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Published in:
Science of the Total Environment

DOI:
10.1016/j.scitotenv.2019.04.353

Do globalization and renewable energy contribute to carbon emissions mitigation in Sub-Saharan Africa?

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ABSTRACT

This study examines the impact of globalisation (measured in terms of foreign direct investment and trade openness), and renewable energy on carbon emissions using 46 sub-Saharan African countries for the period 1980-2015. Using fixed and random effect estimation techniques, the study found that renewable energy and foreign direct investment contribute to the reduction of carbon emissions while trade openness deteriorates the environment. It was also found that population growth and financial development contribute to the increase in carbon emissions. The study found evidence for Environmental Kuznets curve hypothesis. Our results revealed that institutional quality measured using regulation has a less pronounced effect for reducing carbon emissions. However, regulation moderates economic growth and foreign direct investment to reduce carbon emissions. These results are robust to alternative estimators such as the instrumental variable generalised method of moment and dynamic fixed effect estimators. The study further demonstrated that there are variations in the results among the regions within sub-Saharan Africa. The policy implications of the paper are discussed.

Keywords: Carbon emissions; Trade; FDI; Renewable energy; Regulation

1. Introduction

Globalisation, energy consumption and climate change are three issues defining the world economy. Though sub-Sahara Africa (SSA) is the least integrated and pollutes the environment the least, it is the most vulnerable to future climate change (Conway and Schipper, 2011). It is noted that the negative impacts of climate change have fallen disproportionately on the poor and more importantly, the effect is even going to worsen in the future if nothing is done to mitigate its effects (Troulmin, 2009). This is attributed to the high dependence on agriculture and limited capacity to adapt (Collier, Conway, and Venables, 2008; Shackleton et al., 2015). Even worrying is the fact that climate change vulnerability and food insecurity are amplifying the risks of conflict and civil unrest in over 30 countries (Climate Change and Environmental Risk Atlas, 2015). The Climate Change Vulnerability Index (2015) also indicates that two countries (Nigeria and Ethiopia) out of five most vulnerable countries in the world are in Africa and five more (Sierra Leone, South Sudan, Chad, Central African Republic and Eritrea) from the region are in the top ten. It is imperative that researchers and policymakers focus more on strategies to reduce change effects.

All of the identified effects of climate are known to have been made worse by the globalisation of the world economy while other analysts argue otherwise. Globalisation in this sense refers to the opening of the markets or the integration of the world economy through trade, foreign direct investment (FDI) and finance. Generally, globalization has led to a reduction in tariffs, and taxes to aid in export expansion and subsidies to help firms bring in required inputs to promote productivity in product development (Egger et al., 2019; Olivera, 2019). The pro-globalists argue that globalisation has a positive effect on environmental quality while the anti-globalists suggest otherwise. To appreciate the importance of the debate on globalisation, it will be essential to discuss the trend in global dynamics in the last 50 years. Both openness to trade and the influx of FDI into the SSA region has occurred at an increasing rate. Liberalisation of trade and FDI regimes accelerated since the late 1990s but slowed after the economic crisis of 2008. The total exports volume of African countries that stood at $85 billion in 1982 increased to $150 billion in 2000, and by 2008, this figure had risen to over $570 billion (World Trade Organization, 2018). Despite bearing no responsibility for the crisis, the poorer developing countries have fared the worst as they were hit the hardest and expected to hit even harder if nothing is done (Bellmann et al., 2010). It is important to mention though that since 2011, the growth of trade volume was highest in 2017. Cyclical factors such as increase in consumption expenditure and investment are the forces behind the upsurge in the volume of trade. In value terms, merchandise and commercial exports grew at 10.7% and 7.5% respectively, and these growth rates reflect the increase in commodity price and exports (World Trade Organization [WTO], 2018). It is expected that growth in world merchandise trade will reach 4.4% in 2018 and 4.0 in 2019. The OECD and WTO reports suggest that promoting trade instead of aid could be a primary instrument for achieving the sustainable development goals (SDGs).

FDI has been suggested to be a critical factor in promoting economic development and environmental quality. These twin benefits have led to many advocates and analysts providing policy recommendation for developing countries to put in policies to attract FDI. It is not surprising that one of the key tenets of the New Partnership for Africa's Development (NEPAD) is to promote the inflows of FDI to Africa (Nsouli and Funke, 2003). For example, the FDI inflows doubled from $18 billion to $36 billion in 2006 and reached $71 billion in 2014, after which there was a decline in 2015 and 2016 to $61 billion and $59 billion respectively (World Investment Report [WIR] 2008, 2017). The decline in FDI flows was due mainly to weak oil prices and lingering effects from the commodity bust. The WIR (2018) notes a further decline in 2017 to $42 billion from the 2016 figure of $59 billion, representing a reduction of over 20% for Africa, which is higher than the 10% average for developing countries but lower than the average of 37% for developed countries. The big question is, what is the effect of this dramatic inflows of trade and FDI on the environment? Does the data support the pollution haven or pollution halo hypothesis? These are issues the study seeks to address.

Additionally, the SSA region has the highest energy poverty with nearly 600 million without access to electricity, and many die due to pollution caused by inefficient energy sources (World Health Organization [WHO], 2015). Analysts and international agencies have therefore suggested the use of renewable energy (Africa Progress Report, 2016; Shabbaz et al., 2017). The Africa Progress Report (2015, 2016) note that renewable energy could be employed to mitigate the adverse effects of climate change and more importantly promote economic growth. However, there has not been much research on the issue. This gap motivates our study. The objective of the study, therefore, is to examine the effect of FDI, trade openness and renewable energy on carbon dioxide emissions

In achieving the research objective, we contribute to the literature in three man ways. First, we provide empirical evidence on the role of renewable energy in mitigating carbon emissions. Second, in March 2018 the African region formed one of the largest trade region (CFTA) in the world with nearly 1.7 billion by 2030. It is essential to appreciate how this is impacting not just on economic growth but importantly its effect on the environment as they seek to achieve the SDGs goals by 2030. Third, the study also contributes to the literature by examining the direct and indirect mechanisms through which institutional quality affects the environment. Finally, to achieve the research objective, we employ various econometric estimation technique such as a fixed effect, random effect, dynamic fixed effect and IV-GMM to determine the robustness and consistency in our results. This study used 46 Sub-Saharan African countries over the period 1980-2015. We expect that the findings of the study could provide policy informed evidence in dealing with Africa's giant triplets of energy poverty, climate change, and income inequality to achieve the SDGs.

2. Literature Review

Many contrasting views are employed to explain the globalisation – environmental degradation link, however, two of the most popular are the pollution haven (PHH) and the pollution halo hypotheses. The pollution haven framework refers to the fact that polluting firms in developed countries usually relocate to developing countries with lax environmental regulations, which results in pollution of the environment (Walter and Ugelow, 1979). Some scholars argue that industries relocate from environmentally regulated economies to less regulated economies which, therefore, becomes a haven for the pollution firm or industry (McGuire, 1982, p.335). Thus, with liberalisation, industries operating under stringent environmental regulation in the developed economies shift to the less developed economies with relaxing environmental regulation leading to pronounce environmental pollution in the developing economies (Doytch and Uctum, 2016).

On the other hand, the pollution halo thesis suggests that trade and FDI have a positive effect on the host economy and environment as these are associated with the transfer of management practices, standards and technology that employ efficient energy sources and lower carbon emissions (Zarsky, 1999). The pollution halo thesis proposes a win-win situation for both the relocating firm and the host economy, while the pollution haven suggests improved profits of the firm at the expense of environmental quality of the host economy (Stavropoulos et al., 2018). The *halo effect hypothesis* argues that foreign direct investment or liberalisation fosters the introduction of environmentally friendly technologies while improving the environmental management practices of domestic industries. Earlier studies on the impact of liberalisation on environmental degradation have also looked at it from the perspective of scale, technique and composition effects. The scale effect indicates that trade openness affects the environment by accelerating economic growth while the technique effects argue that trade liberalisation facilities the transfer of environmentally friendly technologies and strengthens the environmental regulation, which improves the quality of the environment. Additionally, the composition effect contests that trade openness could affect the environment by modifying the structure/composition and techniques of production of the host country (Antweiler, Copeland, and Taylor, 2001). Sbia et al. (2014) claim that free trade improves environmental quality by improving the efficiency in energy use. Both theoretical arguments and empirical findings on the effect of trade liberalisation and FDI on the environment are unclear and contradictory (see Hakimi and Hamdi, 2016).

Farhani et al. (2014) explain that the impact of trade liberalisation on the environment depends on the magnitude of composition, technique and scale effect. It is not surprising that the empirical findings have not yielded consistent estimates. For example, Balsalobre-Lorente et al. (2018) examine five EU countries for the period 1985-2016 and find that while trade has a positive effect on economic growth, it has a negative effect on environmental quality. Sinha and Shahbaz (2018) investigate the case for India during the period 1971-2015 and report that renewable energy and trade openness are negatively correlated with carbon dioxide emissions. However, in a related study, Inglesi-Lotz and Dogan (2018) employing panel estimation techniques robust to cross-sectional dependence for the ten biggest electricity generators in Sub-Saharan Africa for the period 1980 to 2011 demonstrate that while renewable energy has positive effect on the environment, nonrenewable energy has a negative effect and trade openness does not have a significant effect on carbon dioxide emissions. In a recent study, Acheampong (2018) demonstrate that trade openness improves environmental quality by reducing carbon emissions at the global level, sub-Saharan Africa, Asia-Pacific, Middle East and North Africa countries (MENA). In their study of developing countries based on cointegration techniques, Hu et al. (2018) report that renewable energy contributes to the reduction in carbon emissions in the short-run while it increases carbon emissions in the long-run. The authors also found that commercial service trade improves the environment by reducing carbon emissions. Shabazz et al. (2017) study 105 countries using panel VEC causality models for the period and demonstrate different results for the different country groupings. For example, there is a bidirectional relationship between trade and carbon emissions at the global level and for the middle-income countries while unidirectional causality runs from trade to carbon emissions in high and low-income countries. Managi et al. (2009) find that trade liberalisation reduces Carbon dioxide and Sulphur dioxide pollutant emissions only in OECD countries but the opposite effect in non-OECD countries, while Chang et al. (2018) demonstrated that trade liberalisation increases carbon emissions in low-income countries but improves the environmental quality in high-income economies. In an earlier study of 19 African countries during the period 1971-2012, Shahbaz et al. (2016) show that globalisation (used the KOF index of globalisation) reduces carbon emissions when using the entire sample; however, the impact of globalisation on carbon emissions varies across countries. Antweiler et al. (2001) investigate 40 developed and developing countries and report that generally, trade liberalisation improves environmental quality.

Similarly, contrasting results are found for FDI. Using PVAR, Bakirtas and Cetin (2017) show that FDI increases environmental pollution in five countries, Australia, Indonesia, Mexico, South Korea and Turkey. Similarly, Seker et al. (2015) examined the case for Turkey for the period

1974-2010 using the ARDL and found that both energy consumption and FDI have a detrimental effect on carbon dioxide emissions. On the other hand, Zhang and Zhou (2016) employ the STIRPAT model to examine the impact of FDI on carbon dioxide emissions in China and reported that FDI improves the quality of the environment supporting the pollution halo thesis. In a related study of 150 Chinese city-level data that considers spatial spillovers, Jiao et al. (2018) indicate that FDI contributes to the reduction in carbon emissions. Equally, Ning and Wang (2018) investigate the effect of FDI on 280 Chinese prefectural cities for the period 2003 -2012 using spatial econometric models and found that that FDI improves the quality of the environment. Recently, Acheampong and Boateng (2019) demonstrated in their sensitivity analysis that trade openness reduces carbon emissions in Australia, Brazil, India and the USA while it increases China's carbon emissions. Their results further reveal that FDI contributes to carbon emissions mitigation in Brazil and China while it increases Australia, USA and India's carbon emissions.

Others have also reported differential effects of FDI for different countries and regions of the world. Shahbaz et al. (2016b) investigated the globalisation –environment nexus for 19 African countries over the period 1970-2012 and found that globalisation decreases carbon dioxide emissions across the panel; however, there were variations in the results among the individual countries. Doytch et al. (2016) examine the case for a global sample and found that the effect of FDI on the environment is driven by the level of development. The results show that FDI has a positive effect and negative effect on the developed and developing countries' environment respectively. Kostakis et al. (2017) report that while FDI contributed to environmental degradation in Brazil, it had the opposite effect in Singapore based on FMOLs and ARDL estimates for the period 1970-2010. The results also suggest that while the EKC was valid for Singapore, there was no such relationship for Brazil. Hakimi et al. (2016) investigate the case for Morocco and Tunisia using VECM models and find that both FDI and trade openness led to high-energy consumption and a subsequent negative impact on the environment though they impacted positively on economic growth through the creation of employment opportunities. Sinha and Shahbaz (2018) show that both renewable energy and trade openness have a significant negative impact on carbon dioxide emissions in Pakistan over the period 1971-2015 based on ARDL. However, Jugurnath and Emrith (2018) use fixed effects and SUR techniques to determine the case of SIDS, and the results show that there is no significant relationship between FDI and carbon dioxide emissions. Similarly, considering spatial effects for 285 Chinese cities, Liu et al. (2018) demonstrate that FDI does not necessarily translate into greater carbon dioxide emissions.

Recent studies have included institutional variables in environmental pollution models to prevent variable omission bias. For example, Joshi and Beck (2018) in a study of 109 countries (made up of 22 OECD) show that democracy matters. The findings reveal that politically free non-OECD countries experience higher CO_2 emissions, while insignificant effects of emissions for politically free transition non-OECD countries. In a related study of 144 countries during the period 1970-2011, however, Povitkina (2018) reports that democracy only reduces carbon emissions in countries with a low level of corruption. The authors conclude that where corruption is high, the type of political system does not have a significant effect on carbon emissions. Using instrumental variable quantile regression technique with fixed effects, Chang et al. (2018) also investigated the case for a panel of 65 countries over the period 1981-2012 and show that government ideology contributes to the reduction in carbon emissions. Other studies have used other measures of institutions, for example, Bhattacharya et al. (2017) use economic freedom while Al-Mulali and Ozturk (2015) employ political stability as a measure of institutional quality. This study argues for a more comprehensive measure of the institutional environment that considers both the political and economic institutions to reduce estimation bias as noted above. The discussion to date shows that a complex interaction of variables in explaining the determinants of carbon emissions and for that strategies to be employed in mitigating the effects of climate change. As an empirical investigation, this study contributes to the literature in identifying the intersection of globalisation (FDI and trade openness), renewable energy and the climate change debate. The methodology used to achieve the research objective is discussed next.

3. Methodology and Data

3.1 Empirical model

This study follows the empirical model of Shahbaz, Nasir, and Roubaud (2018) and Tamazian and Bhaskara Rao (2010) to investigate the effect of renewable energy, trade openness and foreign direct investment on carbon emissions. Thus, carbon emission (*$lnCO_2$*) is specified as a function of income (*lnRGDP*), square of income (*$lnRGDP^2$*), foreign direct investment (lnFDI) renewable energy (*lnREW*) and trade openness (lnTRA). Therefore, the empirical model to examine the direct effect of financial development on carbon emissions is given in Eq. (1):

$$lnCO_{2_{it}} = \beta_1 + \beta_2 lnRGDP_{it} + \beta_3 lnRGDP^2{}_{it} + \beta_4 lnFDI_{it} + \beta_5 lnREW_{it} + \beta_6 lnTRADE_{it} + \emptyset_1 X_{it} + \varepsilon_{it} \qquad (1)$$

Where $i = 1 \dots \dots .46$ and $t = 1980 \dots \dots .2016$, X is a set of control variables which have a potential effect on carbon emissions, $\beta_1 \dots \dots \dots \beta_6$ are the coefficient to be estimated, $\emptyset_1$ is the coefficient to of the control variables to be estimated; and ε_{it} is the stochastic error term. This study controls for population (*lnPOP*) and financial development (*lnDCP*). Additionally, this study controls for institutions since previous studies have argued that institutions have an important effect on environmental quality (see Tamazian et al., 2010). The above model was estimated using fixed and random effect estimators. However, because of the inability of the fixed and random effect to control for endogeneity, the above empirical model was also estimated using IV-GMM to address various econometric issues such as endogeneity problem, variable omission bias and produce consistent estimates. The dynamic fixed effect estimators was also used in addition to IV-GMM to determine the robustness and consistency in our results.

3.2 Data

Data for the study is over the period 1980-2016 for 46 Sub-Saharan African countries[1]. Carbon emission was proxied using carbon emissions measured in kiloton (kt). Real GDP per capita growth was used to represent income. Renewable energy consumption was represented using renewable energy consumption as a share of total final energy consumption. Foreign direct investment was proxied using foreign direct investment, net inflow as a percentage of GDP while trade openness was proxied using (Export +Import) as a percentage of GDP. Population was proxied using total population while financial development was represented using the domestic credit to private sectors. Institutions were proxied using government regulation, and it was sourced from (Gwartney, Lawson, and Hall, 2014). The rest of the data were sourced from the World Bank (2016). Table 1 provides a summary of the descriptive statistics of the variables.

[***INSERT TABLE 1 HERE***]

[1] See the Appendix Table 1 for the countries used for the study.

Table 2 shows that the highest correlation coefficient among the independent variables is 0.730, which is the correlation coefficient between economic growth and renewable energy. In this regards, Dranove (2009, p. 9) argue having an observation[2] of more than 100 or 200 can results in a correlation coefficient between 0.7 and 0.8 without causing a problem in regression estimates. This proves that there is no multicollinearity among the independent variables.

[***INSERT TABLE 2 HERE***]

The statistics from the correlation matrix[3] shows that renewable energy has a negative relationship with carbon emissions while trade openness, foreign direct investment, economic growth, population, financial development and regulation have a positive relationship with carbon emissions. On the other hand, Fig. 1-2 shows the bivariate relationship between FDI, trade openness and carbon emissions.

[***INSERT FIG 1- 2 HERE***]

4.0 Empirical results

Table 3 presents the baseline empirical results from two estimators. Models [1] to [6] displays Fixed Effect (FE) estimates, while [7] to [12] presents the estimates from Random Effect (RE). Note that, in all estimations, the reported coefficients are in natural logarithms hence should be interpreted as the long-run elasticities. Column [1] shows the baseline results without the globalisation indicator, and the findings reveal that four of the variables have a significant influence on CO_2 emissions. Mainly, there is strong evidence that carbon emissions decrease with

[2] The total number of observations is 674.
[3] See the Appendix Table 2 for the correlation matrix for the three regions considered in this study.

the increasing use of renewable energy, as shown by the coefficient of *lnrewntnc*. While this findings strongly corroborate the empirical result of Ben Jebli et al. (2016) and Dong et al. (2018) who found that renewable energy consumption renders a substantial role in mitigating carbon emissions, we find the current energy consumption situation in SSA quiet worrying since more than 90% of the countries in our sample are noted for using non-renewable energy, which substantially induces carbon emissions. This suggests that the continued use of fossil fuel energy for commercial purposes has reached an exponential growth among countries in SSA as against the use of natural gas; thereby contributing to carbon emissions. Besides, and to some extent, the increasing use of more non-renewable energy and the absence of substitutable energy in SSA seems to be the most prominent challenge to reduce global warming, a situation that calls for attention.

It is also apparent from the findings that Real GDP growth (*lnrgdpc*) worsens CO_2 emissions in SSA. This is revealed by the positive and significant coefficient of *lnrgdpc*, which signals that higher growth induces CO_2 emissions. This result is quite revealing since, unlike advanced countries, economies at their early stages of economic development employ techniques that are less sophisticated to reduce the extent of carbon emissions into the atmosphere during resource extraction process. As a result, the degree to which CO_2 is emitted in developing countries tends to outstrip that of the developed economies. Notwithstanding, the observed impact of the quadratic term of *lnrgdpc* (*lnrgdpc2*) lend support or validates the EKC theory, which states that there is a threshold point at which the positive impact of economic growth on environmental deterioration turns to diminish. These findings are consistent with other studies that suggest a Laffer curve effect of income growth on CO_2 emissions (for a review, see Apergis 2016; Begum et al., 2015; Dinda, 2004; Halicioglu, 2009; Narayan and Narayan, 2010; Onafowora and Owoye;

2014). We also find that increase population growth (*lnpop*) worsens CO_2 emissions. Financial development (*lndcp*) was seen to have an insignificant effect on carbon emissions.

The results indicate that trade openness (*lntrade*) has a significant positive effect on carbon emissions and consistent with the empirical findings of Ben Jebli and Ben Youssef (2015). Additionally, Shahbaz et al. (2014) found that increasing exports reduce CO_2 emissions. Perhaps, the positive impact of trade in SSA since the region's imports far outweigh its export of goods and services. In column [3], we include foreign direct investment (*lnfdi*) and consistent with our expectation, we find a negative and significant impact of *lnfdi* on CO_2 emissions. Specifically, a 1% rise in *lnfdi*, due to globalisation, mitigates the extent of carbon emissions by 2 to 4%. This result contradicts the findings of Kivyiro and Arminen, (2014) who found that FDI increases carbon emissions in sub-Saharan Africa. However, the estimated parameter of its quadratic term (*lnfdi2*) did not provide any significant demonstration of a threshold effect of *lnfdi* on CO_2 emissions in SSA. There are several possible explanations for these results. First, foreign investors in SSA mostly originates from advanced countries with well-developed technologies that are more innovative to influence the consumption of energy in SSA. As argued by Balsalobre-Lorente et al. (2018), environmental quality is intuitively affected by energy innovations, and the spillover effect of such innovations in developed countries would lessen or mitigate the extent of CO_2 emissions in developing countries. The second explanation relates to the pollution-halo hypothesis where foreign investors apply the universal environmental standard in their operation in the host country that tends to spread greener technology to reduce the extent of environmentally unfriendly emissions. This result is consistent with the study of Pao and Tsai (2011), Zhang and Zhou (2016) and Zhu et al. (2016) that substantiate the significance of FDI to reducing environmental degradation but contradicts the studies from other emerging economies such as Lau et al. (2014), Tang and Tan (2015); Baek (2016) and Hitam et al. (2012).

Although the previous analysis between FDI and CO_2 emissions shows an inverse relationship, an essential aspect of this study is to examine the potential impact of regulation quality in resolving the economic impact of institutions on CO_2 emissions. Columns [4] to [6] display the results after controlling for regulation quality in the model. First, the results show a negative but insignificant find negative association between regulatory quality and CO_2 emissions. We notice that, while improving the quality of regulation in could mitigate CO_2 emissions in SSA, the insignificant effect is an indication that less emphasis is placed on environmental regulation strategies to yield substantial impact in reducing CO_2 emissions. However, when interacted with *lnfdi* and renewable energy, regulations have an indirect reduction impact on CO_2 emissions through *lnfdi* but positive indirect impact through renewable energy. While the estimated results of the interaction effects between *lnfdi* and regulation to meet our *a priori* expectation, it is quite surprising to observe positive interaction effects between regulation and renewables (*regulation* × *lnrewntnc*) when examined within the context of SSA. The plausible explanation is that in SSA, the energy sector is poorly regulated and renewable energy is least consumed and hardly managed. The relatively weak regulations in the energy sector and the lack of attention given to renewable energy consumption and its potential effect explains the positive interactive impact between regulation and renewables in SSA.

[***INSERT TABLE 3 HERE***]

4.1 Robustness Checks

4.1.1 Alternative Estimators

While the FE and RE findings are consistent with past studies, these empirical techniques are often constrained by their lack of producing efficient estimates in the presence of endogeneity. Therefore as a first robustness check, we employ the IV-GMM techniques to check the consistency of the results after controlling for endogeneity and arbitrary heteroscedasticity of the unknown form (see Baum, Schaer and Stillman, 2002). The estimated results are displayed in Table 4. From Table 4, we find that all the variables maintained their theoretically expected signs. Note that employing the IV-GMM estimator does not in any the way overturn our earlier findings obtained from that of FE and RE regarding signs. However, the magnitude and levels of statistical significance differ quite dramatically. As part of the robustness check, the second alternative taken is to test the consistency of the earlier findings from a dynamic perspective of our modelling process, and the estimated results are displayed in Table 5. Similar to the IV-GMM, renewable energy and foreign direct investment retained their negative and significant impact on CO_2 emissions. Additionally, trade openness retained its positive and significant effect on carbon emissions. Except for financial development, the remaining vital variables maintained their theoretically expected signs and significant levels. By implication, the findings indicate that adopting a particular empirical strategy would not have any policy dilemma about making inferences from any empirical techniques adopted to estimate the results. The *F-statistics* and a probability value of the Hansen test show that the instruments used in the IV-GMM are relevant and not over-identified.

[***INSERT TABLE 4 HERE***]

[*INSERT TABLE 5 HERE*]

4.1.2 *Comparative analysis across regions in SSA*.

To gain more insight of the impact of globalisation and renewable energy on carbon emissions in SSA countries, and given the several structural differences between the countries we are dealing with, this sub-section presents a discussion of the impact of renewable energy, FDI and trade openness on CO_2 emissions regions in SSA. We achieve these differences by splitting our dataset into three sub-regions in SSA. These are Western-SSA, Southern-SSA and Central-Eastern-SSA. After regrouping countries into these regions, we then estimated separate equations. The estimated results are displayed in Table 6. The findings show that the direct effect of *lnrewntnc* remains negative and significant across all sub-regions implying that more renewable energy consumption reduces CO_2 emissions. However, the results suggest that the rate at which *lnrewntnc* reduces CO_2 emissions by countries situated in the Central-Eastern part of SSA is much higher relative to economies located in the Southern and Western part of SSA. Another critical finding in Table 4 relates to the role of *lnrgdpc* and its squared results. For Southern SSA countries, *lnrgdpc* and *lnrgdpc2* have a significant positive and negative effect respectively on carbon emissions while for Western SSA and Central-Eastern part of SSA countries, *lnrgdpc* and *lnrgdpc2* have a negative and positive impact respectively on carbon emissions. These findings reveal that the EKC hypothesis only holds for countries in the Southern part of SSA. In contracts, the evidence in Western SSA and Central-Eastern part of SSA economies did not follow EKC path. Thus, an inverted U-shaped relationship exists between economic growth and carbon emissions in the Southern part of SSA while a U-shaped relationship exists between economic growth and carbon emissions in Western SSA and Central-Eastern part of SSA countries. Moreover, in all regions, increased population growth (*lnpop*) lead to a rise in CO2 emissions. It is also revealed that while financial development (*lndcp)* has a significant reduction effect on CO_2 in Western-SSA while it exerts a significant positive influence on carbon emissions across the Southern and Central-Eastern SSA sub-region. However, the effect of financial development on carbon emissions in Southern-SSA is not pronounced. Another interesting observation about these findings is the role of regulatory quality on CO_2 emissions across the sub-regions under consideration. The results indicate that, while the quality of regulation in the Western part of SSA directly (see Model 1-3) worsens carbon emissions, the regulations in countries found within the Southern and Central-Eastern part of SSA were found to reduce emissions.

The estimated coefficient the globalisation variables, *lnfdi*, suggests that globalisation leads to a significant reduction in CO_2 in all the regions. Secondly, we find also that the square term of lnfdi is negative and significant only for Western and Southern-SAA. Additionally, the estimated coefficient of trade openness (*lntrade*) is positive and statistically significant across Western and Southern-SAA; however, trade openness (*lntrade*) significantly reduces carbon emissions in Central-Eastern Africa. Thus, trade openness facilitates the introduction of green technologies in Central-Eastern Africa resulting in carbon emissions reduction. Contrarily, the pollution haven hypothesis exists in Western and Southern-SAA countries. Further analysis shows that while regulations have a mixed direct impact on CO_2 emissions, it apparent from Table 4 that it reinforces the negative effect of *lnfdi* on emission, except in Southern and Central-Eastern SSA model. Like the whole sub-Saharan Africa sample, there is a positive interaction effect between regulation and renewables on carbon emissions across the regions in SSA but only significant in Western-SAA countries. This gives credence to the fact that the energy sector is poorly regulated and renewable energy is least consumed and hardly managed. The relatively weak regulations in the energy sector and the lack of attention given to renewable energy consumption and its potential effect explains the positive interactive impact between regulation and renewables.

Additionally, the interaction effects between regulation and economic growth on carbon emissions are negative in Western-SAA countries while is positive in Southern and Central-Eastern SSA countries. The implication could be that Southern and Central-Eastern SSA countries have weaker institutions, which is not capable of facilitating economic efficiency leading to an increase in carbon emissions. Other the hand, the results suggest that Western-SSA countries have a better institutional quality which is capable of promoting economic efficiency thereby reducing carbon emissions. It is important to state that, splitting our sample into different regional zones in SSA gives a revealing result that is entirely different from the baseline estimations, which is partly due to the varying economic and cultural features across countries. This heterogeneity among SSA countries implies the need to take into account the importance of the country-specific situation in studying environmental degradation. The *F-statistics* and a probability value of the Hansen test show that the instruments used in the IV-GMM are relevant and not over-identified.

[***INSERT TABLE 6 HERE***]

5.0 Conclusions and Policy Implications

The world has seen an increasing effort to combat the increasing rise in environmental pollution across all countries. As researchers are finding solutions to address the global warming issue, this paper tackles the situation from two perspectives. First, we address how globalisation and renewable energy consumption contribute to CO_2 emission in developing countries. Secondly, we examine how the countries' geographical position influence CO_2 emission. In this paper, we examine the impact of globalisation and renewable energy on CO_2 emission in SSA. Third, we examine the robustness of our findings by employing different empirical techniques.

Our findings can be summarised in three main parts. (1) Renewable energy consumption and foreign direct investment have decreasing impact on CO_2 emission in SSA. (2) Key factors such as population growth, financial development, income growth and trade openness are pollutant inducing. (3) The factors that influence CO_2 emission tend to differ across countries. Our study, therefore, highlights the importance of SSA economies to make the transition from the consumption of non-renewables to renewable energy, which is found to mitigate environmental or global warming. Additionally, given that FDI reduces the extent of CO_2 emissions in SSA, the region should attract more foreign investors to invest in the region. However, for FDI inflows to yield significant effect in reducing the rising level of CO_2 emissions in the region, the quality of regulation should be improved in order to moderate the activities of such investors for the region to enjoy substantial gains in their investment. Given that renewable energy reduces carbon emissions, sub-Saharan Africa should shift from its over-reliance on fossil energy and make a substantial investment in renewable energy. Africa has a lot of untapped renewable energy resources; therefore, in the face of growing carbon emissions, renewable energy should be incorporated into its energy portfolio. Additionally, given the deteriorating effect of trade liberalisation on the environment, policymakers should put trade liberalisation on their agenda when designing and implementing environmental conservation policies in Sub-Saharan Africa. Thus, sub-Saharan Africa needs to implement and monitor stringent environmental regulatory framework to effectively deal with the degrading effect of trade liberalisation. Finally, there is the need to ensure that country-specific heterogeneous effects are taken into consideration when implementing CO_2 emission strategy.

APPENDIX

Appendix Table 1: Countries included in the study

Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Congo, Dem. Rep., Congo, Rep., Cote d'Ivoire, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, South Africa, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia and Zimbabwe.

[***INSERT APPENDIX TABLE 2 HERE***]

Acknowledgements

The authors wish to deeply thank Damià Barceló (Co-Editor in Chief) and Huu Hao Ngo (Associate Editor) for their time and support. We are also thankful to the two anonymous reviewers for their valuable comments that help us to improve the quality of this paper. Nevertheless, the authors are responsible for all remaining errors.

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TABLES

Table 1: Variables descriptive statistics

	Mean	sd	min	Max
lnco2kt	7.272	1.715	3.497	13.129
lnrewntnc	4.088	0.787	-1.038	4.588
lnrgdpc	6.895	1.021	4.752	9.920
lnpop	15.470	1.588	11.055	19.015
lntrade	4.164	0.527	1.844	6.276
lndcp	2.507	0.929	-1.856	5.076
regulation	5.738	1.204	0	8.52
lnfdi	0.332	1.822	-11.485	5.087

Table 2: Correlation matrix

	lnco2kt	lnrewntnc	lnrgdpc	lnpop	lntrade	lndcp	regulation	lnfdi
lnco2kt	1							
lnrewntnc	-0.451	1						
Lnrgdpc	0.547	-0.730	1					
Lnpop	0.552	0.286	-0.295	1				
lntrade	0.174	-0.442	0.558	-0.379	1			
lndcp	0.556	-0.725	0.587	-0.043	0.339	1		
regulation	0.348	-0.415	0.478	-0.048	0.302	0.437	1	
lnfdi	0.083	-0.090	0.170	0.006	0.400	-0.014	0.227	1

(observations=674)

Table 3: Fixed and Random effect results

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
	Fixed Effect						Random Effect					
lnrewntnc	-0.730**	-0.752***	-0.777***	-0.771***	-1.668**	-0.755***	-0.691***	-0.721***	-0.745***	-0.750***	-1.824***	-0.727***
	(0.273)	(0.242)	(0.236)	(0.238)	(0.662)	(0.241)	(0.268)	(0.251)	(0.246)	(0.247)	(0.680)	(0.249)
lnrgdpc	2.894**	2.584**	2.540**	2.307*	1.959	2.576**	2.744**	2.507**	2.454**	2.284**	1.782	2.498**
	(1.395)	(1.174)	(1.194)	(1.151)	(1.232)	(1.189)	(1.346)	(1.164)	(1.183)	(1.126)	(1.216)	(1.180)
lnrgdpc2	-0.162*	-0.147*	-0.146*	-0.103	-0.101	-0.146*	-0.144	-0.131	-0.129	-0.092	-0.079	-0.130
	(0.094)	(0.080)	(0.080)	(0.079)	(0.083)	(0.081)	(0.092)	(0.080)	(0.081)	(0.078)	(0.083)	(0.081)
lnpop	0.962***	1.072***	1.085***	1.138***	1.030***	1.078***	0.931***	0.983***	0.992***	1.020***	0.968***	0.990***
	(0.165)	(0.149)	(0.146)	(0.140)	(0.138)	(0.149)	(0.095)	(0.086)	(0.083)	(0.081)	(0.079)	(0.085)
lntrade	0.200***	0.227***	0.262***	0.213***	0.226***	0.229***	0.211***	0.253***	0.290***	0.244***	0.245***	0.257***
	(0.066)	(0.070)	(0.066)	(0.068)	(0.068)	(0.072)	(0.066)	(0.070)	(0.066)	(0.068)	(0.066)	(0.072)
lndcp	0.027	0.052	0.058	0.046	0.053	0.054	0.024	0.046	0.052	0.040	0.048	0.048
	(0.053)	(0.053)	(0.053)	(0.048)	(0.052)	(0.053)	(0.052)	(0.051)	(0.051)	(0.046)	(0.050)	(0.051)
regulation	-0.010	0.002	0.001	0.331**	-0.556*	-0.000	-0.011	0.003	0.003	0.318**	-0.669**	0.000
	(0.024)	(0.019)	(0.019)	(0.143)	(0.328)	(0.019)	(0.022)	(0.016)	(0.016)	(0.127)	(0.337)	(0.016)
lnfdi		-0.031**	-0.043***	-0.033**	-0.030**	-0.015		-0.032**	-0.044***	-0.032***	-0.031***	-0.006
		(0.012)	(0.011)	(0.012)	(0.012)	(0.048)		(0.012)	(0.011)	(0.012)	(0.012)	(0.045)
lnfdi2			-0.004*						-0.004*			
			(0.002)						(0.002)			
regulation× lnrgdpc				-0.053**						-0.050**		
				(0.023)						(0.020)		
regulation×lnrewntnc					0.127*						0.153**	
					(0.074)						(0.076)	
regulation×lnfdi						-0.003						-0.005
						(0.008)						(0.008)
Constant	-17.490***	-17.989***	-18.015***	-18.896***	-11.244*	-18.068***	-17.029***	-17.019***	-16.973***	-17.576***	-9.421	-17.103***
	(4.986)	(4.496)	(4.497)	(4.258)	(6.119)	(4.483)	(4.776)	(4.277)	(4.330)	(4.070)	(6.019)	(4.276)
Observations	739	674	674	674	674	674	739	674	674	674	674	674
r2_w	0.727	0.752	0.755	0.757	0.756	0.752	0.726	0.750	0.752	0.754	0.755	0.750
r2_o	0.811	0.787	0.786	0.773	0.827	0.789	0.850	0.857	0.859	0.854	0.876	0.859
r2_b	0.824	0.771	0.770	0.752	0.813	0.772	0.862	0.853	0.855	0.846	0.871	0.854
rho	0.927	0.944	0.944	0.948	0.935	0.943	0.891	0.902	0.899	0.907	0.904	0.901
rmse	0.193	0.183	0.182	0.181	0.181	0.183	0.200	0.190	0.189	0.188	0.188	0.190

Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4: IV-GMM results

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
lnrewntnc	-0.466***	-0.546***	-0.543***	-0.604***	-4.071***	-0.545***
	(0.080)	(0.092)	(0.092)	(0.089)	(0.691)	(0.092)
lnrgdpc	1.578***	1.996***	1.735***	2.027***	1.007**	1.991***
	(0.328)	(0.385)	(0.379)	(0.382)	(0.419)	(0.382)
lnrgdpc2	-0.039*	-0.070***	-0.053**	-0.042	-0.001	-0.070***
	(0.022)	(0.027)	(0.027)	(0.030)	(0.029)	(0.027)
lnpop	1.029***	1.062***	1.069***	1.062***	1.065***	1.062***
	(0.017)	(0.017)	(0.017)	(0.017)	(0.018)	(0.017)
lntrade	0.093	0.272***	0.343***	0.245***	0.213***	0.272***
	(0.069)	(0.075)	(0.075)	(0.076)	(0.078)	(0.073)
lndcp	0.266***	0.218***	0.216***	0.215***	0.188***	0.218***
	(0.039)	(0.042)	(0.042)	(0.042)	(0.043)	(0.042)
regulation	-0.041**	-0.023	-0.020	0.392**	-2.165***	-0.024
	(0.018)	(0.019)	(0.019)	(0.177)	(0.409)	(0.019)
lnfdi		-0.081***	-0.100***	-0.078***	-0.074***	-0.072
		(0.017)	(0.018)	(0.017)	(0.018)	(0.072)
lnfdi2			-0.015**			
			(0.006)			
regulation× lnrgdpc				-0.065**		
				(0.027)		
regulation×lnrewntnc					0.489***	
					(0.094)	
regulation×lnfdi						-0.002
						(0.012)
Constant	-16.581***	-18.836***	-18.246***	-19.786***	0.339	-18.815***
	(1.118)	(1.243)	(1.231)	(1.285)	(3.971)	(1.246)
Observations	690	635	635	635	635	635
r2	0.891	0.899	0.901	0.900	0.906	0.899
j	2.306	1.550	1.863	1.479	2.284	1.537
jp	0.129	0.213	0.172	0.224	0.131	0.215
F-statistics	12178.071	10149.386	10161.573	9025.605	44.909	10180.200

Robust standard errors in parentheses. *J* is Hansen J-statistics, *jp* is the p-value of Hansen J-statistics. *F-statistics* is the F-statistics for weak instrument identification. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 5: Dynamic Fixed Effect

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
L.lnco2kt	0.500***	0.476***	0.472***	0.470***	0.472***	0.476***
	(0.135)	(0.142)	(0.142)	(0.140)	(0.139)	(0.142)
lnrewntnc	-0.344**	-0.378***	-0.392***	-0.395***	-1.112**	-0.379***
	(0.141)	(0.131)	(0.130)	(0.131)	(0.476)	(0.129)
lnrgdpc	1.542**	1.569**	1.558**	1.403**	1.077*	1.566**
	(0.737)	(0.637)	(0.651)	(0.612)	(0.633)	(0.643)
lnrgdpc2	-0.089*	-0.093**	-0.093**	-0.065	-0.056	-0.093**
	(0.047)	(0.041)	(0.042)	(0.039)	(0.042)	(0.041)
lnpop	0.529***	0.564***	0.573***	0.613***	0.534***	0.566***
	(0.131)	(0.136)	(0.136)	(0.142)	(0.128)	(0.133)
lntrade	0.154***	0.163***	0.179***	0.155***	0.163***	0.164***
	(0.043)	(0.049)	(0.049)	(0.046)	(0.047)	(0.049)
lndcp	-0.008	0.015	0.018	0.011	0.016	0.015
	(0.027)	(0.026)	(0.027)	(0.024)	(0.026)	(0.026)
regulation	-0.004	0.002	0.002	0.215**	-0.443*	0.001
	(0.012)	(0.010)	(0.010)	(0.095)	(0.251)	(0.010)
lnfdi		-0.013**	-0.019**	-0.015**	-0.013**	-0.007
		(0.007)	(0.007)	(0.007)	(0.006)	(0.025)
lnfdi2			-0.002			
			(0.001)			
regulation× lnrgdpc				-0.034**		
				(0.015)		
regulation×lnrewntnc					0.102*	
					(0.057)	
regulation×lnfdi						-0.001
						(0.004)
Constant	-10.007***	-10.385***	-10.454***	-11.067***	-5.055	-10.420***
	(3.231)	(3.045)	(3.077)	(3.054)	(3.759)	(3.008)
Observations	739	674	674	674	674	674
r2	0.830	0.842	0.843	0.844	0.845	0.842
r2_w	0.830	0.842	0.843	0.844	0.845	0.842
r2_o	0.943	0.942	0.941	0.933	0.958	0.942
r2_b	0.952	0.944	0.942	0.932	0.961	0.943
rho	0.856	0.882	0.884	0.893	0.859	0.882
rmse	0.153	0.146	0.146	0.145	0.145	0.146

Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6: Regional analysis (IV-GMM results)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12	Model 13	Model 14	Model 15	Model 16	Model 17	Model 18
	WEST AFRICA						SOUTHERN AFRICA						CENTRAL AND EASTERN AFRICA					
lnrewntnc	-0.896***	-0.887***	-0.922***	-0.887***	-2.437***	-0.938***	-1.431***	-1.221***	-1.172***	-1.279***	-2.001	-1.222***	-2.449***	-2.366***	-2.380***	-2.512***	-9.958**	-2.318***
	(0.110)	(0.116)	(0.116)	(0.115)	(0.621)	(0.112)	(0.221)	(0.170)	(0.164)	(0.159)	(1.397)	(0.167)	(0.418)	(0.443)	(0.440)	(0.432)	(4.761)	(0.450)
lnrgdpc	0.630	-0.033	-0.470	-0.572	-0.751	-0.343	7.318***	6.458***	6.420***	7.035***	6.067***	6.453***	-1.089**	-1.208**	-1.285***	-1.420***	-1.216***	-1.269**
	(0.831)	(0.879)	(0.921)	(1.001)	(0.959)	(0.892)	(0.999)	(0.798)	(0.771)	(0.804)	(0.830)	(0.788)	(0.440)	(0.504)	(0.495)	(0.506)	(0.469)	(0.494)
lnrgdpc2	0.002	0.051	0.082	0.127	0.105	0.075	-0.451***	-0.388***	-0.387***	-0.484***	-0.362***	-0.388***	0.169***	0.179***	0.183***	0.158***	0.184***	0.182***
	(0.061)	(0.064)	(0.067)	(0.086)	(0.071)	(0.066)	(0.073)	(0.058)	(0.056)	(0.069)	(0.059)	(0.057)	(0.029)	(0.034)	(0.033)	(0.034)	(0.033)	(0.034)
lnpop	1.084***	1.100***	1.101***	1.109***	1.082***	1.105***	1.211***	1.382***	1.399***	1.431***	1.369***	1.408***	1.261***	1.279***	1.280***	1.264***	1.334***	1.278***
	(0.021)	(0.023)	(0.024)	(0.023)	(0.024)	(0.023)	(0.034)	(0.045)	(0.044)	(0.043)	(0.051)	(0.048)	(0.036)	(0.036)	(0.036)	(0.037)	(0.052)	(0.036)
lntrade	0.484***	0.653***	0.681***	0.642***	0.657***	0.633***	0.260**	0.925***	0.948***	1.045***	0.886***	0.988***	-0.560***	-0.478***	-0.443***	-0.441***	-0.507***	-0.436***
	(0.092)	(0.107)	(0.108)	(0.106)	(0.105)	(0.103)	(0.132)	(0.166)	(0.166)	(0.152)	(0.177)	(0.168)	(0.072)	(0.075)	(0.090)	(0.071)	(0.079)	(0.068)
lndcp	-0.080*	-0.102**	-0.110***	-0.098**	-0.095**	-0.093**	0.109*	0.038	0.067	0.013	0.051	0.026	0.351***	0.342***	0.339***	0.350***	0.342***	0.347***
	(0.043)	(0.043)	(0.043)	(0.043)	(0.042)	(0.043)	(0.061)	(0.067)	(0.068)	(0.061)	(0.068)	(0.068)	(0.040)	(0.040)	(0.041)	(0.040)	(0.039)	(0.039)
regulation	0.030*	0.032**	0.031*	0.524*	-1.078**	0.019	-0.143***	-0.037	-0.007	-0.882***	-0.515	-0.026	-0.074**	-0.066**	-0.064**	-0.549**	-5.915*	-0.069**
	(0.016)	(0.016)	(0.016)	(0.284)	(0.445)	(0.020)	(0.047)	(0.058)	(0.057)	(0.331)	(0.780)	(0.058)	(0.033)	(0.032)	(0.032)	(0.215)	(3.482)	(0.032)
lnfdi		-0.054**	-0.056**	-0.054**	-0.050*	0.143*		-0.164***	-0.175***	-0.171***	-0.157***	-0.378***		-0.047***	-0.055***	-0.047***	-0.045***	-0.266***
		(0.026)	(0.027)	(0.026)	(0.026)	(0.083)		(0.027)	(0.023)	(0.027)	(0.029)	(0.141)		(0.017)	(0.018)	(0.015)	(0.015)	(0.074)
lnfdi2			-0.019**						-0.021***						-0.004			
			(0.009)						(0.006)						(0.007)			
regulation× lnrgdpc				-0.078*						0.122**						0.076**		
				(0.046)						(0.049)						(0.034)		
regulation×lnrewntnc					0.254**						0.114						1.298*	
					(0.101)						(0.181)						(0.773)	
regulation×lnfdi						-0.037***						0.032						0.038***
						(0.014)						(0.022)						(0.011)
Constant	-12.129***	-10.815***	-9.222***	-10.514***	-1.400	-9.488***	-34.589***	-38.543***	-39.135***	-38.907***	-33.490***	-39.229***	-0.786	-1.453	-1.225	1.485	31.855	-1.535
	(2.690)	(2.783)	(2.970)	(2.873)	(5.054)	(2.877)	(3.029)	(2.767)	(2.703)	(2.683)	(8.006)	(2.812)	(2.859)	(3.157)	(3.134)	(3.359)	(21.268)	(3.177)
Observations	243	227	227	227	227	227	207	194	194	194	194	194	240	214	214	214	214	214
r2	0.935	0.941	0.942	0.941	0.943	0.942	0.943	0.956	0.958	0.958	0.956	0.957	0.928	0.934	0.935	0.935	0.940	0.938
j	0.003	0.017	0.010	0.070	0.131	0.049	4.354	1.535	1.856	0.594	2.456	1.368	3.881	1.758	1.791	1.911	1.500	2.135
jp	0.959	0.896	0.919	0.791	0.717	0.825	0.037	0.215	0.173	0.441	0.117	0.242	0.049	0.185	0.181	0.167	0.221	0.144
F-statistics	1519.699	1356.304	1334.096	1341.850	18.709	1308.101	1011.003	945.953	892.358	861.126	9.933	942.872	215.846	209.165	219.719	192.081	12.476	209.210

Robust standard errors in parentheses. *J* is Hansen J-statistics, *jp* is the p-value of Hansen J-statistics. *F-statistics* is the F-statistics for weak instrument identification. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Appendix Table 2: Correlation matrix for the three regions considered

WEST AFRICA

	lnco2kt	lnrewntnc	lnrgdpc	lnpop	lntrade	lndcp	regulation	lnfdi
lnco2kt	1.0000							
lnrewntnc	-0.1259	1.0000						
lnrgdpc	0.7056	-0.4750	1.0000					
lnpop	0.7970	0.2049	0.4575	1.0000				
lntrade	0.2412	-0.5342	0.3831	-0.0198	1.0000			
lndcp	0.3605	-0.5345	0.5235	0.1818	0.4636	1.0000		
regulation	0.3339	-0.2548	0.4393	0.1820	0.3534	0.1937	1.0000	
lnfdi	0.2544	-0.3548	0.3063	0.1173	0.5332	0.2889	0.3977	1.0000

SOUTHERN AFRICA

	lnco2kt	lnrewntnc	lnrgdpc	lnpop	lntrade	lndcp	regulation	lnfdi
lnco2kt	1.0000							
lnrewntnc	-0.5842	1.0000						
lnrgdpc	0.4889	-0.8807	1.0000					
lnpop	0.5092	0.2709	-0.4507	1.0000				
lntrade	-0.2909	-0.2465	0.4038	-0.7562	1.0000			
lndcp	0.7022	-0.7550	0.7712	-0.0619	0.1607	1.0000		
regulation	0.2134	-0.6841	0.7550	-0.4841	0.4577	0.4993	1.0000	
lnfdi	-0.2442	0.1244	-0.0665	-0.0689	0.3167	-0.1632	0.1896	1.0000

Eastern and Central AFRICA

	lnco2kt	lnrewntnc	lnrgdpc	lnpop	lntrade	lndcp	regulation	lnfdi
lnco2kt	1.0000							
lnrewntnc	-0.5779	1.0000						
lnrgdpc	0.6103	-0.6943	1.0000					
lnpop	0.6133	-0.2301	0.7497	1.0000				
lntrade	0.5770	-0.3914	0.5449	0.5065	1.0000			
lndcp	0.3599	-0.6192	0.5029	0.1542	0.6491	1.0000		
regulation	0.1186	-0.1576	0.3106	0.0870	0.2741	0.5842	1.0000	
lnfdi	0.3351	0.0708	0.3598	0.4430	-0.0543	-0.1976	0.2841	1.0000

FIGURES

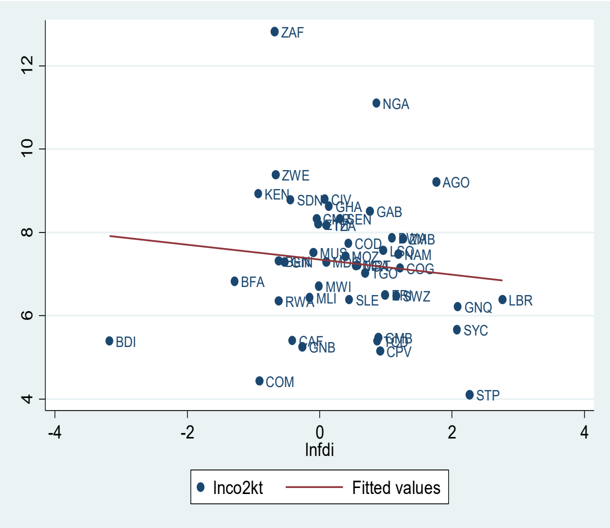

Fig 1: relationship between carbon emissions and FDI

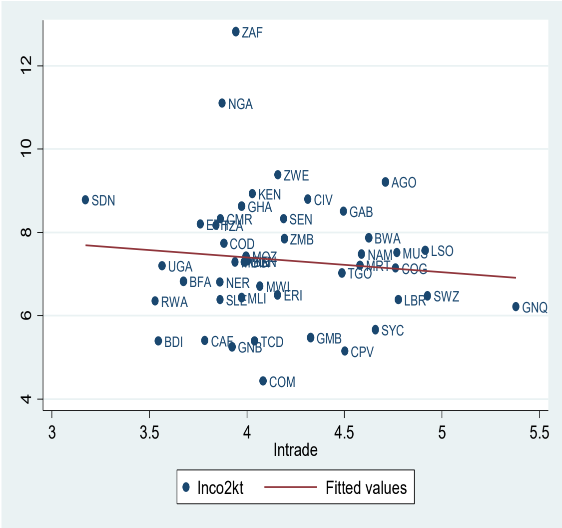

Fig 2: relationship between carbon emissions and trade openness