to the interconnectedness of the study variables, although not as a whole as done in this work. Again, very little research has been done on African soil with respect to the variables under study. This research becomes important in that it throws light on the environmental factors determining the sub region and the causative factors. Even where researchers attempted, different models were employed to measure the relationship between these variables. By means of quantile regression models, we investigate the bond between FDI, energy consumption, economic growth, and carbon emissions in the sub-region of Africa. The variables employed in the work are used by Sreenu, choosing India as the case study, and Odugbesan & Adebayo, using Nigeria as the case study. Although different, this study infers from these studies because of the similarities between the study areas. We document conclusively that FDI influences economic growth in the region. The other highlights of this paper are that energy consumption as well as carbon emissions in the sub region are on the rise throughout the period of study and the causing factors are economic growth and FDI. The quest by the governments in the region to increase economic growth carries a lot of weight on the environment that hasn't caught the attention of the media and/or governments in the region. Economic growth in the region is impacted by FDI (Rao et al. 2020 and Raza et al. 2021), energy consumption (Rao et al. 2020 and Rahman & Velayutham 2020), and carbon emissions (Y. Chen et al. 2019). Most economies in the region seek to improve the living standards of their residents as well as increase the country's production of goods and services. This requires heavy investment, and therefore a lot of pressure comes on the governments in the region to make their markets conducive enough to attract foreign investment. The problem, however, arises as these foreign investors, knowing very well how needy these countries are, decide to cut corners, and sometimes in doing so, the environment suffers in the long run. Again, because very little attention is given to the environment in the region because of its vast forest reserves, governments don't feel the need to put environmental laws in place to check the operations of multinational corporations, and even where these laws exist, very little is done to enforce them.

FDI contributes enormously to economic growth in the region, but how it also contributes greatly to energy consumption and carbon emissions is very alarming. This, if left unchecked, will affect the air quality and harsh weather conditions as summer or harmattan becomes hotter and drier and the dreadful rainy seasons. In the long run, these will affect mortality rates (Sinha 2014; Rasoulinezhad et al. 2020; Shobande 2020) and food supply (Surahman et al., 2018) in the region. We therefore recommend that governments as soon as possible put stricter laws in place to protect the environment. This could be done collectively as a region to ensure that no economy has an "advantage" over another. Also, the environmental protection agencies in the region should be well equipped to do their jobs as the constitution requires. We also admonish the governments to put punitive measures in place to deter corporations from cutting corners. Finally, more education should be given on using environmentally friendly forms of energy like solar systems and hydroelectricity. Business organisations should also be encouraged to use greener and energy-saving processes for their production. This we believe in the long-run will help reduce the carbon emission as well as the energy consumption in the region as well as keeping economic growth on the rise.

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