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## **Effects of Economic Growth, Trade Openness, Deforestation and Agricultural Trade on African Environmental Quality (1960-2008): A 2SLS Approach**

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# **29- EFFECTS OF ECONOMIC GROWTH, TRADE OPENNESS, DEFORESTATION AND AGRICULTURAL TRADE ON AFRICAN ENVIRONMENTAL QUALITY (1960-2008): A 2SLS APPROACH**

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## ***Abstract***

*This study ascertained the effects of agricultural commercialization (agricultural net exports), deforestation as represented by exports of forestry products, economic growth and trade liberalization on the level of green house gas (CO<sub>2</sub>) emissions in Africa. It relied on World Bank data (economic development indicators) between 1960 and 2008. Two Stage Least Squares (2SLS) regression model (using logged variables) was applied in the study. Standard econometric diagnoses such as specification test, heteroscedasticity, autocorrelation and endogeneity tests were performed and their results validated the model's use. All variables in the main equation were statistically significant and conformed to theoretical expectations. It was confirmed from our hypotheses tests that agricultural commercialization ( $p < 0.03$ ), forestry trade or deforestation ( $p < 0.01$ ), trade openness ( $p < 0.01$ ) as well as economic growth ( $p < 0.01$ ) all exerted significant influences on the level of CO<sub>2</sub> emissions in Africa over the period in review. Surprisingly, urbanization, contrary to earlier researchers' findings indicated a positive and significant influence on CO<sub>2</sub> emission. Hence we recommended that Africa should begin to integrate policies that will reduce pollution especially (CO<sub>2</sub> emission) in her drive for agricultural and economic growth. Environmentally efficient technologies that will build up less CO<sub>2</sub> in African environment should be developed and adopted by farmers across the continent as they target the export markets; while regional efforts should be made to regulate trade and investment with the aim of reducing the adverse effects of trade activities such as deforestation and pollution of the environment.*

**Key words:** Africa, Economic Growth, Environmental Kuznet Curve (EKC), Climate Change, Agricultural Commercialization, Deforestation, Trade Openness, Two Stage Least Squares (2SLS).

## INTRODUCTION

It has been noted that agriculture exerts significant impacts on the environment, using on average over 40% of water and land resources in Organization for Economic Cooperation and Development (OECD) countries. Impacts occur on and off farm, and include both pollution and degradation of soil, water and air, but also the provision of environmental services, such as biodiversity, flood and drought control, and a sink for greenhouse gases (OECD, n.d.). It was also noted that reform of agricultural and food trade policy provides 70 percent of the global gains from merchandise trade reform—\$265 billion of a total of \$385 billion (Mensbrughe & Beghin, 2005). The global gains were shared roughly equally between industrial and developing countries, but developing countries gained significantly more as a share of initial income. The above World Bank report added that significant income gains occurred in developing-countries' agriculture, where poverty tends to be concentrated. While it is unarguable that agricultural trade benefits both developing and developed economies, the negative aspects of agricultural commercialization equally appeared daunting. The worry becomes more pertinent with respect to Africa especially noting the World Bank's alert that even though climate change is a threat to all countries, developing countries (especially Africa) were the most vulnerable. The World Bank (2009) estimated that they would have to bear some 75 to 80 percent of the costs of damages caused. A global 2°C warming above pre-industrial temperatures could result in permanent reductions in GDP of 4 to 5 percent for Africa, the report noted. The African continent warmed by about 0.5°C last century, largely as a result of Green House Gas emissions (including CO<sub>2</sub> emissions) and deforestation all in pursuit of economic growth. This century, average annual temperatures are projected to rise by 3 to 4°C. Climate models concur that many arid areas will become drier and humid areas wetter. In Sub-Saharan Africa two-thirds is desert or dry land, there is high exposure to droughts and floods. These will increase with climate change. Domestic energy supply is mainly from biomass. Rainfed agriculture provides a third of GDP and jobs for two thirds of the population. Climate change is therefore a key development issue for Sub-Saharan Africa given the region's widespread poverty, unique geography and complex climate system. The FAO estimates that by 2050 the world will need to double food production in order to feed everyone. This would require commercialization of agriculture and departing from dependence on small-scale farming alone. Climate change and its consequences will have a decisive impact on productivity in agriculture. Failure to manage agricultural climate change adaptation will be met with a "sharp decline in food production, famine and unprecedented setbacks in the fight against poverty in developing countries" (especially sub-Sahara Africa) (International Institute for Environment, IIED, 2006). Adapting agriculture to climate change is the key to food security in the 21st century, warned IIED. The significance of this study may be viewed from the fact that in Africa the contribution of agriculture to GDP stood at an estimated average contribution of 21% (ranging from 10 to 70%) of GDP (Mendelsohn, Dinar & Dalfelt, 2000). This sector is particularly sensitive to climate, including periods of climate variability. In many parts of Africa, farmers and pastoralists also have to contend with other extreme natural resource challenges and constraints such as poor soil fertility, pests, crop diseases, and a lack of access to inputs and improved seeds. These challenges are usually aggravated by periods of prolonged droughts and/or floods and are often particularly severe during El Niño events (Mendelsohn, Dinar & Dalfelt, 2000, Vogel, 2005; & Stige et al., 2006). Such extreme events

are associated with global warming. Against this backdrop this study charted and discussed the trend of environmental quality degradation as proxied by CO<sub>2</sub> emissions in Africa; and then evaluated the major determinants of CO<sub>2</sub> emissions with particular reference to the roles of economic growth, agricultural commercialization, forestry trade and trade liberalization on African environmental quality.

The rest of the study proceeded with a review of related literature on the conceptual and empirical issues relating to environmental quality and economic growth and trade (especially agricultural and forestry trade). Some relevant theories relating to the issues discussed were cited. Then the methodology of the study was presented followed by presentation and discussion of results of the econometric analysis. At the end of the paper conclusion and relevant recommendations based on the study's outcomes were made.

### **Theoretical and Conceptual Issues**

Spanning from 1991, when economists first reported a systematic link between income changes and environmental quality, the relationship known as the Environmental Kuznets Curve (EKC) has become standard fare in technical discourse about environmental policy (Grossman & Krueger 1991). When first brought to public knowledge, EKCs indicated a surprising outcome. The early estimates showed that some important indicators of environmental quality such as the levels of sulfur dioxide, carbon dioxide and particulates in the air actually improved as incomes and levels of consumption rose up. Prior to the advent of EKCs, many well-informed people were of the opinion that richer economies damaged and even destroyed their natural resource endowments at a faster pace than poorer ones. They erroneously held that environmental quality could only be achieved by escaping the clutches of industrialization and the desire for higher incomes. The EKC's paradox inspired a large number of researchers.

According to Yandle, Vijayaraghavan and Bhattarai (2002) EKCs could be seen as statistical artifacts that summarized a few important aspects of collective human behaviour in two-dimensional space. Environmental Kuznets Curve chart revealed how a technically specified measurement of environmental quality changes as the wealth of a nation or other large human community change. Costantini and Monni (2006) rightly noted that the effects of economic growth and development on the environmental quality had been mainly analyzed through the so-called Environmental Kuznets Curve (EKC). Pioneering contributions stressed the importance of pure economic growth (in terms of income per capita) as a major source of environmental degradation (Grossman & Krueger, 1995; Shafik, 1994 as cited in Costantini & Monni, 2006). Costantini and Monni (2006) also noted that a higher value of trade and manufacture were associated with higher CO<sub>2</sub> emissions, isolating the composition effect and the scale effect claimed for a supply-side explanation of the EKC. This, they noted was consistent with previous scientists (Chichinilsky, 1994, and Suri & Chapman, 1998). They noted that increasing openness to trade was associated with increasing pollution emissions especially for developing countries due to the delocalization of polluting industries known as the pollution heaven effect (Copeland & Taylor, 2004).

Hettige, Lucas and Wheeler (1992) found that manufacturing (proxied by non-food production index in this present study) in low income countries was not more toxic, nor manufacturing in high-income ones less toxic. Manufacturing, which is just one part of GDP, did not become cleaner or dirtier as income changed. Instead, manufacturing became smaller relative to services and trade in expanding economies. This suggested that higher income leads to a demand for a cleaner environment regardless of whether the environment has been damaged by a toxic producing manufacturing sector, they noted. They therefore concluded that the GDP-based intensity result was due solely to a broad shift from industry toward lower-polluting services as development proceeded.

Yandle, Vijayaraghavan and Bhattarai (2002) concluded that the normal EKC suggested that as the development process picks up, when a certain level of per capita income is reached, economic growth helped to undo the damage done in earlier years. If economic growth were good for the environment, policies that stimulate growth (trade liberalization, economic restructuring and price reform) ought to be good for the environment, they added. However, income growth without institutional reform is not likely to be enough; and that the improvement of the environment with income growth is not automatic but depends on policies and institutions. GDP growth creates the conditions for environmental improvement by raising the demand for improved environmental quality and makes the resources available for supplying it. Whether an environmental quality improvement materializes or not, when and how depends critically on government policies, social institutions and the completeness and functioning of markets. Their investigation indicated that the toxic intensity of manufacturing output in these countries rises when the governments protect their chemical manufacturing sector with tariffs and non-tariff trade barriers. They also found that outward-oriented high-growth less developed countries had slow-growing or even declining toxic intensities of manufacturing, while toxic intensity increases more rapidly in inward-oriented economies—those with less trade.

Their findings on trade policy and toxic-intensity suggested a revised view of the displacement phenomenon or “pollution-haven” theory (Yandle, Vijayaraghavan & Bhattarai, 2002). Rapidly increasing toxic intensity does not seem to characterize all manufacturing in less developed countries in the 1970s, when environmental regulation in industrialized countries became stricter. Rather, toxic intensity in manufacturing has grown much more rapidly in economies that are relatively closed to international trade, added Yandle, Vijayaraghavan and Bhattarai (2002). This point was corroborated by Goklany (2001) and stressed by Grossman and Krueger (1991) when they observed that open economies improved their environments. More open economies have had higher growth rates of labour-intensive assembly activities that are also relatively low in toxic intensity. Highly protected economies had more rapid growth of capital-intensive smokestack sectors, they noted.

Similarly, trade economists have developed a conceptual framework for examining how trade opening can affect the environment, especially climate change (World Trade Organization, WTO, 2013). This framework, according to WTO, which was first applied to study the

environmental impact of the North American Free Trade Agreement (NAFTA), separates the impact of trade liberalization into three independent effects: scale, composition and technique.

The “scale” effect refers to the impact of trade on greenhouse gas emissions from the increased output or economic activity resulting from freer trade. It was generally presumed that trade opening will increase economic activity and hence energy use. All other things being equal, this increase in the scale of economic activity and energy use will lead to higher levels of greenhouse gas emissions.

The “composition” effect refers to the way by which trade liberalization changes the mix of a country’s production towards products where it has a comparative advantage. This re-allocation of resources within a country therefore is how trade improves economic efficiency. It was concluded that the effect on greenhouse gas emissions will depend on the sectors in which a country has comparative advantage. The composition effect will result in less greenhouse gas emissions if the expanding sectors are less energy intensive than the contracting sectors. Whether the composition effect results in higher or lower greenhouse gas emissions is therefore difficult to predict in advance, maintained WTO.

Finally, trade opening can also lead to improvements in energy efficiency i.e. the “technique” effect, so that the production of goods and services generates less greenhouse gas emissions. This decline in emission intensity can come about in two different ways. First, freer trade may increase the availability and lower the cost of environmentally-friendly goods, services and technologies. This is particularly significant for countries that have no access to these goods, services and technologies or whose domestic industries do not produce them in sufficient scale or at affordable prices. For exporters, additional market access is capable of providing incentives to develop new products, services and technologies to mitigate climate change. Second, the increase in income brought about by trade can lead society to demand better environmental quality, in other words, less greenhouse gas emissions.

Similarly, it was found by Verburg et al (2008) that liberalisation leads to a further increase in greenhouse gas emissions adding to an already observed increase in emissions observed in the baseline scenario. CO<sub>2</sub> emission increase is caused by vegetation clearance due to a rapid expansion of agricultural areas in South America and South East Asia. They equally found that increased methane emissions also calculated in these areas were caused by less intensive cattle farming. The observation agreed with a previous study by van Meijl et al (2006) who noted that regional changes in crop and livestock production could affect greenhouse gas emissions since the production of ruminant livestock increases methane emissions strongly. Cropland and pastures were known for storing CO<sub>2</sub> to a certain extent, they noted.

In their own findings, Cropper and Griffith (1994) as cited in Yandle, Vijayaraghavan and Bhattarai (2002) found that per capita income levels in most countries in Latin America and Africa were to the left of (lower than) the respective peaks of their estimated EKC’s (\$5,420 and \$4,760 in 1985 U.S. dollars), or about \$8,900 and \$7,800 in 2001 U.S. dollars. In other words, they have not reached their turning points. However, for countries in these two continents, as income increased, the rate of deforestation leveled off.

In terms of foreign aids effects on the economy, the World Bank (2004) established that increased aid was essential to meeting the MDGS and economic growth; but however noted that the gains from trade integration were estimated to be far larger than any contemplated increase in aid flows. Empirical investigations have indicated mixed results with respect to effects of foreign aid on economic growth. For instance, Burnside and Dollar (2000) concluded that foreign aid had positive effects on economic growth especially in economies where it is combined with good fiscal, monetary, and trade policies. A recent study (Doucouliagos & Paldam, 2009) on the other hand found that the effect of aid on growth was rather insignificant. Ekanayake and Chatrna (no date) in their study indicated that foreign aid had mixed effects on economic growth in developing countries.

In a study to ascertain the nature of relationship between urbanization and green house gas emission levels, Satterthwaite (2009) reviewed carbon dioxide emission levels for nations and how they changed between 1980 and 2005 (and also between 1950 and 1980)> It was found in the study that there was little association between nations with rapid population growth and nations with rapid greenhouse gas emission growth. The study indeed noted that it was mostly nations with very low emissions per person (and often only slowly growing emissions) that had the highest population growth rates. This findings need to be tested with respect to African case.

## **RESEARCH METHODS**

**Study Area:** The study focused on African continent's economy. Africa is a continent with a population of 0.8 billion and a per capita Gross National Income (GNI 1998=100) of 122. Her population growth rate was estimated at 2.5% and 2008 GNI per capita was estimated at \$1,082 (World Bank, 2013). Agriculture provides source of livelihood for about 75 percent of her population. She had benefitted from several International Development Aids over the decades. According to the World Bank (2013) the global financial crisis halted a half decade of high economic growth in many African countries significantly pulling down the average growth rates from 6.2 percent in 2007 to a projected 1.7 percent in 2009. Remittances and the private capital flows were also diminished, slowing down progress toward the Millennium Development Goals.

### **Data Collection and Sampling Techniques**

The major data used for empirical analysis in this work were obtained from the World Bank data base available at World Bank's website. The data, which were all economic development indicators were secondary data spanning across 49 years (1960 – 2008) were used for the study. The sampling was purposive: only the number of years that has available data on all the variables of interest were chosen. These variables included agricultural trade value (exports and imports, which were added and divided by total merchandise in Africa to ascertain share of agricultural trade in the continents total international trade) in Africa. Other variables included the annual CO2 emission levels, GDP, Trade Openness, forestry import and export values, urban population counts, index of non-food production (proxy for manufacturing) and value of net international aid flow into the continent.

It is certain that the EKC hypothesis established a relationship between economic growth and environmental quality. However the relationship between international aid and environmental quality may be gleaned as an indirect link which emanates as a result of the effect of foreign aid on economic growth. Burnside and Dollar (2000) hypothesized that aid influences growth but that its impact is conditional on the same policies that affect economic growth. Asirvatham (2010) asserted that the standard model used to justify aid was the “two-gap” model of Chenery and Stout which built on previous works of developmental economists such as Arthur Lewis (1954) and Rostow (1960). In the Chenery and Stout model as cited in Asirvatham (2010) economic growth depends on investment as a share of GDP, adjusted for factors that reveal whether investment is of high or low quality. The amount of investment will be the sum of domestic savings and foreign aid. Asirvatham applied a two stage least squares approach (2SLS) to test Burnside and Dollar (2000) hypothesis. It was affirmed from the study that aid had a negative but significant relationship with economic growth. This finding agreed with Burnside and Dollar’s (2000) hypothesis that aid will be effective in economic growth given a good policy environment.

### Data Analysis Technique

Descriptive statistics especially use of charts were employed to aid in describing the trends of agricultural trade (international trade), CO2 emissions and the representation of empirical EKC in the African economy over the period in review. The second objective, determination of the influences of agricultural trade, economic growth, deforestation and trade openness effects on CO2 emission in Africa over the review period was attained using Two Stage Least Squares (2SLS) model. Studies of this sort which have suspected endogenous variable (e.g. GDP) would require a more robust model that can capture the endogeneity problem in the model. Similar works have previously applied this model lately. For instance Bulte *et al* (2005) and Isham *et al.* (2003 as cited in Costantini & Monni, 2006).

### Theoretical Model

If the regressors of one or more equations are correlated with the disturbances  $(E[u_i^T X_i] \neq 0)$ ,

OLS, WLS, and SUR estimates are biased. This can be circumvented by a two-stage least squares (2SLS), weighted two-stage least squares (W2SLS), or a three-stage least squares. At first the first stage new (“fitted”) regressors are obtained by

$$\hat{X}_i = Z_i \left( Z_i^T Z_i \right)^{-1} Z_i^T X_i.$$

Then, these “fitted” regressors are substituted for the original regressors in Equationn 1

$$\hat{\beta} = \left( X^T \hat{\Omega}^{-1} X \right)^{-1} X^T \hat{\Omega}^{-1} y. \quad \dots 1$$

Whose covariance matrix of the coefficient can be estimated by

$$\widehat{COV} [\hat{\beta}] = \left( X^T \hat{\Omega}^{-1} X \right)^{-1} \quad \dots 2$$

This can be done to obtain unbiased 2SLS, Weighted 2SLS or 3SLS estimates of  $\beta$  by

$$\hat{\beta} = \left( \hat{X}^T \hat{\Omega}^{-1} \hat{X} \right)^{-1} \hat{X}^T \hat{\Omega}^{-1} y, \quad \dots 3$$

Where

$$X = \begin{bmatrix} \hat{X}_1 & 0 & \dots & 0 \\ 0 & \hat{X}_2 & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & \hat{X}_G \end{bmatrix} \quad \dots 4$$

An estimator of the covariance matrix of the estimated coefficients can be obtained from Equation 4 analogously. Hence we get

$$cov[\hat{\beta}] = (X^T \hat{\Omega}^{-1} X)^{-1} \quad \dots 5$$

The two-stage least squares (2SLS) estimator is based on the same assumptions about the disturbance terms as the OLS estimator. Accordingly,  $\hat{\Omega}$  in Equation 10 is equal to  $IG\_T$  and thus, cancels out. Like for the OLS estimator, the whole system can be treated either as one single equation with  $\hat{\Omega}$  in Equation 5 equal to  $\hat{\sigma}^2 I_{G \cdot T}$ , or the disturbance terms of the individual equations are allowed to have different variances with  $\hat{\Omega}$  in Equation 5 equal to  $\hat{\Sigma} \otimes I_T$

$$\text{Where } \hat{\sigma}_{ij} = 0 \forall i \neq j \text{ and } \hat{\sigma}_{ii} = \hat{\sigma}_i^2$$

### Empirical Model

Following Asirvatham (2010) and other researchers cited in Costantini & Monni (2006) we applied the 2SLS to model the relationship between environmental quality as proxied by CO2 (a green house gas) and its explanatory variables. The model whose implicit form is

$$\log CO_2 = f(\log AGRITRAD, \log GDP, \log TOP, \log URBPOP, \log FORSTRAD, \log NONFOOD, u) \quad \dots 6.$$

is specified as follows using a 2SLS model as follows:

$$\log CO_2 = \beta_0 + \beta_1 \log AGRITRAD + \beta_2 \log GDP + \beta_3 \log TOP + \beta_4 \log URBPOP + \beta_5 \log FORSTRAD + \beta_6 \log NONFOOD + u \quad \dots 7.$$

$$\log GDP = \Phi_0 + \Phi_1 \log AGRITRAD + \Phi_2 \log NETAID + \Phi_3 \log GCF + \Phi_4 \log GDP + \Phi_5 \log TOP + \Phi_6 \log URBPOP + \Phi_7 \log FORSTRAD + \Phi_8 \log NONFOOD + v \quad \dots 8.$$

Where CO<sub>2</sub> = CO<sub>2</sub> emissions (metric tons per capita); AGRITRAD = Annual Agricultural trade (FAO, current US\$) as share of total merchandise (\$US current); GDP = Annual GDP per capita (current US\$); TOP = The ratio of Africa's annual total trade (exports + imports) to the GDP; URBPOP = Population in urban agglomerations of more than 1 million (% of total population); FORSTRAD = Annual forestry export trade as share (or percentage of total trade); NONFOOD = Annual Gross non-food production index (2004-2006 = 100) used as proxy for manufacturing index; GCF = Annual Gross Capital Formation in constant 2005 \$US (used as proxy for GDP in construction of instruments); NETAID = Net official development assistance and official aid received (current US\$) (Served as proxy for GDP while selecting instrumental variables for GDP equation following Burnside & Dollar, 2000); log = log to base 10 of the respective variables; u = stochastic error term of the primary equation (CO<sub>2</sub> as

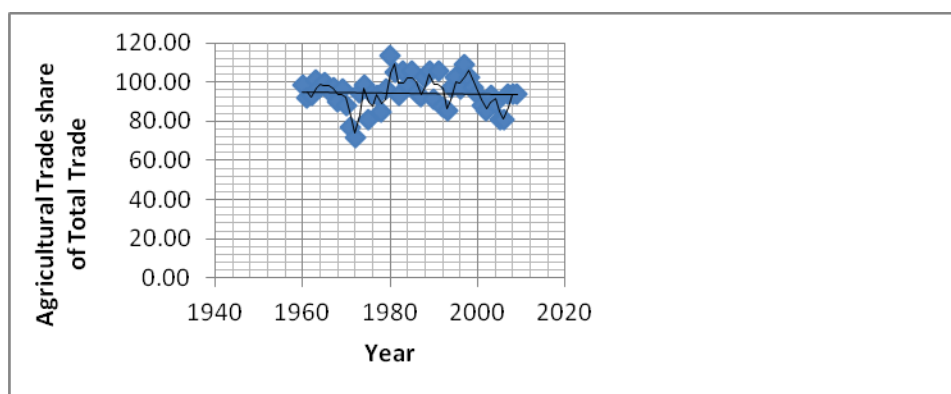
endogenous variable);  $v$  = stochastic error term of the endogenous variable (GDP) equation;  $\beta_0$  = intercept of the primary model;  $\gamma_0$  = intercept of the secondary equation (i.e. GDP or X);  $\beta_1 - \beta_6$  = parameters to be estimated (slope coefficients of respective variables or elasticities);  $\gamma_0$  = intercept of the endogenous variable equation (GDP)

$\Phi_1 - \Phi_8$  = parameters to be estimated (slope coefficients of respective variables in the second equation).

The model was subjected to several diagnostic tests including test for weak instruments. We followed Kennedy (2008); Stock and Yogo (2005) and conducted test for “weak instruments”. It was necessary to test the endogenous variable (GDP) equation to find out whether the instrumental variables selected actually correlate strongly with the suspected endogenous variable in the first equation (GDP) or not. This is to avoid modeling in the presence of endogeneity bias in the model which will make the estimates of our coefficients’ standard errors bias and thus making hypothesis testing unreliable. The bottom line of the issue is that Instrumental Variable/2SLS/GMM results would be preferred to OLS if the significance test for excluded instruments produces an F-statistic at least equal to 10 (i.e. F ratio = or > 10) among other qualities. For details see Kennedy (2008) and Stock, and Yogo (2005). In our case the GDP equation gave an estimated F ratio of 206.6364 which is greater than 10 (See Appendix 2). We therefore conclude that our instrumental variables are strong but not “weak instruments”. They will produce coefficient estimates which will be reliable in hypothesis testing.

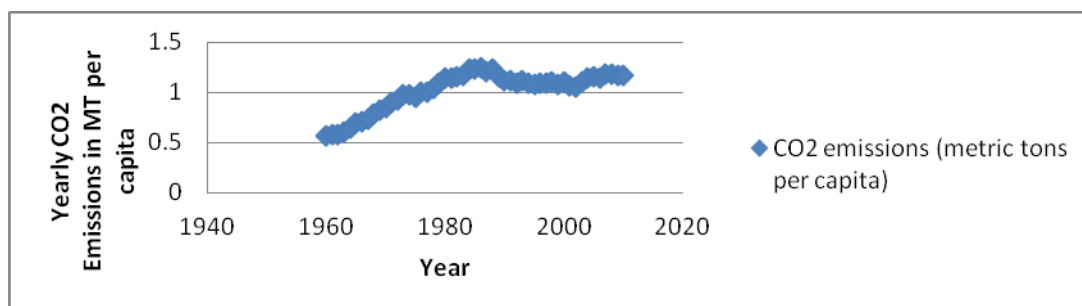
## RESULTS AND DISCUSSION

The chart in Figure 1 depicts the trend of agricultural trade performance in Africa from 1960 – 2009. From the graph it could be observed that African agricultural trade has been fluctuating over the decades and the variations may not be dissociated from both natural factors (such as environmental factors like drought, climate variability; political economy tides of the continent and global economic indices. Around 1970s (early 70s) for instance which coincided with the period of oil boom there appeared to be a drop in the level of contribution of agricultural trade as a share of African GDP. This is not surprising as many African countries depend on oil and other natural resources for their economic growth. The oil wealth used to develop the urban areas appeared then to take its toll on farming as rural urban drift heightened and the aged farmers who may not be able to contribute much to commercial agricultural production were left to take control of agricultural production. Just after this era, there appeared to be increased agricultural development initiatives such as the Green Revolution of the 80s, a development that propelled agricultural trade upwards in the 80s and 90s. The trend decreased for a short period in the early 90s and picked up again before picking up and rising steadily until the later part of 2000s which saw agricultural trade plunging sharply around 2007 which coincided with the global food crisis era and then the global financial meltdown. Around 2009 onwards the trend of agricultural trade appears to be rising again.



*Figure 1. Agricultural Export Trade Performance in Africa from 1960 – 2009 (Source: Charted by the authors using World Bank Data, 2013).*

The general outlook of CO<sub>2</sub> emission in Africa over the period in review as shown in Figure 2 indicated that CO<sub>2</sub> emission reached a threshold in the late 90s and started decreasing from then till middle of the first decade of the millennium. It started rising again since the around 2006 and by 2008 onwards its rise was no longer so sharp may be due to increased awareness about the effects of global warming as a result of green house gas emissions. It would be noted that around this era (late 2000s) so many policies and regional agreements have been contracted in Africa and the world over to curb the increase in global emissions of CO<sub>2</sub> and other green house gases. It thus seemed that the efforts were paying off.



*Figure 2.0 Long Run Trend of CO<sub>2</sub> Emissions in Africa (1960-2009).Source: Charted by the authors using World Bank Data (2013).*

A look at the trend charted in *Figure 3* indicated that African economic growth had been swinging up and down since 1960 to 2010. The finding conformed to Juma's (2013) observation that African economy had been shifted severally by major trends that were shaping the continent. These included deepening regional integration; shifting trade relations; and the rise of technocratic presidencies. To some scholars who did not glean the cause of the fluctuations from this perspective, noted Juma, there were doubts regarding the claims over "Africa Rising". Some even

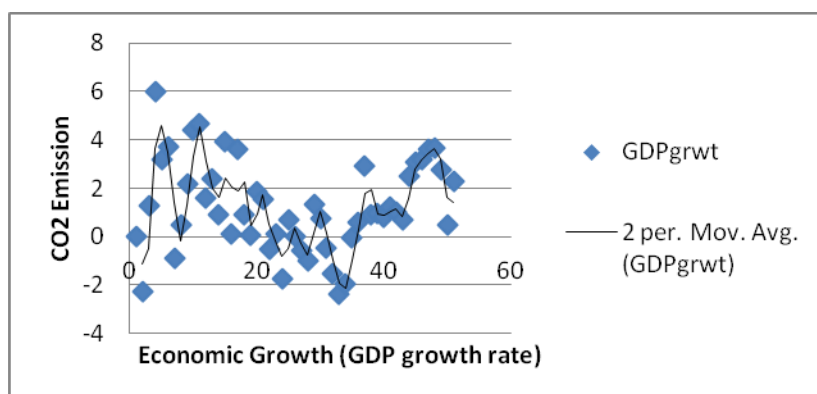


Figure 3.0 GDP Growth Rate and CO2 Emissions (*Economic Growth and Environmental Quality in Africa 1960-2009*). Source: Charted by the authors using World Bank Data (2013).

argued that Africa's growth was underestimated. Juma's explanation appeared to explain the major reasons for fluctuations in the growth pattern of African economy among other issues including, possibly, climate change and other environmental factors too unaccounted for. Fluctuations in other macro variables such as inflows of foreign aid, gross capital formation and population growth could also be possible causes of the shifts in the growth trend of African economy recorded in this study.

#### **Determinants of Environmental Quality in Africa over the Review Period (1960-2008)**

*Model Fitness Tests results:* Results of econometric analysis regarding the influences of agricultural trade, economic growth (GDP), trade openness, urbanization, forestry trade and manufacturing on African environmental quality (CO2 emission) are presented in Table 1 while the relevant econometric diagnostic analysis of the model's estimates are summarized in Table 2. It would be seen from Table 1 that the model recorded an adjusted R square of 0.75 approximately indicating that 75 percent of the variation in the CO2 emission rate in the model was explained by the explanatory variables in the 2SLS model applied. The model also indicated an F-ratio of 25.71 approximately enabling us to reject null hypothesis of no significant joint effects of the explanatory variables in the model. These two results imply that the model is very fit.

*Diagnostic Checks:* In 2SLS estimation one of the most important tests of model fitness is the endogeneity test as represented by the J-statistic estimate. The estimated J statistic 4.621 at a probability level of 0.099 did not indicate the presence of significant endogeneity in the selected instruments of the 2SLS model used in this study. We therefore accept the null hypothesis of no endogeneity in the instrumental variables of the 2SLS model at 10 percent level of significance.

**Table 1. Estimates of the 2SLS Regression Model**

Dependent Variable = logCO2			Obs = 49	(1960-2008)
Variable	Coefficient	Std. Error	t-Statistic	Prob.
<i>Intercept</i>	-1.233	0.984	-1.253NS	0.217
<i>LOG(AGRITRAD)</i>	0.254	0.080	3.188***	0.003
<i>LOG(GDP)</i>	0.505	0.173	2.923***	0.006
<i>LOG(TOP)</i>	-0.433	0.083	-5.198***	0.000
<i>LOG(URBPOP)</i>	0.764	0.190	4.024***	0.000
<i>LOG(FORSTRAD)</i>	-0.006	0.002	-3.670***	0.001
<i>LOG(NONFOOD)</i>	-0.655	0.119	-5.498***	0.000
<i>R-squared</i>	0.786	Sum of sq. resid SSR	0.1021	
<i>Adj. R-squared</i>	0.755	Second-Stage SSR	0.1021	
<i>S.E. of regression</i>	0.049	Instrument rank	9	
<i>F-statistic</i>	25.712			
<i>Prob(F-statistic)</i>	0.000			
<i>J-statistic</i>	4.621			
<i>Prob(J-statistic)</i>	0.099NS			

NS= Not significant at 5%. (\*\*\*) = Figures are statistically significant at 1 percent.

Source: Computed by the authors using E Views econometric package.

**Table 2. Econometric Diagnostic test results summary**

SN	Type of Test	Estimated Statistic	Prob.	Remark
1	Jarque Bera test for Normality of Residual Distribution	0.667	0.710	Accept null hypothesis of non-normality of residual distribution of the model
2	Heteroskedasticity Test: Breusch-Pagan-Godfrey (F ratio)	0.985	0.448	Accept the null hypothesis of no significant heteroscedasticity in the model
3	Breusch-Godfrey Serial Correlation LM Test:	5.949	0.051	Accept the null hypothesis of no significant or severe autocorrelation in the model
4	Ramsey RESET Test (Model Specification Test)( F-ratio)	0.652	0.424	Accept the null hypothesis of no omitted variables or wrong specification of the model
5	J-statistic (Exogeneity test)	4.621	0.099	Accept the null hypothesis of no endogeneity in the instrumental variables of the 2SLS model

Source: Computed by the authors using E Views econometric package

All other diagnostic checks as could be observed in Table 2 indicated that the model was not threatened by severe autocorrelation, heteroscedasticity nor misspecification of the model. Hence we can proceed and use the estimated parameters of the 2SLS for our economic analysis since the model passed the required econometric tests.

### *Major Findings and Implications*

All the variables returned estimated parameters whose signs were in sync with theoretical expectations. For instance agricultural trade (net agricultural export value) in the African economy, GDP (economic growth) and urban population growth indicated positive signs in their slope coefficient estimates signifying that they contributed positively to the increase in green house gas (CO<sub>2</sub>) emissions in the continent.

The slope coefficient for agricultural trade (0.254) which was statistically significant at  $p \leq 0.01$  implies that a unit increase in agricultural trade over the period resulted in a rise of CO<sub>2</sub> emission by approximately 25 percent. This effect is quite high and implies that agricultural export trade activities in Africa were seriously influencing the level of toxicity of the environment. The finding is in tandem with Verburg (2008) and van Meijl et al (2006) who noted that regional changes in crop and livestock production could increase greenhouse gas emissions. The findings also lend credence to the earlier position of Monni (2006) who noted that a higher value of trade was associated with higher CO<sub>2</sub> emissions.

With respect to economic growth (GDP), it was indicated that its slope coefficient was 0.505 with an estimated t-statistic of 2.923 (which is statistically significant at  $p \leq 0.01$ ). The result meant that a unit increase in the continent's GDP was associated with an increase in CO<sub>2</sub> emissions by 2.92 percent approximately. This figure is also an affirmation of the deleterious effect of economic growth on the environment. The finding is in line with the hypothesis postulated in the Environmental Kuznets Curve analysis that economic growth is to some extent correlated positively with green house gas emission. The findings agreed with Costantini & Monni (2006), Yandle, Vijayaraghavan and Bhattarai (2002); Grossman and Krueger (1995) and other researchers who noted the importance of pure economic growth (in terms of income per capita) as a major source of environmental degradation.

With respect to urbanization, the study showed that the increase in the variable was associated with rise in CO<sub>2</sub> emissions in Africa. Urbanization indicated a slope coefficient of 0.76 (t-statistic = 4.024) which was statistically significant at  $p \leq 0.01$ . This finding implies that urbanization, contrary to earlier finding by Satterthwaite (2009) was a significant determinant of green house emissions.

Trade openness indicated a negative slope coefficient which implies that a CO<sub>2</sub> emission in Africa was a decreasing function of trade openness. The variable recorded an elasticity of -0.433 with respect to CO<sub>2</sub> emission. Its t-statistic estimated (-5.198) was significant at  $p \leq 0.01$  too just like the other explanatory variables. The finding goes to affirm the school of thought held by Goklany (2001) amplified by Grossman and Krueger (1991) when they observed that open economies improved their environments. Similarly the findings agreed with NAFTA's

theory of trade openness and environmental quality, specifically the “composition effect” and the “technique effect” already explained by World Trade Organization (WTO, 2013). We have seen how trade openness can help efforts to mitigate and adapt to climate change, for example by promoting an efficient allocation of the world's resources (including natural resources), raising standards of living (and hence the demand for better environmental quality) and improving access to environmental goods and services. This and improvements in energy efficiency (as a result of technique effect) must have explained why trade openness in our empirically finding here appeared to favour decrease in African green house gas (CO<sub>2</sub>) emission.

The effects of deforestation on the level of CO<sub>2</sub> emissions appeared to be negative and statistically significant at 1 percent level implying that the continent seemed to be conducting the forestry trade under a sustainable atmosphere. In other words it may be said, following the New Zealand Ministry for Natural Resources (2013) that when forests are harvested and replanted the planted ones can restore the existing effect of the forest as a natural means of carbon sequestration, hence the negative sign. However, the elasticity of this variable with respect to CO<sub>2</sub> emission was very low, -0.006. This implies that the response of CO<sub>2</sub> emissions with respect to forestry trade in Africa over the review period was still very low.

The proxy for manufacturing variable, log of annual nonfood production index, was negatively signed. This implies that as the rate of manufacturing deepened there was a decrease in the rate of CO<sub>2</sub> emission. This variable had an elasticity estimate of -0.655 (t-statistic = -5.498) which was statistically significant at  $p \leq 0.01$ . The findings conformed to Yandle, Vijayaraghavan and Bhattacharai (2002) who found that outward-oriented high-growth less developed countries (as in Africa) had slow-growing or even declining toxic intensities of manufacturing, while toxic intensity increases more rapidly in inward-oriented economies—those with less trade.

## CONCLUSION

The study applied the 2SLS approach to model the influences of agricultural trade, economic growth, trade liberalization, urbanization and forestry exports on green house gas (CO<sub>2</sub>) emissions in Africa from 1960-2008. The findings indicated that all the above hypothesized drivers of environmental quality estimated in the model exerted statistically significant influences on CO<sub>2</sub> emissions in Africa. Their signs equally conformed to theoretical expectations. Surprisingly, however, the former, though recent, hypothesis canvassed by some researchers (e.g. Satterthwaite, 2009) that urbanization had no significant influence on green house gas emission was proved wrong by the findings of this study. Based on the findings of this study, this study recommends that environmental sustainability considerations should be effectively built into private and public investment decisions in agriculture and other sectors of the economy. This may involve adopting laws and policies that support environmentally sustainable private investment and protect the rights of the most vulnerable. This can be achieved for instance (with respect to agricultural production) by adopting FAO's (2007, 2012) recommendations on sustainable agricultural investment and production, which include using Command-and-control policy; financial penalties and charges principle; removing perverse incentives; establishing property rights to an externality and payments for environmental

services (PES). Environmentally efficient technologies that will build up less CO<sub>2</sub> in African environment should be developed and adopted by farmers across the continent as they target the export markets; while regional efforts should be made to regulate trade and investment with the aim of reducing the adverse effects of trade activities such as deforestation and pollution of the environment. Since trade openness appeared to decrease CO<sub>2</sub> emissions in Africa over the period in review it would benefit African countries's environment if they liberalize their trades as gains from trade may lead to effective utilization of energy thus reducing the expected deleterious effects of trade liberalization on the continent's economy.

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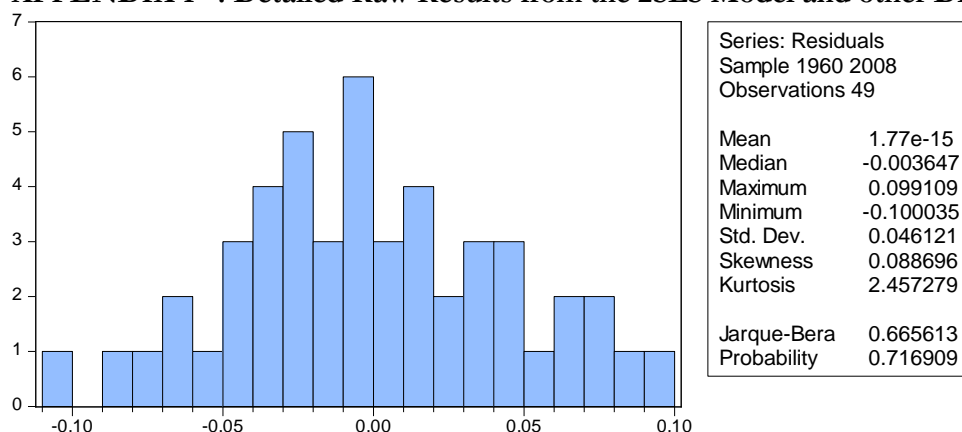
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#### APPENDIX 1 : Detailed Raw Results from the 2SLS Model and other Diagnostic test results



Dependent Variable: LOG(CO2)  
Method: Two-Stage Least Squares  
Date: 03/05/13 Time: 10:12  
Sample: 1960 2008  
Included observations: 49  
Instrument specification: LOG(GDP) C LOG(AGRITRAD) LOG(GCF)  
LOG(NETAID) LOG(TOP) LOG(URBPOP) LOG(FORSTRAD)  
LOG(NONFOOD)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1.232571	0.983810	-1.252854	0.2172
LOG(AGRITRAD)	0.253740	0.079584	3.188324	0.0027
LOG(GDP)	0.505181	0.172847	2.922709	0.0056
LOG(TOP)	-0.432645	0.083239	-5.197642	0.0000
LOG(URBPOP)	0.764139	0.189877	4.024382	0.0002
LOG(FORSTRAD)	-0.006317	0.001721	-3.669779	0.0007
LOG(NONFOOD)	-0.654676	0.119078	-5.497860	0.0000
R-squared	0.786009	Mean dependent var		-0.699605
Adjusted R-squared	0.755439	S.D. dependent var		0.099702
S.E. of regression	0.049306	Sum squared resid		0.102105
F-statistic	25.71167	Durbin-Watson stat		1.343657
Prob(F-statistic)	0.000000	Second-Stage SSR		0.102105
J-statistic	4.620514	Instrument rank		9
Prob(J-statistic)	0.099236			

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	0.984882	Prob. F(6,42)	0.4477
Obs*R-squared	6.043821	Prob. Chi-Square(6)	0.4183
Scaled explained SS	3.235420	Prob. Chi-Square(6)	0.7788

Breusch-Godfrey Serial Correlation LM Test:

Obs*R-squared	5.949368	Prob. Chi-Square(2)	0.0511
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Ramsey RESET Test

Equation: UNTITLED

Specification: LOG(CO2) C LOG(AGRITRAD) LOG(GDP) LOG(TOP)

LOG(URBPOP) LOG(FORSTRAD) LOG(NONFOOD)

Instrument specification: LOG(GDP) C LOG(AGRITRAD) LOG(GCF)

LOG(NETAIDINFLOW) LOG(TOP) LOG(URBPOP) LOG(FORSTRAD)

LOG(NONFOOD)

Omitted Variables: Squares of fitted values

	Value	df	Probability
t-statistic	0.807257	41	0.4242
F-statistic	0.651664	(1, 41)	0.4242
Difference in J-stats	1.393810	0	NA

F-test summary:

	Sum of Sq.	df	Mean Squares
Test 2SSR	0.001887	1	0.001887
Restricted 2SSR	0.102105	42	0.002431
Unrestricted 2SSR	0.100217	41	0.002444
Unrestricted SSR	0.118747	41	0.002896

J-statistic summary:

	Value
Restricted J-statistic	4.620514
Unrestricted J-statistic	3.226704

## APPENDIX 2 : OLS Result for Comparison

Dependent Variable: LOG(CO2)

Method: Least Squares

Date: 03/06/13 Time: 10:40

Sample: 1960 2008

Included observations: 49

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1.232571	0.983810	-1.252854	0.2172
LOG(AGRITRAD)	0.253740	0.079584	3.188324	0.0027
LOG(GDP)	0.505181	0.172847	2.922709	0.0056
LOG(TOP)	-0.432645	0.083239	-5.197642	0.0000
LOG(URBPOP)	0.764139	0.189877	4.024382	0.0002
LOG(FORSTRAD)	-0.006317	0.001721	-3.669779	0.0007
LOG(NONFOOD)	-0.654676	0.119078	-5.497860	0.0000
R-squared	0.786009	Mean dependent var		-0.699605
Adjusted R-squared	0.755439	S.D. dependent var		0.099702
S.E. of regression	0.049306	Akaike info criterion		-3.049986
Sum squared resid	0.102105	Schwarz criterion		-2.779726
Log likelihood	81.72466	Hannan-Quinn criter.		-2.947450
F-statistic	25.71167	Durbin-Watson stat		1.343657
Prob(F-statistic)	0.000000			