REVIEW OF CARBON EMISSION CONCERN OF INDUSTRIALIZATION: EXPERIMENTAL EVIDENCE FROM NIGERIA

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Abstract

This review investigated the impact of industrialization on carbon emissions in Nigeria during 1981-2016, within the Environmental Kuznets Curve hypothesis. Estimation of the autoregressive distributed lag (ARDL) model provided both long-run and short-run results. Industrial value added and urbanization are major determinants of manufacturing carbon emission in Nigeria in both the long-run and short-run. There is little evidence of the validity of inverse-EKC hypothesis in the Nigeria's industrial sector (with manufacturing carbon emission) in the long-run but much evidence in the short-run. Increase in the urbanization rate leads to reduction in manufacturing emission in the long-run but a rise in the emission in the short-run. In the long-run, industrial share of output (GDP) and urbanization are the two main drivers of transport carbon emission in Nigeria, while only urbanization has significant (negative) effect on it in the short-run. The industrial share of output has a significant positive influence on transport carbon emission in the long-run. There is little evidence of the validity of the EKC hypothesis in the Nigeria's industrial sector (with transport carbon emission) in both the long-run and short-run. Therefore, industrialization and urbanization drive industrial carbon emissions in Nigeria. These findings inform recommendations well articulated in the paper.

Keywords: *Industrialization; carbon emission, time series modeling, Urbanization, Output, Industrial Value Added and Nigeria*

Introduction

Industrialization involves industrial policy reform and sustained investment in industrial activities that engendered increased contribution of the industrial sector to national output. Industrialization is central to diversification strategies of an economy as it strives for economic development and competitiveness in globalised world. As observed in the industrialized, as well as the newly industrializing countries such as China, increased industrial activities, which increases income, is often associated with high level of environmental pollution which has become a serious global concern. Thus, the increased environmental and global warming problems have been critical contending factors in achieving sustainable industrialization (Saboori and Sulaiman, 2013).

In the theoretical literature, increased income level is expected to raise the level of environmental pollution initially but further increase in income beyond a certain level tends to reduce pollution (Kuznets, 1955). This is the popular Environmental Kuznets Curve (EKC) hypothesis. Specifically, the changing composition of output (GDP) as a result of increased industrial sector's contribution (in terms of product varieties, export and high value added) raises national income, which engenders increased pollution (''composition effect'' in the EKC hypothesis: Grossman and Kruger, 1995). High level of industrial activities (complemented by huge investment in the critical sectors such as power and transportation) involves intensive use of energy consuming machines and equipment, which result in high level of carbon emission. However, based on the EKC, as the industrial sector generates increased income overtime, energy and carbon efficient production techniques can be adopted which ultimately reduce environmental pollution.

This study becomes important in the case of Nigeria because, although the contribution of industrial value added to total output (GDP) fell from about 35% in 1982 to about 21% in 2014 after reaching peaks of about 53% and 52% in 1992 and 2000 respectively, the growth rate of the sector has been volatile, while carbon emission in country increased from 65,603 kilotons in 1982 to about 88,000 kilotons in the mid and late 2000s. With the new industrial revolution plan and the Economic Recovery and Growth Plan (ERGP: 2017-2020), Nigeria's industrial sector is projected to contribute 7.7%, 6.11, 6.07 and 8.02 to real GDP growth in 2017, 2018, 2019 and 2020 respectively. This high industrial growth targets may further raise the level of carbon emission in the country. Against this background, the emerging questions are: how and to what extent have industrial activities contributed to carbon emission in Nigeria? Are there variations in the impact of the industrial sector activities on carbon emissions in the manufacturing and transport sectors in Nigeria? What are the policy lessons for the Nigeria's industrial growth targets of 2017-2020 as contained in ERGP? These are the policy issues which this study seeks empirical answers.

A number of studies have been conducted in this area and results have been mixed. While there is evidence of the positive (increasing) effect of industrialization on carbon emission (Wang et al, 2011; Cherniwchan 2012; Tian et al, 2014 and Li and Lin), negative (reducing) impact of industrialization on carbon emission was also reported (Lin et al, 2015) and an inverted-U shaped pattern was confirmed in some studies (Shahbaz et al, 2014 and Xu and Lin, 2015). The gaps noticed in the literature include the use of only industrial value added to capture industrialization instead of both industrial value added and industrial share of output (to capture both scale and composition effects in EKC hypothesis) as well as urbanization. Moreover, although, Lin et al, 2015 examined the pollution effect of industrialization in Nigeria, his analysis was done at the aggregate level, while sectoral analysis and forecasts, which could have deepened policy analysis, were ignored.

Against the above background this study sets out to investigate the carbon emission (Manufacturing and transportation) implication of industrialization in Nigeria during 1981-2016. Following the introductory section, the rest of the paper is structured as follows: the followed up section provides a brief stylized fact on emission and industrializationin Nigeria. Section three reviewsthe literature. Section 4 specifics the theoretical framework and methodology, while section 5 presents and discusses the empirical findings. Section 6 concludes the paper with some policy implications.

Brief Stylised Facts on Nigeria Environmental Pollution and Industrialization

Premised on World development indicator (WDI, 2017) data; the Nigerian economy, measured by GDP per capita, is a total of $1649.24 in 1981 and $1281.56 in 2000 averaging $1520.21 on approximationbetween 1981 and 1985. On a five years average, the GDP per capita figure decline to $1286.17 during the 1991-1995 fiscal years and recorded an annual value of $2548.17 in 2015. Table 1 presents the trends on a five years average in Nigeria from 1981 to 2015. A scrutiny of Table 1 shows that Nigeria environmental pollution (measure in carbon emission metric tons per capita) on a five years average has not being stable throughout the sample period. The country pollutant was on the high side during the earlier period ranging between 0.87 in 1981 to 0.78 metric tons per capita in 1988. The emission values recorded a lower value in the mid-1990s and begin to rise in 2000s. This later reduction in emission value was as a result of several environmental promulgated policies that were put in place during the late 1990s[160]. On a five years average, the worst and best recorded carbon emission value of 0.83 and 0.41 metric tons per capita was achieved between 1981-1985 and 1996-2000. The carbon emission was approximately 0.58 metric tons per capita in 2010 but currently stood at 0.0.57 metric tons per capita in 2015.

Nigeria industrialization (measure as Industry, value added) on a five years average has recently being on the decline, especially during the earlier period of 1996 up till now. The country industrial value added value of 52.99 per cent was achieved in 1992 and on a five years average, the value stood at 43.26 and 25.41 per cent between 1996-2000 and 2011-2015. The industrial value addition was approximately 28.35 per cent in 2011 but currently stood at 20.38 per cent in 2015. The trend of the Nigeria's manufactures exports (% of merchandise exports) recently witnesses a major decline in value during the fiscal years of 1999 up till 2007 and later in 2011 through 2013. Although, the figure has being fluctuating yearly, it however, reach a value of 6.7 per cent in 2010 and on a five years average, the value stood at 0.06 and 3.93 per cent in between 1981-1985 and 2011-2015. On a yearly basis, the figure was approximately 0.21 per cent in 2000 and rise to 6.45 per cent in 2014 and currently stood at 4.39 per cent in 2015.

Table 1: Pollution, Income and Industrialization indicators in Nigeria from 1981 to 2015

Year	*CO2 emissions (metric tons per capita)*	*GDP per capita (constant 2010 US$)*	*Industry, value added (% of GDP)*	*Manufactures exports (% of merchandise exports)*
1981-1985	0.830	1520.206	32.896	0.058
1986-1990	0.632	1256.743	36.624	0.168
1991-1995	0.469	1286.165	44.063	0.387
1996-2000	0.413	1268.362	43.255	1.550
2001-2005	0.717	1552.548	38.748	2.176

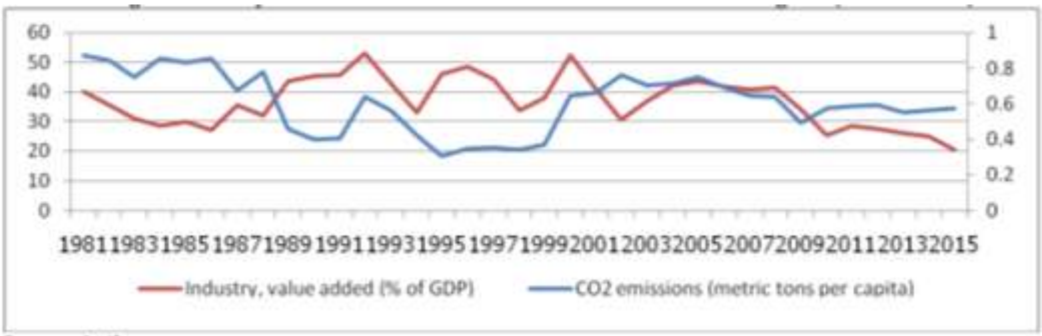
160 The National Environmental Standards and Regulations Enforcement Agency (NESREA), Kyoto protocol, and the recent clean energy initiate and renewable energy programme.

2006-2010	0.609	2130.274	36.715	3.863
2011 – 2015	0.573	2464.282	25.405	3.930

Source: Author's computation, underlying data from World Bank World Development Indicators (WDI), 2017-online version

To determine the onset relationship between the environmental pollution and industrialization in Nigeria, Figure 1 provides a direct view of the association by plotting a two-scale graph relationship of the series from 1981 to 2015. An inspection of the Figure reveals a trending positive relationship between emission and industrial value added in Nigeria. That is, high industrial value addition periods witnessed relatively higher emission. In addition to this visual inspection, the relationship will further be investigated through the uses of econometric techniques, so as to analysis the nexus between environmental pollution implications of industrialization in Nigeria.

Figure 1: Analysis of Pollution and Industrial value addition in Nigeria (1981 to 2015)



Source: Authors

Literature Review

The literature on the relationship between economic growth and environmental pollution is recent with growing research interest each day. However, while much efforts have focused on growth-carbon emission nexus (Soytas and Sari, 2003; Bento and Moutinho, 2015; Magazzino, 2016; Ouyang and Lin,2016 andMirza and Kanwal, 2017), the role of industrialization in carbon emission is becoming popular with overriding positive effect (Wang et al, 2011; Cherniwchan, 2012; Tian et al, 2014; Xu and Lin, 2015;Shahbaz et al, 2014 and Li and Lin, 2015). Thus, existing studies are review in line with these two areas of relationship.

At the global level, Shuai et al (2017) estimated panel and time series STRIPAT model for the drivers of carbon emission between 1990 and 2011. They showed evidence that affluence has the greatest impact on carbon emission and this influence is more pronounced for low-income group. Also, applying VECM Granger-causality for various countries during 1971-2010, Esso and Keho (2016) revealed that economic growth causes CO2 emissions in the short-run in Benin, Democratic Republic of Congo, Ghana, Nigeria and Senegal. However, in the long-run, they found that economic growth causes CO2 emissions in Benin, Cote d'Ivoire, Nigeria, Senegal, South Africa and Togo 12 Sub-Sahara African countries. In China, this submission was confirmed by Lin and Nelson (2017) in a quantile regression analysis where GDP, as well as energy intensity and carbon intensity, has high impact on transport carbon emission during 1980-2012.Investigating this relationship for the case of Bahrain, Jafari et al. (2015) used Toda-Yamamoto to establish unidirectional relationship running from economic growth to CO2 emissions during 1980-2007.Moreover, extending the analysis to Israel between 1971 and 2006, Magazzino (2015)found similar results.Estimating STRIPAT model for the case of Taiwan during 1990-2014, Yeh and Liao (2017) found that per capital GDP has negative effect on carbon emission. Similarly, Bento and Moutinho (2015) analyzed the relationship between economic growth and carbon emission, as well as electricity production and trade in Italy during 1960-2011. Their Autoregressive Distributed Lag (ARDL) model estimates showed that high growth reduces CO2 emissions.Analyzing the case of India, Ahmad et al (2016) used VECM Granger-causality to show a feedback effect between economic growth and carbon emissions from 1971 to 2014, a result that is consistent with that suggested by Mirza and Kanwal (2017) who applied the same method for Pakistan between 1971 and 2009.

Contrary to the foregoing finding, few studies provided evidence of increasing effect of income on carbon emission. Using production-theoretical decomposition (PDA) and index decomposition analyses (IDA) on data ranging from 2001 to 2011, Li et al (2017) reported that economic activity contributes the most to increases in carbon dioxide emissions in most Chinese provinces. According to the dynamic panel regression estimates of Kais and Sami (2016), per capita GDP has statistically significant positive impact on CO2emission amongselected 58 countries between 1990 and 2012.

In an attempt to validate or refute the Environmental Kuznet Curve (EKC), which represent major theoretical development on the economic growth-carbon emission nexus in recent years, a number of empirical investigation have been conducted. Employing ECM Granger causality technique, Ouyang and Lin

(2016) discovered the existence of an inverted U-shaped relationship between income growth and CO2 emissions in China and Japan during 1978-2011, thus confirming the EKC hypothesis in these countries. In the same vein, using panel cointegration approach, this quadratic relationship was established by Arouri et al (2012) among MENA countries between 1981 and 2005. Also, adopting panel GMM estimator and fixed effect regression similar results are also reported by Zaman and Moemen (2017) among Low, middle and high income countries from 1975 to 2015 while the feasible generalized least squares estimates of Moutinho et al (2017) suggest the presence of both inverted U-shaped EKC and inverted N–shaped relationship between economic growth and emissions in Portugal and Spain during 1975–2012.In addition, while Cross-correlation coefficients (CCC) of Narayan et al (2015) support EKC hypothesis in 21 out of 181 countries during 1960–2008, income growth tend to reduce emissions in the future in 49 countries. Among the ASEAN countries, Zhu et al (2016) employed panel quantile regression and reported that greater economic growth reduces emissions between 1981 and 2011.

Many studies could not establish significant impact of income on carbon emission. This is evident in Romero and Jesus (2016) for the case of 22 Latin American and Caribbean Countries during 1990-2011, andSoytas and Sari (2003) for the case of Turkey between 1960 and 2000. Similarly, applying ARDL, Ozturk and Acaravci (2010) and Magazzino (2016) found neutrality relationship between economic growth and carbon emission in Turkey and Italy during 1968-2005 and 1970-2006 respectively. Also, estimated from Granger causality tests applied by Joo et al. (2015) and Pao and Tsai (2010) could not establish a role for income in determining carbon emission in Chile (1965-2010) and the BRIC countries (1971–2005) respectively.

With respect to the role of industrialization carbon emission, single-country studies have concentrated on the Asian economies. In China, Wang et al (2011) examined the environmental impact of heavy industrial change during 1978-2008. Their ECM-Granger-causality results indicate that heavy industrial structure has increasing effect on carbon emission. Tian et al (2014) conducted similar analysis for the same country using input-output and structural decomposition analysis (SDA) between 1996 and 2010. They discovered that industrial structure changes from sectors such as agriculture, mining, and light manufacturing to resource-related heavy manufacturing contributes immensely to increases in carbon emissions. However, the VAR estimates of Xu and Lin (2016) suggest that industrialization exerts decreasing effect on carbon emission in China during 1980-2014, though this impact is insignificant. In another study of the same country, Xu and Lin (2015) employed non-parametric additive regression models on provincial panel data covering the period 1990-2011 to obtain an inverted U-shaped nonlinear effect of industrialization on carbon emissions in the three regions of China. A similar confirmation of EKC was obtained by Shahbaz et al (2014) using ARDL and Innovative accounting approach (IAA) Granger-causality for the case of Bangladesh during 1975-2010.

In Nigeria, VECM analysis of Lin et al (2015) showed that industrial value-added has significant inverse impact on CO2 emissions between 1980 and 2011.For cross-country analysis, Li and Lin (2015) estimated STIRPAT and threshold regression models for 73 low, middle and high-income countries during 1971–2010 and reported that industrialization increases CO2 emissions. Similar submission was made by Cherniwchan (2012) who adopted least squares with dummy variables (LSDV) for 157 countries from 1970 to 2000, and obtained an elasticity of 11.8. The foregoing review of literature suggests that research interest in the role of industrialization in environmental pollution is recent and developing, while much efforts have been directed towards the relationship between income and environmental pollution. Apart from multi-country analysis, studies focusing on the relationship between industrialization and carbon emission seems to have been conducted only for China (Wang et al, 2011; Tian et al, 2014; Xu and Lin, 2015;Xu and Lin, 2016 and Ding and Li, 2017), Bangladesh (Shahbaz et al, 2014) and Nigeria (Lin et al, 2015). While there is huge consensus on the increasing effect of industrialization on carbon emission, significant decreasing effect was reported for Nigeria, a finding that calls for further investigation. In addition, industrialization has been capture across studies using industrial value added while industrial export has been given no attention. These are the gaps that this study seeks to fill.

Table 2: Summary of literatureon Coal consumption, economic growth and carbon emissions

S/N	*Author & Year*	*Country (s) & scope*	*Methodology*		*Findings*
			Variables	Estimation methods	
1	Li and Lin (2015)	73 countries (1971–2010)	Y, URB, Y (Industrial), CO2, P, T	STIRPAT and threshold regression models	In the middle-/low-income and high-income groups, industrialization increases CO2 emissions. In for the middle-/high-income group industrialization

					was found to have an insignificant impact on CO2 emissions
2	Cherniwchan (2012)	157 countries (1970–2000)	Y (industrial), SO2, K and P	Least Squares with Dummy Variables (LSDV)	Industrialization has significant impact on changes in emissions with elasticity of 11.8.
3	Wang et al (2011)	China (1978-2008)	CO2, EC, Y (industrial)	ECM-Granger-causality	Heavy industrial structure has a positive effect in on carbon emissions
4	Shahbaz et al (2014)	Bangladesh (1975-2010)	CO2, Y(industrial), EL, FD and TO	ARDL and IAA Granger-causality	EKC holds between industrial development and CO2 emissions
5	Tian et al (2014)	China (1996–2010)	Y (various sectors) and CO2	Input-output and structural decomposition analysis (SDA)	Industrial structure changes from agriculture, mining, and light manufacturing to resource-related heavy manufacturing increases CO2 emissions
6	Xu and Lin (2015)	China (1990-2011)	CO2, EC, URB, X, Y, Y (industrial) and Pop	Nonparametric additive regression models and linear fixed effects model	Inverted U-shaped nonlinear relationship exist between industrialization and CO2 emissionsin the three regions in China
7	Lin et al (2015)	Nigeria (1980-2011)	CO2, Y, Y (industrial), Pop, EI and CI	VECM	Industrial value-added has an inverse and significant impact with CO2 emissions
8	Xu and Lin (2016)	China (1980-2014)	CO2, Y, Y (industrial), URB, EE and ES	VAR	Industrialization exert negative but insignificant effect on carbon emission
9	Ding and Li (2017)	China (2000-2013)	Sectoral Y, CO2 emissions, EC, Pop	LMDI (Logarithmic Mean Divisia Index) model	Industrial structural change drives carbon emission upward but economic

					development has the greatest impact
10	Shuai et al (2017)	125 countries (1990–2011)	CO2, U, EI and Y	Panel and time series STIRPAT	At global level (more pronounced for low-income group), affluence has the greatest impact on carbon emission
11	Yeh and Liao (2017)	Taiwan (1990-2014)	CO2, Y, URB and Pop	STIRPAT model	Per capital GDP has negative effect of carbon emission
12	Ouyang and Lin (2016)	China and Japan (1978-2011)	Y, URB, CO2 and EI	ECM Granger-causality	Quadratic relationship exists between income growth and CO2 emissions.
13	Mirza and Kanwal (2017)	Pakistan (1971-2009)	CO2, Y and EC	VECM	Bidirectional causality between economic growth and the CO2 Emissions
14	Bento andMoutinho (2015)	Italy (1960-2011)		ARDL	High growth reduces CO2 emissions
15	Jafari et al. (2015)	Bahrain (1980-2007)		Toda-Yamamoto	Unidirectional relationship fromGrowth to CO2 emissions
16	Joo et al. (2015)	Chile (1965-2010)		Granger causality	Unidirectional relationship from CO2 to Growth
17	Magazzino (2015)	Israel (1971-2006)		Causality	Unidirectional relationship from growth to CO2 emissions
18	Arouri et al (2012)	MENA countries (1981–2005)		Panel cointegration	GDP exhibits a quadratic relationship with CO2 emissions
19	Pao and Tsai (2010)	BRIC countries (1971–2005)		Engle-Granger	Unidirectional causality from CO2 to GDP

20	Romero and Jesus (2016)	22 Latin American and Caribbean Countries (1990-2011)		Estimated cubic EKC	No association between Growth and CO2 emissions
21	Magazzino (2016)	Italy (1970–2006)		ARDL	No causality exists between Growth and CO2
22	Soytas and Sari (2003)	Turkey (1960–2000)		VAR, E-G	No causality exists between CO2 and GDP
23	Lin and Nelson (2017)	China (1980-2012)	Y, CO2, URB, CI and EI	Quantile regression analysis	GDP, energy intensity and carbon intensity has high impact in transport carbon emission
24	Li et al (2017)	China (2001-2011)	Y, EC, L, K and CO2	Production-theoretical decomposition analysis (PDA) and index decomposition analysis (IDA).	Economic activity contributes the most to increases in carbon dioxide emissions while GDP technology change and potential energy intensity change have considerable effects on carbon dioxide emissions in most provinces.
25	Ozturk and Acaravci(2010)	Turkey (1968–2005)		ARDL, E-G	No causality betweenEN and GDP
26	Zaman and Moemen (2017)	Low, middle and high income countries (1975–2015)	CO2, Y, FDI, Pop, HDI, TO, EC, Y (sectoral) and GE	Panel GMM Estimator and Fixed Effect Regression	GDP and its square have significant effect on CO2 (EKC is confirmed) while industrialization has significant negative effect.
27	Moutinho etal (2017)	Portugal and Spain (1975–2012)	EC, CO2, Y (with square and cubed)	feasible generalized least squares	Inverted U-shaped EKC and inverted N-shaped relationship

					between economic growth and emissions.
28	Kais and Sami (2016)	58 countries (1990–2012)	CO2, EC, Y, URB and TO	Dynamic Panel regression	Per capita GDP has positive and statisticallysignificant impacton CO2
29	Narayan et al (2015)	181 countries (1960–2008)	CO2 and Y	Cross-correlation coefficient (CCC)	EKC hypothesis.is supported in 21 countries while income growth wreduce emissions in the future in 49 countries.
30	Ahmad et al (2016)	India (1971–2014)	CO2, EC and Y and Y square	VECM Granger-causality	Feedback effect exists between economic growth and carbon emissions.
31	Zhu et al (2016)	ASEAN-5 (1981-2011)	CO2, EC, Y, Pop, TO, Y (industrial), FDI and FD	Panel quantile regression	Greater economic growth reduces emissions.
32	Esso and Keho (2016)	12 Sub-Sahara African countries (1971-2010)	CO2, EC and Y	VECM Granger-causality	Economic growth causes CO2 emissions in the short-run in Benin, Democratic Republic of Congo, Ghana, Nigeria and Senegal. In the long-run, economic growth cause CO2 emissions in Benin, Cote d'Ivoire, Nigeria, Senegal, South Africa and Togo
33	Adewuyi and Awodumi (2017)	11 West Afrcan countries (1980-2010)	CO2, Biomass, H, K, URB and TO	3SLS	Economic growth has significant effect on carbon emission in Senegal and Niger
34	Bloch et al. (2012)	China (1977-2008 & 1965-2008)	CO, Y, L, K, CP and CO2	VECM	Economic growth has significant effect on carbon emission

Note: Y=Gross domestic product (GDP)/per capita; CO2 = Carbon emission; FDI = Foreign direct investment; GE = Government expenditure; ID = Industrialization; VECM=Vector Error-Correction Model; N=Natural Gas; CP=Coal prices; OL = Oil; EC= Total energy consumption; STIRPAT = Stochastic Impacts by Regression on Population, Affluence and Technology; IAA = Innovative accounting approach; VECM = Vector error correction mechanism;TO= Trade openness; K=capital; L=Labour; X = Export; FD = Financial Development; URB=Urbanization; Carbon intensity; H = Human capital;EL = Electricity consumption; Energy intensity; P= Population; LR = Long-run; SR = Short-run; ECM = Error correction method; VAR = Vector autoregressive model; PMG = Pooled mean group estimator; GM = Group mean estimator; SER = Service value added; STRIPAT = Stochastic Impacts by Regression on Population, Affluence, and Technology; EC = Energy consumption; T = Technology; P = Population; Energy efficiency; Energy structure; HDI = Human development index

Source: Compiled by the authors

Theoretical Framework and Methodology

Theoretical Framework

This study explores the theoretical postulation of the Environmental Kuznets Curve (EKC) hypothesis to analyze the role of industrialization in environmental pollution.The EKC hypothesis,developed by Kuznets (1955), explains the relationship between environmental degradation and income. According to the hypothesis, initially, carbon emission tends to increase continuously with rising income until a certain higher level of income is reached, after which a further increase in income leads to a decline in carbon emission. The initial economic growth may reflect increased economic activities, which increases energy consumption and engender carbon emission. Overtime, higher income enables the economy to adopt environmentally-friendly techniques of production which eventually reduce emission, thereby giving rise to an inverted U-shaped relationship between economic growth and carbon emission (Moutinho et al, 2017 andZaman and Moemen, 2017).

The EKC hypothesis was subsequently developed in what led to three major environment-economic activity linkage effects (Grossman and Kruger, 1995) namely scale, composition and technology effects.The scale effect suggests that increase in carbon emission is a result of increased economic activities that raise the level of income. The rising industrial production requires higher consumption of energy which mainly comes from non-renewable energy source which magnifies the level of carbon emission. Moreover, changes in production structure of an economy in favour of pollution intensive industries have magnification effect on environmental pollution. This is the composition effect of the EKC. This effect reflects the increased industrial activities and gradual decline of primary production activities (such as mining and agriculture)leading to high level of pollution. The technique effect stems from changes in the techniques of production which alters the level of environmentalquality. This occurs when there is a shift from one method of production to another which alters the level of carbon emission. For instance, a movement away from carbon-intensive production techniques to energy and carbon efficient technology engenders lower pollution and thus represents the technique effect of EKC.

Industrialization process involves deliberate action of the government and other stakeholders in the industrial sector to commit huge investment towards increased productivity of the sector. Such investment includes intensive deployment of domestic and foreign capital as well as development of manpower, while providing associated enhancing environment such as adequate infrastructure. Such industrialization process requires high energy consumption which largely comes from petroleum products, especially in the developing countries such as Nigeria. Thus, increased industrial activities and rising industrial output (and export) relative to other sectors eventuallycontributes to higher levels of carbon emission. However, where foreign direct investment (FDI) is high, there is tendency for energy and carbon-efficient capital inputs (machinery and equipment) to be gradually substituted for the prevalent high carbon-emitting inputs. This gives rise to increased production of clean goods whose production reduces carbon emission and generates minimal adverse environmental effects.

The level of environmental quality is therefore explained by industrialization process (scale, composition and technique). Furthermore, environmental quality has also been associated with the level of urbanization where higher influx of people into urban centres is associated with higher levels of energy consumption with its attending carbon emission.

Methodology

Model Specification and Estimation Technique

For empirical purpose, the Kaya Identity has been variously employed to explain the drivers of environmental pollution (O'Mahony, 2013; Lin and Xie, 2014 andLin et al, 2015). These drivers include population (P), income per capita (Y), energy intensity (EI) and carbon intensity (CI).

$CO2 = f(P, Y, EI, CI)$ …………………………………………..1

Where CO2 is carbon emission. This identity however only captures the scale and technique effects of the EKC.This identity is modified in line with EKC. First, the identity is re-specified in per capita terms where population is normalized and urbanization is introduced instead. Also, industrial output (IND), its square (IND^2) and the ratio of industrial output to GDP (INDG) replace income per capita while carbon intensity is dropped. This gives rise to the following equation:

$CO2 = f(IND, IND^2, INDG, URB, EI,)$ …………………………2

Disaggregate or sectoral carbon emission models are also specified to investigate the implication of industrialization on transportation and manufacturing emissions.

The econometric form of this model is specified for aggregate sectoral carbon emissions as follows;

$$\ln(MCO2_t) = \alpha_0 + \alpha_1 \ln(IND_t) + \alpha_2 \ln(SIND_t) + \alpha_3 INDG_t + \alpha_4 \ln(U_t) + \pi_t \quad \text{……………………………..} \quad 3$$

$$\ln(TCO2_t) = \alpha_0 + \alpha_1 \ln(IND_t) + \alpha_2 \ln(SIND_t) + \alpha_3 INDG_t + \alpha_4 \ln(U_t) + \pi_t \text{ ………………………………..} 4$$

Where

***MCO2** = Manufacturing Carbon emission per capita; **TCO2** = Transport Carbon emission per capita*

***IND** = Industrial value added per capita; **SIND** = Square of Industrial value added per capita*

***INDG**= Ratio of industrial value added to GDP; **U** = Urbanization*

Π = White noise disturbance term

The Autoregressive Distributed Lag (ARDL) modelis employed to analyze the specifiedfunctional forms. This method also includes a bound test for cointegration whichallows the estimation of the co-integration relationship using the ordinary least square (OLS). ARDL can alsocombine regressors that are stationary at either levels I(0) or first difference I(1) in the same model. Moreover, it is possible to simultaneously estimate both the long run and short run parameters of the models (Pesaran et al, 2001).

The ARDL representations of the above equations are specified as follows:

$$\Delta InMCO2_t = \alpha_2 + \theta_1 InMCO2_{t-1} + \theta_2 InIND_{t-1} + \theta_3 InSIND_t + \theta_4 INDG_t + \theta_5 InU_t + \sum_{i=0}^{m} \beta_i \Delta MCO2_{t-i} + \sum_{i=0}^{m} \beta_i \Delta IND_{t-i} + \sum_{i=0}^{m} \beta_i \Delta SIND_{t-i} + \sum_{i=0}^{m} \beta_i \Delta INDG_{t-i} + \pi_{2t}$$

$$\Delta InTCO2_t = \alpha_3 + \theta_1 InTCO2_{t-1} + \theta_2 InIND_{t-1} + \theta_3 InSIND_t + \theta_4 INDG_t + \theta_5 InU_t + \sum_{i=0}^{m} \beta_i \Delta TCO2_{t-i} + \sum_{i=0}^{m} \beta_i \Delta IND_{t-i} + \sum_{i=0}^{m} \beta_i \Delta SIND_{t-i} + \sum_{i=0}^{m} \beta_i \Delta INDG_{t-i} + \pi_{3t}$$

All variables remain as defined earlier, except the fact that they are now in their natural logarithm form.Decision on the cointegrating relationship among the variables is made by comparing the calculated F-statistics from the ARDL bound testto theupper and lower critical values. In the event where the computed F-statistic falls below the lower bound value, I(0), then the null hypothesis of no level relationship cannot be rejected. However, if the computed F-statistic is greater than the upper critical bound value, I(1) the null hypothesis of no level relationship can be rejected, implying the existence of co-integration among the variables, hence short-run impact can be examined. Inference is inconclusive where thecalculated F-statistics falls within the band.

Data and Variable Description

Empirical analysis in this study covers the period 1981-2016 due to data availability constraint. The description of the variables used in the analysis, as well as, data sources is presented in Table 3.

Table 3: Variable Description and Data Sources

Variable	*Description*	*Measurement*	*Data Sources*
TCO2	Transport emissions	CO2 emissions from transport (Megatons per capita)	Computed from World Development Indicators
MCO2	Manufacturing emissions	CO2 emissions from manufacturing industries and	World Development Indicators

		construction (Megatons per capita)	
INDG	Ratio of industrial value added to GDP	Industrial value added per capita (constant 2005 US$) divided by population, total	Computed from World Development Indicators
IND	Industrial value added per capita	Industrial value added per capita (constant 2005 US$)	World Development Indicators
SIND	Square of Industrial value added per capita	Square of industrial value added per capita (constant 2005 US$)	Computed
U	Urbanisation	Urban population as a % of total	World Development Indicators

Source: Author's compilation[161]

EMPRICAL RESULTS AND DISCUSSIONS

Descriptive and Correlation Analysis

Results of the descriptive analysis of the variables used in the regression analysis are reported in Table 4. Square of Industrial value added per capita (SIND), Industrial value added per capita (IND) and Transport carbon emission per capita (TCO2) and Manufacturing carbon emission per capita (MCO2) have higher values of mean, minimum and maximum values that are higher than that of industrial output as a ratio of GDP (INDG) and Urbanisation (U). However, INDG followed by U has the lowest variability with a standard deviation of about 0.083 and 0.214 while all the variables are negatively skewed their kurtosis and Jarque-Bera statistics tends to the positive side.

Table 4: Descriptive Statistics

	INDG	*MCO2*	*MCO2*	*IND*	*SIND*	*U*
Mean	0.443	4.027	5.597	6.288	39.550	3.522
Median	0.471	4.065	5.651	6.289	39.552	3.520
Maximum	0.552	4.815	6.065	6.442	41.499	3.867
Minimum	0.261	3.200	4.939	6.114	37.387	3.121
Std. Dev.	0.083	0.483	0.322	0.105	1.325	0.214
Skewness	-0.595	-0.144	-0.317	-0.058	-0.042	-0.134
Kurtosis	2.054	2.031	1.871	1.640	1.633	1.999

161 Transport and manufacturing emissions were calculated by multiplying their values (as a percentage of total fuel combustion) by total carbon emissions. The values in kilotons are multiplied by 1000 to convert to megatons.

Jarque-Bera	3.371	1.492	2.447	2.717	2.734	1.566
Probability	0.185	0.474	0.294	0.257	0.255	0.457
Sum	15.512	140.952	195.903	220.081	1384.259	123.275
Sum Sq. Dev.	0.236	7.922	3.517	0.378	59.651	1.564
Observations	35	35	35	35	35	35

Source: Author's computation

Table 5 presents the results of correlation analysis need to establish the level of association among the variables used in the regression analysis. This result is of particular importance; as it determines the type of association between emissions and industrialization which has implication for their inclusion in the same models. The results suggest that the correction between these two variables is moderate and can co-exist in the same model.

Table 5: Correlation Results

	INDG	*MCO2*	*TCO2*	*IND*	*SIND*	*U*
INDG	1.000					
MCO2	0.018	1.000				
TCO2	-0.096	0.654	1.000			
IND	-0.488	0.039	0.130	1.000		
SIND	-0.489	0.041	0.131	1.000	0.999	
URB	-0.607	-0.499	-0.221	0.631	0.631	1.000

Source: Author's computation

Stationarity (Unit root) and Co-integration Tests

The Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests were conducted for each series, and the results are presented in Table 6. It is found that only Uis series that is stationary at level, while all others are stationary after first difference.

Table 6: Results of Unit Root Tests

Variable	*Augmented Dickey-Fuller (ADF)*			*Phillip Perron (PP)*			*Decision*
	Level	First Difference	I(d)	Level	First Difference	I(d)	
INDG	-0.6659	-7.1239*	I(1)	-0.6637	-7.0404*	I(1)	I(1)
MCO2	-2.5775	-6.3985*	I(1)	-2.4704	-7.6208*	I(1)	I(1)
TCO2	-2.2143	-5.4867*	I(1)	-2.2659	-5.7088*	I(1)	I(1)
IND	-1.4943	-3.5286*	I(1)	-2.0937	-5.6335*	I(1)	I(1)
SIND	-1.9209	-5.5831*	I(1)	-2.0910	-5.6450*	I(1)	I(1)
U	-3.4714**	-4.5743*	I(0)	-2.9829**	-7.2589*	I(0)	I(0)

Source: Author's computation

However, due to the mixture of stationarity among the selected variables, the paper proceeds with the standard approach to estimating the co-integration relationship using the ARDL-bounds test approach. The results for each of the two models are presented in Table 7. For manufacturing carbon emission model, the F-statistics of 3.4961 is greater than the upper bound critical value at 5% level. Henceforth the null hypothesis of no co-integration is rejected and long-run co-integration relationship is established among the emission, urbanisation, industrialisation and the EKC series in this model. In the transport carbon emission model, the F-statistics exceeds the lower and upper bounds critical values at 10%. Thus, the result established long-run relationship among the variables in the model. Both long-run and short-run analyses are conducted for the two models.

Table 7: ARDL Bounds Test for Co-integration Relationship

Model	*F-Statistics*	*K*	*90% level*		*95% level*		*99% level*	
			I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
MCO2	3.4961	4	1.90	3.01	2.26	3.48	3.07	4.44
TCO2	4.3643	4	3.03	4.06	3.47	4.57	4.40	5.72

Source: Author's computation

Effect of industrialization on Carbon Emission in Nigeria

Effect of industrialization on Carbon Emission from Manufacturing

In the above model, both the short-run and long-run ARDL results on the impact of industrialization on carbon emission from manufacturing are presented in Table 8. The post estimation diagnostic tests confirm that the estimated model satisfied all the required properties. Thus, the residual series are found to be normally distributed, no serial correlation and homoscedastic as suggested by the insignificant Jarque–Bera statistics; Breusch–Godfrey LM test and ARCH test respectively. Similarly, the significant of the Ramsey RESET test confirmed that the model is well specified with the correct non-linear functional form by the introduction of industrial EKC into the model. In addition to the above post estimation results, the CUSUM and CUSUM square parameter stability test was conducted and presented in figure 3 and 4 to show that the estimated parameters is stable during the sample period (1981-2016).

The long-run results show that only industrial value added (per capita square) and urbanization generate statistically significant effects on manufacturing carbon emission. While industrial value added (per capita square) has positive effect, urbanization produces negative impact on manufacturing carbon emission. Thus, increased scale of industrialisation (as reflected by square of per capita industrial value added) triggers more manufacturing carbon emission in Nigeria. The signs of the coefficient of the industrial value added (although not statistically significant) and its square (which is statistically significant) mirror inverse-EKC hypothesis. Urbanisation in Nigeria is negatively related to emission from manufacturing; thus, 1% increase in the urbanization rate will lead to a reduction in manufacturing emission.

Consistent with the long-run results, the short-run estimates show that the industrial value added, its square and urbanization have significant impact on manufacturing carbon emission. While the effects of industrial value added and its square alternate, the impact of urbanization is positive. The signs of the coefficients of the industrial value added and its square align with the inverse of the EKC hypothesis. Thus, at the initial stage, a rise in industrial activities in Nigeria will lead to a reduction in the manufacturing carbon emission, while overtime, a further rise will escalate the emission. The significant coefficient of the error correction term (ECT) suggests that about 80% of deviation from the long-run equilibrium level of manufacturing carbon emission is corrected annually.

Table 8: Regression Results for the Effect of industrialization on Carbon Emission from Manufacturing

Variable	*Long-run*	*Short-run*
INDG	0.3941 (0.2395)	0.3134 (0.2424)
IND	-1.2617 (-0.8396)	-2.2633 (-1.0548)
IND(-1)		-1.6886*** (-1.7901)
SIND	0.4254** (2.1537)	0.3383** (2.1332)
U	-1.6848*** (-1.7509)	31.8329*** (1.6936)
ECM (-1)		-0.7953* (-3.9576)
R-SQUARE	0.7886	
AdJ. R-SQUARE	0.6879	
AIC	-0.3876	
SIC	0.1162	
F-Statistic	7.8331*	
D-WATSON	2.4001	
J–B normality test	0.0076	

Breusch–Godfrey serial correlation LM test	2.1448 (1)
ARCH test	0.0039 (1)
Ramsey RESET test	3.5862* (1)

Source: Author's computation

Figure 3: Stability test, Recursive Estimates (OLS) CUSUM Test

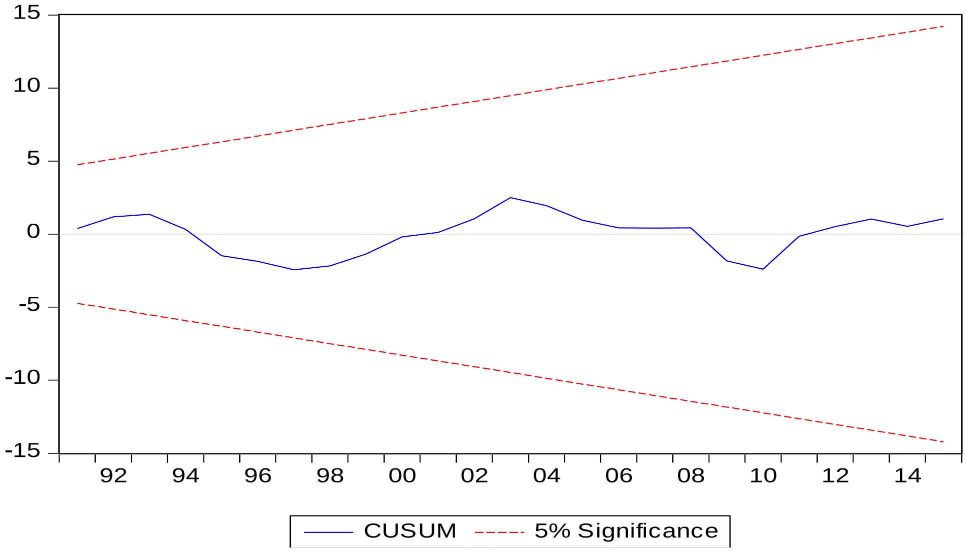
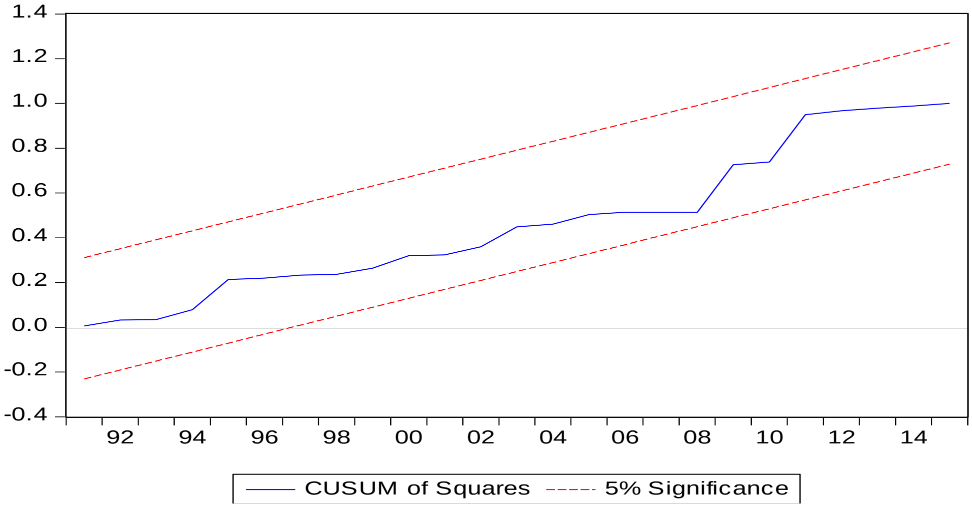


Figure 4: Stability test, Recursive Estimates (OLS) CUSUM of Squares Test



Effect of industrialization on Carbon Emission from Transportation

Table 9 presents the short and long-run ARDL estimates on the impact of industrialization on carbon emission resulting from transportation. All the post diagnostic tests were similar to that of the first model and thus also, confirm the estimated model; to satisfy all the required properties, while, the CUSUM and CUSUM square parameter stability test show that the estimated parameters is also stable during the sample period (1981-2016).

In the long-run, results reveal that industrial share of output (GDP) and urbanization are the two main drivers of emission in the transport sector in Nigeria. The industrial share of output has a significant positive influence on carbon emission from transport. Thus, 1% improvement in industrial share of output would raise carbon emission from transportation in Nigeria by about 4.22% in the long-run. Although the coefficients of the industrial value added and its square are not statistical significant, their signs follow the EKC hypothesis, which means at the initial stage, increases in industrial value added will raise emission level, but after some time further increase will lead to reduction in the emission level. Furthermore, high rate of urbanisation will engender reduction in emission in the transport sector of the economy; as 1% rise in the rate of urban development will lead to a reduction of about 30.51% in emission from transportation in Nigeria. This suggests that urban development in Nigeria is both less energy and pollution (carbon) intensive.

Short-run estimates depicted in the second right hand side of Table 9 show that only urbanization has significant short-run effect on transport carbon emission in Nigeria. Thus, the higher the rate of urbanization, the lower the carbon emission from transport. As in the long-run, although the coefficients of industrial value added and its square are statistically insignificant. their signs reflect the EKC hypothesis. The statistically significant trend variable in the models (both short and long-run) provide evidenced of deterministic changes in transport carbon emission in Nigeria. The coefficient of the error correction term (ECT) which is significant suggests that 45% of deviation from the long-run equilibrium level of transport carbon emission is corrected annually.

Table 9: Regression Results for the Effect of industrialization on Carbon Emission from Transportation

Variable	*Long-run*	*Short-run*
INDG	4.2161* (3.3014)	-0.0572 (-0.0775)
IND	162.1142 (1.2482)	73.0051 (1.5886)
SIND	-12.9844 (-1.2547)	-5.8473 (-1.5968)
U	-30.5133* (-3.7697)	-9.6136 (-0.9361)
U(-1)		-72.4427* (-2.9525)
U(-2)		50.3956* (4.0188)
C	-407.7484 (-1.0472)	

@TREND	0.6747* (3.9570)	0.3038* (4.7898)
ECM (-1)		-0.4503* (-3.2459)
R-SQUARE	0.6572	
AdJ. R-SQUARE	0.5612	
AIC	0.6561	
SIC	1.0189	
D-WATSON	1.8915	
J-B normality test	0.4929	
Breusch-Godfrey serial correlation LM test	0.1977 (1)	
ARCH test	0.5216 (1)	
Ramsey RESET test	0.7825 (1)	

Source: Author's computation

Figure 5: Stability test, Recursive Estimates (OLS) CUSUM Test

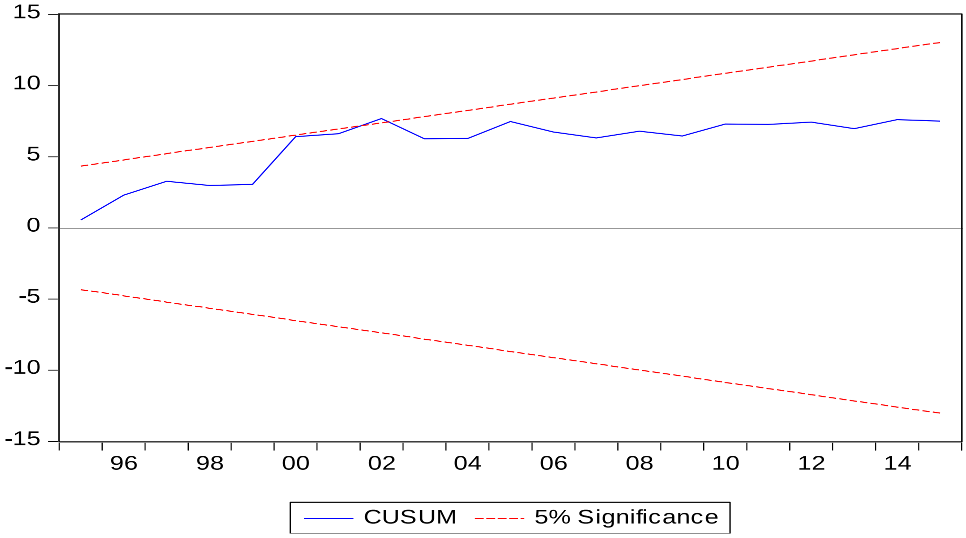
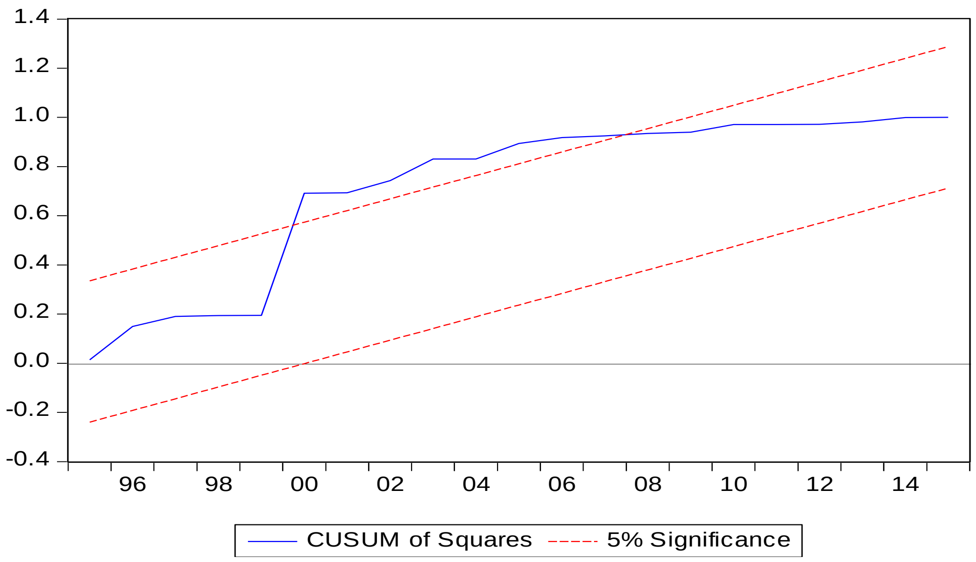


Figure 6: **Stability test, Recursive Estimates (OLS) CUSUM of Squares Test**



SUMMARY OF FINDINGS, CONCLUSION AND POLICY RECOMMENDATIONS

This study investigated the impact of industrialisation on carbon emission (manufacturing and transport) in Nigeria during 1981-2016, Based on the Environmental Kuznets Curve (EKC) hypothesis, analysis was conducted using the autoregressive distributed lag (ARDL) model to generate both long-run and short-run effects of industrialisation on carbon emission (manufacturing and transport).

Industrial value added and urbanization are major determinants of manufacturing carbon emission in Nigeria in both the long-run and short-run. There is little evidence of the validity of inverse-EKC hypothesis in the Nigeria's industrial sector (with manufacturing carbon emission) in the long-run but much evidence in the short-run. This suggest that, at the initial stage of industrialisation manufacturing emission reduces, while over time as the industialisation rate rises the emission increases. Increase in the urbanization rate leads to reduction in manufacturing emission in the long-run but a rise in the emission in the short-run.

In the long-run, industrial share of output (GDP) and urbanization are the two main drivers of transport carbon emission in Nigeria, while only urbanization has significant (negative) effect on it in the short-run. The industrial share of output has a significant positive influence on transport carbon emission in the long-run. Thus, the higher the rate of urbanization, the lower the carbon emission from transport in both the long-run and short-run. There is little evidence of the validity of the EKC hypothesis in the Nigeria's industrial sector (with transport carbon emission) in both the long-run and short-run.

Some policy recommendations could be drawn from the empirical findings of this study. It is evidenced that industrailisation will generate some effects (either positive or negative) on pollution in Nigeria, therefore, there is need to prepare for such effects. The diverse effects of industrialization on manufacturing and transport carbon emissions should be taking into consideration in the Nigeria's industrial revolution plan. Industrialisation which is associated with technological advancement should be made less emerging consuming so as to achievement environmental friendliness and sustainable development. If it is more energy consuming, there is need to invest in renewable (clean) energy sources so as to minimize environmental pollution.

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