# Testing the Environmental Kuznets Curve Hypothesis for the Depletion of Natural Resources in Sub-Saharan African Countries

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**Abstract**

*The relationship between economic growth and environmental degradation indicators, referred to in environmental economic literature as the Environmental Kuznets Curve (EKC) hypothesis has been widely investigated, with a plethora of studies finding enough evidence to support the hypothesis. However, many of these studies employ an aggregate measure of economic activity such as Gross Domestic Product (GDP) per capita, thus failing to establish empirical evidence of the hypothesis for disaggregated or sectoral measures of economic activities. Therefore, this work was motivated from the understanding that disaggregated measures of economic activities produce relatively specific environmental effects. It is in this regard that this study sets out to investigate in to the validity of the EKC hypothesis for total natural resources depletion in 26 Sub-Saharan African (SSA) countries. The study uses panel data from 1981-2016 obtained from the World Development Indicators (WDI) of the World Bank. Natural resources rents and natural resources depletion were used as measures of economic activity and environmental degradation respectively. Panel unit root tests were conducted to test for stationarity of the variables and panel cointegration test was used to establish the presence of a longrun relationship among the variables. Based on the Hausman test, the panel fixed effects model was selected for empirical analysis. Results of the study confirm, contrary to expectation the absence of an inverted U-shaped relationship between rents from natural resources and natural resource depletion. A monotonically increasing relationship was found. The implication of this finding is that there is no point in time at which, exploitation of natural resources is going to be an asset and not a liability to the environment. It is recommended that the governments of SSA countries should design and implement strict environmental policies where they are absent and enforce these policies where they are present in a bit to mitigate the adverse effects of the exploitation of natural resources as well as other economic activities on the environment.*

**Key Words:** Environmental degradation, Natural resources exploitation, natural resources rents, economic growth, resource depletion

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## 1. INTRODUCTION

The relationship between the indicators of economic performance and those of environmental degradation remains an important subject of discussion in environmental economics literature. This relationship which today has become known as the Environmental Kuznets Curve (EKC) hypothesis, named after Simon Kuznets (1955) stipulates that an inverted U-shaped non-linear relationship exist between environmental degradation and per capita income along a country's growth path. Kuznets hypothesized that income inequality increases first, then decreases with an increase in growth over time. According to the EKC hypothesis, environmental degradation increases in the early stages of growth in per capita income but beyond a certain income level, the trend changes such that an increase in income per capita improves the environment (Stern, 2004). This relationship suggests that growth is detrimental to the environment during the early stages of development because economic resources are ineffectively used while technological progress and economic growth improves environmental quality at some point in the later stages of development (Kubatko, 2008). The EKC concept first became known in economic literature with the works of Grossman and Krueger (1991) and Shafik and Bandyopadhyay (1992), who adopted it from Kuznets.

While the desire to achieve a sustained increase in economic growth and development remains a primary and permanent objective of all countries particularly those of the African continent, the attainment of this objective has consequences for the environment. The EKC framework provides the basis for understanding the arguments advanced by scholars regarding the possible effects of economic activities on the environment. On the one hand are those who argue that production activities create detrimental effects on the environment (Adewuyi, 2001; Gutti et al, 2012; Omorede, 2014) and the best way to protect the environment and even the economy is to reduce the scale of economic activities while on the other hand are those who believe that technological advancement and economic progress are the ways through which environmental improvement can be achieved (Panayotou, 2003). Believers of this thought hold that as incomes increase, the demand for less material-intensive goods and services also increases. Also, there is an increase in the demand for improved environmental quality that triggers the adoption of environmental regulation (Ajide and Oyinlola, 2010) as cited in Sunday (2015). Most empirical studies on the EKC hypothesis are therefore being motivated by the need to understand whether economic activities, as measured by an economic growth indicator are necessarily good or bad for the environment.

The current study is carried out within the same context, though it focuses on natural resources exploitation.

It is an established fact that Africa, especially Sub-Saharan Africa (SSA) is endowed with both a great volume and variety of natural resources. The continent is well known as a home to some of the largest deposits of natural resources. For instance, Ethiopia is richly endowed with small reserves of gold, platinum, copper, potash, natural gas and hydropower (Central Intelligence Agency [CIA] World Fact Book, 2018). Lyakurwa (2011) have noted that Angola and Nigeria produce substantial portions of world crude oil; South Africa and other African countries are the major world producers of gold; Zambia is endowed with large copper deposits, Botswana, Democratic Republic of Congo (DRC) and Sierra Leone are major diamond producers while other strategic minerals such as coltan, chrome, manganese and bauxite are major exports from many African countries. Moreover, a significant quantity of world tropical hardwood (timber), cocoa, coffee and rubber exports is from Africa. These resource potentials do not only attract foreign direct investment, but as noted by Adewuyi (2001), are an important source of foreign earnings used in developing infrastructure, providing for social amenities as well as offering employment opportunities to the unemployed population. In short, the livelihoods of African people largely revolves around the exploitation and utilization of natural resources.

Though countries harness their natural resources with the primary objective of achieving their growth and development goals, this is often at the expense of rapid environmental degradation which threatens human existence because environmental resources are often non-sustainably exploited. Gutti et al. (2012) pointed out that a lot of negative effects are created by man on the environment in the struggle for survival and development. In the same light, Adewuyi (2001) posited that the production and consumption of agricultural products have consequences for the environment, and this is a well-established fact. Agricultural production activities involving application of scientific methods such as the use of fertilizers, insecticides, pesticides and other chemicals clearly affect soil fertility in the long run and the application of the traditional slash and burn methods also have environmental implications. Also, the consumption of agricultural products generates wastes disposed in to the environment, leading to the accumulation of waste which consequently results to environmental pollution with its detrimental effects on the health and well-being of man. Adewuyi (2001), Gutti et al. (2012) and Phimphanthavong (2013) have identified some adverse environmental effects of exploiting natural resources as pollution and natural resources overexploitation, wildlife habitat loss, soil erosion, destruction of cultivable pieces of land, deforestation and climate change. Some serious environmental problems such as desertification, insect infestation and wetland degradation are also typical of Africa.

Environmental economics literature has widely discussed the relationship between the level of aggregate economic activity, measured by per capita income and environmental indicators, the highly celebrated EKC hypothesis. Many studies have found support for the EKC hypothesis such as those of Shafik and Bandyopadhyay (1992), Panayotou (1993), Grossman and Krueger (1995), Kubatko (2008), Jiang et. al (2008); Tevie et al. (2011), Yaduma et al. (2013), Phimphanthavong (2013) and Wolde (2015). The environmental indicators for which EKC evidence exist are urban and local air quality indicators such as sulfur dioxide emissions (SO2), suspended particulate matter (SPM), carbon monoxide emissions (CO) and nitrous oxides (N2O) though turning points vary for the different indicators (Borghesi, 1999). A few studies such as those of Harbough et al. (2002), Stern (2003) and Burnett (2009) have shown that growth is ever detrimental to the environment thereby refuting the EKC hypothesis. Shafik and Bandyopadhyay (1992) showed that for some environmental indicators such as carbon dioxide ($CO_2$) emissions, municipal waste per capita and lack of safe drinking water, evidence of the EKC relationship does not exist. Yet, for water quality indicators such as the amount of heavy metals and toxic chemicals discharged in water as a result of human activities (lead, cadmium, mercury, arsenic and nickel), concentration of pathogens in water (measured by faecal and total coliforms) and the amount of heavy metals and toxic chemicals discharged in water by human activities (lead, cadmium, mercury, arsenic and nickel) and measures of deterioration of water oxygen regime (dissolved oxygen, biological and/or chemical oxygen demand), the empirical evidence of the EKC is mixed.

Most EKC studies use an aggregate measure of economic activity such as real per capita GDP. The problem with the use of this aggregate output indicator is that different production stages generate different levels of somewhat similar identical environmental indicators. This implies that their respective income per capita and environmental degradation relationships would may be different and would be more meaningful than in the case where activities are aggregated. It is for this reason that this study decomposes aggregate output and is using an activity within the primary sector; exploitation of natural resources. Scholars have also argued that most of the EKC literature is statistically weak (Stern, 2003; Aslanidis, 2009). According to Stern (2003), this weakness is because little attention is given to diagnostic econometric tests especially the statistical characteristics of data such as serial dependence or stochastic trends. Furthermore, tests of model adequacy are not often conducted. To Perman and Stern (2003), cited in Stern (2003), when such statistics or tests have been taken in to account and appropriate techniques applied, the EKC hypothesis fails to hold. These defects are taken in to consideration in this study.

While most studies have considered the effects of economic growth on the environment, many other studies focus on the environmental effects of exploiting different natural resources. These include works such as those of Adewuyi (2001), Ayuba (2012), Balogun and Kareem (2013), Omorede (2014) on oil and gas resource exploitation, Kaya (2001) on mineral exploitation, Gutti et al. (2012) and Budnuka et al. (2015) on a series of environmental resources. The main shortcoming of these studies is that the important question of whether the economic system can continue to grow without undermining the natural systems which are its ultimate foundation, to the best of my knowledge has not been given adequate attention. This question is particularly important within the Subsaharan African context especially considering the pace at which their natural resources are undergoing exploitation. The current study therefore closes these gaps by attempting to provide an answer to the sustainability question within the EKC framework. Does an EKC exist for natural resource depletion in SSA countries and what are the implications for sustainable development?

The continued dependence of SSA countries on their natural resources has not only resulted to an increased overexploitation and depletion of the resources but has also brought other negative socioeconomic effects such as the loss of indigenous and cultural identity and violation of land-rights of communities with little or no compensation; conflicts relating to ethnic rivalry and the ownership of land; child labour, forced labour, unfair wages, the lack of freedom of association, pollution of drinking water; corruption perpetrated by investors and governments and violent clashes between communities, regions and countries because the gains from resource extraction are unfairly distributed (Appiah and Zhang, 2013). In fact, the negative environmental effects of natural resources exploitation are varied and quite feasible in the communities in which the exploitation of these resources takes place.

Besides environmental/natural resources management policies taken at country levels to ensure environmental sustainability, SSA countries have signed a number of international agreements aimed at protecting the environment in the midst of the growing need to foster economic growth and an increasing pressure on the resources by the growing populations.

The overall goal of these policies is to foster sustainable development, which has now been embraced as a national policy objective. However, because these laws are sector-specific, efforts to develop a cross-sectoral and sectoral issues related to natural resource management and the environment are yet to achieve the desired aim.

Despite the putting in place of environmental policies or laws, the shocking and most disturbing thing with most SSA countries is that the policies remain an expression of what the authorities are yet to do to protect the environment rather than what they are actively doing. This therefore presents weak environmental regulation on the part of the authorities but however represents a step in the right direction towards not only designing but enforcing appropriate environmental policies. So, the problem is not necessarily environmental policy formulation but more that of implementation. Notwithstanding efforts made, environmental problems as earlier highlighted remains an issues of concern for all SSA countries. It is against this backdrop, that this study is motivated to assess the effects of natural resource exploitation on environmental degradation in SSA by considering the question of whether or not the exploitation of these resources is good or bad for the environment. Specifically, this study seeks to;

1) Determine the extent to which rents from the exploitation of natural resources is a driver of natural resources depletion in SSA countries by empirically testing for the existence of the EKC hypothesis.
2) Evaluate the effects of population growth and trade on natural resources depletion.

The rest of this manuscript is organized as follows; section two explores the literature on the environmental effects of exploiting natural resources as well as the EKC literature. In section three, the analytical methods adopted in the study are presented. Empirical findings of the study are presented and discussed in section four while section five concludes and recommends the possible ways in which the environment as well as development can be sustained.

## 2. LITERATURE REVIEW

### 2.1 Empirical Literature

Budnuka et al. (2015) examined the effects of the unplanned exploitation of environmental resources in Nigeria. According to this study, owing to agricultural and modern technological development, there is a rising human impact on environmental resources which does not take in to consideration the effect on future generations. Unplanned exploitation of environmental resources has negatively affected both man and his environment in one hand and government on the other hand. The unplanned exploitation of natural resources has resulted to dumping of waste, water pollution, and air pollution amongst others and is regarded as anti-society, hence the need to honour all international treaties on environment is recommended. The study also recommends that the government and her agencies, should beyond the immediate gains from these resources, focus more on planned exploitation of environmental resources. The findings also suggest that the nation is seating on the keg of gunpowder if resources exploitation is not checked very fast. Until appropriate legislation on exploitation of resources is put in place, the study acknowledges that the risk of cancer and heart diseases will continue to increase.

An exploratory and descriptive analysis of the environmental impacts of oil exploration and exploitation was carried out in the Niger Delta of Nigeria by Ayuba (2012). The study brings to light the fact that though oil exploration and exploitation in the Niger Delta is important in sustaining the livelihoods of the indigenous people and benefitting the Nigerian state greatly in terms of contributions to oil revenues, the activity however has disastrous environmental effects. The unsustainable exploitation of oil has made the Niger Delta region one of the five most severely petroleum damaged ecosystems in the world. The results indicate that pollution from oil caused by spillages from the oil industry located mainly in the Niger Delta region of Nigeria has resulted to the massive destruction to farmlands, fishing grounds and declination of fish, sources of drinking water, mangrove forest, crabs, periwinkles, molluscs and birds. The destruction of large areas of mangrove forest over a wide area has affected terrestrial and marine resources. Some oil spillage resulted to the complete relocation of some communities, leading to the loss and surrendering of ancestral homes, fresh water pollution, loss of forest and agricultural land, destruction of fishing grounds hence the reduction of fish population, which constitutes a major source of income for the Niger Delta region population. The study recommends that legislations should be updated and revised, licenses of oil companies and fines should be reviewed in order to ensure compliance, even though it’s difficult for the state to systematically or frequently monitor these sites. Also, environmentally friendly technology that minimizes impacts of petroleum development on the environment should be adopted.

Omorede (2014) assessed the effects of oil and gas resource exploration on the environment of selected oil-producing communities in the Delta state of Nigeria. The work established that some of the problems associated with oil resource exploration include oil spillage; vegetation growth retardation, ill-health to community members; socio-economic deprivation; constant protestation of host communities; and perceived marginalization of the people. This research concludes that oil rich communities of the state have not been compensated adequately for the harm done to them in terms of ecosystem degradation resulting from the many years of oil exploration. The study argues that the oil resource wealth of the community has been turned to a resource curse, disempowering and condemning the area to perpetual underdevelopment. Based on the findings of the study, it was recommended that the government should intensify efforts in maintaining strict compliance of its legal instruments by oil participating companies for sustainable development in the region.

In the same light, the effects of oil spillage on the aquatic environment in the Ilaje community of Nigeria were uncovered by Ayuba (2013). Massive unemployment, health hazards, high death rates, incessant communal clashes, destruction of aquatic life were identified as some of the consequences of environmental degradation and ecological problems resulting from the activities of companies exploiting oil. These problems are due largely to hydrocarbon toxicity which pollutes the sea surface and underground water. The paper argues that compensation paid by government and the oil companies to residents of the affected areas is inadequate to sustain their livelihoods in the long run.

In a similar study, Gutti et al. (2012) investigates in to the environmental impact of natural resources exploitation in Nigeria. The study admits that deforestation, mining and exploration of petroleum have damaged the natural environment in different forms including destruction of natural flora and fauna, air, water and land pollution, ecological disturbances, instability of soil and rock masses, degradation of landscape, desertification and global warming. Waste of arable land and economic crops and trees is the resultant effect of environmental damage. It is recommended that government and the natural resource industry must take precautionary and remedial measures aimed at minimizing the negative effects of natural resources exploitation. The study also suggest a shift of emphasis from waste disposal to waste minimization which is possible through sorting, recycling, bioremediation, afforestation, sewage treatment and pollution control. The regulatory legislation should be provided with appropriate sanctions by government or attach importance on enforcement of the laws and implementation of policies where these regulatory bodies already exist. In addition, compulsory precautions, remedies or compensation for damage done is expected to be carried out by oil and gas industries, mining companies and other natural resources exploitation bodies.

Etuonovbe (2009), like other researchers, assessed the devastating effects of environmental degradation in the Niger Delta Region of Nigeria. The study identifies several environmental issues in the region including flood disasters; heavy soil erosion; salinization or alkalization, desertification resulting from the effects of shifting agriculture on fragile soils, water, air and land pollution which is the result of improper industrial and domestic wastes disposal; noise pollution and pollution due to oil spillage; forest clearing in areas prone to erosion prone and floods; animal over-grazing; poor road construction and maintenance; congestion of traffic and houses in urban areas which lead to the lack of open spaces for active outdoor recreation; proliferation of slums in urban areas and unsanitary and unsafe housing. All these problems affect the health and socio-economic welfare of human beings especially women and children of the Niger Delta region. The study suggests that adopting sustainable development policies will resolve the so-many environmental problems facing the region. Amongst the measures recommended to solve these problems include, gravity, surface sink/tree planting, smokeless fuels, precipitation, air pollution reduction by exhaust, treatment, bag filters, wet collectors, incineration, source separation and international/national legislations.

Grossman and Krueger (1995) examined the link between economic growth and the environment by estimating a reduced-form relationship between income per capita and various indicators of environmental degradation. Four environmental indicators including urban air pollution, fecal contamination of river basins, the state of the oxygen regime in river basins, and contamination of the river basins by heavy metals were used in this study. This study employed panel data from the Global Environmental Monitoring System's (GEMS) tracking of urban air and water quality for different developing and developed countries in the world. After estimating a random effects model, there was no evidence to conclude that environmental quality falls steadily with growth. The results rather showed that for most indicators, economic growth first initially deteriorates the environment and later on improves it. This suggests the existence of EKCs for the pollutants. The turning points vary for the pollutants, but are in most cases reached before a per capita income of $8000.

Day and Grafton (2001) explores the relationship between economic growth and environmental indicators in Canada. The study uses 10 measures of environmental damage; carbon dioxide emissions ($CO_2$), nitrogen dioxide ($NO_2$), carbon monoxide concentrations (CO), ground-level ozone ($O_3$), sulphur dioxide ($SO_2$), total suspended particulate matter (TSP), concentrations of dioxin, fecal coliform and dissolved oxygen. Little evidence was found to support the fact that the quality of the environment would increase as the country's real per capita income increases. The study recommends a sectoral analysis in adequately assessing the relationship linking economic growth and environment degradation.

Burnett (2009) found no evidence to support the traditional hypothesized inverted U-shaped relationship between economic growth and environmental degradation in the United States of America (USA). However, a statistically significant U-shaped relationship existed for some pollutants but the evidence was too weak to suggest the validity of the traditional inverted U-shaped relationship between growth and indicators of environmental degradation. The study employed indicators of environmental degradation for air pollution in over 100 metropolitan statistical areas in the USA from 2001 to 2005, with the relationship being tested at the state level. The air pollution indicators considered in this study included sulfur dioxide, particulate matter, ozone, nitrogen dioxide and carbon monoxide.

Tevie, Grimsrud and Berrens (2011) empirically tested for the existence of the EKC hypothesis for biodiversity risk in the USA using state-level data for all 48 contiguous states. The study measures biodiversity risk using a Modified Index (MODEX) developed at a state-level and modified or adapted from the national biodiversity risk assessment index (NABRAI). The MODEX was used because it accounts for the impact of human activities and measures of conservation. The study uses spatial econometric techniques which automatically accounts for the effects of spatial autocorrelation inherent in the data. The results do not support the presence of an EKC hypothesis for biodiversity risk in the USA. The spatial lag regression results show that increasing the human population density by 1% would increase biodiversity risk by 0.19%. Spatial dependence explained 30% of the variations given the spill-over effect of risks from one state to the other. The study recommends coordinated efforts both at the state and federal levels to combat the problem of biodiversity loss.

The relationship between economic growth and environmental degradation was examined for Laos by Phimphanthavong (2013) using time series data from 1980 to 2010. Carbon dioxide ($CO_2$) emissions per capita were used as the proxy for environmental degradation. Tests for stationarity were carried out using the Augmented Dickey-Fuller unit root test. The study was especially out to test the validity of the EKC hypothesis which suggests an inverted U-shaped relationship environmental degradation and economic growth. Results show evidence of the EKC hypothesis. Environmental quality first falls in the early stages of economic growth but starts rising after a certain point along the growth path. Results also revealed that factors such trade openness, industrial extension, and becoming a full member of ASEAN were important and significant determinants of environmental degradation in Laos. For Laos to achieve their sustainable development goal, it was recommended that strong environmental and natural resource protection policies be put in place for current and future development.

Yaduma et al. (2013) explored the $CO_2$ environmental Kuznets curve within the OECD and the non-OECD countries and six geographical regions- East Europe, West, East Asia, West Asia, Latin America and Africa using the quantile fixed effects technique. The study took in to consideration two groups of countries with different levels of development. Comparing the findings from this technique with those of conventional fixed effects method, it was revealed that results of the conventional fixed effects method may suggest a flawed summary of the income-emissions nexus depending on the conditional quantile examined. The Machado and Mata decomposition methods were also extended to the Kuznets curve framework in order to explore the most important reasons for the $CO_2$ emissions gap between the OECD and Non-OECD countries. Empirical results also depict a statistically significant OECD-Non-OECD emissions gap, which turns to reduce as the emissions distribution rises. The decomposition also reveals the presence of some non-income related factors working against the Non-OECD group's greening. The study tentatively concluded that deliberate and systematic mitigation of current $CO_2$ emissions in the Non-OECD group is required.

Wolde (2015) empirically tested the relationship between economic growth and environmental degradation in Ethiopia with time series data from 1969/70-2010/2011 in a VECM analysis. In line with other empirical studies, the study confirms the existence of the EKC hypothesis for $CO_2$ emissions in Ethiopia. The study recommends a friendly environmental economic policy.

### 2.2. Theoretical Foundation

The environmental Kuznets curve (EKC) hypothesis, named after Simon Kuznets (1955) states that environmental degradation initially rises as a country grows richer, but then eventually decreases with further income gains. The environment gets worse-off at low levels of economic activity, peaks as economic activities increase and eventually improves as the country grows richer. The EKC hypothesis therefore stipulates an inverted U-shaped relationship between per capita income and environmental degradation (Shafik and Bandyopadhyay, 1992; Panayotou, 1993; Grossman and Krueger, 1995; Dinda, 2004; Jiang et al., 2008; Kubatko, 2008; Tevie, Grimsrud and Berrens, 2011; Yaduma et al., 2013; Phimphanthavong, 2013; and Wolde (2015).

It was based on actual data on sulphur dioxide emissions ($SO_2$). Per capita emissions of $SO_2$ were said to rise with increases in the gross national product per capita up to the turning point level of income after which these emissions started falling steadily. Figure 2.1 depicts a typical shape of the EKC relationship. If the EKC hypothesis held generally, economic growth would be a means to improve the environment. Environmental quality would fall as the country moves towards higher stages in its growth process.

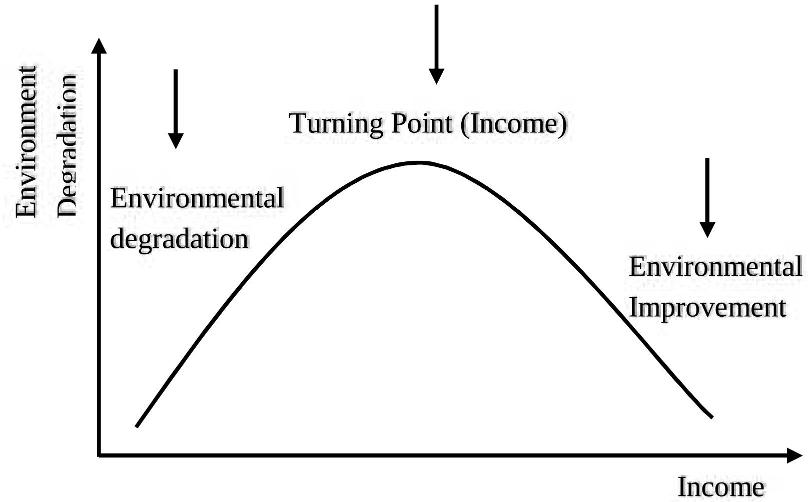


**Figure 2.1: Relationship between Income and the Environment**
**Source:** Yandel et al (2000)

The inverted U-shaped relationship linking income per capita and indicators of environmental degradation is justified on many grounds. According to Kuznets (1955), cited in Wolde (2015), environmental degradation increases in the early stages of growth because agriculture is the dominant economic activity during that stage, with expansion in agricultural activities and land use pattern changes imposing environmental costs. As the economy grows and becomes more dependent on industry, environmental degradation reaches a maximum point, and then later on services dominate the economy and environmental degradation starts improving with economic growth. Panayoto (1993) adds that according to proponents of the EKC hypothesis, an increase in environmental quality at higher levels of development is due to the increasing environmental awareness, technological advancement, increase environmental expenditures and enforcement of environmental laws. Moreover, Kubatko (2008) argues that economic growth is detrimental to the environment during the early stages of growth because of the ineffective use of economic resources while during the later stages of growth, technological progress and economic growth improves environmental quality. These justifications are summarized in what Grossman (1995) calls the scale, composition and technology effects which are the three main channels through which income growth can affect environmental quality.

First, economic growth exerts a scale effect on the environment in the sense that environmental degradation increases as the scale of economic activity increases. This is because to increase output, more inputs are needed and these inputs generate wastes (Borghesi, 1999). Second, through the composition effect, income growth can improve the environment by increasing the share of cleaner activities in the Gross Domestic Product (GDP). Panayotou (1993), noted that structural changes in the economy from rural to urban, agricultural to industrial turn to increase environmental degradation while changes in the structure of economic activities from energy- intensive industry to services and technological-intensive industry increases environmental quality. Third, the technology effect of growth on the environment occurs when countries have the capacity to replace obsolete and dirty technology for cleaner technology as they grow. Thus, environmental degradation increases with per capita income growth during the early stages of growth due to the negative impact of the scale effect but falls with per capita income growth during the later stages of growth because the scale effect is outweighed by the positive effects of the composition and technology effects.

## 3. METHODOLOGY

The data for this study is obtained from the World Development Indicators of the World Bank database covering a time scope of thirty-five (35) years, beginning from 1981 to 2016 inclusive. The study covers 33 countries of SSA, Ethipoia inclusive. The basis for selecting the countries for the study was data availability. The list of SSA countries included in the study are presented on table 3.1. The causal comparative research design is implied, as effects of natural resource rents on natural resources depletion are ex-post.

**Table 3.1:** Sub-Saharan African Countries included in the Study

| | | |
|---|---|---|
| 1. Benin | 10. Gambia | 19. Rwanda |
| 2. Burundi | 11. Ghana | 20. Senegal |
| 3. Botswana | 12. Kenya | 21. Sierra Leone |
| 4. Burkina Faso | 13. Lesotho | 22. South Africa |
| 5. Cameroon | 14. Mali | 23. Togo |
| 6. Congo Democratic | 15. Mauritania | 24. Uganda |
| 7. Congo | 16. Mozambique | 25. Zambia |

| | | |
|---|---|---|
| 8. Ethiopia | 17. Niger | 26. Zimbabwe |
| 9. Gabon | 18. Nigeria | |

It has been argued that relationships between per capita income and environmental indicators can only be better understood within the framework of a general equilibrium model because these relationships are complex and multifaceted. Computational general equilibrium models better account for feedbacks within the economic system and requires data on a wide range of environmental indicators. However, most empirical studies do estimate reduced-form models due to such data unavailability. The problem with reduced-form models is that as Grafton and Day (2001) argue, such models do not explain the growth-environmental quality relationship but measure only the nature of the relationship by relating indicators of environmental quality to those of growth. Just like most studies, this study estimates reduced-form models of natural resources rents and natural resources depletion but incorporates some policy variables within the regression which can enable us better explain the link between resource exploitation and environmental degradation.

The relationship between per capita GDP and measures of environmental pollution is often studied by including a quadratic or cubic order terms in the right hand side of the functional relationship between the per capita concentration of emissions and per capita income with the addition of other key determinants of environmental degradation. This standard functional form adopted in the EKC literature is of the form;

$$E_t = \alpha_0 + \alpha_1 y_t + \alpha_2 y_t^2 + \alpha_3 y_t^3 + \beta X_t + U_t$$

(3.1) where $E_t$ is the per capita emission of the environmental degradation proxy, $y$ is per capita GDP, X is a vector of fundamental determinants of environmental degradation, U is the error term, t is the time trend and $\alpha_0$ to $\alpha_3$ and $\beta$ are estimable coefficients. In a panel study, equation (3.1) becomes;

$$E_t = \rho_i + \gamma_t + \alpha_0 + \alpha_1 y_{it} + \alpha_2 y_{it}^2 + \alpha_3 y_{it}^3 + \beta X_{it} + U_{it} \qquad (3.2)$$

The terms $\rho_i$ and $\gamma_t$ on the right-hand side of equation (3.2) are intercept parameters that vary across countries or regions i and years t. The take care of time and country specific features. It is assumed that though emissions per capita may be different over countries at any particular level of income, the income elasticity is similar in all countries at a given income level. The year or time specific effects are incorporated to take care of time-varying characteristics and stochastic shocks that are common to all countries meanwhile the country-specific effects are included to account for country-specific features which are time invariant (Sunday, 2015).

Following the EKC literature and the empirical literature on the determinants of environmental degradation, the drivers of environmental degradation include amongst other factors natural resources exploitation including forest, natural gas, minerals, coal and oil; population growth, economic growth, trade openness and the quality of institutions. Pollutants which have often been used in the literature as the proxies for environmental degradation include concentration of carbon dioxide, sulphur dioxide, nitrogen oxide, nitrogen dioxide, carbon monoxide, water pollution measures or land-use changes, ground level ozone and total suspended particulate matter.

For the purpose of this study, natural resources depletion as % of GNI is adopted as the proxy for environmental degradation for the simple reason that it better measures the destruction of the environment which is the result of the exploitation of different types of natural resources both renewable and non-renewable. In addition, the independent variables used for this study are total natural resource rents (% of GDP), used as proxy for natural resource exploitation as it represents the value of output from exploiting natural resources, value added in agriculture (% of GDP), value added in industry (% of GDP) and population growth. The model for this study is therefore specified thus:

$$dNRD_{it} = \rho_i + \gamma_t + \alpha_0 + \alpha_1 dNRR_{it} + \alpha_2 NRR_{it}^2 + \alpha_3 NRR_{it}^3 + \alpha_4 dPOP_{it} + \alpha_5 dTRD_{it} + U_{it} \tag{3.3}$$

The variables of equation (3.3) are defined as follows;

**NRD** is per capita natural resource depletion. Natural resource depletion (% of GNI) is defined as sum of net forest depletion, energy depletion, and mineral depletion.

**NRR** is per capita natural resource rents. Total natural resource rents (% of GDP) is defined as the sum of oil rents, natural gas rents, coal rents (hard and soft), mineral rents, and forest rents.

**NRR$^2$** and **NRR$^3$** is the per capita natural resource rents at a later period. Total natural resource rents (% of GDP) is defined as the sum of oil rents, natural gas rents, coal rents (hard and soft), mineral rents, and forest rents.

**POP** is population growth (annual %) defined as the exponential rate of growth of midyear population from year t-1 to t, expressed as a percentage

**TRD** is defined as the sum of exports and imports of goods and services measured as a share of gross domestic product.

$\alpha_0$ to $\alpha_5$ are the coefficients to be estimated, i and t respectively represent a particular country and time and U is the error term.

The signs of $\alpha_1$ and $\alpha_2$ are expected to define the nature of the relationship between variables of interest. If $\alpha_1 = \alpha_2 = 0$ then no relationship exists between NRD and NRR; if $\alpha_1 > 1$ and $\alpha_2 > 1$ then a monotonically increasing or linear relationship exist between NRD and NRR; if $\alpha_1 < 1$ and $\alpha_2 < 1$, a monotonically decreasing or linear relationship exist between NRD and NRR; if $\alpha_1 > 1$ and $\alpha_2 < 1$ then an inverted U-shape relationship exist between NRD and NRR; if $\alpha_1 < 1$ and $\alpha_2 > 1$, a U-shape relationship exist between NRD and NRR. The coefficients $\alpha_3$ to $\alpha_5$ are expected to be positive because an increase in agricultural production, industrialization and population growth are expected to increase environmental degradation.

It is common practice that any meaningful study involving the use of time series data requires the data to be stationary so as to eliminate the possibility of biased estimates and nonsensical or spurious regression. This study uses the Levin, Lin and Chu (t-stat) common unit root test to test for the stationarity of the variables after a graphical plot of the variables to determine whether an intercept term or trend or both intercept and trend existed in the series. These tests were conducted under the null hypothesis of no unit root and validated by comparing the test statistics with the test critical values at various levels of significance. Both the random and the fixed effects model were estimated and the decision of whether or not the fixed effects model was selected was validated by employing the Hausman test. To establish whether a long run relationship exist, panel cointegration technique was used.

This paper employs statistical tests such as the multiple coefficient of determination (adjusted $R^2$), t-statistics and F-ratio test to test the reliability of estimated coefficients. Multicollinearity was tested using the pairwise correlations. Breusch-Pagan LM, Pesaran scaled LM and Bias-corrected scaled LM were used to test for cross sectional dependence and the Durbin-Watson statistic used to test for autocorrelation.

## 4. RESULTS AND DISCUSSION

## 4.1 Results

This study was out to investigate in to the existence of the EKC hypothesis for the depletion of natural resources in twenty six (26) SSA countries using panel data. Data for the study was first subjected to the Levin, Lin and Chu (t-stat) common unit root test since the panel was balanced and the results are presented on table 4.1. This was done after carrying out graphical analyses of the variables, which

**Table 4.1: Unit Root Test**

| Variables | Levin, Lin and Chu (t-stat) Test Statistic | P-Value | Remark |
|---|---|---|---|
| NRD | -16.0537 | 0.0000 | I (1) |
| NRR | -16.3110 | 0.0000 | I (1) |
| $NRR^2$ | -3.24305 | 0.0006 | I (0) |
| $NRR^3$ | -3.69986 | 0.0001 | I (0) |
| POPG | -14.0460 | 0.0000 | I (0) |
| TRD | -13.2120 | 0.0000 | I (1) |

**Source: Computed by Author using E-views 9**

The unit root test results presented on table 4.1 show that natural resources depletion (NRD), trade (TRD) and natural resources rents (NRR) are stationary at first difference, meaning they contain a unit root meanwhile the squared and cubic terms of NRR are all stationary at their levels indicating the absence of a unit root. This is confirmed by the p-values of the variables which are all significant at 1% level.

To verify if an EKC fits the data on natural resources rents and natural resources depletion for the selected SSA countries, we employed panel fixed effects model as suggested by the results of the Hausman test. The p-value of the Chi-square statistic of Hausman test is 0.0020 which is significant at 1% level indicating that the fixed effects model is appropriate. Empirical results based on the fixed effects model are therefore presented on table 4.2.

**Table 4.2: Panel Fixed Effects Result**

**Dependent Variable:** Natural Resources Depletion (NRD)
**Method:** Panel Least Squares
**Sample Adjusted:** 1982-2016
**Total panel (balanced) observations:** 910

| Variable | Coefficient | Std. Error | t-statistic | P-value |
|---|---|---|---|---|
| D(NRR) | 0.429061 | 0.018692 | 22.95462 | 0.0000*** |
| $NRR^2$ | 0.006589 | 0.000371 | 17.76021 | 0.0000*** |
| $NRR^3$ | 0.0000679 | 0.00000383 | 17.72804 | 0.0000*** |
| POP | 0.294006 | 0.162532 | 1.808907 | 0.0708* |

| | | | | |
|---|---|---|---|---|
| D(TRD) | 0.019483 | 0.012957 | 1.503742 | 0.1330 |
| **Diagnostic Tests** | | | | |
| Adjusted R-saquared | 0.786448 | | | |
| F-statistic | 112.5857 | | | |
| Prob(F-statistic) | | | | 0.0000 |
| Durbin-Watson Stat | 2.294217 | | | |

**Source:** Computed by Author from Data *** = significant at 1%; * = significant at 10%

The empirical results of the study reveal that natural resources rents (NRR) have a positive effect on the depletion of natural resources in SSA since the coefficient of NRR is positive. An increase in rents from the exploitation of her natural resources would lead to an increase in the depletion of these resources, all things being equal. Precisely, a 1% increase in resource rents would increase resource depletion by 0.43%. This result is highly significant at 1% level given a p-value of 0.000. Furthermore, the squared and cubic terms of NRR are positive implying that natural resources rents at a later time would still have a positive effect on the depletion of natural resources in SSA, everything else being equal. The coefficients of the squared and cubic terms of natural resources rents, $NRR^2$ and $NRR^3$ are also very significant. These results point to a monotonically increasing relationship between total natural resources rents and depletion in SSA. This implies that there is no turning point level of natural resources output where the exploitation of natural resources could lead to a fall in natural resources depletion, suggesting the absence of an EKC for the depletion of natural resources in SSA. The empirical results also show that an increase in population (POP) and trade (TRD) all have a positive effect on natural resources depletion. Accordingly, a 1% increase in population and trade will lead to a 0.29% and 0.019% increase in natural resources depletion respectively. However, only population is significant, given a p-value of 0.0708.

The multiple coefficient of determination (adjusted R-squared) shows that about 79% of the variations in natural resources depletion are explained by natural resources rents, population and trade with about 21% explained by variables not included in the model. The p-value of the F-statistic is significant at 1% indicating that the overall regression result is 99% reliable and can be used for policy recommendation. The value of D.W statistic (2.29) also indicates the absence of autocorrelation in our model. Breusch-Pagan LM, Pesaran scaled LM and Bias-corrected scaled LM test were used to test for cross sectional dependence in the panel under the null hypothesis of no cross sectional dependence. The p-values of these tests are all 0.0000. We therefore reject the null hypothesis at 1% level and conclude that there is no cross section dependence in the panel.

The Kao Residual Cointegration Test was employed to establish the existence of a long run relationship among the variables in the study under the null hypothesis of no cointegrattion. The p-value of the ADF statistic is 0.0000 meaning we reject the hypothesis of no cointegration in favour of that of cointegration. This means that a long run relationship exist between natural resources rents and resource depletion.

**4.2 Discussion**

This study was out to test for the existence of an EKC hypothesis for natural resources depletion in SSA countries using a panel data of twenty-six (26) SSA countries from 1981-2016 selected on the basis of data availability from the World Development Indicators of the World Bank. Using panel least squares to estimate the data based on the Hausman test, the results reveal that no EKC exist for the depletion of natural resources in SSA. Rather, a monotonically increasing relationship between total natural resources rents and natural resources depletion is confirmed, suggesting that as long as SSA countries continue in the exploitation of their natural resources, those resources would continue to deplete. There is no turning point level of natural resources rents where it could be expected that an increase in exploitation would lead to a fall in depletion of the resources and hence environmental improvement. This result makes some sense within the African context because most African economies are known to depend for the most part on their natural resources to sustain their economies despite the fact that the resource-curse is very eminent. Under such circumstances, one would normally expect that an increased exploitation of these resources should translate in to an increase in the overexploitation and degradation of these resources besides other socioeconomic impacts on the environment. This result is in line with that of those who argue that economic activities will always ever result to environmental degradation such as Harbough et al. (2002), Stern (2003) and Burnett (2009). In addition, it has been shown by Shafik and Bandyopadhyay (1992) that for some environmental indicators such as carbon dioxide ($CO_2$) emissions, municipal waste per capita and lack of safe water, evidence of the EKC relationship does not exist.

The absence of the hypothetical EKC theory for natural resources depletion can be explained partly by the ever-increasing population of Africa and volume of trade as shown by these results and beyond. Of the world's population of over 7.6 billion, Africa makes up approximately 1.3 and is increasing, and with agriculture being the backbone of most if not all SSA economies, this rising population is said to put enormous pressure on the natural resources leading to their eminent depletion. An increase in the demand for farmland, building land, energy resources and the need for people to feed their families increases the demand for all types of resources, resulting in their degradation. Thus, not only is agriculture the predominant economic activity, its scale is also said to be increasing to match up with the increase demand for tradeables and food supply to feed the African families.

Again, Africa's increasing trade in largely unprocessed natural resources, driven by the need to settle huge debts contracted from countries of the West is also a reason for the rapid depletion of natural resources. Most SSA countries owe international institutions such as the International Monetary Fund (IMF) and World Bank and other countries of the west billions of US dollars which is always paid in hard currencies. Since Africa is less competitive in manufactured goods and services at the world market, natural resources get degraded because of the need to export. It is also important to note that poor or the complete absence of institutions is a key factor that determines the exploitation and hence depletion of our natural resources. Following the latest Country Policy and Institutional Assessment (CPIA) of SSA countries, it is noted that countries of SSA have weaker institutions amid a difficult global economic landscape, difficult domestic conditions and weaker terms of trade. However, the case is better for resilient economies such as those Côte d'Ivoire, Ethiopia, Kenya, Rwanda, Senegal, and Tanzania. These countries tend to have better quality institutions and policies that foster sustainable growth and the reduction in poverty than other countries.

## 4. Recommendations and Conclusion

From the findings of this study, it is recommended first that the governments of SSA countries should design and implement strong environmental policies where they are absent and enforce them where they are present in a bit to mitigate the adverse effects of the exploitation of natural resources as well as other economic activities such as agriculture and trade on the environment. Policies geared towards birth control also have to be adopted and implemented so as to gauge the rate of growth in population in order to ensure that it does not put unnecessary pressure on the natural resource base.

There is absolute necessity for SSA countries to reduce exports of agricultural commodities such as timber, crude oil, bananas, coffee, and cocoa amongst others and to rather consider the options of revamping their industrial sectors which transforms these raw materials in to finished products for domestic and foreign consumption. Economic progress would need transformation both in the agricultural and the industrial sector. The sustainable development of Africa would require that the practice of exploiting natural resources with little or without any value addition as the case may be with many African countries should seize because such a practice benefits the country only marginally.

This study was out to investigate in to the existence of the EKC hypothesis for natural resource depletion in twenty six (26) SSA countries using the panel least squares method. The empirical results show that no inverted U-shape relationship exists between natural resource rents natural resources depletion. A monotonically increasing relationship was observed indicating that the exploitation of natural resources would always result to resource depletion.

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