SUNTEXT REVIEWS

SunText Review of Economics & Business
ISSN: 2766-4775

Open Access
Research Article
Volume 4:4

The Relationship between CO_2 Emission and Foreign Direct Investment

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Received date: 29 November 2023; **Accepted date:** 08 December 2023; **Published date:** 12 December 2023

Citation: Turay A, Seraj M, Ozdeser H (2023) The Relationship between CO2 Emission and Foreign Direct Investment. SunText Rev Econ Bus 4(4): 198.

DOI: https://doi.org/10.51737/2766-4775.2023.098

Abstract

This study uses yearly time series data from 1980-2020 and employ the Nonlinear Autoregressive distributed Lag model by Shin et al (2014) to check the asymmetric effect of the independent variables on the dependent variable ($C0_2$). In order to support the environmental Kuznet curve and pollution haven hypotheses in Sierra Leone, this study analyzes the link between CO_2 emissions, urban population growth, energy consumption, and foreign direct investment. The result from the ADF test shows that Energy consumption, Economic growth and urban population growth are integrated at level (I (0)) at 1% level of significance for both EC and GDP and at 5% significance level for UPG. FDI and CO_2 are integrated at first difference at 1% significant level. The NARDL bound test by Shin verify the existence of long run cointegrating relationship among the variables this study supports the pollution haven hypothesis in Sierra Leone, as both positive and negative shocks in FDI reduces the effect of CO_2 emission in the short run. This is in corroboration with strict laws and regulations impose by the government and also encourage foreign and domestics firms to import sophisticated plant and machinery, ban on the importation of used cars more than 5 years and other carbon emission prone machine and other equipment with high environmental degradation propensity. Both positive and negative shocks on urban population growth contribute significantly in reducing CO_2 emission in Sierra Leone. An increasing in urban population decreases the use of using traditional meaning of cooking practices in most rural communities. The result of this study supports the Environmental Kuznets curve and pollution haven hypotheses in Sierra Leone. This study shows that both increase and decrease changes in GDP reduces $C0_2$ emissions, also both positive and negative change in FDI reduces Carbon dioxide emissions in the short run. The error correction term (ECT) shows a high speed of adjustment (103%) in correcting any disequilibrium in the long run. The findings of this study recommend that the central government continue to institute laws that will encourage green environmental practices and in turn protect the environment from future depletion. The approved FDI inflows in Sierra Leone must be well coordinated and restricted to a productive and innovative technological imprint which support FDI, Urbanization, clean energy consumption and a significant growth in the economy. To address the issues of environmental sustainability, polies that aim at combating the negative effect of climate change should be induce.

Keywords: Sierra Leone; Economic growth; Non-linear ARDL; Foreign direct investment; CO_2 emissions

Introduction

It has become a global concern to reduce global warming which pose a global threat to all living thing including humans. In response to global outcry for GHG emission, the United Nations Framework Convention on Climate Change (UNFCCC) entered into an agreement in Paris climate conference to develop a new worldwide climate change response system to replace the Kyoto Protocol. The Kyoto Protocol either prohibited or restricted developing nations from responsibilities or allowing them to choose the degree of assistance they get decrease voluntarily both emerging and developed countries performed poorly in comparison GHG emissions must be reduced despite the fact that the degree to which industrialized countries, the rate of Reduction of greenhouse gas emissions is vastly higher. As a result, determining whether foreign direct investments (FDI) operate as a foreign migration channel for high-GHG-emitting companies is a critical problem in the global economy. However, no comprehensive empirical studies

on this topic have yet been done. As a result, the current study investigates whether FDI inflows into developing nations boost their GHG emissions. Furthermore, it is empirical that this study examines the problem using a model that focuses on understanding linkages between carbon dioxide (CO2) emissions, energy consumption, GDP, and foreign direct investment (FDI) in Sierra Leone. There is a near connection among monetary improvement and power intake. It is predicted that power intake contributes to the build-up of greenhouse gases. A predicted 75% of all CO2 emissions also are resulting from the industrialized nations. Achieving a huge variety of monetary projection, it is able to additionally cause the disturbance of human, plant and animal habitat and make contributions to environmental improvement. Quality via extensive and green pollutants abatement methods population size [1,2]. Growing gas emissions in additional advance industrialize nations have exacerbates excusable interest regarding the connection between a rise in growth objectives and climate change. Climate change isn't equally distributed. The results of global climate change are felt by completely different groups, equivalent to the poor and also the rich people. The foremost vulnerable countries are people who are most littered with the effects of rising ocean levels and other factors such as food production and ecosystems. Less developed countries, on the opposite end, are susceptible to the effects of climate change thanks to their low capability to develop and implement effective acclimatizing strategies. These countries got to shoulder the value of promoting and adopting different mitigation strategies. To accelerate economic growth and eliminate poverty, emerging countries must invest in industrial development and raise living standards.

GHG emissions are growing as a result, causing substantial changes in the climate. There are several aspects to environmental quality. Climate, precipitation, and soil nutrients all have an influence on the efficiency of our resources in the creation of products and services. The most significant source of global warming is greenhouse gas (GHG), which is totally influenced by human activity. The CO2 gas emitted by the usage of fossil fuels. One of most vital reason is basically attributed to the growing quantity of demand and supply, at the side of the quantity of energy needed in production, is taken into account as one of the most important factors for the degree of rise in CO2 emissions. Foreign direct investment, in particular, will have a control on the CO2 emissions levels of countries concerned within the economic internationalization. Global greenhouse gas emissions from energy combustion and commercial processes increased to its greatest yearly level ever in 2021. A 6% rise from 2020 increased emissions to 32.4 gigatons (Gt), according to the IEA's detailed region-by-region and fuel-by-fuel study, which drew on the most recent official national knowledge as well as publicly available competitive energy, economic, and meteorological data. The Covid-19 epidemic had a significant influence on energy demand in 2020, lowering global CO2 emissions by 5.2%. However, the world has had a rapid economic rebound since then, fuelled by enormous commercial and financial stimulus and a rapid – if unequal – roll-out of vaccinations. The energy sector accounts for almost two 2⁄3 of GHG emissions, and the costs of mitigation is predicted to be USD 50-170 billion by 2030, with poor nations bearing half of the cost. UN Environment Programme (2011). Anthropogenic impacts are a significant source of carbon dioxide emissions in forestry. The forestry industry contributes significantly to GHG emissions, but it also has a large remediation capability that exceeds the predicted rise in greenhouse gases by 2030. Ethiopian forestry emissions are driven by agricultural degradation. Compost GHG emissions in Sierra Leone are large, with three major sources: the use of artificial fertilizers, the application of manure to fields, and the reintroduction of agricultural wastes into the soil. (UNDP, 2011). The restoration of power demand in 2021 became exacerbated by poor climatic and electrical market circumstances, which resulted in more coal being burned despite renewable energy generation posting its highest ever yearly increase. Majority of the country's rural population lived on deprived arable land in 2010, up 68 percent in ten years period, pushing the proportion of rural inhabitants living on deplorable agricultural land to 17 percent of the entire rural populace in 2020 (Ministry of Agriculture rural population report). Environmental degradation may have a significant impact on people's livelihoods by denying them access to essential ecosystem services (such as food and water), raising the likelihood of impoverishment. Between 2010 and 2020, the number of individuals living in isolated deteriorating farming region that encountered restricted urban market penetration rose by 58%, reaching 82 thousand people. Remote populations have limited alternatives for the control rural property and taking advantage of other socioeconomic possibilities.

In Sierra Leone, only around ten percent to twelve percent of the urban population and about two percent of the rural population can boast of electricity access. Since most locations lack an adequate and efficient public power source, gasoline or diesel generators are frequently used. Lighting is mostly provided by kerosene, battery lights, or candles. 95.3 percent of the population cook using firewood or charcoal. Reusable energy, particularly solar energy and hydroelectric power, has enormous potential. The country's energy statistics are difficult to get, particularly for sustainable energy. Despite traditional thermal energy consumption and production trends have been published, there is no integrated collection of information for Sierra Leone's overall power status. This is also mirrored in international reports, such as IRENA's "Renewable Energy Statistics 2017" report, which claims that Sierra Leone's solar power capacity is 0MW. Greenhouse gases, widely considered a serious ecological challenge facing mankind,

is as a result of the use of fossil fuels to fulfil energy demands. As the usage of fossil hydrocarbons, gasoline, and coal increases, the quantity of atmospheric carbon dioxide grows, causing rising temperatures (IPCC, 2008). Carbon dioxide is the most important gas emitted by human activity, contributing significantly to global warming [3]. During the last two decades, researchers have focused on environmental deterioration, global warming and climate change. Global warming is causing sea levels to rise, altering precipitation and snow patterns, ice melting, extreme weather events, and diseases. The United Nations Framework Convention on Climate Change (UNFCCC), signed in 1994, and the Kyoto Protocol (KP), enacted in 2005, are the most significant legislative rules to address this environmental catastrophe (IPPC, 2008). In this framework, countries must meet their obligations to address climate change and decrease GHG emissions. Advanced economies begin to concentrate in green industry goods. These countries essentially shipping their pollutants to these emerging nations. This really is the less optimistic scenario, as it implies that relatively clean ecosystems in wealthy nations come at the price of deteriorating conditions in poorer nations. (Brian, 2007), because least developing nations adopt the production mechanism of developed nations in increase Co2 emission. Fragile socio-economic development has exacerbated air pollution by increasing reliance on aging cars and polluting fuels. Vehicles must be inspected on a regular basis in several nations, especially industrialized ones, to ensure that those that do not meet the minimum requirements are removed. Old, hazardous automobiles that are no longer usable in those nations are occasionally transported to developing countries, especially Sierra Leone with weak regulatory and monitoring mechanism.

According to research, finance spent by develop nations in achieving clean energy posed a dared consequences for third world countries by suing developing countries as a dumping site for unwanted automobile with higher emission of GHG. (2009 African Review Report). Corporations that generate goods and services utilizing economic resources such as resources and energy, with some of the input utilized in the production process returning to the ecosystem as wastage. Exhaust fumes, co2, hydrogen sulphide, sewage sludge, and wastewater are examples of impurities that cause pollution or impose indirect cost to society [4]. Energy is seen as a propelling element for economic progress, as well as an increase in the quality of life, because any economic activity necessitates it. A report by the World Resources Institute Climate Analysis Indicators Tool (WRI CAIT), the land-use change and forestry (LUCF) sector make up a majority of Sierra Leone's 2019 GHG emissions, accounting for 51.3 percent of the country's overall emissions. Modifications in forest cover provided 95 percent of the industry's emissions in the LUCF sector. Agriculture was the second-largest source of emissions (25.7%), with rice cultivation and animal enteric fermenting accounting for 58 percent of annual emissions. Waste and industrialized procedures (IP) accounted for 21.0 percent and 2.0 percent, respectively, of the overall emissions. Sierra Leone has developed a draft of its energy policy strategy for national comment. It entails steps that will allow for primarily domestic emission reductions by 2035. The recommended actions to meet the pledges will expand on current policies and initiatives. By 2030, business as usual (BAU) emissions are expected to reach 6.6 MtCO2e. This does not include upstream resource extraction activity. Sierra Leone has over 20 hydro potential locations, with the Bumbuna Dam having effectively exploited. The Bumbuna dam, which has been completed, has a 70megawatt capacity. For the power industry, this was deemed the most practical mitigation strategy. If five of these hydro potentials, including Bumbuna, are used, the electrical industry might produce nearly no emission. The construction industry, which has a gross reduction capability of 1.2 Mt CO2e, accounts for the great bulk of emission increase and remediation possibilities. In addition, greater use of efficient biomass (e.g., agro residues), energy conservation technologies, and combined heat and power are among the primary mitigating mechanisms highlighted by the cement industry. (UNDP, 2011). Carbon dioxide emission is thought to be the primary cause of global warming. Significant amount of the greenhouse gas content is due to CO2 concentrations in the atmosphere. As a result, in modern environment of fast economic growth, it is critical for academics to discover the relationship with relation to carbon dioxide emissions (Sakib bin et al). This study is subdivided in to five sections, Section 1 captures the introduction of the study and the Sierra Leone economy, section 2 provides reviews on the related literatures examine in this study. Section 3 comprises of data and methodology, section 4 empirical and analysis of result and finally section 5 discusses summary and policy recommendation.

Literature Review

There has been considerate amount of literature which has been explore by researchers and various conclusion has been reached in understanding the relationship linking economic growth, energy consumption, C02 emissions and foreign direct investment. Most of these studies have been largely linked to the understanding and predictability of the Environmental Kuznets Curve. The literatures that are review in this study can be discuss in three folds. The Environmental Kuznets Curve Hypothesis is a graphical representation which shows an initial pollution and environmental damage may surpassed the level of income per Capita as countries developed. However, the trend might reverse and there may exist the possibility to decouple the impact of growth on the environment i.e., growth can lead to environmental upgrade and eventual fall in per capita emission per dollar of national output.

The Environmental Kuznets Curve Hypothesis

The Kuznets (1955) developed a hypothesis that is downward U-shape which at its early stage of development shows the relationship between C02 emissions and Income per capita. However, latter studies have incorporated FDI, Energy consumption etc., in explaining the linkage of the above-mentioned variables in society. The Second fold will seek to explore the correlation of causality among energy usage and economic growth. The literature will examine three hypotheses of this nexus.

1. Growth Hypothesis: The growth hypothesis explicitly explains there exist a unilateral causal relationship from energy consumption to income growth i.e., energy consumption granger causes economic growth.
2. Feedback Hypothesis: The notion of this hypothesis is an existence of a bilateral causal relationship linking energy usage and income growth. Hence, any change in both variables will have a corresponding effect in both variables.
3. Neutrality Hypothesis: This hypothesis indicates a no causal relationship in both variables. By implication policies on energy of countries does impact growth insignificantly (Apergies Payne 2009)

The third fold focuses on foreign trade and pollution. Previous research has shown that the effect of FDI on the environment is significant. This literature will focus on the Pollution Haven hypothesis. As stated by Eskeland and Harrison (1997), an increase in global environmental awareness causes nations to work towards enhancing energy regulatory legislations and policies by imposing punitive sanctions and penalties. The reality of advance economies putting measures in place leads to dirty investment fleeing from rich countries to developing nations. Poor Economies, on the other hand, have a tendency to gloss over environmental issues due to weak environmental laws. They liberate themselves from the cost of management and monitoring these rules and also attract profit driven firms looking to avoid cost regulatory compliance in their countries. The pollution effect, on the other hand implies an increase in FDI improves the quality of the environment in poorer nations by the advancement of sophisticated technology and better management [5]. International businesses that engage in foreign trade have a proclivity to transmit their green energy and environmentally friendly materials to the receiving country, while the receiving country can reduce carbon emissions through leaving and copying effect.

Theoretical Literature

Using yearly data for their calculation for the years 1980–2005, investigates the long-term link amongst energy utilization and GDP for 19 Common Market for Eastern and Southern Africa (COMESA) nations. All data set are integrated at first difference, according to the panel stationarity test, and the data set are cointegrated as determined by the panel cointegration test. For the high-income COMESA nations, the outcome of their panel error correction model demonstrates a cointegrating bidirectional link between GDP and energy demand as well as the direction of the causation stream from energy consumption to GDP. In a Vector Auto Regressive (VAR) paradigm, Tiwari A viral Kumar (2011) investigates both the steady and dynamic causation between energy consumption, CO2 emissions, and economic development in India. Their research also demonstrates that while energy usage has a good influence on Emissions of co2, it has a deleterious effect on India's population and economic growth. The Environmental Kuznets Curve Hypothesis is used by in their study to examine the relationship between CO2 emissions and economic growth for a list of industrialized nations, including Austria, Belgium, Canada, Chile, Denmark, France, Ireland, Japan, Korea Republic, and the United States [6]. Inverse Kuznets Curve-shaped nonlinear growth on CO2 emissions was found in these nations between 2000 and 2007 according to their estimation results. The outcome also shows that GDP has a negative impact on CO2 emissions before the anticipated threshold but has a positive impact on CO2 emissions after the calculated threshold. Their study effectively disproves the Kuznets curve Hypothesis in these nations. Sharif Hossain in his paper evaluate the dynamic causal relationship between Carbon dioxide emissions, energy consumption, economic growth, foreign trade and urbanization by employing time series data from the period 1960-2009 [7]. The result From the ARDL estimation procedure and granger causality test shows a short run unidirectional causality can be seen from energy consumption and trade openness to carbon dioxide emissions, from trade openness to energy consumption, from carbon dioxide emissions to economic growth and from economic growth to trade openness. The result from the long run bound test reveals the existence of long run relationship among the variables. Jonathan P. Danladi and Kehinde John Akonolafe use the Granger causality test to investigate the veracity of the claims that environmental degradation lowers economic development and foreign direct investment [8]. Additionally, their research looks at the relationship between FDI and pollution, economic expansion, and pollution. The results of their investigation demonstrate that there is no causal relationship between GDP growth rate and FDI or GDP growth rate and CO2, however there is a one-way causal relationship with FDI expansion rate and pollution rate of increase in Nigeria. Uses the research span of 1965–2010 to examine the causative link between GDP, energy consumption, and CO2 emissions in Hong Kong. The results of the Granger causality test and the VAR model show that there is a unidirectional causal relationship between CO2 emissions and GDP in Hong Kong as well as between CO2 emissions and energy consumption. It was also discovered that there is a causative relationship between GDP and energy use that is two-way.

Between 1960 and 2009, evaluated the causation between energy consumption, economic growth, and CO2 emissions in three

different Southern European countries: Portugal, Spain, and Greece. Both the panel causality test and the panel cointegration estimation approach are used in their study [9]. The FMOLS and DOLS are also used in their study to forecast the long-term link between the variables. The findings also suggested a short-term bidirectional causal link between the variables under study. Additionally, it demonstrates that there is a long-term linear causation relationship between CO2 emissions and energy utilization and economic development as well as a bidirectional causal relationship between these two variables. Cuma Bozkurt and Yusif Akan use yearly time series data from 1960 to 2010 to evaluate the relationship between economic growth, CO2 emissions, and energy consumption in Turkey [10]. They tested for cointegration by using the maximum likelihood (ML) method developed by Johansen (1988) and Johansen and Juselius (1990). The empirical finding demonstrates that CO2 emissions have an adverse effect on economic growth whereas energy use has a favourable impact. The dynamic link between carbon dioxide emissions, energy use, economic growth, and FDI in Vietnam from 1980 to 2010 was explored by Dinh L. Linh and Shin-mo Lin [11]. The environmental Kuznets curve Hypothesis forms the basis of the investigation. The cointegration test and the granger causality test are used to analyze the direction of the relationships between the variables. Their research refutes the EKC theory in Vietnam. But the Granger causality test's findings reveal a dynamic connection among CO2 emissions, energy use, FDI, and economic development. Their data also indicate a reciprocal association between income and FDI inflow, which supports the idea that rising GDP will act as a springboard for attracting foreign capital. Study the nonlinear causal connection between CO2 emissions, energy consumption, economic development, and foreign direct investment in the most populous Asian nations [12]. The findings prove the pollution haven hypothesis, according to which less stringent environmental restrictions in the countries of origin have drawn FDI inflows, as well as the prevalence of both short- and long-run causal relationships among the variables. Eleazar Zerbo used the ARDL bound test by Peseran, Shin, and Smith in his analysis and understanding of the complex connection between CO2 emissions, economic expansion, energy demand, and FDI in a list of African countries, including Botswana, Cameroon, Gabon, Ivory coast, Kenya, Senegal, Togo, and South Africa (2001) [13]. According to the analysis's outcomes, energy use has a short-term beneficial impact on CO2 emissions in Botswana, Kenya, South Africa, and Togo. While commercial openness is important for South Africa, it has little impact on Kenya's efforts to enhance quality of the environment. Aassesses whether the GCC nations of Bahrain, Saudi Arabia, Kuwait, and Oman have a variance decomposition of their GDP per capita, FDI inflows, and imports [14]. His research uses 256 observations from the years 2000 to 2010 to estimate using the Vector Error Correction Model (VECM). The estimation's findings indicate that foreign direct investment inflows significantly affect GDP. Additionally, the results show that an increase in CO2 emissions in the atmosphere is strongly correlated with FDI and the import of goods, both of which the GCC states have failed to recognize as having a harmful effect on the environment.

In their 2019 study, Alfred A. Haug and Meltem Ucal examine the impact of trade and FDI on CO2 emissions in Turkey [15]. When analyzing the asymmetric impact on exports, imports, and FDI Co2 emissions per capita, they use both the ARDL and NARDL Models. The outcome indicates that there is an asymetric influence of exports, imports, and FDI on CO2 per capita emissions. The results also show that while an increase in exports does not have a statistically significant impact, an expansion in imports results in an increase in CO2 emissions over the long term. Additionally, the outcome supports the environmental kuznet curve theory in the context of turkey. According to Nigeria's carbon emissions are decreased by the GDP, trade integration, FDI inflows, GDI, and capital [16]. Their analysis uses improved Vector Auto Regressive estimation from 1980 to 2018 and ARDL bound testing. The results of the bound testing support the presence of a long-term link between the variables. The projected outcome also demonstrates that a rise in Nigeria's GDP, capital, and FDI inflows is statistically significant in lowering carbon dioxide emissions. The causality test shows a two-way causal relationship between CO2 emissions and FDI inflows, but only a one-way relationship between capital and CO2 emissions. Based on the EKC hypothesis and the pollution haven hypothesis, explore the relationship between sustainable energy, energy consumption, and CO2 emissions in BRICS countries [17]. Their study adopts the method of moment's quantiles regression (MMQR) estimation approach. The empirical research' findings support the EKC theory for the BRICS countries. The outcome further shows that the coefficient for the consumption of regenerative energy is negative through all quantiles (1st to 9th) for the emissions of CO2, suggesting that regenerative energy and financial inclusion are effective ways to reduce CO2 emissions. Investigate the impact of FDI, tourism, energy consumption and economic development on Co2 emissions in Bangladesh between 1980-2019 [18]. The study employs the error correction model and the granger causality test. Their findings indicate FDI, energy consumption and economic development have significant and positive long-term effect on Co2 emissions. Tourism produces a long-term negative effect. Conclusively, their result show that the nexus between economic growth and Co2 emission is U-shape which support the EKC hypothesis in Bangladesh.

Data and Methodology

This study employs secondary data for all the variables used. Data for this study are source from World Bank data bank (WDI), IMF data log, Statistics Sierra Leone (SSL), Environmental Protection

and Climate change secretariat Sierra Leone, Ministry of Finance and Economic Planning Sierra Leone, and the Bank of Sierra Leone.

Unit root

Stationarity is essential for examining time series data. A time series is considered to be stationary if its mean and variance do not change over time. To evaluate the stationarity characteristics of the data consumption, many scientific estimating techniques like ADF and PP are frequently used. As a result, most scientific articles typically employ the ADF test and PP test to check for stationarity. The simplest case of unit root testing conducted on Autoregressive process is

$$Y_t = kY_{t-1} + \varepsilon_t \qquad (1)$$

Where Y_t represent time series, $Y_{(t-1)}$, for the value of $Y_{(t-1)}$ delayed (time), k represent the coefficient and ε_t symbolized the stochastic term. Stationarity is present in the series if k<1 i.e., no unit root present. It is however non-stationary if k=1 (unit root). The aforementioned unit root validation is commonly referred to as the ADF test, that may also express by deducing $Y_{(t-1)}$ from both the left and right hand said of the autoregressive equation.

$$\Delta Y_t = (k-1)Y_t + \varepsilon_t \qquad (2)$$

Let δ=k-1 then equation 2 can be written as

$$\Delta Y_t = \delta \cdot Y_{t-1} + \varepsilon_t \qquad (3)$$

Where δ<0 and δ>0 are the criteria for stationarity and non-stationarity. The ADF test, however, will just be applicable to autoregressive processes. The ADF test, which allow for P-lagged values of Y_t as well as the inclusion of a constant and a linearization trend, should be employ if AR procedure is required as stated as follows

$$\Delta Y_t = \alpha + \beta \cdot t + \delta \cdot Y_{t-1} + \sum_{j=1}^{p} (\emptyset_j \Delta Y_{t-j}) + \varepsilon_t \qquad (4)$$

The stability value, the linear time trend coefficient and the autoregressive sequence of lags are each define as α, β and P in the above equation. The series is a random process involving no drift when both α and β equal to zero (0) and it is a random process when just β=0. Accordingly, the null hypothesis of the ADF test states Y_t is not stationary therefore has a unit root. The series is stationary and Y_t does not have a unit root, according to the opposing argument (alternative hypothesis). To check for stationarity, the ADF test statistics is evaluated at an associated significant threshold, with the decision rule state that, if the test statistics absolute value is less than the critical value, the null hypothesis cannot be rejected.

Cointegration and NARDL model

In the presence of stationary linear combination or the existence of long-term nexus between variables, such is relationship is referred to as cointegration. Conventional techniques like Engle-Granger or Johansen are widely used in assessing if the variables have long run association. However, Maximum-Likelihood Johansen technique and Engle-Granger approach may lead to the presentation of inaccurate result with respect to the long run relationship between variables integrated at either level or first difference. To combat the above-mentioned problem of spurious cointegration result Pesaran and Shin suggested the Autoregressive Distributed Lag (ARDL) approach which provide reliable and trustworthy estimate results irrespective of the order of integration of the variables I (0) or I (1) respectively. When evaluating time series data, the ARDL model consist of two parts: both AR (auto regressive) lagged values of the explained variable and the DL (distributed Lag) of the exogeneous variables, having lag can be an influence on the current value of the regressors.

The basic form of the ARDL model is written below

$$Y_t = \alpha_0 + \beta_1 + \alpha_1 \cdot Y_{t-1} + \beta_0 \cdot X_t + \beta_1 \cdot X_{t-1} + \varepsilon_t \qquad (5)$$

An Autoregressive distributed lag framework demonstrates that the lag order for both explanatory and explained variables is 1.

Given such a scenario, the coefficients of X regression cointegration equation is written as follows

$$K = \frac{\beta_0 + \beta_1}{1 - \alpha_1}$$

The error correction model of the Autoregressive Distributed lag can be written as

$$\Delta Y_t = \alpha_0 + (\alpha_0 - 1) \cdot (Y_{t-1} - k \cdot X_{t-1}) + \beta_0 \cdot \Delta X_{t-1} + \varepsilon_t \qquad (6)$$

The convention form of the ARDL model that comprises of one regression (Y) and multiple regressors $X_1, X_2, X_3, , , , , , X_n$ can be written as ARDL $(P_0, P_1, P_2, P_3, , , , , , P_n)$ as P_0 represent the order of lag Y and P_1 - P_n represent the lags of X_1-X_n respectively. Hence equation 6 can be written as

$$Y_t = \alpha + \sum_{i=1}^{P0} (\beta_{0,i} \cdot Y_{t-i}) + \sum_{j=0}^{P1} (\beta_{1,j} \cdot X_{1,t-j}) + \sum_{k=0}^{P2} (\beta_{2,k} \cdot X_{2,t-k}) + \sum_{l=0}^{P3} (\beta_{3,l} \cdot X_{3,t-1}) + \cdots + \sum_{m=0}^{Pn} (\beta_{n,m} \cdot X_{n,t-m}) + \varepsilon_t \qquad (7)$$

The primary stage in employing the ARDL model is by employing the ARDL bound testing approach to test if the variables are cointegrated. The unrestricted error correction model equation of the ARDL is illustrated below.

$$\Delta Y_t = \alpha + \sum_{i=1}^{P0} (\beta_{o,i} \cdot \Delta Y_{t-i}) + \sum_{j=0}^{P1} (\beta_{1,j} \cdot \Delta X_{1,t-j}) + \sum_{k=o}^{P2} (\beta_{2,k} \cdot \Delta X_{2,t-k}) + \sum_{l=0}^{P3} (\beta_{3,l} \cdot \Delta X_{3,t-l}) + \cdots + \sum_{m=0}^{Pn} (\beta_{n,m} \cdot \Delta X_{n,t-m}) + \lambda_0 \cdot Y_{t-1} + \lambda_1 \cdot X_{1,t-1} + \lambda_2 \cdot X_{2,t-i} + \lambda_3 \cdot X_{3,t-1} + \cdots + \lambda_n \cdot X_{n,t-1} + \varepsilon_t \qquad (8)$$

To verify the existence of cointegration, the hypothesis is tested:

The null hypothesis $H_0: \lambda_0 = \lambda_1 = \lambda_2 = \lambda_3 \ldots = \lambda_n$ which represent no long run relationship against the alternative hypothesis $H_1: \lambda_o \neq \lambda_1 \neq \lambda_2 \neq \lambda_3 \ldots \neq \lambda_n$ (presence of long run relationship. The decision rule state that if the F-statistics is greater than the upper bound critical value at the conventional level of significance we reject the null hypothesis as against the alternative hypothesis. Alternatively, if the F-statistics is lower than the I (0) (lower bound) we fail to reject the null hypothesis. When the status of cointegration among the variables have been attain, we perform various diagnostic test to validate the robustness of the model. Irrespective of the verserlity of the ARDL model in incorporating both I (0) and I (1) order of integration of the variables, it also possess other unique advantages over other estimating procedures. To begin with, the ARDL model have the ability to produce statistically significant result using a small simple size. The ARDL cointegration technique allows for different order of lags in the variables, while other cointegrations estimation procedures require the same lag order. The ARDL model uses only one equation of OLS estimation technique instead of different types of equations using in other models. Because of the unique characteristics of the ARDL model we employ the NARDL model to check the effect of asymmetry of the independent variables on the dependent variables. Under the conditional error correction framework display below

$$\begin{aligned}\Delta CO2_t = \alpha + \sum_{i=1}^{P0}(\beta_{0,j} \cdot \Delta CO2_{t-i}) + \sum_{j=0}^{P_1^+}(\beta_{1,j}^+ \cdot \Delta FDI_{t-j}^+) + \sum_{j=o}^{P_1^-}(\beta_{1,j}^- \\ \cdot \Delta FDI_{t-j}^-) + \sum_{k=o}^{P_2^+}(\beta_{2,k}^+ \cdot \Delta GDP_{t-k}^+) + \sum_{k=o}^{P_2^-}(\beta_{2,k}^- \\ \cdot \Delta GDP_{t-k}^-) + \sum_{l=0}^{P_3^+}(\beta_{3,l}^+ \cdot \Delta EC_{t-l}^+) + \sum_{l=0}^{P_3^-}(\beta_{3,l}^- \\ \cdot \Delta EC_{t-l}^-) + \sum_{m=0}^{P_4^+}(\beta_{4,m}^+ \cdot \Delta UPG_{t-m}^+) + \sum_{m=0}^{P_4^-}(\beta_{4,m}^- \\ \cdot \Delta UPG_{t-m}^-) + \lambda_0 \cdot CO2_{t-1} + \lambda_1^+ \cdot FDI_{t-1}^+ + \lambda_1^- \\ \cdot FDI_{t-1}^- + \lambda_2^+ \cdot GDP_{t-1}^+ + \lambda_2^- \cdot GDP_{t-1}^- + \lambda_3^+ \\ \cdot EC_{t-1}^+ + \lambda_3^- \cdot EC_{t-1}^- + \lambda_4^+ \cdot UPG_{t-1}^+ + \lambda_4^- \\ \cdot UPG_{t-1}^- + \varepsilon_t \qquad (10)\end{aligned}$$

The above equation GDP represent Gross Domestic Product growth rate, FDI represent Foreign Direct Investment, CO2 represent Carbon dioxide emissions in metric tons, EC represent energy consumption and UPG represent Urban Population Growth (Annual). The ''+'' and the ''- '' signs of the explanatory variables represent the positive and negative partial sum decomposition.

$$FDI_t^+ = \sum_{i=1}^{t} \Delta\, FDI_i^+ = \sum_{i=1}^{t} \max(\Delta FDI_{i,}\, 0)$$

$$FDI_t^- = \sum_{i=1}^{t} \Delta FDI_i^- = \sum_{i=1}^{t} \min(\Delta FDI_i, 0)$$

$$GDP_t^+ = \sum_{i=1}^{t} \Delta GDP_i^+ = \sum_{i=1}^{t} \max(\Delta GDP_i\,, 0)$$

$$GDP_t^- = \sum_{i=1}^{t} \Delta GDP_i^- = \sum_{i=1}^{t} \min(\Delta GDP_i\,, 0$$

$$EC_t^+ = \sum_{i=1}^{t} \Delta EC_i^+ = \sum_{i=1}^{t} \max(\Delta EC_i\,, 0)$$

$$EC_t^- = \sum_{i=1}^{t} \Delta EC_I^- = \sum_{i=1}^{t} \min(\Delta EC_i\,, 0)$$

$$UPG_t^+ = \sum_{i=1}^{t} \Delta UPG_i^+ = \sum_{i=1}^{t} \max(\Delta UPG_i\,, 0)$$

$$UPG_t^- = \sum_{i=1}^{t} \Delta UPG_i^- = \sum_{i=1}^{t} \min(\Delta UPG_i\,, 0) \qquad (11)$$

Empirical Result

Table 1 shows the summary statistics of the variables use in this study which include the minimum and maximum values, standard deviation, skewness and kurtosis, mean and median values as well as Jacque Bera and probability values (Table 1). The information above shows that foreign direct investments, gross domestic product and urban population growth are negatively skewed i.e they are skewed to the left, while CO2 and energy consumption are positively skewed. The result also shows that C02 and UPG leptokurtic (kurtosis value less than 3), whereas EC, FDI, and GDP are said to be platykurtic. (Table 2) present the unit root result for all variables in level and first difference. To avoid untrustworthy result, it is imperative that the variables used in this study are tested to know their stationarity levels and to avoid using variables that are integrated at their second difference I (2). The result from the ADF test shows that Energy consumption, Economic growth and Urban population growth are integrated at level (I (0)) at 1% level of significance for both EC and GDP and at 5% significance level for UPG. FDI and CO2 are integrated at first difference at 1% significant level. The ADF test set the premise of employing the ARDL (NARDL) model. We employ the NARDL bound test by Shin et al (2014) to verify the existence of long run cointegrating relationship among the variables. The decision rule which state that if the value of the F-statistics is higher than the upper bound I (1) critical value we reject the null hypothesis of no cointegration and accept the alternative hypothesis. But if the value of the F-statistics is lower than the lower bound I (0) we fail to reject the null hypothesis. However, if the value of the F-statistics is between the higher and lower bound, the decision is said to be inconclusive. From the cointegration bound test presented in (Table 3), the value

of the F-statistics (7.358444) is clearly higher than the upper bound I (1) value (3.15) at the conventional significant level of 5%. The above result justifies the existence of long run relationship among the variables.

Table 1: *Descriptive Statistics.*

	CO2	EC	FDI	GDP	UPG
Mean	0.115854	0.014418	-1.09E+08	2.478678	3.041970
Median	0.110000	0.012180	-10413410	3.464600	3.248860
Maximum	0.200000	0.115350	1.40E+08	26.41730	5.300357
Minimum	0.030000	0.006402	-9.50E+08	-20.59880	0.251402
Std.dev	0.039559	0.016396	2.13E+08	8.329434	1.280996
Skewness	0.207109	5.887376	-2.278947	-0.155264	-0.680025
Kurtosis	2.551386	36.80738	8.451304	5.342861	2.922042
J. Bera	0.636920	2189.372	86.25565	9.541772	3.170347
Probability	0.727268	0.000000	0.000000	0.008473	0.204912
Sum sq.dev	0.062595	0.010753	1.82E+18	2775.179	65.63805
observation	41	41	41	41	41
Summary Statistics.					

Table 2: *Unit Root Test.*

Variables	Augmented Dickey Fuller Test		
	Level	First difference	Order of Integration
CO2	-2.229410 (0.1995)	-7.884747 (0.0000) *	I (1)
EC	-6.320314 (0.0000) *	-10.51242 (0.0000)	I (0)
FDI	-2.417406 (0.1435)	-6.660167 (0.0000) *	I (1)
GDP	-5.697244 (0.0000) *	-10.25413 (0.0000)	I (0)
UPG	-3.345455 (0.0196) **	-3.152520 (0.0308)	I (0)
Augmented Dickey fuller test.			

Table 3: *Cointegration Bound test.*

F Statistics	10%		5%		2.5%		1%	
	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)
7.358444	1.85	2.85	2.11	3.15	2.33	3.42	2.62	3.77
NARDL Bound test.								

Table 4: *Long Run Nardl.*

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.345489	0.818239	0.422235	0.6776
C02(-1)	-1.033614	0.169203	-6.108725	0.0000
EC_POS	-7.790981	6.254001	-1.245760	0.2280
EC_NEG	-6.530978	2.719057	-2.401928	0.0267
FDI_POS	1.57E-10	6.81E-11	2.310337	0.0323
FDI_NEG	-2.63E-11	5.76E-11	-0.455762	0.6537
GDP_POS	-0.002232	0.000654	-3.413530	0.0029
GDP_NEG	0.001882	0.000902	2.087669	0.0505
UPG_POS	0.043786	0.010679	4.100229	0.0006
UPG_NEG	-0.015141	0.006471	-2.339691	0.0304
Long run asymmetry result.				

Table 5: *Short Run Nardl.*

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(FDI_POS)	-6.38E-11	3.48E-11	-1.834322	0.0823
D(FDI_NEG)	1.04E-10	2.15E-11	4.838924	0.0001
D(GDP_POS)	-0.000783	0.000277	-2.825567	0.0108
D(GDP_NEG)	0.000664	0.000260	2.560300	0.0191
D(UPG_POS)	-0.065426	0.009652	-6.778232	0.0000
D(UPG_NEG)	0.050671	0.007071	7.165648	0.0000
CointEq(-1)*	-1.033614	0.099257	-10.41346	0.0000
Short run Asymmetry result.				

Table 6: *Diagnostic Test.*

Test	Name	Prob value
Heteroscedasticity	B.P Godfrey test	0.2754
Serial correlation	Breusch-Godfrey test	0.2661
Specification	Ramsey Reset test	0.1105
Normality test	Histogram Normality	0.904680

(Table 4) present the long run asymmetry results of the NARDL model. The result shows that a positive increase in energy consumption will lead to a decrease in CO2 emission though not statistically significant. However, a negative shock on Energy consumption will lead to an increase in CO2 emission. That is for every 1 unit decrease in energy use will result to a 6.531 unit in CO2 emission. The long run result shows that positive shocks to energy consumption have a statistically significant effect on CO2 emission, while negative shock to energy consumption increase CO2 emission. The result further reveals that positive shock on foreign direct investment led to an increase in CO2 emission, while negative shocks are not statistically significant. Both positive and negative shock to GDP will lead a decrease in C02 emission, whereas both negative and positive urban population growth will lead to a statistically significant rise in CO2 emission. The short run result (Table 5) reveals that both increase and decrease in FDI are necessary in decreasing CO2 emission. From the result, it can be seen that a unit increase in FDI will lead to a 6.38 unit decrease in CO2 emission, while a unit a unit decrease in FDI will lead to 1.04 unit in CO2 emission. Also, the result justifies that both positive and negative partial decomposition of GDP is statistically significant in reducing CO2 emission. Also, both positive and negative shocks to urban population growth are highly significant in reducing CO2 emission. The error correct term (ECT-1.0336) shows a high speed of adjustment (103%) in correcting any disequilibrium in the long run. The table below (Table 6) shows various diagnostic test conducted to validate the accuracy and robustness of the model. The result of the B.P Godfrey test indicate that the probability value is above the 5% significant level, which means that the model is homoscedastic. Also, other results from table 6 indicate that the model is free from serial correlation, the model is correctly specified and the variables are normally distributed.

Stability test

The structural stability of regression coefficients is assessed using the cumulative sum (CUSUM). The CUSUM, as shown in (Figure 1), is inside the 5% critical constraint, indicating stability in the model.

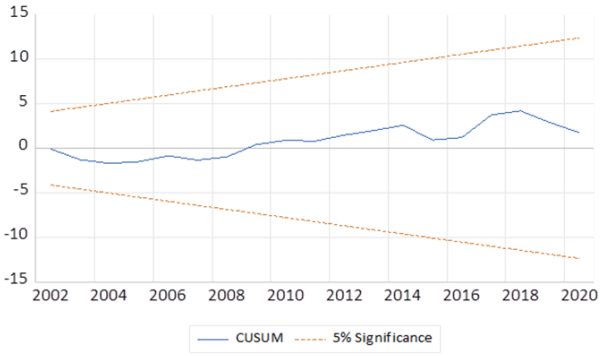

Figure 1: *Cusum stability test.*

Conclusion and Recommendation

This study examines the relationship between, CO2 emission, GDP, FDI, UPG, and EC in Sierra Leone. It employs the NARDL model estimation procedure to understand the asymmetric changes of the independent variables on the dependent variable (CO2) [19-27]. The result of this study is supported by studies done and it is in contravention of the Environmental Kuznet Curve Hypothesis studies. Result shows that both positive and negative change in the short run will lead to a decrease in CO2 emission. This study supports the Environmental Kuznets Curve Hypothesis in Sierra

Leone, with the justification, when the country strives on increasing economic growth pathway, lessen the carbon dioxide emission in the Atmosphere. This study also supports the pollution haven hypothesis in Sierra Leone, as both positive and negative shocks in FDI reduces the effect of CO2 emission in the short run. This is in corroboration with strict laws and regulations impose by the government and also encourage foreign and domestics firms to import sophisticated plant and machinery, ban on the importation of used cars more than 5 years and other carbon emission prone machine and other equipment with high environmental degradation propensity. Both positive and negative shocks on urban population growth contribute significantly in reducing CO2 emission in Sierra Leone. An increasing in Urban population decreases the use of using traditional meaning of cooking practices in most rural communities. For policy formulation, the findings of this study recommend that the central government continue to institute laws that will encourage green environmental practices and in turn protect the environment from future depletion. The approved FDI inflows in Sierra Leone must be well coordinated and restricted to a productive and innovative technological imprint which support FDI, Urbanization, clean energy consumption and a significant growth in the economy. To address the issues of environmental sustainability, polies that aim at combating the negative effect of climate change should be induced.

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