Economic Growth and Emissions: Testing the Environmental Kuznets Curve Hypothesis for ECOWAS Countries.

Douglason G. Omotor
Department of Economics,
Delta State University, Abraka,
Nigeria.
+2348034083112
yomotor@yahoo.com

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Introduction

History of the economic discuss on the environment-growth relationship which underpins the Environmental Kuznets Curve (EKC) dates back to the 1970s when some scientists began to question how natural resource availability could be compatible with sustained economic growth (Meadows, Meadows, Zahn, and Milling, 1972). The other strand of the divide were the neoclassical economists championed by the class of Beckerman (1972) and Jahoda (1973) among others; who adversely reacted that limits to growth due to resource constraints were not a problem. More importantly, as the general interdependence between ecosystems and economies started to become accepted, economists broadened their view on the relation between the environment and the economy. A new discipline was born towards the end of the 1980s; *Ecological Economics*, which explicitly explains the account of this interdependence. Ecological economics acknowledges that the environment is not merely a source of resources; it provides services of waste absorption and general ecosystem maintenance (Luzzati, 2003).

A comprehensible observation about the relationship between environmental quality and economic growth was first alluded to by Grossman and Krueger (1991), in their remark that during the early stages of economic development, environmental degradation will increase until a certain level of income is reached (known as the turning point) and then environmental improvement will occur. What is implied in this analysis is that when agriculture and allied activities as well as light manufacturing dominate the typical economy (early stage of economic development), pollution intensity will be generally low. However, as the economy moves into heavy industry, pollution will tend to increase. Besides, as the economy shifts into high technology and services, pollution intensity will tend to decline. According to Grossman and

Krueger, this produces an inverted U-shaped curve, analogous to the relationship propounded to exist between income inequality and average national income by Kuznets (1955). Kuznets had hypothesized that economic inequality increases over time and then after a threshold becomes more equal as per capita income increases, hence the income-environment relationship was dubbed the "environmental Kuznets curve" (EKC).

Since the seminal works of Grossman and Krueger's (1992) particularly, on the potential environmental impacts of NAFTA, and the 1992 World Bank Report (Shafik and Bandyopadhyay, 1992; World Bank, 1992), interest in studies on the environment-income relationship has been aroused through efforts to estimate, interpret and understand the existence and shape of the EKCs with respect to various emissions and greenhouse gases. Grossman and Krueger testing the impact of Mexico's inclusion in NAFTA on pollution; the results show that environmental degradation, as denoted by the ambient air concentration of sulphur dioxide (SO_2), dark matter and suspended particles (SPM), have an inverted U-shaped relationship with income per capita. The findings have since provoked numerous theoretical and empirical studies. In the tot up, EKCs are now known to have different shapes depending on the distinctive measurement of environmental degradation and datasets employed (see Cole and Neumayer, 2005; Stern, 2004; Yandle, Bhattarai and Vijayaraghavan, 2004 for overviews).

In recent years, a number of studies have provided empirical evidence in favour and against the existence of the EKC for different pollutants (see for example, Barbier, 1997; Orubu and Omotor, 2011; Baiard, 2012; Sayed and Sek, 2013; Skaza and Blaise, 2013 Martinez-Zarzoso and Antonello, 2013; Kim, 2013, Ching-Yao and Yang, 2014; Miyama and Managi, 2014). In all of these, the results have been mixed and the window of debate on the validity of the EKC and its determinants still open.

Despite the indecisive make-up of the results, the significance of testing for the existence of an EKC stems from the fact that, it is far from a mere academic exercise. If an EKC is indeed a generalized phenomenon, this will be an indication, *ceteris paribus*, that environmental degradation will automatically fall in the long run as incomes rise. Nevertheless, if the EKC proposition does not hold, this would be an indication that policy intervention would be necessary to curb pollution and make sustainable development a reality. A large deviation would be an indication that policy action is still required to reduce current pollution intensities even as income rises. The modifying effects would provide the framework for a holistic approach to environmental policy design.

The dawn of the EKC has so far raised some questions; do all aspects of environmental quality deteriorate or improve systematically with economic development? Can the pattern of growth versus environmental impact as established by the developed countries EKCs be replicated for developing countries path? For how long will developing countries have to wait before tunneling the EKC? Is the policy ramification for poor countries that they should grow themselves out of environmental problems rather than implementing stricter regulation now?

Although the study addresses some of the questions hoisted about EKCs, it similarly acknowledges the verity that there have been scores of empirical EKC publications since Grossman and Krueger's path-breaking work. The major focus of the study is to estimate EKCs for ECOWAS countries using two specific measures of environmental indicators. These are carbon dioxide (CO_2) emissions and sulfur dioxide (SO_2). Our choice of these indicators of environmental degradation is based on the fact that, although a number of studies of the EKC with respect to developing countries exist for some pollutants, detailed studies that deal specifically with ECOWAS countries using sulphur dioxide emission are mute. Second, the existence of a relatively consistent country level data series for the ECOWAS countries selected for the study, also informed the choice. The specific objectives of this study are thus to:

- estimate the EKCs model based on the emissions and determine a threshold income level for ECOWAS countries.
- ascertain the effect of other control variables such as population density and policy influences on the quality of the environment.

Scope of the Study

The scope of this study shall be limited to the analysis of the relationship between environmental emissions and per capita income as implicit in the environmental Kuznets Curve hypothesis. The EKCs would precisely be estimated for two indicators of AQI, drawing on panel data for selected ECOWAS countries. These environmental emissions (AQI) are carbon dioxide (CO_2) and sulphur dioxide (SO_2).

The effects of policy variables such as population density, technological change, quality of institutions, environmental tax and literacy rate on the selected AQI are also explored. The anticipation is that such policy variables which could lower pollution concentration if adequately captured in the analyses, should strengthened the policy implications of the study. The analyses shall be limited in scope to time series of the ECOWAS countries for which the relevant data are steadily available.

2. Review of Related Literature

The basic hypothesis of the environmental Kuznets curve is that there exist an inverted "U"-shape relationship between economic growth and environmental degradation. The explanation is that in the early stages of economic growth, environmental quality improves until it reaches the peak, afterwards it declines when the income per capita increases, subsequently, economic development will eventually lead to environmental improvement (De Groot, Linders, Rietveld and Subramanian, 2004).

Series of papers have in the course developed theoretical models on how preferences and technology interact to result in different time paths of environmental quality (Lopez, 1994; Selden and Song, 1995; McConnel, 1997; Stokey, 1998; Andreoni and Levinson, 2001) among others. This notwithstanding, the EKC though an essentially empirical phenomenon, most of the literature is econometrically weak (Stern, 2003) and their results are inconclusive.

Studies that confirm the EKC hypothesis for many different pollutants are Shafik and Bandyopadhyay (1992), Selden and and Song (1994), Aldy (2005), Ang (2007) and, Iwata, Okada and Samarth (2010). In the literature, studies have questioned the real existence of an inverse-U-shaped figure by empirical evidence. Khanna's (2002) result is a U-shaped relationship instead of the inverted-U-shaped EKC. Other studies which refute the EKC hypothesis are Carson, Jeon and McCubbin (1997), Cialani (2007), He and Richard (2010). Friedl and Getzner (2003), Akbostanci, Turut-Asik and Tunc (2009) find an N-shaped curve for CO_2 and; PM_{10} and SO_2 respectively. Lekakis (2000) however, find no relation between economic growth and environmental degradation.

The techniques of analyzing the EKC relationship over time have also varied, so also are the various forms of dataset ranging from time series, cross-sectional, cross-country to panel or longitudinal analyses with a set of control variables widely used in the empirical literature. Examples of such control variables are literacy rate (Gangadharan and Velenzuala, 2001; and Orubu and Omotor, 2011); trade and structural change (Suri and Chapman, 1998), technology and technological progress (Islam, 1995; Bianchi, Calidora and Menegatti, 2009 and Baiardi, 2012), corruption (Leitao, 2010) among others.

At some other instances, studies (though not directly on determining the existence of an EKC) have also embarked on designing economic instruments for environmental regulation. Part of the argument is that urbanization accompanies rapid increase in human population and the subsequent expansion of economic activities leads to increased demand for fossil fuels including gasoline which increases emissions of carbon pollutants. This increased fuel consumption poses serious threat to the environment (Ziramba, Kumo and Akinboade, 2009). As income rises, however, there is an observed increased demand for improved environmental quality and greater pressure upon policy makers for more regulations and investment on environmental control (Orubu, Omotor and Awopegba, 2008). Studies which have designed and analyzed impact of economic instruments on environmental regulations are Feenberg, Mitrusi and Porteba, 1997; Graham and Glaister, 2002; Orubu, Fajingbesi, Odusola and Magbagbeola, 2002; Orubu, 2004; Santos and Catchesides, 2005; Ziramba, et.al, 2009 among others. For instance, West (2004) suggests that environmental taxes particularly gasoline tax are mildly regressive and hence not popular option in policy design. Ziramba, et.al, conclusion in the case of the South Africa is that fuel expenditures are progressive and that fuel tax would be an effective and desirable instrument for pollution control.

3. Environmental Issues in ECOWAS: Stylized Facts

As note earlier, the two emissions used in this study are Sulphur Dioxide (SO_2) and Carbon Dioxide (CO_2). SO_2 is emitted when fuels containing sulphur are combusted. In the air, it can form tiny particles called aerosols, creating new ones or building up old ones. Aerosol particles help form cloud drops and potentially changes amount of rainfall. Both clouds and the aerosols themselves reflect sunlight and reduce the amount of energy absorbed by the planet (Smith, et.al; 2011). Sulphur dioxide has the potential to acidify rain, soil and lakes, and it can counteract some of the warming effect of carbon dioxide. The subsequent impacts of acid deposition can be significant, including adverse effects on aquatic ecosystems in rivers and lakes and damage to forests, crops and other vegetation (EEA, 2011).

As for CO_2 emissions, it has both natural and human sources. Examples of natural sources include decomposition, ocean release and respiration. Human sources of CO_2 consist of activities like cement production, deforestation as well as the burning of fossil fuels like coal, oil and natural gas (Quéré, et.al; 2012). Carbon dioxide is a greenhouse gas caused by the burning of fossil fuels such as oil and gas. There is no doubt that the carbon dioxide increase is anthropogenic. The circumstantial evidence is that increase in human population increases carbon dioxide and that the amount of carbon dioxide in the atmosphere is strongly correlated to temperature (Ernst-Georg, 2010). Carbon dioxide emission leads to sea level rise; it impacts on agriculture productivity; results in depletion of the ozone layer; causes warmer climate meaning CO_2 continuous increase would lead to more droughts and floods, and more frequent and stronger storms. CO_2 aid spread of diseases and causes the ecosystem to change with the net effect of most organisms moving towards the North and South Poles. These concerns no doubt are worrisome and have aided the shift in the frontier of environment-development treatise.

The environment-development paradigm which shifted to sustainable development began in the 1970s with the aim of formulating sustainable development policies that will curtail emissions in the development process. The dialogues which followed the discourse were to conserve the deteriorating environment and these resulted in series of government commitments covering at least nine treaties. Chief among these action plans are the Framework Convention on Climate

Change (Signed in 1992), Vienna Convention for the Protection of the Ozone Layer (1985), Montreal Protocol for Chlorofluorocarbon Control (1987), United Nations Convention on the Law of the Sea (1982), Convention on Biological Diversity (Earth Summit in 1992), United Nations Framework Convention on Climate Change also known as the Kyoto Protocol (1997), Convention on International Trade in Endangered Species of Wild Fauna and Flora (adopted in 1973 and entered into force in 1975), United Nations Convention to Combat Desertification (1994, 1996) and the most recent in these group; the Stockholm Convention which is an international legally binding instrument to protect human health and the environment from persistent organic pollutants. The Stockholm Convention was adopted in 2001 but put into force in 2004 (World Development Indicators, 2010:211).

According to data from Mitchell (2015) as reported in Table 1, since 1800 till date; 2015 inclusive, Multilateral Environmental Agreements and Modifications are well up to 1257. Among these are 540 Agreements and 222 Protocols. Bilateral Environmental Agreements for the period from 1300 to 2015, inclusive are 1586 Agreements and Modifications which include 1433 Agreements and 67 Protocols. Other Environmental Agreements (non-multi/non-bilateral) for the period from 1940 to 2015, inclusive stand at 245; made up of 197 Agreements and 47 Protocols. These numbers are still counting; however, as observed in the World Development Indicators (2010: 211), signing of these treaties does not always guarantee that governments will comply with treaty obligations. This notwithstanding how has the ECOWAS sub-region fared relatively in some of these environmental agreements and profile in the midst of industrialized nations?

One approach to measuring the evidence of government commitment to sound environmental management is by evaluating national environmental strategies and participation in environmental treaties. These action plans and strategy often supported by the World Bank and other development agencies identify the primary causes of environmental challenges, how actions needed to deal with them are put together and policies formulated. Equally required is a stipulation of plans, investment strategies, legislation and institutional arrangements required to execute the actions (World Development Indicators, 2010). A cursory look at Table 1 reveals the extent of commitment by governments of ECOWAS countries in environmental management and attestations to international treaties and agreements.

An inference from Table 1 is that while all ECOWAS countries have participated in signing the entire treaties as outlined, the United States of America for instance, did not sign some of the international treaties and agreements launched in the wake of the 1972 United Nations Conference on Human Environment in Stockholm and the 1992 United Nations Conference on Environment and Development (Earth Summit) in Rio de Janeiro. It was only recently in 2012 surprisingly the United States became the first major industrialized nation in the world to meet the United Nation's original Kyoto Protocol 2012 with target for CO_2 reductions without ever ratifying it (Watts, 2013). The Kyoto Protocol was an international agreement proposed in December 1997 which required nations to reduce CO_2 emissions by 5.2% by 2012. It became international law when Russia ratified it in November 2004. The United States never ratified Kyoto Protocol even though then Vice President Al Gore of the US signed it. A second observation is that Germany and Japan are probably yet to prepare national environmental profiles and biodiversity strategies and profiles.

The ECOWAS Environmental Policy (2008) highlights a number of environmental challenges that confront the region, among them are: (i) land degradation, erosion and desertification (ii) loss of bio-diversity through deforestation, loss of tree resources, pasture land degradation and trivialisation of landscapes (iii) river and lake water resources degradation (iv) coastal ecosystems degradation (v) degradation processes brought about by the development of mineral resources, (vi) Urban and industrial pollution which includes water and air, and of course (vii) poor sanitation facilities and practices. While the African Development Bank (2007) Report on Gender, Poverty and Environmental Indicators on African Countries unarguably advocated widespread poverty reduction as the center of development paradigm for the continent, the use of natural resources in economic activities to address poverty reducing growth strategy should not only be sustainable as stressed in the Report, it must address environmental concerns and ensure efficient and sustainable utilization. As further enunciated in the 2007 Report, a short coming of its framework is ignoring global linkages between economic growth, poverty reduction and environmental degradation as global warming for instance, has shown.

The warming of the Earth as predicted causes glaciers to melt; rise in sea levels and these have been linked to changes which result in anthropogenic impacts and even water erosion (Karin, 2009). Global warming has been scientifically tested to have potentials of wreaking serious havoc on natural systems and human populations alike. Water erosion is getting worse and contributing to further loss of lands, lakes and arable lands through immediate silting which has seriously threaten agricultural production and food security in the region. In 2000-2005, the ECOWAS sub-region on an annual rate of 1.17 % lost 899 000 hectares of forest and woodlands through deforestation. Equally documented in the literature are claims that lot of sicknesses, diseases and medical conditions that affect people are primarily caused by factors related to environmental degradation (ECOWAS Environmental Policy 2008). Figure 1 for instance, shows the box plots of anthropogenic sulfur dioxide (SO_2) emissions in gigagrams (Gg) for six ECOWAS countries. The lower edge of the box represents the 25th percentile value and the upper edge the 75th. The height of each box shows the interquartile range and is an indicator of the variability of the values. Mean values are indicated by black circles and the line across the box indicates the median (50th percentile). Boxes indicate the quartiles and vertical bars indicate the maximum and minimum. Safe for Cote d'Ivoire and Senegal as detailed by the keys in Figure1, there is relative high variability of SO_2 concentration among the selected ECOWAS countries. A comparative examination of the data (Smith, et.al, 2011) shows that SO_2 emission in ECOWAS countries ranked relatively lower than what obtained in some industrial countries; though not surprising. For example, the mean or average SO_2 concentration for the period, 1960-2005 for Benin, Cote d'Ivoire, Ghana, Nigeria, Senegal and Togo stood at 2.5, 20.1, 18.8, 361.7, 20.5 and 202 Gg respectively; while those of China, Germany, Japan, UK and USA (see Figure 2), stood at 14224.6, 5597.1, 2057.6, 4070.7 and 22147.7 respectively (Smith, et.al, 2011). For example, a fundamental lesson to be deduced from Figure 3 which combines SO_2 concentrations for some selected ECOWAS countries and Industrial nations is that, ECOWAS countries may have the benefit of learning early and by involving in environmental activism and awareness do not need to wait for too long for per capita income to improve to the levels recorded in industrial nations before they begin to appreciate cleaner environment. In other words, the challenge developing countries including those in the ECOWAS region face is how to improve the EKC for instance by pressing it downward, or by reaching the turning point faster, in their future development (Kander, 2002).

It can be argued that, given the current level of economic development in the ECOWAS region, recorded carbon per capita is relatively high and worrisome. This fear is buttressed by the fact that the region is in quest for rapid industrialization and carbon per capita may aggravate as the region industrializes. Figure 4 depicts the composition of physical and natural sources of CO_2, while Figure 5 shows that the amount of carbon dioxide in the atmosphere is increasing at an increasing rate. In 1960 the rate of increase per year was 0.71 PPM (parts per million) while the rate of increase was 2.14 PPM per year in 2005 (Ernst-Georg, 2010). Comparatively, average measures of CO_2 per capita for ECOWAS countries are relatively low, compared to the numbers recorded for industrial countries. For example, CO_2 for China, Japan, UK and USA stood at 2.23, 8.41, 10.08 and 19.81 respectively in 1965-2009 (World Bank, 2013). Compare these figures to those of Benin, Burkina Faso, Cote d'Ivoire, Gambia The, Ghana, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone and Togo measured at 0.19, 0.06, 0.48, 0.19, 0.29, 0.46, 0.05, 0.09, 0.60, 0.42, 0.33 and 0.21 respectively (World Bank, 2013). The ECOWAS averages are equally less than the SSA average.

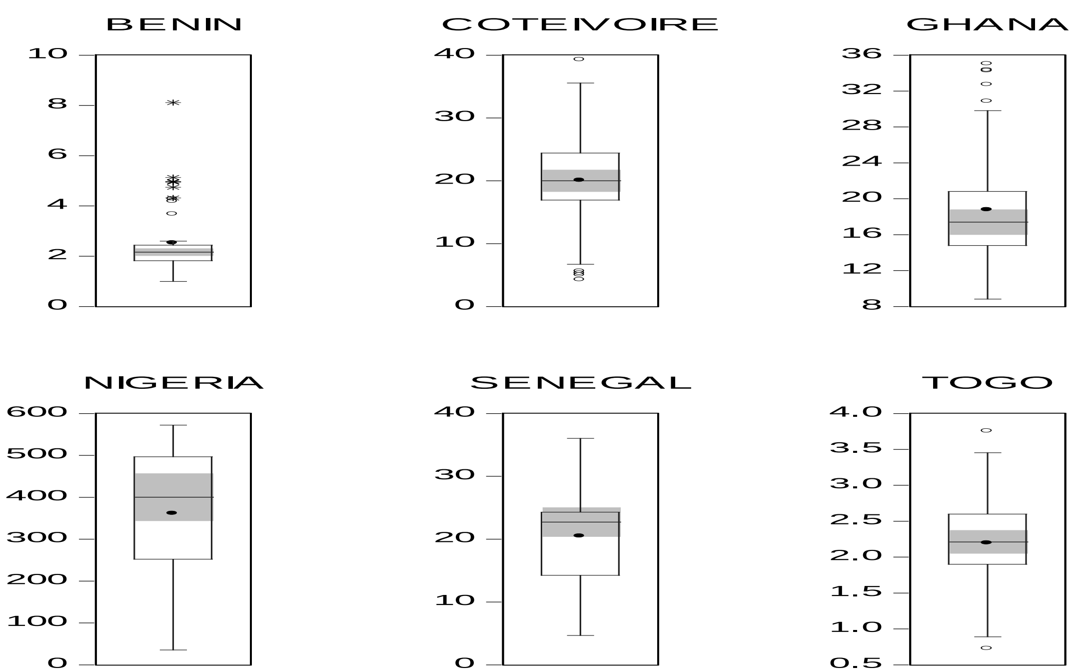

Figure 1: Box Plot of Anthropogenic Sulfur Dioxide Emissions of Selected ECOWAS in Gigagrams of SO_2

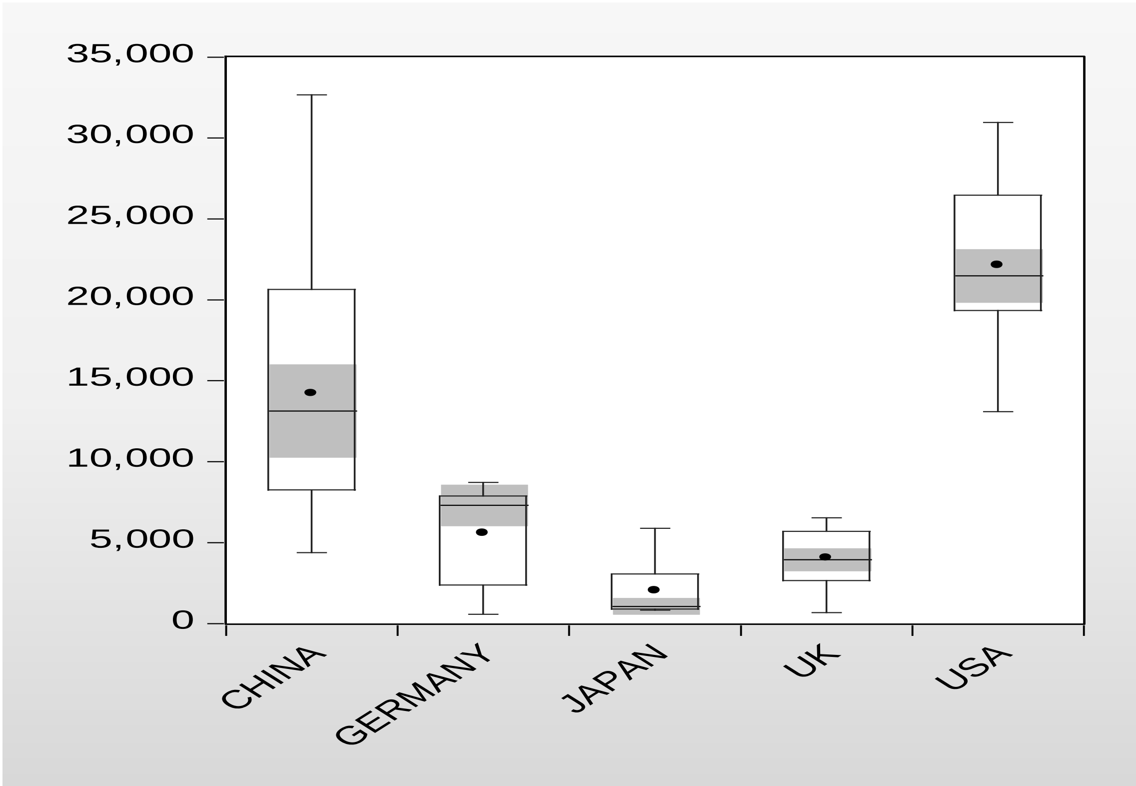

Figure 2: Box Plot of Anthropogenic Sulfur Dioxide Emissions of Industrial Countries in Gigagrams of SO_2

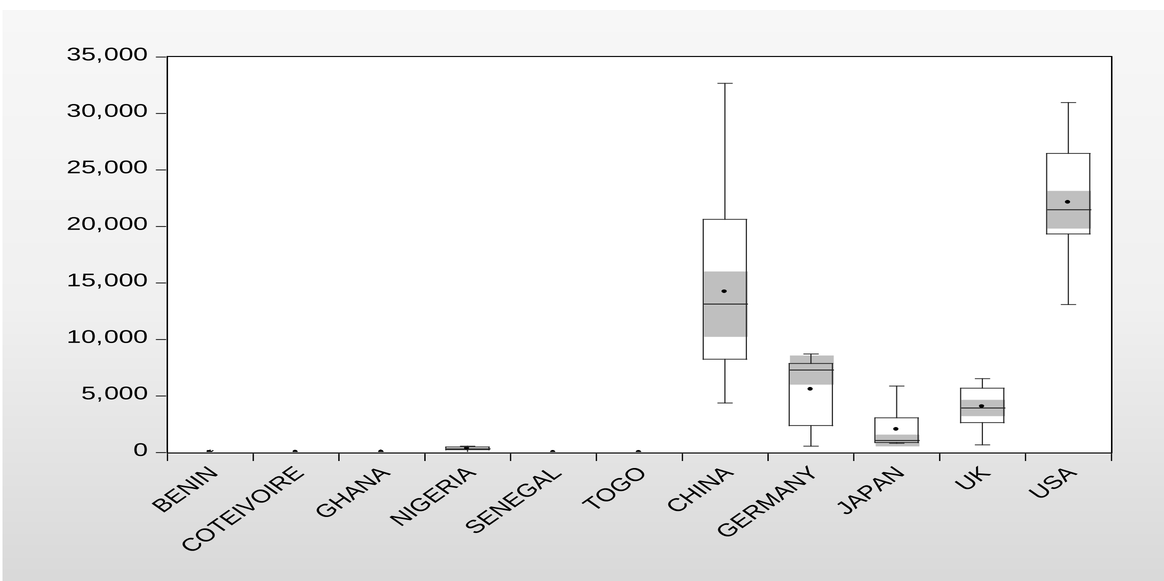

Figure 3: Box Plot of Anthropogenic Sulfur Dioxide Emissions of ECOWAS and Industrial Countries in Gigagrams of SO_2

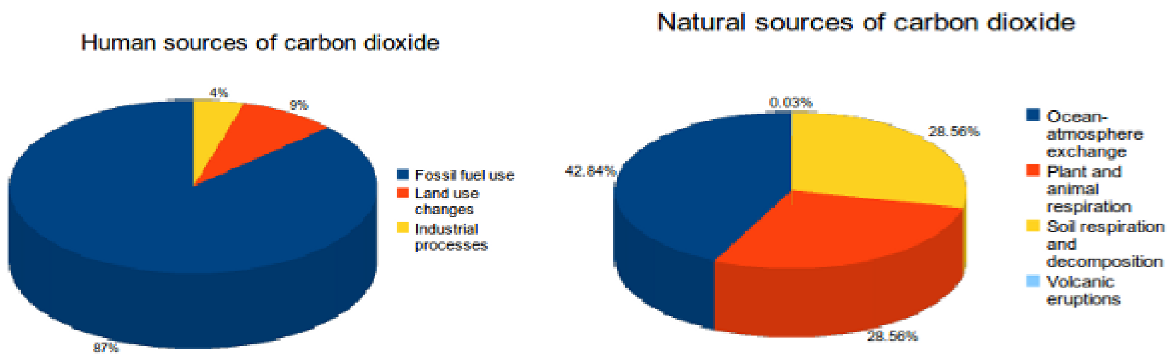

Figure 4: Composition of human and natural sources of CO_2. **Source:** Le Quéré, C. et al. (2013).

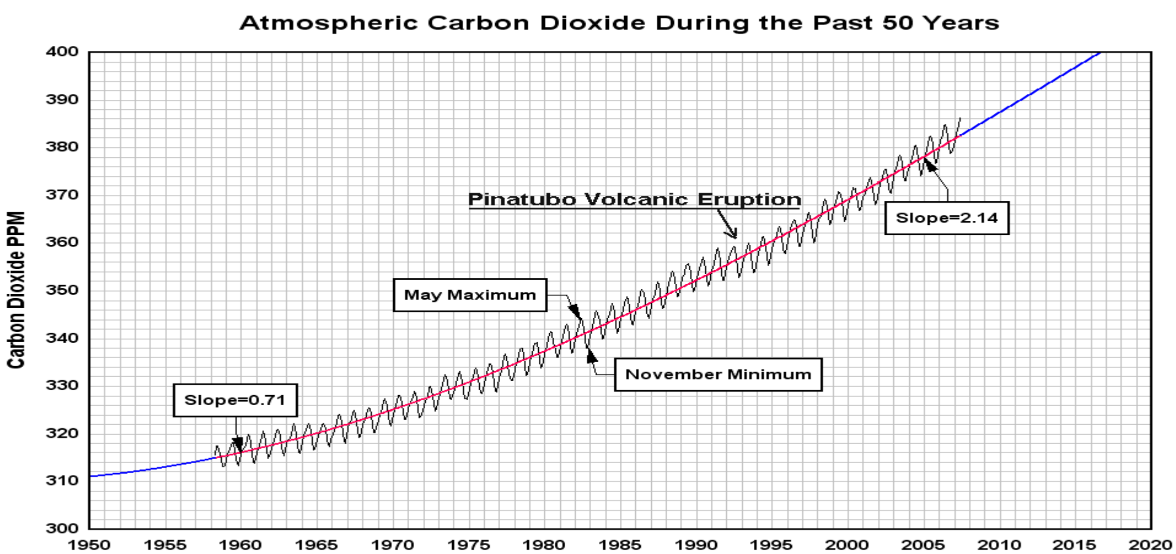

Figure 5 Carbon Dioxide Concentrations

It is interesting to note that the role developing countries should play in the curbing of emissions have been expressed in different forums. This worry is not unfounded as the African continent particularly and thence the ECOWAS region ascends into the new phase of development despite current global development challenges. While it has been amplified that the poorest segment of society are the most adversely affected by environmental degradation (Orubu, Omotor and Awopegba, 2005), significant strides have been made by most ECOWAS countries individually and as a group in the acceptance of the principles of sustainable development as expressed in the

ECOWAS Environmental Policy (2008). The fear that the environment may degrade further as the new phase takes-off is still a concern and the need to mainstream and strengthen policy in the planning process of the region's development and the African continent generally, has been canvassed (ADB, 2004).

4. Theoretical Framework and Model Specification

Many environmental economists take the EKC as a stylised fact that needs to be explained by theory, despite the pieces of evidence that it may not apply to all pollutants or environmental impacts (Stern, 2004). According to the literature, the economic factors identified to drive changes in environmental impacts that may be responsible for rising and declining environmental degradation are the *scale effect*; *structural effect* and *abatement effect* among others. The scale effect arises from the simple analogy that as the scale of production in an economy expands all other things equal, the increase in scales will necessarily bring a proportionate increase in pollution or emission (Chen, 2007) as measures to control certain pollution may not be practicable at small scales of production (Orubu, et.al, 2008). This relation is represented by Figure 5(a).

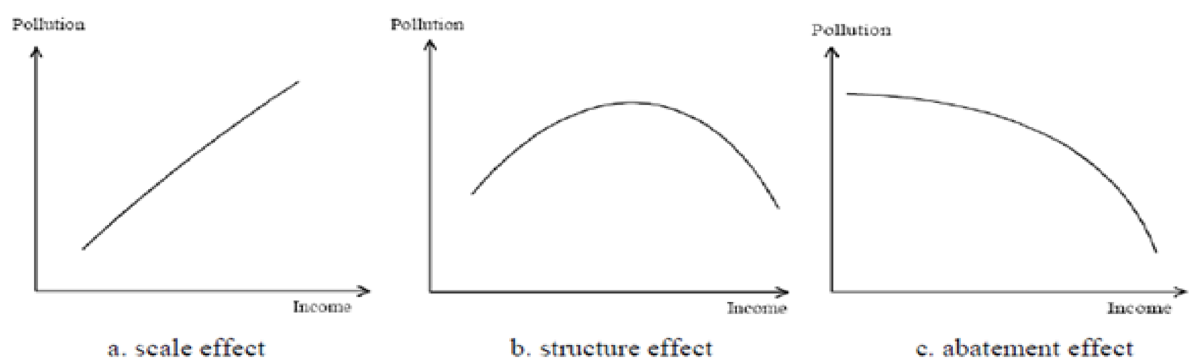

Figure 5: Different Effects of Income on Environment;

Source: Islam, N., J. Vincent and T. Panayotou (1999)

Table 1: ECOWAS Governments Commitment

Country	Environmental strategies or action plan	Biodiversity Strategies, or action plan	Participation in Treaties								
			Climate Change	Ozone Layer	CFC Control	Law of the Sea	Biological Diversity	Kyoto Protocol	CITES	CCD	Stockholm Convention
Year of Commencement →			**1992**	**1986**	**1987**	**1982**	**1992**	**1997**	**1973**	**1994**	**2001**
Benin	1993		1994	1993	1993	1997	1994	2002	1984	1996	2004
Burkina Faso	1993		1994	1989	1989	2005	1993	2005	1989	1996	2004
Cote d'Ivoire	1994	1991	1995	1993	1993	1994	1994	2007	1994	1997	2004
Gambia	1992	1989	1994	1990	1990	1994	1994	2001	1977	1996	2006
Ghana	1992	1998	1995	1989	1989	1994	1994	2003	1975	1996	2003
Guinea	1994	1988	1994	1992	1992	1994	1993	2000	1981	1997	nil
Guinea Bissau	1993	1991	1996	2002	2002	1994	1995	nil	1990	1995	2008
Liberia	Nil	Nil	2003	1996	1996	2008	2000	2002	2005	1998	2002
Mali	Nil	1989	1995	1994	1994	1994	1995	2002	1994	1995	2003
Niger	Nil	1991	1995	1992	1992	nil	1995	2004	1975	1996	2006
Nigeria	1990	1992	1994	1988	1988	1994	1994	2004	1974	1997	2004
Senegal	1984	1991	1995	1993	1993	1994	1994	2001	1977	1995	2003
Sierra Leone	1994	Nil	1995	2001	2001	1994	1994	2006	1994	1997	2003
Togo	1991	Nil	1995	1991	1991	1994	1995	2004	1978	1995	2004
China	1994	1994	1994	1989	1991	1996	1993	2002	1981	1997	2004
Germany	Nil	Nil	1994	1988	1988	1994	1993	2002	1976	1996	2002
Japan	Nil	Nil	1994	1988	1988	1996	1993	2002	1980	1998	2002
United Kingdom	1995	1994	1994	1987	1988	1997	1994	2002	1976	1996	2005
United States	1995	1995	1994	1986	1988	nil	nil	nil	1974	2000	nil

Source: World Development Indicators, 2010

The structural effect which is accompanied by a shift in production/consumption patterns is related to the composition effect of the economic growth process. As the economy shifts initially from subsistence level to agricultural economy (more material), then to energy-intensive manufacturing sector (pollution levels rise) and towards a more environmentally-friendly service sector, there is a down-turn in pollution level (Bouvier, 2004). The structural effect is depicted in Figure 5(b).

The abatement effect is essentially communicating the technological change and goes with the structural effect. The upgrading of industrial structure needs the support from technology. Shift in technology allows for the possibility of “cleaner” technologies to substitute for “dirtier” ones in the production process. With technical progress it becomes possible to replace the heavily polluting technology with cleaner technology. The abatement effect as illustrated in Figure 5(b) is generally exemplified by relatively low pollution intensities.

Popular discussions and models of the EKC emphasize the role of the income elasticity of demand for environmental quality as a driving force for the inverted U-shaped relationship between income and pollutants (McConnell, 1997). These discussions- both theoretical and empirical – make different simplifying assumptions about the economy, in terms of how literacy, technology, preferences, population density and other intervening variables relate to produce an inverted U-shaped curve. In all ramifications, as income rises, increased demand for cleaner environment will be required as policy makers will be pressured to stringent environmental regulations, investment and control.

Although some substantial efforts have been made to provide a theoretical framework that rationalizes the subsistence of the EKC as an observable fact, the rest of this section which draws heavily from Orubu, et.al. (2009), offer an interesting micro-structure from Levinson (2000). The

Levinson micro model which is derived from a polynomial pollution-income curve is based on the utility maximizing behaviour of economic agents in which pollution rises at lower levels of income, but falls at higher levels. In the modified Levinson's Model, the EKC explanation can be collapsed into five basic equations (a social utility function, a pollution function, a modified pollution function, an abatement function, and a constraint, respectively);

$$U = U(C, P);\ P = P(C, F),\ P = C - C^{\alpha}F^{\beta},\ A = C^{\alpha}F^{\beta},\ C + F = Y \qquad (1)$$

Where, U = total utility, C = consumption, P = Pollution effect of the processes of production and consumption in the economy, F = effort expended in abating pollution, A = total abatement, Y = income, while α and β are parameters. From these equations, the consumption-income, and pollution-income equations can be derived.

Defining five basic assumptions individually, the social welfare function or the total derived utility is expressed as,

$$U = U\ (C, P), \qquad (2)$$

$Where; U_1 > 0;\ U_2 < 0$

Implying that social welfare is positively dependent on consumption (C), and negatively related to pollution effect (P). Therefore, as increased consumption increases social welfare or total utility, pollution effect is a disutility.

The pollution function expressed as:

$$P = P(C, F) \qquad (3)$$

$Where; P_1 > 0;\ P_2 < 0$

Accordingly, increased processes of production or consumption create pollution and since abatement of pollution goes with cost of disposal, society must undertake some manifest effort (*F*) to abate pollution. Increased effort is thus expected to reduce or abate pollution and hence the negative relationship.

The modified pollution function expressed as:

$$P = C - C^{\alpha} F^{\beta} \quad (4)$$

And for simplicity, we normalize the relative costs of *C* and *F* to be 1, the relative constraint faced by society in apportioning resources (income) between consumption and abatement effort can be stated as:

$$C + F = Y \quad (5)$$

And further assuming that total abatement can be stipulated as,

$$A = C^{\alpha} F^{\beta} \quad (6)$$

Considering a simple case where social welfare or total utility is assumed to be additive and linear in *C* and *P*, consumption and pollution wield equal but inverse impacts on social welfare, the total utility function can be restated as,

$$U = C - mP \quad (7)$$

$$m > 0$$

where $m > 0$ is the constant marginal disutility of pollution.

In order to optimize abatement subject to resource constraint, society optimal levels of consumption and pollution can be solved for by maximizing Equation (6);

$$A = C^{\alpha} F^{\beta} \quad (8)$$

subject to the constraint (Equation 5);

$$C + F = Y \quad (9)$$

Transforming Equation (8), subject to the constraint of Equation (9) and hence consumption and effort have standard Cobb-Douglas solution, the Lagrange can be set up as:

$$W = \alpha InC + \beta InF + \lambda(Y - C - F) \quad (10)$$

$$\frac{\partial W}{\partial C} = \alpha \frac{1}{C} - \lambda = 0 \quad (11)$$

$$\frac{\alpha}{C} = \lambda \quad (12)$$

$$\frac{\partial W}{\partial F} = \beta \frac{1}{F} - \lambda = 0 \quad (13)$$

$$\frac{\beta}{F} = \lambda \quad (14)$$

$$\frac{\partial W}{\partial \lambda} = Y - C - F = 0 \quad (15)$$

By equating Equations (12) and (14)

$$\frac{\alpha}{C} = \frac{\beta}{F}$$

$$\alpha F = \beta C$$

$$F = \frac{\beta}{\alpha} C \quad (16)$$

$$C = \frac{\alpha}{\beta} F \quad (17)$$

Substituting Equation (16) into Equation (9),

$$C + \frac{\beta}{\alpha} C = Y$$

$$C\left(1 + \frac{\beta}{\alpha}\right) = Y$$

$$C = \frac{Y}{1 + \frac{\beta}{\alpha}} = \frac{Y}{\frac{\alpha + \beta}{\alpha}} = \left(\frac{\alpha}{\alpha + \beta}\right) Y$$

$$\therefore \bar{C} = \left(\frac{\alpha}{\alpha + \beta}\right) Y \quad (18)$$

Substituting Equation (17) into Equation (18)

$$\frac{\alpha}{\beta}F + F = Y$$

$$\left(\frac{\alpha}{\beta} + 1\right)F = Y$$

$$F = \frac{Y}{\frac{\alpha}{\beta} + 1} = \frac{Y}{\frac{\alpha + \beta}{\beta}} = \left(\frac{\beta}{\alpha + \beta}\right)Y$$

$$\therefore \bar{F} = \left(\frac{\beta}{\alpha+\beta}\right)Y \qquad (19)$$

To derive the optimal level of pollution, substitute $\bar{C}$ (Equation 18) and $\bar{F}$ (Equation 19) into the pollution equation,

$$P = C - C^{\alpha}F^{\beta}$$

$$P = \left(\frac{\alpha}{\alpha + \beta}\right)Y - \left[\left(\frac{\alpha}{\alpha + \beta}\right)Y\right]^{\alpha}\left[\left(\frac{\beta}{\alpha + \beta}\right)Y\right]^{\beta}$$

$$\therefore \bar{P} = \left(\frac{\alpha}{\alpha+\beta}\right)Y - \left[\left(\frac{\alpha}{\alpha+\beta}\right)Y\right]^{\alpha}\left[\left(\frac{\beta}{\alpha+\beta}\right)Y\right]^{\beta}Y^{(\alpha+\beta)} \qquad (20)$$

The derivation of Equation (20) represents the environmental Kuznets curve:

$$\frac{\partial P}{\partial Y} = \frac{\alpha}{\alpha+\beta} - (\alpha + \beta)\left(\frac{\alpha}{\alpha+\beta}\right)^{\alpha}\left(\frac{\beta}{\alpha+\beta}\right)^{\beta}Y^{(\alpha+\beta-1)} \qquad (21)$$

The sign of which depends on the parameters α and β.

From Equation (20), note that if $(\alpha+\beta)>1$, abatement will reflect increasing returns to scale, and the pollution curve will correspond to the EKC in Figure 1B. If $(\alpha+\beta)<1$, then abatement exhibits diminishing returns to scale; EKC is convex and when, $(\alpha+\beta)=1$, effort spent abating pollution has constant returns to scale, and income-pollution is constant, as in Figure 7a.

4.1 Model Specification

With the foregoing, and given the framework already considered above, the basic foundation of the EKC formulation is that pollution intensity worsens as income levels rise, but eventually falls once income crosses some threshold. By this postulation, the prime quadratic EKC equation in logarithms can be specified as:

$$In(e)_t = \alpha_1 + \beta_1 In(y)_t + \beta_2 In(y)^2 + \mu_t \qquad (22)$$

where e = indicator of environmental degradation or indicator

y = GDP per capita at constant prices (US 2000) or inform of concentrations

t = time

In = natural logarithm of the relevant variable

μ = disturbance term with zero mean and finite variance

For the EKC hypothesis to be established, $\beta_1 > 0, \beta_2 < 0$, and both must be statistically significant. In a longitudinal data analysis, a parametric specification of Equation (22) would be formulated as:

$$In(e_{it}) = \alpha_i + \gamma_{it} + \beta_1 In(y_{it}) + \beta_2 (In(y_{it}))^2 + \mu_{it} \qquad (23)$$

In this specification, the focus is still on the logarithms of both per capita GDP, denoted by y_{it}, and per capita of the emission or environmental degradation index, denoted by e_{it}. Within this framework and in this paper $i = 1, . . . , N$ indicates the country and $t = 1, . . . , T$ is the time mark. In qualitative terms, similar results have also been obtained when using levels instead of logarithms (Wagner and M¨uller-F¨urstenberger, 2005). The stochastic error term of Equation (23) is denoted by μ_{it} with the appropriate assumptions concerning serial correlation. The first two terms on the right hand side in Equation (23), are intercept parameters that vary across countries (i), and years (t). The above formulation of the EKC posits a strong *homogeneity* assumption which implies that although environmental degradation may vary among countries at any given level of income, the income elasticity is the same for all countries at a given level of income. In a further strand, the time specific intercepts take care of time-varying variables that are omitted from the model, including stochastic shocks. Panel data analysis combine the features of both time series and cross-sectional analysis and are often specified to take care of fixed and random effects (for details, see Torres-Reyna, 2007). In equation (23), if β_1 > 1, β_2 < 1 and are statistically significant, then the estimated curve has a maximum turning point per capita income level, calculated as $Y^* = exp(-\beta_1/2\beta_2)$.

Fixed effects (FE) models treat α_i and γ_t as regression parameters, while random effects (RE) models treat them as components of the random disturbance.

In the literature, some theoretical discourses and studies have also included a cubic term in their estimations (see for example, Dijkgraaf and Vollebergh, 2001; Martinez-Zarzoso and Bengochea-Morancho, 2003; Galeotti, Manera and Lanza, 2006; Poudel, Paudel and Bhattarai, 2009; Haulman, 2012 and Stern, 2014). In some of such specifications, the cubic model is cast as:

$$In(e_{it}) = \alpha_i + \gamma_{it} + \beta_1 In(y_{it}) + \beta_2 (In(y_{it}))^2 + \beta_3 (In(y_{it}))^3 + \mu_{it} \qquad 24$$

If β_3>0 in equation (24), this would be symptomatic of an N-shaped curve. In modelling the EKC relationship, Shafik (1994) expanded the variables considered; thus suggesting that income is only one of the several factors which help to determine declining environmental quality generally. Shafik hypothesized that other determinants of environmental quality in any country as; 1) endowment such as climate or location; 2) the structure of production, urbanization, and consumption patterns of private goods, 3) exogenous factors such as technology that are available to all countries but change over time; and 4) policies that reflect social decisions about the provision of environmental public goods depending on institutions. Khanna (2002) also identified such other critical factors that may influence the EKC existence as race, education, population density, housing tenure and the structural composition of the workforce.

In the strict case, establishing an EKC in the presence of other moderate factors provides a more convincing basis for validation of the hypothesis. We therefore experiment by expanding the basic model to include such factors as population density (PDEN), trade openness (TPN), and political economy (POEC). The higher the population density, the greater will be the intensity of pollution, as well as the pressure brought to bear on environmental services and resources.

If the income variables are statistically significant, we will then calculate the turning point(s) for the EKC sample estimations. The formulae to calculate the first and second turning points are respectively:

$$\tau = exp\left(\frac{-\beta_2+\sqrt{\beta_2^2-4\beta_1\beta_3}}{-2\beta_1}\right) \qquad \tau = exp\left(\frac{-\beta_2-\sqrt{\beta_2^2-4\beta_1\beta_3}}{-2\beta_1}\right) \qquad (24)$$

One other purpose for a crossbreed EKC model is to establish if the observable fact of the EKC hypothesis (basic model) is stable in the presence of other variables as eulogized above. If the cubic term in Equation (24) is dropped, the estimable equation for simplicity is,

$$In(e_{it}) = \alpha_i + \gamma_{it} + \beta_1 In(y_{it}) + \beta_2 (In(y_{it}))^2 + \varphi_j \sum_{j=1}^{n} (In(X_{it}))^3 + \mu_{it} \quad (25)$$

where,

X = vector of other explanatory variables. The basic estimable model setup for our analysis can be concisely summarized as follows:

$$e = \alpha + \sum_{j=1}^{p} \beta_j X_j + \varepsilon, \qquad (26)$$

4.2 Sources of the Data

The data for the two indicators of environmental quality and other variables used in study were obtained from the World Bank (2012, 2013) source, *World Development Indicators;* Smith, et.al. (2011), *Anthropogenic Sulfur Dioxide Emissions*: 1850–2005; and Marshall & Jaggers (2014), *Polity IV*. The African Development Bank's publication, *Gender, Poverty and Environmental Indicators on African Countries* was used to complement some gaps in the data series. The definition of variables and their sources are summarized in Appendix 1.

4.3 Description of the Data

The trend analysis of the variables and their descriptive statistics are highlighted in this sub-section for the respective ECOWAS countries selected for the analysis. The choice of countries as presented in Appendix 2 and time frame used in the analysis is influenced by data availability and consistency.

4.3.1 Sulphur dioxide (SO_2)

Sulfur dioxide is a colourless non-flammable gas and if oxidized forms acid aerosols. SO_2 is a precursor to sulphates, which are some of the main components of respirable particles in the atmosphere. About 99% of the sulfur dioxide in air comes from human sources. Health effects caused by exposure to high levels of SO_2 include breathing problems, respiratory illness, changes in the lung's defenses, and worsening respiratory and cardiovascular disease.

A consistent annual data series for SO_2 is available for 6 ECOWAS countries for the period 1960 – 2005, as indicated in Appendix 2. This makes a total of 46 cross-sectional observations for each ECOWAS country, and total balanced panel observations of 276 for all the ECOWAS countries included in the sample. The smallest minimum value of 1Gigagrams (Gg) recorded for SO_2 occurred from 1961 for Benin, while the highest maximum value of 572.4 Gg for the ECOWAS countries under review occurred in 1979 in Nigeria. This observation is consistent with the trend of the mean values recorded for SO_2. The highest mean value 361.72 Gg, and progressively declined until the smallest observed mean value of 2.199. If these observations are anything to go by, the indication is that SO_2 emission, on the average, has been on the decline in the ECOWAS countries included in the study sample over time. A feel of the associative relationship between SO_2 and per capita income is captured by the Pearson correlation coefficient, calculated at 0.84, 0.08, -0.09, 0.68, -0.69 and 0.38 (see Appendix 3), for Benin, Cote d'Ivoire, Ghana, Nigeria, Senegal and Togo respectively. Thus, indicating a possible inverse relationship between SO_2 emissions and per capita income for Ghana and Senegal, and positive relationship for Benin, Cote d'Ivoire, Nigeria and Togo.

The summary statistics of ECOWAS SO_2 and its covariates for the period 1965 to 2009 are presented in Appendix 4. The Table shows that the average growth rate of SO_2 concentration in the region to be 4.93%. This is explained by the pollution concentration growth of 7.2%, 4.07%, 6.44%, 2.96%, 3.53 % and 5.04% of Togo, Senegal, Nigeria, Ghana, Cote d'Ivoire and Benin respectively. It is also noted that more densely populated countries relatively emit higher levels of SO_2 concentration.

4.3.2 Carbon dioxide (CO_2)

CO_2 is an unregulated, invisible, odorless gas with no direct human health effects. Carbon dioxide releases constitute the largest of all greenhouse gas emissions resulting from human activities, particularly from industrial processes such as the burning of fossil fuels and the manufacture of cement. The CO_2 variable is measured in metric tons per capita/per annum. ECOWAS member average per capita carbon dioxide emissions range from 0.05 tons to 0.59 tons for Mali and Nigeria respectively. The ECOWAS average for the twelve countries as shown in Appendix 5 and 6 is below the 0.876 tons for sub-Saharan average, 19.81 and 10.08 tons for the United States of America and the United Kingdom respectively. The variation in per capita emissions is largely dissimilar from the variation evident in the ratios of the U.K and U.S. per capita emissions. Within the period under review (1965-2009), the ratio of maximum to minimum per capita carbon dioxide varied widely for Benin, Liberia and Sierra Leone. For the other nine ECOWAS countries reviewed, the maximum to the minimum per capita emissions among them were substantially similar. From the descriptive statistics of CO_2 emissions summarized the total of 45 cross-sectional observations for each ECOWAS country, and total balanced panel observations of 540. The total average per capita CO_2 for the twelve ECOWAS states is 5.35; this is about four times less than the US average and equal to average total emissions of Canada per annum. The relatively low per capita CO_2 emissions for the ECOWAS countries would obviously suggest that they should sustain the temple by increasingly enhancing other ways of reducing emissions, for example through the use of environmental regulations.

4.3.3 Income per capita (y)

Among the numerous variables that affect per capita carbon dioxide production, per capita income is the factor which has prompted the largest amount of theoretical and empirical analysis. Our measure of income per capita is GDP per capita at constant prices (US 2000) since this measure of GDP is more reliable and available than measure of GNP and both measures are highly correlated. There is an abundance of economic literature and empirical support of the EKC for series of pollutants. Economic Growth and the Environment, by Grossman and Krueger (1995), formed the fundamental basis for many econometric tests of the EKC done over time (Peterson, 2009). Some other controlled variables so far used in the EKC empirical literature are;

4.3.4 Population density

Population density is measured as people per sq. km of land. The supposition as earlier noted is that countries with less dense, dispersed populations emit high levels of CO_2, due to high transportation costs (Neumayer, 2003; Emrath, 2008; Grazi, 2008; Peterson, 2009). In urban areas where the population is denser, on the other hand, there is tendency to produce relatively less CO_2, as people travel less distance and may make use of public transportation. Population density data is extracted from the World Bank (2013) data set.

4.3.5 Openness

Openness is proxied as trade (% GDP) and is measured in this instance as the ratio of the sum of export and import to the GDP. Trade as suggested in the literature is a major determinant of international technology adoption and diffusion. This occurs through imports of intermediate input, learning-by-exporting experience, foreign direct investment (FDI), communication, etc (Kinda, 2011). These processes encourage the use of modern technology that promotes pollution abatement. The trade (% GDP) data is obtained from the World Bank, World Development Indicators (2013) data set

4.3.6 Population growth

Population growth may have a result in growth of emissions (independently of the growth in per capita incomes) via the demand for public goods that are pollution-intensive, such as infrastructure and defense, as argued, for example, by Ravallion et al (1997) and (Mitsis, 2012).

In Table 3, we present the summary statistics of ECOWAS SO_2 and its covariates for the period 1960 to 2005. The Table shows that the average growth rate of SO_2 concentration in the region to be 4.93%. This is explained by the pollution concentration growth of 7.2%, 4.07%, 6.44%, 2.96%, 3.53 % and 5.04% of Togo, Senegal, Nigeria, Ghana, Cote d’Ivoire and Benin respectively. It is also noted that more densely populated countries relatively emit higher levels of SO_2 concentration. Table 4 presents the summary statistics of CO_2 for twelve (12) ECOWAS countries and its covariates for the period 1970 to 2009. The Table shows that the average growth rate of CO_2 emission in the region is 11.84% with an average emission of 0.28 metric tons per capita. Countries which recorded an average below the regional average are Benin, Burkina Faso, The Gambia, Mali, Niger and Togo whose respective averages are; 0.19, 0.06, 0.19, 0.05, 0.06 and 0.21 metric tons per capita. Countries which recorded averages above the regional are; Cote d'Ivoire, Ghana, Liberia, Nigeria, Senegal and Sierra Leone whose averages are 0.48, 0.29, 0.46, 0.60, 0.43 and 0.33 respectively. Nigeria recorded the highest emission, though not unexpected being the most populated and industrialized, while Mali recorded the lowest average. This is equally reminiscent of the degree of development.

4.3.7 Polity variable

The polity variable captures the quality of institutions and the data is obtained from Marshall, and Jaggers (2014), *Polity IV*. Polity IV contains, amongst many other variables, yearly composite indicators measuring both "institutionalized democracy" and "autocracy". A summary "polity" measure is then defined as the difference between the democracy and autocracy scores, with 10 indicating "strongly democratic" and –10 indicating "strongly autocratic" Fazin and Bond (2004). The specification assumes that the quality of institutions, political regime and openness of the state to environmental preferences of the public can be captured using this index. The relationship between environmental quality and economic is consummated with political institutions in sharpening policy formulation. As often aptly underscored, "*The connection between environmental protection and civil and political rights is a close one. As a general rule, political and civil liberties are instrumentally powerful in protecting the environmental resource-*

base, at least when compared with absence of such liberties in countries run by authoritarian regimes" (Dasgupta and Maler, 1995:2412). During the period under review, most of the countries in the ECOWAS region were either under authoritarian regimes or just emerging from civil crises.

5. Empirical Results

Panel FE, RE and OLS estimates

The variants regression approaches to the test of the EKC model using the quadratic form in the sulphur (SO_2) model are displayed in Table 3-5. The regressors here are the per capita income (Per capita GDP and its squares (Per capita GDP^2). These techniques of analysis enable us to test whether the economic growth and SO_2 emission consistently hold for the ECOWAS countries used in the panel.

All slope parameters are statistically significant at 5% as *'a priori'* expected and rightly signed; indicating that income per capita is an important factor in estimation of SO_2 emissions. The implication is that the EKC hypothesis holds for local pollutants like SO_2.

Specifically, the random effect model displays similar results in terms of signs of coefficients. Income per capita and income per capita square coefficients are respectively 28.31 and -2.25 and are significant. However, effects of income per capita and per capita square appeared to have greater impacts in the random effect model. The coefficients of determination are not to be worried about as they give highly negligible explanatory power of the regressors. This may be due to other fundamental variables omitted from the basic model. The collinearity perceived to exist between the regressors is not a major problem as this is not meant for forecast.

The panel OLS results are not different from the random effect model. However, as for the choice between the fixed and random effect which becomes academic in a situation like this, the Husman's and Fixed redundant effect tests favour the random effect (0.23) and thus the null hypothesis that unobservable effects are correlated with regressors is rejected. Therefore, the random effect becomes the most consistent estimator.

On the basis of the expected coefficients, we computed the turning points of the income per capita. For the fixed effect model, the income per capita turning point was about $5,650 dollars over the period and thus this is the income that exists at the inverted U-shaped EKC. The turning point income per capita for the random effect counterpart was approximately $114,800 dollars over the period and very much higher than those of the fixed income model. The turning point values are higher than the region's average gross domestic product (GDP) per capita which ranges from USD 800 in Niger to USD 4,400 in Cape Verde, suggesting that regulation of this pollutant may be difficult to achieve if left to income alone.

Table 3.Quadratic FE, RE and OLS estimates for ECOWAS countries (SO_2 as dependent variable)

Independent variables	FE	RE	OLS
Constant	-75.86(-3.20)	-85.89(-3.77)	-85.89(-4.01)**
GDPPC	25.02(3.20)**	28.31(3.75)**	28.31(3.99)**
$GDPPC^2$	-1.20 (3.06)**	-2.25(-3.84)**	-2.25(-3.84)
Hausman Test		0.23	
Fixed Red. Test	1.00		
R^{-2}	0.16	0.11	0.11
Turning Point		$114,800	

Table 4. Cubic FE, RE and OLS estimates for ECOWAS countries (SO_2 as dependent variable)

Independent. variables	FE	RE	OLS
Constant	102.92(0.36)	-16.71(-0.06)	-16.71(-0.07)
GDPPC	-63.72(-0.45)	-6.03(-0.05)	-6.03(-0.05)
$GDPPC^2$	12.66(0.54)	3.42(0.16)	3.42(0.17)

$GDPPC^3$	-0.80(-0.62)	-0.31(-0.26)	-0.31(-0.28)
Hausman Test		0.30	
Fixed Red.Test	1.00		
R^{-2}	0.16	0.11	0.11

Table 5. Augmented Parsimonious Quadratic FE, RE and OLS estimates for ECOWAS countries (SO_2 as dependent variable)

	FE	RE	OLS	FE	RE	OLS
Constant	-45.39 (-3.04)	-35.79 (-2.47)	-35.79(-2.17) **	-12.79 (-0.74)	-8.05 (-2.93)**	-6.82 (-3.41)**
GDPPC	5.77 (2.17) **	5.90 (2.23) **	5.90 (2.08) **	3.59 (1.61)***	11.49 (2.13)**	11.49 (1.75)***
$GDPPC^2$	-0.10 (-3.24) **	-0.19(-3.48) **	-0.19(-3.42)	-0.58 (-1.64)***	-0.74(-1.68)***	-0.74 (-1.93)***
DEM	0.06(1.67)	0.02(1.51)	0.02(1.33)	-0.59 (-2.29)**	0.12 (1.67)***	
PG	-0.51(-4.37)**	-0.59(-5.47)**	-0.59(-4.81)**			
POD	4.25 (21.53)**	2.96(19.79)**	2.96(17.40)**	4.22 (20.35)*	2.13 (16.56)*	2.31 (13.62)*
OPN	0.51(4.88)**	0.21(2.09)**	0.21(1.84)**			
GDPPC*DEM				0.11 (2.49)**	-0.03 (-1.62)***	-0.03 (-1.66)***
Hausman Test	0.00				0.00	
Fixed Red Test		0			0	
R^{-2}	0.74	0.6	0.6			
SE	0.97	1.11	1.11	0.64	0.48	0.64
F-stat	12.55	58.45	58.45	11.13	51.73	51.73

We examined the robustness of the EKC hypothesis by estimating the pooled panel cubic EKC using the FE, RE and OLS. The results are awful as they were not significant, though rightly signed.

The behaviour of the augmented quadratic EKC results for SO_2 when other control variables were included in the analysis similarly indicates the existence of an inverted-U relationship with income. The parsimonious results are the mostly devoid of insignificant variables. The GDP per capita has positive effect on SO_2 emission and statistically significant, while the parameter of the squared GDP per capita is negative and significant at 5 percent level.

The political institution variable (DEM) is not significant and does not have the expected sign suggesting that the period under review in the ECOWAS region may have been marred by political violence and lack of political openness and public voice. While rise in income alone is not enough to drive climate change policies, what may be playing out is that ECOWAS countries require higher levels of democratization to mitigate rising emission as they move to the next stage of higher industrialization. Population density in ECOWAS countries tends to intensify pollution from SO_2 concentration more than any other sources in the estimations, suggesting deliberate policy intervention in urban planning.

The openness variable as trade literature suggests is a major determinant of international technology adoption and diffusion. This variable has a positive significant impact on emissions with a coefficient greater than zero; implying a monotonically increasing trend connoting that increasing trade is accompanied by a rise in the level of the emission. This evidence gives credence to the pollution haven hypothesis which suggests that developing countries are the destinations for dirty industries or dumping sites of richer nations. Thus, the argument that trade through imports of intermediate input, learning-by-exporting experience, etc could encourage the use of modern technology that promotes pollution abatement increased use of resource efficiency may not necessarily be correct. Rather, the presence of externalities and trade openness could harm environmental quality and sustainable development.

Tables 6-8 report different variants of the panel fixed, random and the pooled OLS results for carbon dioxide (CO_2) emission. The main results of the CO_2 as in SO_2 are robust to specifications of income per capita and income per capita square given that they have the expected signs (0.001 and -6.74E^-07) and significant at the conventional level. Consequently, it can be concluded that the behavior of CO_2; a measure of global emission supports the EKC hypothesis of an inverted-U shaped relationship. The behavior of the other variables in the augmented estimations is not strikingly different from their SO_2 counterparts.

However, given that the polity variable which captures the quality of institutions, voice and accountability of the state to the environmental preferences of the populace was not significant, we re-estimated the CO_2 equation by interacting it with the income per capita variable. The underlining argument is that economic growth alone may be insufficient to improve environmental quality (Fazin and Bond, 2004). The augmented results from all the classes of estimations of this interaction report evidence of an unambiguous EKC relationship between income per capita, income per capita square and $CO_{2;}$ while CO_2 is negatively related to environmental policy variable (through the Per Capita GDP*Polity interaction variable). This affirmative finding that quality of public institutions matter in achieving environmental quality implies that deliberate and conscious choices of environmental policy efforts are required for cleaner environment as income per capita rises. From the CO_2 augmented interactive results, the Hausman test favoured the FE model. However, this conclusion did not necessarily hold in the structural relationship when the polity variable stood alone without and interactive income effect as the Hausman in this case favoured the RE (0.11) as consistent. In all, the results are similar in the classes of estimation techniques applied.

The cubic polynomial model of CO_2 where the income per capita appears in cubic form deviates from the cubic form equation of the sulphur model. The expected sign (4.29 E^-09 and 4.40E^09) and significance of income per capita cube is really an appreciation of the 'N' shaped EKC hypothesis for the ECOWAS countries. The very rapid growing pattern of income seemed to have further increased the degradation turning the scenario to the first case. The random effect model with a Hausman statistic of 0.12 is more consistent than the fixed effect in this case. Figures in Appendix 7 depict the shapes of the EKCs for some of the environmental indicators, based on selected regression results (in their logarithm transformation).

Table (6). Quadratic FE, RE and OLS estimates for ECOWAS countries (CO_2 as dependent variable)

	FE	RE	OLS
Constant	-0.05(-0.87)	-0.07(-1.22)	-0.07(-1.22)
GDPPC	0.001(4.34)**	0.001(4.78)**	0.001(4.78)**
$GDPPC^2$	$-6.74E^{-07}$	$-7.63E^{-07}$**	$-7.63E^{-07}$**
Hausman Test		0.11	
Fixed Red Test	0.38		
R^{-2}	0.23	0.15	0.15

Table (7). Cubic FE, RE and OLS estimates for ECOWAS countries (CO_2 as dependent variable)

	FE	RE	OLS
Constant	-0.47(-3.91)	0.50(-4.26)	-0.50(-4.26)**
GDPPC	0.004(5.11)**	0.005(5.45)**	0.005(5.45)**
$GDPPC^2$	$-7.66E^{-06}$	$-7.97E^{-06}$**	$-7.97E^{-06}$**
$GDPPC^3$	$4.29E^{-09}$	$4.40E^{-09}$**	$4.40E^{-09}$**
Hausman Test		0.12	
Fixed Redundant Test	0.38		
R^{-2}	0.26	0.18	0.18

Table (8): Augmented Quadratic FE, RE and OLS estimates for ECOWAS countries (CO_2 as dependent variable)

	FE	RE	OLS	FE	RE	OLS
Constant	-0.15 (-1.95)	-0.11(-1.60)	-0.11(-1.60)	-0.36 (-3.34)**	-0.26(-3.20)**	-0.26(-3.49)**
GDPPC	0.001 (2.79)**	0.001 (2.31)**	0.001 (2.31)**	0.001 (4.57)*	0.001 (3.98)*	0.001 (3.97)*
$GDPPC^2$	$-3.05E^{-07}$ (-0.99)	$-2.24E^{-07}$ (-0.74)	$-2.24E^{-07}$ (-0.74)	$-8.94E^{-07}$ (-2.62)**	$-6.96E^{-07}$ (2.08)**	$-6.96E^{-07}$ (-2.07)**
DEM	0.003 (1.10)	0.002 (0.80)	0.002 (0.80)	0.03 (5.23)*	0.02 (4.63)*	0.02 (4.62)*
DUMCC	0.25 (2.66)**	0.02 (0.74)	0.02 (0.74)			
OPN	-0.004 (-3.93)**	-0.003(-3.23)**	-0.003(-3.23)**			
POD	-0.003 (5.64)**	0.002 (5.86)**	0002 (5.86)**	0.002 (6.20)*	0.002 (6.24)*	0.002 (6.22)*
PG	0.044 (2.36)**	0.06 (3.55)**	0.06 (3.55)**			
GDPPC*DEM				-7.73 (-5.64)*	-6.03^{E-05} (-4.88)*	-6.03 (-4.86)*
Hausman Test		0.00			0.02	
Fixed Red. Test	0.38					
R^{-2}	0.23	0.26	0.26	0.25	0.24	0.24
F-stat	3.9	22.31	22.31	4.11	30.82	30.81

6.0 Conclusion

In this study, we investigated the relationship between per capita income and environmental degradation in ECOWAS countries, using longitudinal data spread generally between 1960 and 2009. Recognizing the often-cited income-environmental quality relationship, the specific objective was to estimate environmental Kuznets curves for two indicators of environmental quality, namely: sulphur dioxide(SO_2) and carbon dioxide (CO_2) and to establish whether the estimated relationships conform to the inverted U-shape hypothesis.

The results of the empirical investigation generally suggest the existence of environmental Kuznets curves for environmental quality indicators. Other factors such as population density; which is the most significant explanatory variable, openness, income-policy interaction variable were also found to affect environmental quality. Specifically, population density has a positive effect on environmental degradation, particularly for SO_2, while openness tends to reduce global pollution (CO_2). An N-shaped pollution – income curve was also indicated for CO_2– an indication that more stringent policy measures may be required to stem pollution from this source, as incomes rise to higher bounds. The N-shape is however, inverted for the case of SO_2. The turning points estimated for the different indicators of environmental quality are relatively low, thus suggesting a demonstration of the low level of industrial development in the sub-region occasioned by high incidence of poverty. Second, when these turning are compared to evidence from existing studies on the environmental Kuznets curve, they suggest that ECOWAS countries may be turning the corner of the environmental Kuznets curve, much faster, and at lower levels of income than expected. The polity variable which interacted significantly with the income variable to create the inverted-U shape EKC signals the importance of public institutions on environmental quality. Although ECOWAS countries may have benefited from early learning effects and environmental awareness in their appreciation of various Protocols and Agreement they are committed to; the conformity with the EKC hypothesis could also have resulted from the low level of industrialization in the sub-region. Should this latter reason be the case, the implication is that policy makers must to be proactive to sustain the temple as the region enters the phase of industrialization and may not need to wait for too long to improve environmental conditions as the case with developed countries and developing Asia. One of such ways is through the use of environmental tax instruments like fuel tax.

The influence of other factors such as population density, population growth and trade openness on environmental quality provides justification for mainstreaming the environment into the entire process of planning for development in order to ensure environmental sustainability in the ECOWAS region.

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Appendix 1 : Definition of Variables and Sources of Data

Variable	**Description**	**Source**
GDP per capita (GDPPC)	GDP per capita (constant 2005 US$)	The World Bank, World Development Indicators, 2013
Sulphur Dioxide (SO_2)	Sulphur Dioxide measured Gigagrams of SO_2. This variable enters the estimable equation in form of concentrations.	Smith, et.al.' 2011
Carbon Dioxide (CO_2)	The CO_2 variable is measured in metric tons per capita/per annum. This variable enters the estimable equation in per capita form.	The World Bank, World Development Indicators, 2013
Democracy (DEM)	Polity2 indicator to examine the extent to which democracy level and stock have significant, independent effects on SO_2 and CO_2 emissions.	Polity IV, Marshall, M.G. and K. Jaggers (2014). Polity IV contains, amongst many other variables, yearly composite indicators measuring both "institutionalized democracy" and "autocracy". A summary "polity" measure is then defined as the difference between the democracy and autocracy scores, with 10 indicating "strongly democratic" and –10 indicating "strongly autocratic" Fazin and Bond (2004).
Population Growth (PG)	Population Growth Rates	The World Bank, World Development Indicators, 2013
Population Density (POD)	People per sq. km of land	The World Bank, World Development Indicators, 2013
Openness (OPN)	Trade (% GDP)	The World Bank, World Development Indicators, 2013
DUMKy the UNFCCC treaty, and faces emissions reduction obligations; otherwise it takes a value of zero	Dummy variable: Dummy takes a value of one if a country has ratified the Kyoto Protocol and faces emissions reduction obligations; otherwise it takes a value of zero	The World Bank: Environment, World Development Indicators, 2010
DUMUNFCCC The United Nations Framework Convention on Climate Change (UNFCCC)	Dummy variable: Dummy takes a value of one if a country has ratified the UNFCCC treaty, and faces emissions reduction obligations; otherwise it takes a value of zero	The World Bank: Environment, World Development Indicators, 2010
Stockholm Convention is an international legally binding instrument to protect human		The World Bank: Environment, World Development Indicators,

health and the environment from persistent organic pollutants. Adopted in 2001, it entered into force in 2004.		2010

All independent variables are lagged by one year, except for democracy stock, which is lagged by two years (to separate it from the stock variable).

Appendix 2. West African Countries Covered in the Study for the Two Environmental Indicators (marked)

Country	SO_2	CO_2
Benin	*	*
Burkina Faso		*
Cote d'Ivoire	*	*
Gambia		*
Ghana	*	*
Liberia		*
Mali		*
Niger		*
Nigeria	*	*
Senegal		*
Sierra Leone	*	*
Togo	*	*

Sources: *World Development Indicators* (World Bank, 2013), Smith, et.al.(2011) and Marshall, M.G. and K. Jaggers Polity IV (2014).

Table 3a: Summary Statistics of ECOWAS SO_2 and Some Its Covariates

Country	**Description**	Values in Levels		Values in Logs	
		Mean	Std. Dev.	Mean	Std. Dev.
Benin	GDP per capita (constant 2005 US$)	303.50	*28.17*	5.71	*0.09*
	Openness	44.98	*14.36*	3.73	*0.43*
	Population Density	39.54	*15.23*	3.61	*0.37*
	Sulphur Dioxide (SO_2)	2.54	*1.45*	0.80	*0.50*
	Growth of Sulphur Dioxide Concentration	5.04%			
Cote d'Ivoire	GDP per capita (constant 2005 US$)	738.50	*147.23*	6.59	*0.19*
	Openness	70.05	*9.05*	4.24	*0.13*
	Population Density	30.57	*14.29*	3.30	*0.51*
	Sulphur Dioxide (SO_2)	20.10	*8.32*	2.89	*0.53*
	Growth of Sulphur Dioxide Concentration	3.53%			
Gh an a	GDP per capita (constant 2005 US$)	252.62	*30.83*	5.52	*0.13*

	Openness	49.87	*27.50*	5.52	*0.13*
	Population Density	55.70	*19.28*	3.96	*0.35*
	Sulphur Dioxide (SO_2)	18.80	*6.88*	2.87	*0.36*
	Growth of Sulphur Dioxide Concentration	2.96%			
Nigeria	GDP per capita (constant 2005 US$)	351.16	*52.28*	5.85	*0.16*
	Openness	42.78	*17.45*	3.67	*0.42*
	Population Density	91.22	*31.13*	4.46	*0.34*
	Sulphur Dioxide (SO_2)	361.71	*171.59*	5.67	*0.81*
	Growth of Sulphur Dioxide Concentration	6.77%			
Senegal	GDP per capita (constant 2005 US$)	518.86	*45.84*	6.25	*0.09*
	Openness	58.32	*14.08*	4.03	*0.26*
	Population Density	33.56	*12.59*	3.44	*0.38*
	Sulphur Dioxide (SO_2)	20.52	*7.63*	2.93	*0.47*
	Growth of Sulphur Dioxide Concentration	4.07%			
Togo	GDP per capita (constant 2005 US$)	276.32	*36.41*	5.61	*0.14*
	Openness	84.33	*18.27*	4.41	*0.21*
	Population Density	58.69	*22.19*	4.00	*0.39*
	Sulphur Dioxide (SO_2)	2.20	*0.68*	0.73	*0.36*
	Growth of Sulphur Dioxide Concentration	7.20%			
Average	GDP per capita (constant 2005 US$)	406.83			
	Openness	58.39			
	Population Density	51.55			
	Sulphur Dioxide (SO_2)	70.98			
	Growth of Sulphur Dioxide Concentration	4.93%			

N = 46

Table 3b: Summary Statistics of ECOWAS CO_2 and Some Its Covariates

Country	Description	Values in Levels		Values in Logs	
		Mean	Std. Dev.	Mean	Std. Dev.
Benin	GDP per capita (constant 2005 US$)	314.28	*29.30*	5.75	*0.09*
	Openness	49.29	*10.15*	3.85	*0.25*
	Population Density	44.92	*17.65*	3.73	*0.39*
	Carbon Dioxide (CO_2)	0.19	*0.13*	-1.83	*0.62*
Burkina Faso	GDP per capita (constant 2005 US$)	178.96	*41.34*	5.16	*0.22*
	Openness	33.55	*6.81*	3.49	*0.24*
	Population Density	32.26	*10.77*	3.42	*0.33*
	Carbon Dioxide (CO_2)	0.06	*0.03*	-2.94	*0.52*
Cote d' Ivoire	GDP per capita (constant 2005 US$)	738.74	*149.12*	6.59	*0.19*
	Openness	72.92	*9.89*	4.28	*0.14*

	Population Density	35.00	*14.57*	3.46	*0.46*
	Carbon Dioxide (CO_2)	0.48	*0.13*	-0.76	*0.26*
The Gambia	GDP per capita (constant 2005 US$)	581.67	*42.52*	6.36	*0.08*
	Openness	81.75	*21.51*	4.37	*0.27*
	Population Density	86.15	*37.06*	4.36	*0.44*
	Carbon Dioxide (CO_2)	0.19	*0.05*	-1.72	*0.35*
Ghana	GDP per capita (constant 2005 US$)	255.46	*36.63*	5.53	*0.14*
	Openness	51.01	*28.18*	3.76	*0.65*
	Population Density	62.37	*21.17*	4.08	*0.34*
	Carbon Dioxide (CO_2)	0.29	*0.06*	-1.27	*0.21*
Mali	GDP per capita (constant 2005 US$)	200.75	*29.51*	5.29	*0.14*
	Openness	49.93	*13.98*	3.87	*0.29*
	Population Density	6.73	*1.91*	1.87	*0.27*
	Carbon Dioxide (CO_2)	0.05	*0.01*	-3.09	*0.16*
Liberia	GDP per capita (constant 2005 US$)	437.3	*263.6*	0.76	*0.07*
	Population Density	22.82	*7.19*	1.34	*0.13*
	Carbon Dioxide (CO_2)	0.46	*0.34*	-0.46	*0.33*
Niger	GDP per capita (constant 2005 US$)	222.16	*59.09*	5.37	*0.25*
	Openness	45.95	*10.91*	3.73	*0.25*
	Population Density	6.28	*2.61*	1.76	*0.41*
	Carbon Dioxide (CO_2)	0.09	*0.03*	-2.54	*0.43*
Nigeria	GDP per capita (constant 2005 US$)	370.22	*60.07*	5.9	*0.17*
	Openness	46.74	*17.21*	3.77	*0.4*
	Population Density	102.05	*34.31*	4.57	*0.34*
	Carbon Dioxide (CO_2)	0.60	*0.22*	-0.61	*0.47*
Senegal	GDP per capita (constant 2005 US$)	512.20	*37.02*	6.24	*0.07*
	Openness	61.96	*12.26*	4.11	*0.21*
	Population Density	37.94	*13.8*	3.57	*0.37*
	Carbon Dioxide (CO_2)	0.43	*0.11*	-0.93	*0.52*
Sierra Leone	GDP per capita (constant 2005 US$)	249.73	*41.45*	5.5	*0.18*
	Openness	47.91	*11.08*	3.84	*0.25*
	Population Density	51.21	*12.78*	3.91	*0.25*
	Carbon Dioxide (CO_2)	0.33	*0.66*	-1.68	*0.87*
Togo	GDP per capita (constant 2005 US$)	282.79	*26.52*	5.64	*0.09*
	Openness	87.09	*17.06*	4.45	*0.19*
	Population Density	66.35	*24.01*	4.13	*0.37*
	Carbon Dioxide (CO_2)	0.21	*0.07*	-1.61	*0.35*
Average	GDP per capita (constant 2005 US$)	362.02			
	Openness	57.10			

	Population Density	46.17			
	Carbon Dioxide (CO_2)	0.28			
	Growth of Carbon Dioxide Emission	11.84%			

N=45

Appendix 4a: Descriptive Statistics of SO_2 from 1960 2005, ECOWAS Countries

Statistic	BENIN	COTEIVOIRE	GHANA	NIGERIA	SENEGAL	TOGO
Mean	2.434783	20.10870	18.78261	361.7174	20.45652	2.195652
Median	2.000000	20.00000	17.50000	401.5000	22.50000	2.000000
Maximum	8.000000	39.00000	35.00000	572.0000	36.00000	4.000000
Minimum	1.000000	4.000000	9.000000	36.00000	5.000000	1.000000
Std. Dev.	1.485518	8.361893	6.876411	171.4563	7.649856	0.718627
Skewness	1.649635	0.040769	0.840262	-0.761929	-0.262986	0.061456
Kurtosis	5.798792	2.735985	3.140038	2.157802	2.382685	2.623479
Jarque-Bera	35.87698	0.146342	5.450567	5.810261	1.260637	0.300679
Probability	0.000000	0.929442	0.065528	0.054742	0.532422	0.860416
Sum	112.0000	925.0000	864.0000	16639.00	941.0000	101.0000
Sum Sq. Dev.	99.30435	3146.457	2127.826	1322877.	2633.413	23.23913
SO_2-PC Income (ρ)	0.840585	0.084593	-0.09596	0.677444	-0.68741	0.378657
Observations	46	46	46	46	46	46

Appendix 4b: Descriptive Statistics of SO_2 from 1960 2005, Industrialized Countries

Sulfur	CHINA	GERMANY	JAPAN	UK	USA
Mean	14224.59	5597.087	2057.609	4070.696	22147.67
Median	13206.00	7371.000	1136.000	4009.500	21551.00
Maximum	32673.00	8723.000	5886.000	6547.000	30970.00
Minimum	4393.000	573.0000	834.0000	686.0000	13106.00
Std. Dev.	7302.658	3018.685	1520.904	1870.528	5115.286
Skewness	0.444833	-0.748075	1.076233	-0.408942	-0.112025
Kurtosis	2.428786	1.806811	2.845435	1.900615	2.050083
Jarque-Bera	2.142435	7.019146	8.925925	3.598698	1.825702
Probability	0.342591	0.029910	0.011528	0.165407	0.401378
Sum	654331.0	257466.0	94650.00	187252.0	1018793.
Sum Sq. Dev.	2.40E+09	4.10E+08	1.04E+08	1.57E+08	1.18E+09
Observations	46	46	46	46	46

Appendix 4c: Descriptive Statistics of CO_2 from 1965- 2005, ECOWAS Countries

Statistic	BENCO$_2$PC	BFSCO$_2$PC	CDVCO$_2$PC	GAMC O$_2$PC	GHAC O$_2$PC	NIGERC O$_2$PC	LIBC O$_2$PC	MALCO$_2$PC	NGERIACO$_2$ PC
Mean	0.193840	0.059562	0.484195	0.189000	0.286944	0.085491	0.456445	0.046119	0.597090
Median	0.143203	0.062051	0.463145	0.198774	0.276799	0.076865	0.321361	0.047776	0.651080
Maximum	0.564431	0.109665	0.783301	0.259478	0.421717	0.151496	1.070176	0.060505	0.983075
Minimum	0.042957	0.018385	0.265260	0.071647	0.180443	0.024345	0.136702	0.027181	0.121165
Std. Dev.	0.131359	0.025483	0.126948	0.052165	0.058705	0.033570	0.343715	0.007114	0.221107
Skewness	1.536587	-0.084850	0.453212	-0.944990	0.314295	0.334185	0.729235	-0.375295	-0.353689
Kurtosis	4.796695	2.214602	2.525124	2.807587	2.543798	2.274872	1.840101	3.161059	2.114374
Jarque-Bera	23.76096	1.210590	1.963331	6.766965	1.131085	1.823495	6.510941	1.104986	2.408847
Probability	0.000007	0.545913	0.374687	0.033929	0.568052	0.401821	0.038563	0.575513	0.299865
Sum	8.722788	2.680281	21.78880	8.505017	12.91247	3.847078	20.54004	2.075350	26.86906
Sum Sq. Dev.	0.759230	0.028573	0.709100	0.119731	0.151635	0.049586	5.198150	0.002227	2.151086
Observations	45	45	45	45	45	45	45	45	45

Appendix A4: Descriptive Statistics of CO_2 from 1960 2005, ECOWAS Countries and Industrialized Countries

Statistic	SENCO$_2$PC	SLECO$_2$PC	TOGCO$_2$PC	CNACO$_2$PC	UKCO$_2$PC	USCO$_2$PC	JAPCO$_2$PC	SSACO$_2$PC
Mean	0.424450	0.333091	0.212177	2.234819	10.08206	19.80506	8.405912	0.875862
Median	0.443775	0.173212	0.222042	2.038411	9.981736	19.74930	8.779892	0.876446
Maximum	0.619061	4.216645	0.532757	5.773794	11.82304	22.51058	9.859492	1.061335
Minimum	-0.020990	0.054366	0.077675	0.574162	7.677910	17.27528	3.912906	0.660713
Std. Dev.	0.114498	0.664698	0.074821	1.309176	0.974377	1.150410	1.419946	0.103667
Skewness	-1.681131	4.860991	1.455903	1.072942	-0.003795	0.254102	-1.749945	-0.247574
Kurtosis	7.370313	27.74665	8.791580	3.582862	2.480164	2.968597	5.669111	2.864267
Jarque-Bera	57.00834	1325.463	78.78941	9.271021	0.506788	0.486109	36.32510	0.494240

Probability	0.000000	0.000000	0.000000	0.009701	0.776162	0.784229	0.000000	0.781047
Sum	19.10026	14.98910	9.547952	100.5669	453.6929	891.2277	378.2660	39.41380
Sum Sq Dev.	0.576832	19.44024	0.246317	75.41342	41.77402	58.23152	88.71486	0.472859
Obs	45	45	45	45	45	45	45	45