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Carbon Emissions Index Decomposition Analysis in Nigerian Transportation Sector

Nwasuka, N.C*[1], Ezirim, K.T[2], Ugwu, H.U[3], Omonini, C[3], Nwaiwu, U[1], Ugoani, A[3], Ekele, N.A[1]

[1]Abia State University, PMB 2000, Uturu, Nigeria.
[2]Federal University of technology Owerri. Nigeria
[3]Michael Okpara University of Agriculture Umudike, Umudike
[4]Akanu Ibiam Polytechnic Uwana,Ebonyi ,Nigeria
*Corresponding author's email: philip.uche2009@yahoo.com

Abstract

This study presents the index decomposition analysis of carbon emissions in Nigerian transportation sector. The primary aim of the paper was to determine the decoupling of Green House Gases (GHG) emissions in Nigeria from 1980 – 2014 and to determine the extent the influence of the selected factors of development had on Nigerian transport sector. A mathematical model was developed to analyse the carbon decomposition index in Nigeria's transportation industries. An Index Decomposition Analysis (IDA) with Log Mean Divisia Index (LMDI) model was applied to detect the roles of these factors and their effects on the development of GHG emissions in Nigeria. In the overall monitored period (2008 – 2014), absolute decoupling took place, GHG emissions reduced by 15.847%, which is the novelty behind this work. Results obtained however, showed that transportation industries had the highest number of shares in GHG. Real estate activities showed a relatively low share in GHG emissions. The GHG emissions of all the examined activities decreased in the period 2008 – 2014. On the other hand, the highest annual drop in GHG emissions occurred in 2009, which is connected with the economic crisis and recession. The scale effect was negative only in 2009 and 2012 and the highest positive increases occurred in 2010 and 2011. The composition effect was positive only in 2010 and 2012, showing highest absolute extent in 2011 (below –2%).

Keywords: *Greenhouse emissions, Decomposition analysis, Index decomposition analysis, climate change*

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1. Introduction

Global warming caused by Green House Gases (GHG) emissions is one of the main issues in the world today and it poses severe threat to all living organisms and resulted from over dependent consumption of fossil fuels Majeed and Mumtaz (2017); EEA (2007); Leal *et al*. (2019); Ang (2005). GHG emissions accounted for 47,599 metric tonnes of carbon dioxide ($MtCO_2$) in 2012 and it approximately tripled during the past six decades reaching 36,138.3 million tons in 2014 from 9385.8 million tons in 1960 with an annual growth rate of 2.6% (USAID, 2016; Shuai *et al*., 2019; Sher and Sher, 2019; Feng *et al*., 2009). Past literatures proved that the last five decades (1963-2012) were often seen as the warmest years because the concentration of GHG was high as documented by International Panel on Climate Change (IPCC, 2014). Anthropogenic activities are held responsible for 95% global climate change resulting from increased emissions from over dependence on fossil fuels (Agnolucci *et al*., 2009; Paul *et al*., 2004). From the global perspective, conventional energy sources are the main reason behind GHG emissions (Meinshausen *et al*., 2009; Sari and Soytas, 2009; Majeed and Mazhar, 2019a; Ščasný and Tsuchimoto, 2011; Scholl *et al*., 1996). The British Petroleum statistics showed a decline of 1.1×109 tons of CO_2 emissions for developed nations while developing countries offset the efforts of developed nations by increasing CO_2 emissions by 6.1×109 tons (Shahiduzzaman and Alam, 2013). According to the United Nations Environmental Protection (UNEP) in 2011, the process of delinking economic growth from GHG emissions is termed as "Decoupling". Later it widened to "decouple environmental pollution from resource consumption''. Decomposition techniques are used to examine variation in CO_2 emissions and energy consumption (Ang, 2004; Zhang and Lahr, 2014; Zhang *et al*., 2011; Zhang *et al*., 2013; Zhang *et al*., 2009) and it also helps to capture regress and variable by a change in a specific regressor (Ang and Lee, 1996). There are two basic techniques that are commonly used for decomposition analysis, namely Structure Decomposition Analysis (SDA) and Index Decomposition Analysis (IDA) (Hoekstra and Bergh, 2003). Due to possible errors in results and lack of complete decomposition in SDA, IDA is preferred over SDA because of Log Mean Divisia Index (LMDI) technique which provides complete decomposition with no error term in the outcome (Ang and Choi, 1997; Fontaras and Samaras, 2007).

2. Materials and methods

2.1 Data collection

The data used in this investigation consists of two independent data sets. Primary Data used in this assessment was obtained from the Nigerian National Petroleum Corporation (NNPC). The second database was obtained from several transportation databases in literature. A preliminary survey on the carbon index decomposition analysis of Nigerian transportation sector was carried out using Log Mean Divisia Index (LMDI) technique and Index Decomposition Analysis (IDA). The study integrated important factors such as: population, GDP per capita, energy structure, energy, and carbon intensity that contribute significantly to economic growth as well as CO_2 emissions, taking cognizant of the following factors: population, GDP per capita, energy structure, energy, and carbon intensity. However, there are also some limitations of the current study. First, due to the unavailability of data, the analysis was done for 1980-2014 only. Secondly, CO_2 emission was taken as a substitute of environmental degradation, other forms of GHG emissions such as methane, nitrous oxide and ozone were also used as proxy for environmental degradation. Finally, in order to have a clearer picture, the impact of fossil fuel energy along with renewable energy consumption were examined in this research.

2.2 Decomposition model

There are numerous methods for decomposition that are used to assess the variations in CO_2 emissions countrywide or globally. Among all of them LMDI decomposition technique is widely used.The model is arranged taking cognizance of five main factors that is demonstrated in Equation (1):

$$C = i = 13C_i = \sum_{i=1}^{3} \mathrm{P} x \frac{G}{P} x \frac{E}{G} x \frac{Ei}{E} x \frac{Ci}{Ei} = \sum_{i=1}^{3} \mathrm{PxAxElxESxCI} \quad (1)$$

where P represents population; G is for GDP, E represents total energy consumption in metric ton of oil equivalent (Mtoe), Ei (Mtoe) demonstrates consumption of i fuel energy, and Ci (Mtoe) depicts the energy-induced CO_2 emission of i fuel. Further, A represents GDP per person, EI represents energy intensity, i.e. energy consumption per unit of GDP, ES represents energy structure i.e. share of i fuel in total energy consumption and CI represents carbon intensity, i.e. CO_2 emissions per unit. i=1, 2 and 3 represent natural gas, petrol, and coal, respectively. LMDI technique along with the chaining decomposition was used in this study to assess CO_2 emission from 1980-2014. Equation (2) depicts the change in CO_2 emissions i.e. decomposed into five factors based on Kaya's (1990) identity:

$$\Delta C = C_t - C_{t-1} = \Delta C_P + \Delta C_A + \Delta C_{EI} + \Delta C_{ES} + \nabla C_{CI} \quad (2)$$

Equation (2) demonstrates the variation in CO_2 emissions due to variation in the population, GDP per person, Energy structure, Energy intensity, and Carbon intensity. These variables were calculated as follows:

$$\Delta P = \sum_{i=1}^{3} \frac{C_{it} - C_{it-1}}{\mathrm{inc}_{it} - \mathrm{inc}_{it-1}} \mathrm{In}[\left(\frac{P_t}{P_{t-1}}\right)] \quad (3)$$

$$\Delta A = \sum_{i=1}^{3} \frac{C_{it} - C_{it-1}}{\mathrm{inc}_{it} - \mathrm{inc}_{it-1}} \mathrm{In}[\left(\frac{A_t}{A_{t-1}}\right)] \quad (4)$$

$$\Delta EI = \sum_{i=1}^{3} \frac{C_{it} - C_{it-1}}{inc_{it} - inc_{it-1}} In[\left(\frac{EI_t}{EI_{t-1}}\right)] \quad (5)$$

$$\Delta ES = \sum_{i=1}^{3} \frac{C_{it} - C_{it-1}}{inc_{it} - inc_{it-1}} In[\left(\frac{ES_t}{ES_{t-1}}\right)] \quad (6)$$

$$\Delta CI = \sum_{i=1}^{3} \frac{C_{it} - C_{it-1}}{inc_{it} - inc_{it-1}} In[\left(\frac{CI_t}{CI_{t-1}}\right)] \quad (7)$$

The Evidence of perfect decomposition of the LMDI is given below by incorporating Equations (3), (4), (5), (6) and (7) into Equation (2).

$$\Delta C = \sum_{i=1}^{3} \frac{C_{it} - C_{it-1}}{inc_{it} - inc_{it-1}} In\left[\left(\frac{P_t}{P_{t-1}}\right)\right] + \sum_{i=1}^{3} \frac{C_{it} - C_{it-1}}{inc_{it} - inc_{it-1}} In\left[\left(\frac{A_t}{A_{t-1}}\right)\right] + \sum_{i=1}^{3} \frac{C_{it} - C_{it-1}}{inc_{it} - inc_{it-1}} In\left[\left(\frac{EI_t}{EI_{t-1}}\right)\right] + \sum_{i=1}^{3} \frac{C_{it} - C_{it-1}}{inc_{it} - inc_{it-1}} In\left[\left(\frac{ES_t}{ES_{t-1}}\right)\right] + \sum_{i=1}^{3} \frac{C_{it} - C_{it-1}}{inc_{it} - inc_{it-1}} In\left[\left(\frac{CI_t}{CI_{t-1}}\right)\right] = \sum_{i=1}^{3} \frac{C_{it} - C_{it-1}}{inc_{it} - inc_{it-1}} In\left[\left(\frac{P_t}{P_{t-1}}\right) + In\left(\frac{A_t}{A_{t-1}}\right) + In\left(\frac{EI_t}{EI_{t-1}}\right) + In\left(\frac{ES_t}{ES_{t-1}}\right) + In\left(\frac{CI_t}{CI_{t-1}}\right)\right] = \sum_{i=1}^{3} \frac{C_{it} - C_{it-1}}{inc_{it} - inc_{it-1}} \left[In\left(\frac{P_t A_t EI_t CI_t ES_t}{P_{t-1} A_{t-1} EI_{t-1} CI_{t-1} ES_{t-1}}\right)\right] = \sum_{i=1}^{3} \frac{C_{it} - C_{it-1}}{inc_{it} - inc_{it-1}} \left[In\left(\left(\frac{EI_t}{EI_{t-1}}\right)\right] = \sum_{i=1}^{3} (E_t - E_{t-1}\right) \quad (8)$$

Equation (8) shows that the LMDI technique gives the perfect decomposition without any residual term. Therefore, it is preferred over the other decomposition techniques. Now by incorporating Equation (2) into (1), decoupling indicator was further decomposed into the following factors:

$$= \frac{\Delta C_p + \Delta C_A + \nabla C_{EI} + \Delta C_{ES} + \frac{\Delta C_{CI}}{CO_{2t-1}}}{\frac{\Delta G}{GDP_{t-1}}} = \frac{\frac{\Delta C_p}{CO_{2t-1}}}{\frac{\Delta G}{GDP_{t-1}}} + \frac{\frac{\Delta C_A}{CO_{2t-1}}}{\frac{\Delta G}{GDP_{t-1}}} + \frac{\frac{\Delta C_{EI}}{CO_{2t-1}}}{\frac{\Delta G}{GDP_{t-1}}} + \frac{\frac{\Delta C_{ES}}{CO_{2t-1}}}{\frac{\Delta G}{GDP_{t-1}}} + \frac{\frac{\Delta C_{CI}}{CO_{2t-1}}}{\frac{\Delta G}{GDP_{t-1}}} = D_p + D_A + D_{EI} + D_{ES} + D_{CI} \quad (9)$$

The factors, D_p, D_A, D_{EI}, D_{ES} and D_{CI} in Equation (9) exhibit the response of population, economic growth, energy intensity, energy structure and carbon intensity to the decoupling progress in Nigeria.

$$C_t = P_t . V_t . \sum_i (f^i . D_t{}^i . F_t{}^i \sum_i (S_t{}^{i.j} . \sum_k (T_t{}^{i.j.k} . e^{i.j.k}))) \quad (10)$$

Consequently, the change in CO_2 emissions, ΔCt, recorded in time t with their level in a base year t=0 was calculated using Equation (11):

$$\Delta C_t = P_t . V_t . \sum_t (f^i . D_t^i . F_t^i . \sum_j (S_t^{i,j} . \sum_k (T_t^{i,j,k} . e^{i,j,k}))) - P_o . V_o . \sum_i (f^i . D_o^i . F_o^i . \sum_j (S_o^{i,j} . \sum_k (T_o^{i,j,k} . e^{i,j,k}))) \quad (11)$$

Each separate factor on the performance on ΔC_t was solved using the following decomposition model:

$$\Delta C_t = \Delta P_t + \Delta V_t + \Delta D_t + \Delta F_t + \Delta S_t + \Delta T_t \quad (12)$$

The explanatory factor for equation 10 can be obtained by considering equation 13-18

$$\Delta P_t = (P_t - P_0) . V_0 . \sum_i (f^i . D_0^i . F_0^i . \sum_j (S_0^{i,j} . \sum_k (T_0^{i,j,k} . e^{i,jk}))) + \frac{1}{2} . \sum_i R_{P,x} + \frac{1}{3} . \sum_i R_{P,x,y} + \frac{1}{4} . \sum_i R_{P,x,yz} + \frac{1}{5} . \sum_i R_{P,x,y,z,w} + \frac{1}{6} . R_{P,V,D,F,S,T} \quad (13)$$

$$\Delta V_t = P_0 . (V_t - V_0) . \sum_t (f^i . D_0^i . F_0^i . \sum_j (S_0^{i,j} . \sum_k (T_0^{i,j,k} . e^{i,j,k}))) + \frac{1}{2} . \sum_i R_{V,x} + \frac{1}{3} . \sum_i R_{V,x,y} + \frac{1}{4} . \sum_i R_{V,x,y,z} + \frac{1}{5} . \sum_i R_{V,x,y,z,w} + \frac{1}{6} . R_{P,V,D,F,S.T} \quad (14)$$

$$\Delta P_t = (P_t - P_0) . \sum_t (f^i . D_0^i . F_0^i . \sum_j (S_0^{i,j} . \sum_k (T_0^{i,j,k} . e^{i,j,k}))) + \frac{1}{2} . \sum_i R_{V,x} + \frac{1}{3} . \sum_i R_{V,x,y} + \frac{1}{4} . \sum_t R_{V,x,y,z} + \frac{1}{5} . \sum_i R_{V,x,y,z,w} + \frac{1}{6} . R_{P,V,D,F,S,T} \quad (15)$$

$$\Delta F_t = P_0 . V_0 . \sum_i (f^i . D_0^i . \left(F_t^i - F_0^i\right) . \sum_j (S_0^{i,j} . \sum_k (T_0^{i,j,k} . e^{i,j,k}))) + \frac{1}{2} . \sum R_{F,x,y} + \frac{1}{4} . \sum R_{F,x,y,z} + \frac{1}{5} . \sum R_{F,x,y,z} + \frac{1}{6} . R_{P,V,D,F,S,T} \quad (16)$$

$$\Delta S_t = P_0.V_0.\sum_t(f^i.D_0^i.F_0^i\sum_j\left((S_t^{i,j} - S_0^{i,j}\right).\sum_k(T_0^{i,j,k}.e^{i,j,k}))) + \frac{1}{2}.\sum R_{S,x} + \frac{1}{3}.\sum R_{S,x,y} + \frac{1}{4}.\sum R_{T,x,y,z} + \frac{1}{5}.\sum R_{T,x,y,z} + \frac{1}{6}.R_{P,V,D,F,S,T} \quad (17)$$

$$\Delta T_t = P_0.V_0.\sum_t(f^i.D_0^i.F_0^i\sum_j\left((S_t^{i,j}\right).\sum_k(T_0^{i,j,k} - T_0^{\ i,j,k}).e^{i,j,k}))) + \frac{1}{2}.\sum R_{T,x} + \frac{1}{3}.\sum R_{T,x,y} + \frac{1}{4}.\sum R_{T,x,y,z} + \frac{1}{5}.\sum R_{T,x,y,z,w} + \frac{1}{6}.R_{P,V,D,F,S,T} \quad (18)$$

For the set U of the examined determinant factors (U= P, V, D, S, T, F), residual terms RQ,x, RQ,x,y, RQ,x,y,z, RQ,x,y,z,w, RP,V,D,F,S,T denote the synergetic effects of 2, 3, 4, 5 and 6 factors. Factor Q corresponds to the examined effect (Q∈ U) and factors (x, y, z, w) ∈ (U -{Q}), x ≠ y≠ z ≠ w. As an example for Q=P, the residual terms RP,x summed up in Equation (4) were as follows

$$R_{P,V} = (P_t - P_o).(V_t - V_0)\sum_i(f^i.D_0^i.F_0^i.\sum_j(S_0^{i,j}.\sum_k(T_0^{i,j,k}.e^{i,j,k}))) \quad (19i)$$

$$R_{P,D} = (P_t - P_o).(V_0).\sum_i(f^i.(D_0^i - D_0^i).F_0^i\sum_j(S_0^{i,j}.\sum_k(T_0^{i,j,k}.e^{i,j,k}))) \quad (19ii)$$

$$R_{P,F} = (P_t - P_o).(V_0).\sum_i(f^i.D_0^i.(F_t^i - F_0^i).\sum_j(S_0^{i,j}.\sum_k(T_0^{i,j,k}.e^{i,j,k}))) \quad (19iii)$$

$$R_{P,S} = (P_t - P_o).(V_0).\sum_i(f^i.D_0^i.F_0^i.\sum_j(S_t^{i,j} - S_0^{i,j}).\sum_k(T_0^{i,j,k}.e^{i,j,k}))) \quad (19iv)$$

$$R_{P,T} = (P_t - P_o).(V_0).\sum_i(f^i.D_0^i.F_0^i.\sum_j(S_0^{i,j}.\sum_k(T_t^{i,j,k} - T_0^{i,j,k}).e^{i,j,k}))) \quad (19v)$$

2.3 Sources of primary data

The data used in this analysis was extracted from World Bank (Wang and Zou, 2005) and Nigerian Petroleum Corporation (Mulder *et al.*, 2013); Paravantis *et al.*, 2007) for a period of 1990-2014, using 1990 as base year according to continuous chaining method. The decoupling indicator i.e. the regressand variable is the index of GDP (constant 2010 U.S dollars) and carbon emissions (kt) (Hubacek *et al*., 2012; Kisielewicz *et al*., 2016; Kwon, 2005; Ma *et al*., 2008; Banister and Stead, 2003; Brizga et al., 2013; Cornillie and Fankhauser, 2004). Time series data were used to calculate GDP, CO_2 emissions, population, GDP per person, energy structure and energy and carbon intensity in this research (Diakoulaki and Mandaraka, 2007; Drastichová, 2014; Duro and Padilla, 2011; Wood and Lenzen, 2009; Wu *et al*., 2005; Xu *et al*., 2013; Zachariadis, 2006; Zha, 2009). Similarly, carbon intensity demonstrated, how much CO_2 was emitted from combustion. Due to data limitations, variables were taken in different measurements such as population in (total), CO_2 in (kt), GDP (constant 2010 US$), GDP per capita (constant 2010 US$), energy intensity (kg of oil equivalent), energy structure (Mtoe) and carbon intensity (Mtoe). The applications of LMDL model converted all the variables into percentages (Lee and Oh, 2006; Stead, 2001; Lise, 2006; Löfgren and Muller, 2010; Hatzigeorgiou *et al*., 2008; Ang and Zhang, 2000; Sun, 1998; Tapio, 2005; UNEP, 2011).

Table 1: Gasoline consumption and the gases emitted

Year	Gasoline (000 L)[a]	Emission (tons)			Total GHGs (CO_2e)
		CO_2	CH_4	N_2O	
1980	3869818	9298360	2415	255	9428108
1981	4860224	11678099	3033	320	11841053
1982	5465344	13132077	3411	360	13315320
1983	5651216	13578688	3527	372	13768163
1984	5381646	12930967	3359	355	13111404
1985	5374591	12914016	3354	354	13094216
1986	4894484	11760420	3355	322	11924523
1987	4942233	11875149	3084	326	12040853
1988	5257146	12631819	3281	346	12808082

1989	5961088	14202606	3689	389	14400787
1990	5901055	14178997	3683	389	14376848
1991	5904312	14186823	3685	389	14384784
1992	5946668	14288596	3711	392	14487976
1993	7212077	17329109	4501	475	17570917
1994	7622474	18315206	4757	502	18570773
1995	5580844	13409597	3483	368	13596712
1996	5385917	12941229	3361	355	13121809
1997	5911286	14203581	3689	389	14401775
1998	3699548	8889238	2309	244	9013277
1999	5930124	14248845	3701	391	14447671
2000	4761073	11439860	2971	314	11599490
2001	7142715	17162447	4458	471	17401929
2002	8687595	20874470	5422	572	21165748
2003	8725938	20966600	5446	575	21259164
2004	8676810	20848556	5415	572	21139473
2005	8644260	20770345	5395	569	21060171
2006	8306985	19959944	5184	547	20238461
2007	8859802	21288247	5529	584	21585299
2008	7206729	17316258	4498	475	17557886
2009	6876577	16522973	4292	453	16753531
2010	6353518	15266172	3965	419	15479193
2011	5688450	13668152	3550	375	13858875
2012	5017535	12056085	3131	331	12224314
2013	3816267	9169690	2382	251	9297642
2014	3969710	9538380	2478	262	9671477
Total	213435847	736988399	133206	14061	519997702

[a]Source: NNPC (1997; 1998; 2008-2014)

Table 2: Gasoline consumption and the gases emitted

Year	**Gasoline (000 L)**[a]	**Emission (tons)**			**Total GHGs (CO_2e)**
		CO_2	**CH_4**	**N_2O**	
1980	2318351	6541866	340	199	6610582
1981	2725912	7691911	400	234	7772707
1982	2909688	8210486	427	249	8296730
1983	3003085	8474031	440	257	8563042
1984	2799597	7899833	410	240	7982813
1985	2569897	7251673	377	220	7327844
1986	2207401	6228790	324	189	6294217
1987	2052459	5791580	301	176	5852415
1988	2266466	6395457	332	194	6462635
1989	2385501	6731348	350	204	8102232
1990	2841477	8018010	417	243	6802054
1991	2842682	8021409	417	244	8105666
1992	2227829	6286432	327	191	6352465
1993	4016018	11332301	589	344	11451336
1994	2755092	7774252	404	236	7855913
1995	2702682	7626362	396	232	7706469

1996	2701144	7622021	396	231	7702083
1997	2486369	7015975	365	213	7089671
1998	1337987	3775499	196	115	3815157
1999	1977203	5579223	290	169	5837827
2000	1985639	5603027	291	170	5661882
2001	2664542	7518739	391	228	7597716
2002	2645976	7466350	388	227	7544777
2003	2375711	6703723	348	204	6774139
2004	1916000	5406522	281	164	5463312
2005	2368000	6681964	347	203	6752152
2006	1649749	4655221	242	141	4704120
2007	1384956	3908036	203	119	3949086
2008	1273203	3592693	187	109	3630431
2009	648417	1829687	95	56	1848906
2010	879368	2481378	129	75	2507442
2011	977892	2759391	143	84	2788376
2012	676728	1909574	99	58	1929632
2013	733822	2070681	108	63	2092432
2014	397898	1122779	58	34	1117750
Total	73704739	207978221	10806	6315	730160537

[a]Source: NNPC (1997; 1998; 2008-2014)

3. Results and discussion

3.1 Consumption of gasoline

Tables 1 and 2 present the quantities of gasoline fuels and emissions (CO_2, CH_4, N_2O and total GHGs) for years from 1980 to 2014. The total volume of gasoline consumed in the country for the period under consideration was 2.13 x 10^{11} litres and 7.37 x 10^{10} litres, respectively. This implies that on volumetric basis, 65.4 % of the fuel consumed was gasoline. Table 1 gives an illustration of the consumption pattern of gasoline. It clearly shows that gasoline was consumed more, as this is evident in both the total volume of the products consumed. Though national statistics to this effect is not available but this assertion is based on results obtained.

Table 1 gives a clear view of the consumption of gasoline in the country, the volume of gasoline consumed increased gradually from 3.87 x 10^9 litres in 1980 to 7.62 x 10^9 litres in 1994 and then witnessed a rapid reduction in quantity from 1994 to 1998 (3.70 x 10^9 litres). From 1998, the volume of gasoline consumed in the country increased sharply to 8.73 x 10^9 litres in 2003, which was relatively steady thereafter with a peak in 2007 (8.86 x 10^9 litres). Reductions in quantity from 8.86 x 10^9 litres in 2007 to 3.82 x 10^9 litres in 2013 was recorded. This was followed by a slight increase in quantity (3.97 x 10^9 litres) in 2014, the trend of gasoline consumed has its minimum and maximum values in 1998 and 2007 which corresponds to 3.70 x 10^9 litres and 8.86 x 10^9 litres, respectively. Gasoline consumption showed a gradual reduction pattern from 2.32 x 10^9 litres in 1980 to 3.92 x 10^8 litres in 2014. The highest quantity of gasoline consumed was recorded in 1993 with a value of 4.02 x 10^9 litres while the lowest volume was in the year 2014 (3.92 x 10^8 litres). A correlation coefficient of 0.167 was obtained between the data for gasoline consumed in the country. This shows a positive and weak relationship between these sets of data. It is therefore evident that both data are independent of another.

3.2 Greenhouse gases emitted from gasoline consumption

The emission factors employed for the estimation of CO_2, CH_4, and N_2O were obtained in literature (IPCC, 2006). The choice of emission factors for both stationary and mobile engines (combustors) was informed by the fuels under consideration in this study.Total amount of GHGs emitted was 5.20 x 10^8 tons of CO_2 equivalent (t CO2e) which translates to emission of 1.33 x 10^5 tons of CH_4, 1.41 x 10^4 tons of N_2O and 5.13 x 10^8 tons of CO_2. Based on these values, yearly average of 3.80 x 10^3 tons, 401.7 tons and 1.47 x 10^7 tons of CH_4, N_2O and CO_2, respectively, were released into the environment. For the year 2014, 9.67 x 10^6 t CO2e of GHGs were emitted into the environment which translates to $145.07 million (N44.97 billion at N305 to $US 1) based on $15/t CO2e (N4725) carbon tax. This can be attributed to the linear nature of the mathematical expressions used for the estimation of the quantities of GHGs. It is worth noting that 98.62 % GHGs (CO_2, CH_4 and N_2O) released into the atmosphere because of gasoline burning in combustors was CO_2. Significantly small amounts of N_2O (4.36 x 10^6 t CO_2e) and CH_4 (2.80 x 10^6 t CO_2e) was emitted compared to CO_2 (5.13 x 10^8 tons) for the year span (1980 to 2014) under consideration.

3.3 Greenhouse gases emitted from gasoline consumption

The amounts of CO_2, CH_4 and N_2O emitted during diesel consumption for 35 years are provided in Table 2. Total amount of GHGs released into the atmosphere for using gasoline was 2.10 x 10^8 t CO_2 e. This quantity comprises of 1.08 x 10^4 tons of CH_4, 6.32 x 10^3 tons of N_2O and 2.08 x 10^8 tons of CO_2. On yearly average, 308.7 tons, 180.4 tons and 5.94 x 10^6 tons of CH_4, N_2O and CO_2, respectively, were released into the atmosphere. It is apparent that the same trend of emissions (amount of CO_2, CH_4 and N_2O) noticed in Table 2 for the volume of gasoline consumed in the country. Again, the quantity of CO_2 was significantly higher than other gases as shown in Table 2. This supports the fact that CO_2 is a major global warming contributor despite its low global warming potential of (1), compared to those of CH_4 (16) and N_2O (44) in terms of CO_2e.

3.4 Total GHGs emitted from gasoline consumption

The estimated amount of GHGs emitted from the consumption of gasoline was 5.20 x 10^8 t CO_2e and 2.10 x 10^8 t CO2e, respectively (Tables 1 and 2). In terms of carbon tax at the present rate of $15/t CO2e (N4725), these values sum up to $7.80 billion (N2.38 trillion) and $3.15 billion (N960.75), respectively. From Tables 1 and 2, it is clear that the quantity of GHGs released in gasoline. This is as a result of volume of gasoline consumed during the period. A total of 7.30 x 10^8 t CO_2e of GHGs was estimated to be released into the environment as a result of 2.15 x 10^{11} litres of gasoline for the 35-year period in the country. From Tables 1 and 2, it was estimated that 71.23 % of GHGs was as a result of gasoline consumption as fuel. Of the estimated total amount of GHGs emitted into the environment, CO_2 emission accounted for 98.96 % of the amount. The cost of carbon tax for the total amount of GHGs was $109.52 billion (N33.40 trillion) while that for the emissions in the year 2014 was $161.84 million (N49.36 billion). According to a report on national GHG inventory under UNFCC for the year 2000, Nigeria contributed about 2.14 x 10^8 t CO_2e of GHG to the atmosphere (National Communication, 2014). The energy sector (fuel combustion and fugitive emissions) was reported to contribute the largest proportion (70 %) to direct GHG emissions in Nigeria (National Communication, 2014). Of this amount, 1.33 x 10^8 t CO_2e were released into the atmosphere due to fuel combustion which consisted of 1.15 x 10^8 tons (114,724 Gg) of CO2, 6.79 x 10^8 tons (679 Gg) of CH4 and 9.0 x 10^3 tons (9 Gg) of N_2O. From this present study, it was estimated that1.70 x 10^7 tons of CO_2, 3.26 x 10^3 tons of CH_4 and 484 tons of N2O (1.73 x 10^7 t CO_2e) were emitted through the use of both gasoline in 2000. From the values aforementioned, it was observed that this study's estimate of GHGs is 13.1 % of that reported for the energy sector in the national GHG inventory. This consists of 14.5 % (CO_2), 0.5 % (CH_4) and 5.4 % (N_2O) of the corresponding gas reported in the energy sector. The significant difference between the value of GHGs obtained in this study and that reported for the sector in the national inventory is largely due to the encompassing inventory of the emissions in the energy sector (energy industries, manufacturing and construction, transport, commercial, residential, agriculture, forestry and fishing activities, gas flaring, petroleum refining and fugitive process) of the country as against the GHG estimation of emissions from gasoline consumption. Also, 40.3% (5.66 x 10^7 t CO_2e) of the GHGs from the energy sector were reported to be from gas flaring activities for the year under consideration (National communication, 2014). In addition, the transport subsector of the energy sector was reported to have emitted 2.57 x 10^7 t CO_2e of GHGs into the atmosphere, which is an amount fairly higher than the value (1.73 x 10^7 t CO_2e) obtained in this study. It is worth mentioning that the GHG inventory for the transport subsector entailed emissions from road, rail, aviation and marine sections.

3.5 Comparison of results

Previous studies on GHGs emission inventory for gasoline and diesel fuels in Nigeria are very scarce in the literature. Emissions of CO_2, CH_4 and N_2O as obtained in this study were compared with those provided by USEIA, World Bank and USDOE (for CO_2) and EDGAR (for both CH4 and N2O emissions). It is pertinent to know that CO_2 emission data for both USEIA and World Bank were only updated to the year 2013 as at the time of reporting this work while those of USDOE were given to the year 2014. From Tables 1 and 2, it can be noticed that the values of CO_2 emissions evaluated in this study were slightly lower than those of USEIA, USDOE and World Bank. This can be linked to the fact that this work only considered CO_2 emission inventory for gasoline all the fossil fuels (gasoline, diesel, kerosene, natural gas, etc.) used in the country. Thus, the difference in emission values observed in table 2 can be due to the other fossil fuels not accounted for in our study but evaluated by USEIA and USDOE. Analysis of variance (ANOVA) carried out on all the CO_2 data from USDOE, USEIA, World Bank and this study showed that the values were significant and statistically different (F-observed (78.26) > F-critical (3.99)) from one another with p-value<<0.05 at 95 % confidence level. Beside USDOE and World Bank having correlation coefficient of unity (1) - showing excellent relationship between the CO2 data sources - other CO2 data correlations revealed weak and positive correlation coefficients (USEIA and World Bank (0.3117), our data and USEIA (0.2519), USDOE and USEIA (0.3116), our data and World Bank (0.2118) and, USDOE and our data (0.3116)). Comparison between the estimated CH4 emissions in this work and those of EDGAR dataset of CH_4 emissions in the country. Relatively similar trends were noticed between the CH_4 emission data from 1980 to 1993. Thereafter, a considerably sharp increase in the amounts of CH_4 emissions due to fossil fuels burning was observed for the EDGAR CH_4 data from 1993 to 2008. This sudden and progressive increase in CH4 emissions from 1993 upward as reflected in EDGAR data for CH_4 may be attributed to the monumental use of natural gas in the industrial sector of the country at that point in time as the EDGAR database provides emission values for fossil fuels combustion, of which only gasoline and diesel were considered and evaluated in this present study. The two CH_4 emission data were found to be statistically not the same (Fobserved (23.32) > Fcritical (4.01)), though significant with P-value <<0.05 at 95 % confidence level. Also, a moderate and positive relationship was noticed between the two emissions data with a correlation coefficient of 0.6281. In comparing the estimated N_2O emissions obtained in this work with those provided by EDGAR database for N_2O emissions, similar pattern to that of CH4 emissions comparison. The only exception is the fact that the quantities of N_2O evaluated in this study were slightly higher than those reported in EDGAR database. Similarly, both data sets were statistically not equal (Fobserved (15.13) > Fcritical (4.0)) with P-value of 0.00027 at 95% confidence level and correlation coefficient of 0.3814. These implied the significance of both data and the existence of a weak-positive relationship between them.

4. Conclusions

Techniques of decoupling and decomposition were employed in this research to investigate the driving forces of CO_2 emissions and to delink economic growth from environmental impact, in order to attain long-lasting economic growth. This study held its significance for Nigeria because it elaborates the nexus between environmental quality and economic growth by adopting novel techniques, such as the IDA decoupling indicator and the LMDI technique. The IDA and LMDI techniques were applied to determine their effects on the development of GHG emissions in Nigeria. In the overall monitored period 2008 – 2014, absolute decoupling took place, GHG emissions decreased by 15.847%, which is the novelty behind this work. Results obtained showed that transportation sector showed the highest shares in GHG, transportation sector activities showed a relatively low share in GHG emissions. The GHG emissions of all the examined activities decreased in the period 2008 – 2014. As regards the year-by-year decomposition analysis, the total effect, i.e. changes in GHG emissions, is negative for five of the years and positive only in 2010. In absolute values, this change showed the lowest magnitude when compared with the extent of this effect in other years. On the other hand, the highest annual drop in GHG emissions occurred in 2009, which is connected with the economic crisis and recession. Accordingly, the significant negative intensity effect in this year was enhanced by the even higher negative scale effect and the slight negative composition effect. The scale effect (GVA annual changes) was negative only in 2009 and 2012 and the highest positive increases occurred in 2010 and 2011 respectively. The composition effect was positive only in 2010 and 2012 and it showed the highest absolute extent in 2011 (below –2%). The intensity effect was negative in all the monitored years and highest in magnitude in 2009, followed by 2014. The relatively high extent of the negative intensity effect in the most recent year is of great importance for further reductions in GHG emissions. Nevertheless, the composition effect at the Nigerian level played its role in the process of decoupling as well. In the IDA of GHG emissions in the overall monitored period 2008 – 2014 and the two partial periods 2008 – 2011 and 2011 – 2014, the absolute values of the composition and the intensity effect surpassed those of the scale effect, while the intensity effect showed the highest absolute magnitude of all in all the periods. In both of the partial periods and the overall period, all the effects were negative, except for the scale effect in 2008 – 2014 and 2011 – 2014. This means that, apart from the period affected by the recession, the scale effect predominantly led to increases in GHG emissions, while both the composition and especially the intensity effect led to their decreases. Accordingly, the negative total effect was achieved in the overall period as well as in both partial periods, which was considerably augmented by the negative intensity effect. The study also covers the drawbacks of previous techniques such as EKC, because the current study gives a complete decomposition of environmental impact with no residual term, and the analysis also gives the annual decoupling status of "environmental harms from economic output" during 1990-2014. In addition, the analysis also helped in determining the main drivers of CO_2 emissions that could help to attain long-term economic growth by restricting the influence of such factors. For decades, there have been concerns about the link between economic growth and environmental impact, with several research studies to investigate the connection between these two. The current study delinked environmental harms from economic output. Based on empirical evidence, certain policy implications are given as follows; firstly, the government should promote environment-friendly technologies in the manufacturing sector to discourage environmental harms. Secondly, because renewable energy is more sustainable and less carbon-intensive, the government should take some strong stance on diverging economy's energy structure from fossil fuels to renewable energy. However, for future work, the analysis could be expanded to the regional/provincial level in Nigeria. Furthermore, the analysis could also be widened to other dimensions of decoupling, such as decoupling economic growth from natural resource use.

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