# The impact of renewable energy consumption and FDI on carbon emission: An empirical analysis for 15 African countries using panel cointegration regression model

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***Abstract***
*This paper adopts panel cointegration (FMOLS and DOLS) methodologies to establish the relationship among carbon dioxide emission, renewable energy consumption and foreign direct investments for a panel of 15 African countries for the period 2000 – 2014. The empirical results affirm a long run relationship among the variables. The long run estimates of the variables aver that renewable energy consumption is negatively related to carbon dioxide emission meaning renewable energy tends to reduce the pollution that results from carbon emission. Meanwhile, foreign direct investment (FDI) has a positive relationship with carbon emission; in other words, FDI increases or causes a rise in carbon emission in the long run. Some recommendations are proposed to ensure the reduction of carbon emission. Governments are advised to; expand the use of renewable energy consumption, create and build low carbon economies, control the activities of pollutants, reduce tropical deforestation and increase vehicle fuel efficiency and support other solutions that reduce oil use*
***Keywords:*** *Carbon emission; Renewable energy consumption; FDI; FMOLS; DOLS*

## 1. Introduction

Carbon emission is one of the leading causes of global warming and climate change. Carbon emission as a causal agent of global warming has received a lot of positive regards from international organizations, governments from different countries and environmental practitioners. To be able to control carbon emissions, relative factors to carbon emission should be adopted in the first instance. Economic growth is an imperative factor that impacts carbon emission (Zhu et al., 2016). It has been a scientific consensus that increasing greenhouse gas concentration owning to human activities has dramatically altered the global environment and led to intensifying climate change. Due to the inherent nature of global public good, the control of greenhouse gas (GHGs) has been widely perceived among economists and policymakers as an issue that requires international cooperation across the globe (Chung-Pin et al, 2019). The World Health Organization argues that 18% of global carbon dioxide (CO2) emissions are attributed to energy and to the fuel used by the residential sector. The expansion of greenhouse gas emissions is a serious danger to the environment and on human health. It is estimated that the adoption of cleaner technologies for renewable energy production (solar, wind, geothermal, biogas, etc.) can substantially reduce emissions of climate change pollutants by about 0.4 to 0.9 billion tons of CO2 emissions between 2010 and 2020 (Nicholas et al. 2018).

To attract foreign investment, developing countries have an inclination to ignore environmental issues through relaxed or non-enforced regulation; in economic theory, this phenomenon is attributed as the pollution haven hypothesis. However, the result of FDI will be inverted once low-carbon technologies are introduced to reduce the greenhouse gas emissions by FDI as an entire or once FDI flows to specialize in the service industry. It's believed that foreign corporations use higher management practices and advanced technologies that are contributive to a clean environment in host countries (Zarsky, 1999), which is known as the halo effect hypothesis. Two contradicting hypotheses have emerged from the argument regarding the environment. The primary one, the pollution haven hypothesis (PHH) suggests that developed countries impose strict environmental policies and warp the prevailing pattern of comparative advantage once the polluting industries shift their operations from the developed to the developing countries to become "Pollution Haven". The second is that the Factor endowment hypothesis (FEH) that assumes that trade openness can result in consistency of trade pattern. This notion relies on the Heckscher-Ohlin- Vanek (HOV) theory of comparative advantage and consists of issue endowment differentials (Saddam 2014). From the analysis of literature, some researchers found out that FDI has a positive relationship with carbon emission. Thereby, FDI increases carbon dioxide emission (Ahmed, 2015 and Yang et al., 2018). Evidence from Huiming et al., (2015), posits that FDI and carbon emissions are negatively related.

As a matter of interest, the variation among these researches has positioned this study to either validate or reject the findings of the above researchers and moreover, infer on the Pollution Haven hypothesis as well as the factor endowment hypothesis. The purpose of this paper is to empirically investigate the relationship between renewable energy consumption, foreign direct investment and carbon emissions. To further ascertain the relationship between the countries and the variables, the countries are categorized into two blocks in terms of GDP per capita to find out the countries that contribute heavily to carbon emissions with FDI as the intervening variable.

The paper is organized as follows; Section 1 contains the introduction, Section 2 outlines the literature review and section 3 includes the methodology and data. The results are presented in Section 4, and the key findings are summarized. Finally, some key conclusions and policy recommendations are drawn in Section 5.

## 2. Literature Review

Countries belonging to the Organization for Economic Co-operation and Development (OECD) are among those with the highest degree of carbon emissions worldwide. Following negotiations, OECD countries resolved to heighten and guide innovation and technology investments in the public and personal sectors aimed toward decreasing carbon emissions. To ascertain the impact of financing innovation to reduce carbon emission, Fortune (2019), conducted a study with Generalized Method of Moments (GMM) analysis to investigate how innovation and technology investments affect carbon emissions in selected OECD countries from 2000 to 2014. The results indicated that, after making use of the dynamic model and controlling for endogeneity, renewable power consumption and spending on studies and improvement have a statistically significant negative relationship with carbon emissions.

Some studies on renewable energy have been of interest to sub-Saharan Africa. Ben Jebli et al. (2015) examined the position that renewable energy consumption can play a major role in the mitigation of carbon emissions. These authors considered a panel of 24 sub-Saharan Africa nations and employ panel cointegration methodologies in their analysis. They proposed that the benefit from technology transfers through trade exchanges are a very good course to increase their renewable energy use and reduce carbon emissions levels. Furthermore, for a panel of fifty-one (51) sub-Saharan Africa nations, Ozturk and Bilgili (2015) analyzed the lengthy-run dynamics between GDP growth and biomass energy consumption. Their proof suggests a sizable effect of biomass consumption on GDP growth. From the analysis of literature, some researchers found out that FDI has a positive relationship with carbon emissions. Thereby, FDI increases carbon emission and has a strong positive effect on carbon emissions (Ahmed, 2015, Samuel and Vladimir, 2019 and Yang et al., 2018). Researches on pollution haven hypothesis (Zakarya et al. (2015) Behera and Dash, (2017); Solarin et al. (2017), confirm the validity of this assumption. Solarin et al. (2017) tested the pollution haven hypothesis for Ghana using the autoregressive distributed lag (ARDL) bounds testing method. Sun et al. (2017) tested the impact of FDI inflows, economic growth, energy use, monetary freedom, urbanization, economic improvement, and trade openness on $CO_2$ emissions the use of the autoregressive distributed lag version. The study confirmed the validity of the pollution haven hypothesis in China and that the fine effect of FDI inflows stems from the huge contribution of manufacturing, mining and energy shifted from the advanced countries. The usage of the fully modified ordinary least squares (FMOLS) and dynamic ordinary least squares regression, Behera and Dash (2017) found a tremendous impact of FDI inflows and electricity consumption on $CO_2$ emissions in 17 south and southeast Asian countries, consequently, confirming the pollution haven hypothesis. Zakarya et al. (2015) determined a long-run impact of FDI inflows and energy consumption on $CO_2$ emissions in Brazil, Russia, India, and China, as a consequence, validating the pollution haven hypothesis via panel causality and FMOLS regression. Zhu et al., (2016), Zhang and Zhou (2016) and Huiming et al., (2015), argued that FDI and carbon emissions are negatively related.

The surveys highlighted above employed diverse econometric techniques, including GMM, ADRL, VAR, panel quantile and cointegration FMOLS regression models. Most adopted carbon emission (which is the largest contributor to global warming amongst all known greenhouse gases) as the environmental quality variable. This paper utilizes three variables thus CO2 emission per capita, renewable energy consumption per capita, and foreign direct investment to examine the influence on carbon emissions.

## 3. Methodology and Data

### 3.1 Data

The study's data consist of panel data of CO2 emissions per capita, renewable energy consumption per capita and foreign direct investment in 15 African countries. The data are obtained from the World Bank Database (World Development Indicators). The data covers the period from 2000 to 2014. The specific definition of each variable is provided here:

1. CO2 emissions per capita (tonnes/capita) (CO2EPC): it refers to the units of CO2 emissions from the consumption of fossil fuels divided by population. It is a dependent variable.

2. Foreign Direct Investment (million US dollars) (FDI): it refers to net foreign direct investment, which is defined as the net increase and decrease in foreign direct investment inflows and outflows in one year. It is an independent variable.

3. Renewable energy consumption (thousand tonnes of oil equivalent) per capita (REPC): it refers to the equivalent production of primary energy for renewable energy, such as the hydro energy, solar energy, wind energy, geothermal energy, tide energy, biofuels energy and wave energy consumed in one year divided by the total population. It is an independent variable.

Foreign direct investment and renewable energy consumption per capita variables are transformed in natural logarithms as it helps to minimize the fluctuations in the data series.

### 3.2 Methodology

The study applies a panel cointegration regression model by using panel unit root tests, Johasen Fischer cointegration test, FMOLS and DOLS, and Pairwise granger causality test methods in this paper to study the effect of renewable energy consumption per capita and FDI on carbon dioxide emission per capita in 15 African countries. By using this model, it can examine the driven factors of carbon emission in African countries in the long run estimations. Testing for cointegration implies testing for the existence of such a long-run relationship between economic variables.

$$CO2EPC = f\,(REPC, FDI) \quad \ldots\ldots (1)$$

Where CO2EPC represents a carbon dioxide emission per capita measured by the metric ton, REPC represents renewable energy consumption per capita and FDI - foreign direct investment inflows measured. However, the data used in logarithmic and the econometric model is written in the following model.

$$Log\,(Co2PC) = \beta 0 + \beta 1\, Log\,(REPC) + \beta 2\, Log\,(FDI) + \mu i \quad \ldots\ldots (2)$$

Where $\beta 0$ is the intercept and $\mu i$ represents error term (disturbances and other factors that were not considered). The study commences with the analysis by testing the panel data, and in order to avoid spurious regression, a group unit root test is conducted. However, for using FMOLS and DOLS model, we have to ensure the possibility of the long-run equilibrium among the variables examined. Furthermore, the trace test is engaged in this study.

## 4. Empirical Analysis and Key findings

### Table 1: Summary Statistics for co2epc, lnrepc, lnfdi

| | CO2EPC | LNREPC | LNFDI |
|---|---|---|---|
| Mean | 10.7323 | 3.6499 | 19.6634 |
| Median | 10.3088 | 4.3704 | 19.7127 |
| Maximum | 12.5996 | 4.5884 | 23.1723 |
| Minimum | 10.0172 | 0.45 | 14.7748 |
| Std. Dev. | 0.8449 | 1.1638 | 1.733 |
| Skewness | 1.0627 | -1.3043 | -0.3236 |
| Kurtosis | 2.4752 | 3.6631 | 2.8841 |
| Jarque-Bera | 44.9327 | 67.919 | 4.0529 |
| Probability | 0.0000 | 0.0000 | 0.1318 |

### Table 2: Results of Panel unit root tests for co2epc, lnrepc, and lnfdi

| | Variables | Levin Chi | IPS | Fisher ADF | Fisher PP |
|---|---|---|---|---|---|
| Levels | CO2EPC | 0.778 | 1.936 | 24.927 | 44.661* |
| | LNREPC | 0.772 | 1.481 | 24.393 | 27.723 |
| | LNFDI | 3.859*** | -1.075 | 37.605 | 35.987 |
| First Difference | CO2EPC | 3.226*** | 4.148*** | 72.207*** | 139.909*** |
| | LNREPC | 4.958*** | 3.424*** | 63.527*** | 125.295*** |
| | LNFDI | 9.108*** | 7.286*** | 108.822*** | 205.648*** |

*Note*: 1. All tests are based on the model with a constant.
2. Lag lengths are chosen from 0 to 1 based on Schwarz Information Criterion.
***Denotes statistical significance at 1% level.
**Denotes statistical significance at 5% level.
*Denotes statistical significance at 10%

### Table 3: Results of Johansen Fisher Panel Cointegration Test for co2epc, lnrepc, lnfdi: Y(co2epc) = *f*(lnrepc, lnfdi)

| Hypothesized No. of CE(s) | Fisher Stat.* (from trace test) | Prob. |
|---|---|---|
| None | 189.6 | 0.0000*** |
| At most 1 | 86.6 | 0.0000*** |
| At most 2 | 68.53 | 0.0001*** |
| | Fisher Stat.* (from the max-eigen test) | Prob. |
| None | 151.9 | 0.0000*** |
| At most 1 | 66.74 | 0.0001*** |
| At most 2 | 68.53 | 0.0001*** |

* Probabilities are computed using asymptotic Chi-square distribution
Notes: "***" indicates statistical significance at the 1% level
Method: Trend assumption; Linear deterministic trend, lags interval (in first difference):1 1, Unrestricted cointegration rank test (trace and maximum eigenvalue)

### Table 4: Results of Long-run panel estimates (panel cointegration regression) for co2epc, lnrepc, lnfdi: Y(co2epc) = *f*(lnrepc, lnfdi)

### Dependent variable: CO2EPC

| Variables | LNREPC | LNFDI |
|---|---|---|
| FMOLS | -0.656<br>(0.0000)*** | 0.029<br>(0.0000)*** |
| DOLS | -0.612<br>(0.0000)*** | 0.033<br>(0.0000)*** |

Notes: "***" indicates statistical significance at the 1% level. P-values are in parentheses. Method for FMOLS: pooled estimation, Cointegration equation deterministic at constant, first stage residuals use heterogeneous long run coefficients, coefficient covariance estimates (Prewhitening with lags =-1 from SIC maxlags = -1, Bartlett kernel, Newey-West fixed bandwidth)
Method for DOLS: pooled estimation, Cointegrating equation deterministic at constant, automatic leads and lags specification (based on SIC criterion, max=*), coefficient covariance computed using default method, long run variance ( Bartlett kernel, Newey-West fixed bandwidth) used for coefficient covariances

The resulting equation:

FMOLS: co2epc = -0.656*lnrepc + 0.029*lnfdi + eqn_01_efct……………………………. (3)

DOLS: co2epc = -0.612*lnrepc + 0.033*lnfdi + eqn_01_efct…………………………….. (4)

**Table 5: Results for the long run relationship among CO2EPC, LNREPC, LNFDI with categorization into high GDP per capita countries and low GDP per capita countries: Y(co2epc) = ƒ(lnrepc, lnfdi)**

| | High GDP per capita | | low GDP per capita | |
|---|---|---|---|---|
| Variables | LNREPC | LNFDI | LNREPC | LNFDI |
| | -0.795 | 0.004 | -0.812 | 0.012 |
| FMOLS | (0.0000)*** | 0.593 | (0.0000)*** | (0.0000)*** |
| | -0.701 | 0.003 | -0.886 | 0.004 |
| DOLS | (0.0000)*** | 0.686 | (0.0000)*** | 0.136 |

Notes: "***" indicates statistical significance at the 1% level. P-values are in parentheses. High GDP per capita countries are Botswana, Egypt, Tunisia, Nigeria, Morocco, Mauritania, Zambia, and Ivory Coast. Low GDP per capita countries are Togo, Burkina Faso, Malawi, Rwanda, DR Congo, Kenya, and Ethiopia.
Method for FMOLS: pooled estimation, Cointegration equation deterministic at constant, first stage residuals use heterogeneous long run coefficients, coefficient covariance estimates (Prewhitening with lags =-1 from SIC maxlags = -1, Bartleth kernel, Newey-West fixed bandwidth). Method for DOLS: pooled estimation, Cointegrating equation deterministics at constant, automatic leads and lags specification (based on SIC criterion, max=*), coefficient covariance computed using default method, long run variance ( Bartlett kernel, Newey-West fixed bandwidth) used for coefficient covariances

**Table 6: Results of Pairwise Granger causality test for co2epc, lnrepc, lnfdi**

| Null Hypothesis: | obs | F-Statistic | Prob. |
|---|---|---|---|
| LNREPC does not Granger Cause CO2EPC | 195 | 0.9205 | 0.4001 |
| CO2EPC does not Granger Cause LNREPC | | 0.8049 | 0.4486 |
| LNFDI does not Granger Cause CO2EPC | 195 | 0.5271 | 0.5912 |
| CO2EPC does not Granger Cause LNFDI | | 1.1452 | 0.3203 |
| LNFDI does not Granger Cause LNREPC | 195 | 1.1305 | 0.325 |
| LNREPC does not Granger Cause LNFDI | | 0.9479 | 0.3894 |

This study applied IPS test, Fisher tests (including Fisher-ADF test and Fisher-PP test) and Levin, lin & chu test to conduct the panel unit root tests, and the results are shown in Table 1. It indicates that lnfdi is stationary with Levin test and co2epc is stationary with Fisher PP test but other tests of all variables with the tests adopted are non-stationary. Thus, we can conclude that all the variables became stationary after taking first differences.

These results not only reveal the non-stationary characteristics of renewable energy consumption per capita, net Foreign Direct Investment and carbon emission per capita but also lay the foundation for the following panel cointegration analysis.

Equation 3 above shows that there is an inverse relationship between the co2epc and the lnrepc. This implies that as one variable increases the other one decreases. It can also be deduced that the model fits the data set well, R2 = 0.989451. This means that 98.95% of the variations in the co2epc are explained by changes in the lnrepc and the lnfdi. From the table, it can be observed that the coefficient of lnrepc is statistically significant and negative at 1% significant level; lnfdi also shows that at 1% significant level the coefficient is statistically significant and positive. A percent change in the co2epc will result in -0.66% in the lnrepc and 0.029% in the lnfdi respectively.

Equation 4 above shows that there is an inverse relationship between the co2epc and the lnrepc. This implies that as one variable increases the other one decreases. It can also be deduced that the model fits the data set well, R2 = 0.991637. This means that 99.16% of the variations in the co2epc are explained by changes in the lnrepc and the lnfdi. From the table, it can be observed that the coefficient of lnrepc is statistically significant and negative at 1% significant level; lnfdi also shows that at 1% significant level the coefficient is statistically significant and positive. A percent change in the co2epc will result in -0.61% in the lnrepc and 0.033% in the lnfdi respectively.

From the empirical analysis using FMOLS and DOLS, both with an intercept and deterministic trends; Table 4 depicts that all the coefficients are statistically significant at 1% level. Furthermore, the results of the two methodologies are very close. According to the elasticity estimates, FDI affects carbon emission positively, in other words, it increases the pollution caused by carbon emission in the long run. Moreover, renewable energy consumption negatively affects carbon emission meaning it reduces the pollution caused by carbon emission in the long run. The positive relationship between FDI and carbon emission affirms that Africa countries are recipient of foreign direct investment inflow rather than outflows and as a result of emerging industries from these FDI inflows pollutions tend to increase due to production of goods and services, also the import of heavy duty machinery that uses fossil fuel for operations are causal parameters of carbon emission.

Per the empirical analysis of the objective to ascertain the long run relationship among the variables by categorizing the countries into two blocks thus countries with high GDP per capita and countries with low GDP per capita; using FMOLS methodology, it was established that lnrepc has a negative relationship with co2epc at 1% significance level with coefficient of -0.795 and lnfdi also showed a positive relationship with co2epc for the high GDP per capita countries in the long run estimates. Moreover, by applying the FMOLS methodology to the low GDP per capita countries, the results depicted the statistical significance of 1% for the two variables with coefficients of -0.812 for lnrepc and 0.012 for lnfdi respectively validating the negative and positive relationship between co2epc and lnrepc & lnfdi respectively. To substantiate the results for the long run variance and estimations, DOLS methodology was applied to the variables and the results showed 1% statistical significance level for lnrepc with a coefficient of -0.701 and lnfdi showed statistical insignificance but positive with a coefficient of 0.686 for the high GDP per capita countries. Considering the low GDP per capita countries with the application of the DOLS methodology, it was established that lnrepc was statistically significant and negative at 1% level with a coefficient of -0.886 and lnfdi were statistically insignificant but positive with a coefficient of 0.004.

From the results of Table 3 and 6, it is established that the calculated fisher statistic is within the critical region at 1% level of significance. Therefore, at all levels of significance, the null hypothesis of the presence of no cointegration and granger causality is rejected. The paper tends to accept and validate the Pollution Have hypothesis and the factor endowment hypothesis because the bisection of the countries with regards to GDP per capita with the application of the two methodologies thus FMOLS and DOLS, lnfdi seemingly became statistically significant with FMOLS at 1% level for low GDP per capita countries but not for high GDP per capita countries. With high GDP per capita countries, both methodologies proved statistically insignificant.

## 5. Conclusion and Policy recommendation

This paper investigated the relationship among carbon dioxide emission per capita, renewable energy consumption per capita and foreign direct investment for a panel of 15 African countries spanning from 2000 – 2014. The study's empirical analysis used many methodologies in relevance to panel data such as panel unit root tests, panel cointegration test, and panel long run estimates with FMOLS and DOLS as well as panel granger causality test.

From the results, it is established that all variables are cointegrated. The two cointegration methodologies thus FMOLS and DOLS infer that renewable energy consumption reduces the level of carbon emissions whiles FDI increases the level of carbon emissions. The positive relationship between FDI and carbon emission affirms that Africa countries are recipient of foreign direct investment inflow rather than outflows and as a result of emerging industries from these FDI inflows pollutions tend to increase due to production of goods and services, also the import of heavy duty machinery that uses fossil fuel for operations contribute to carbon emission. Moreover, low GDP per capita countries are highly polluted through FDI inflows and compared to high GDP per capita countries.

Upon consideration from the econometric outcomes from the panel of countries in terms of socioeconomic development, the following policy recommendations are proposed; Governments should expand the use of renewable energy and transform their energy system to one that is cleaner and less dependent on coal and other fossil fuels. Governments should increase vehicle fuel efficiency and support other solutions that reduce oil use. Governments should place limits on the amount of carbon that polluters are allowed to emit. Governments should create and build a clean energy economy by investing and financing inefficient energy technologies, industries, and approaches. With much emphasis on the foreign direct investments, should be green investments with the aim of protecting the environment from carbon emission. Governments should reduce tropical deforestation and its associated global warming emissions.

The policy recommendations may not be fully implemented due to the economic constraints of African countries because the continent aims to witness an astronomical boom in its economic growth. The study recommends further studies from interested researchers because it believes that it has some constraints which could be looked into.

**Acknowledgment**

I would like to extend my warm gratitude to my supervisor Prof. Jiang Hong Li for her immense contribution and support for this study.

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