Determinants of household direct CO2 emissions: Empirical evidence from Nigeria

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DETERMINANTS OF HOUSEHOLD DIRECT CO_2 EMISSIONS: EMPIRICAL EVIDENCE FROM NIGERIA

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Abstract

The excess concentration of carbon dioxide (CO_2) in the earth's atmosphere has been identified by scientists as the major cause of climate change. If left uncontrolled, this has grave implication for sustainable development. Hence, there is need to formulate and implement informed based climate change mitigation policy. Data on household socio-economic and demographic variables were obtained from the 2015 General Household Survey and household direct CO_2 emissions was estimated using the Linear Multiplier Factor Method. An Environmental Kuznets Curve based econometric model was specified and the parameters were estimated using the Ordinary Least Squares technique. At the national level, results revealed that household income, household size, household head gender, literacy ratio and motorisation have significant positive impacts on carbon emissions. However, literacy ratio contradicts a priori expectation. Male population, polygamy and age of household head have insignificant effects. Both age and household income show significant non-linear relationship with household carbon emissions. For urban and rural households, results revealed that household income, household size and household head gender have significant positive effects. Age and motorisation significantly affects urban household carbon emissions. Other factors do not have significant effects on urban household and rural household carbon emissions. The study concludes that household income, household size, motorisation and literacy ratio are the quantitative factors that influence the level of Nigerian household carbon emissions. Based on the research results, the study recommends policies to the government.

Keywords: Carbon dioxide (CO_2), Environmental Kuznets curve, Household, Nigerian, Rural, Urban

1. Introduction

Seventy-six percent (76%) of global greenhouse gases are accounted for by carbon dioxide emissions (Environmental Protection Agency, 2017), and household activities have been identified as one of the drivers of this. Being society's largest economic agent and the controller of other economic agents (firms and government), the contribution of households to global and national carbon emissions via its consumption of goods and services cannot be underestimated. Findings in both developed and developing countries have x-rayed the monumental contribution of households to total carbon footprint (total amount of carbon dioxide released into the atmosphere by an individual, household, firm, or a country). In the United Kingdom, more than 70% of the total carbon emissions are accounted for by households (Baiocchi, Mint and Hubacek, 2010), 75% by households in India (Pachauri and Spreng, 2002), more than 80% by households in the United

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States of America (Bin and Dowlatabadi, 2005) and 30% by households in China in 2004 (Wang and Shi, 2009).

The consumption pattern of households has been identified as one of the factors influencing the level of global carbon footprint (Serino and Klasen, 2015). Consumption at the household level is chiefly influenced by various socio-economic and demographic characteristics. These demographic and socio-economic characteristics range from household size, household income, dependency ratio, household head gender, et cetera. In Nigeria, the average household size has been on the increase, which by inference implies that total population exhibit the same upward trend. In year 2006, 2008 and 2010, the average household size was 4.8, 5.0 and 5.5 persons respectively (CWIQ[2], 2006; HNLSS[3], 2008/2009 and GHS[4], 2010/2011). At the sectoral level, the average household size of rural and urban households' were 5.9 and 4.9 persons respectively. At the regional level, the average household size in the south was 4.6 persons and 6.6 in the north. The Nigerian household dependency ratio was 1.2. At the sectoral level, dependency ratio for rural household was 1.3 and 1.1 for urban household (NBS, 2012). Household income is another economic factor that influences household consumption pattern. In Nigeria, most households in rural areas are low income earners relative to households in urban areas. This fact speaks volume of urban and rural households' energy choices and their corresponding carbon emissions. In conclusion, differences in socio-economic and demographic characteristics of households in the rural and urban areas of Nigeria will tend to cause variations in average CO_2 emissions in the two sectors.

The behaviour of household energy options in Nigeria has impact on household carbon emissions. In terms of accessibility to electricity, fifty-five percent (55%) households experience electricity supply for an average of thirty-five hours per week with an average associated cost of ₦23, 696. Both the urban and the rural areas have 87.1% and 35.5% electricity supply respectively. It is also reported that electricity service in the urban areas is approximately ₦8,000 more expensive relative to the rural areas. As regard the sources of energy demand for lighting, kerosene and electricity are the most common sources of lighting fuel with over 34% usage in both cases. 57.2% urban households and 20% rural households use electricity for lighting. On a logical note, kerosene reported higher usage levels in the rural areas (41.3%) than in the urban areas (32.8%). It is also reported that 9.5% of the rural households relative to 2.6% of the urban households used firewood. In terms of preference between purchase of the firewood and self-selection, 6.8% of the rural households prefer to forage the firewood as opposed to 2.8% of the rural households who prefer to purchase it. Furthermore on households' energy consumption options, 48% households used kerosene based appliances for cooking and lighting in the absence of electricity. 18.2% households used generators and 27.8% households used rechargeable appliances for lighting during blackout. Some households also substitute cooking firewood for electricity during blackouts. Over 50% blackouts were reportedly a result of high connection fees and unreliability of services rendered (GHS report wave 1, 2010/2011). Figure 1 below shows the percentage of households that used electricity for lighting and kerosene for cooking in Nigeria.

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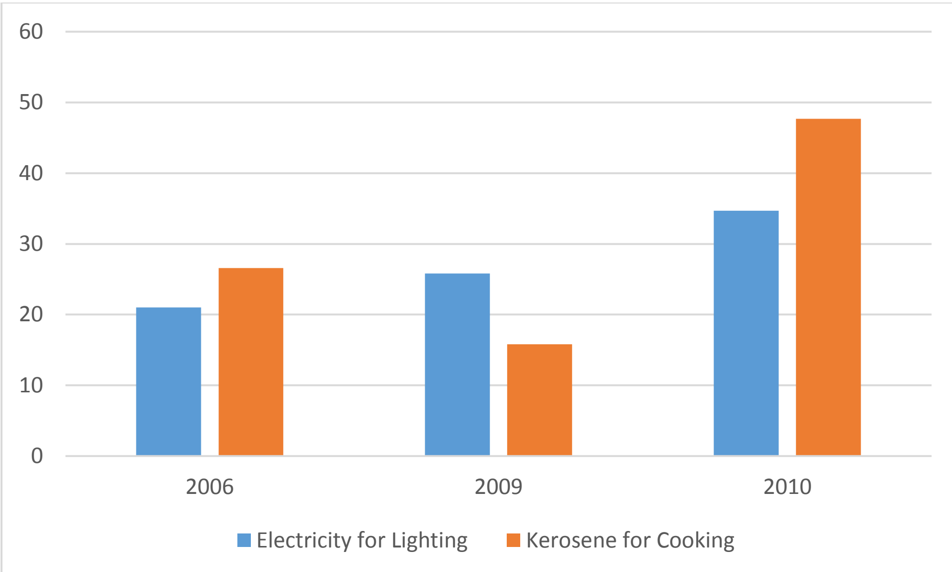
[2] CWIQ: Core Welfare Indicator Questionnaire Survey

[3] HNLSS: Harmonised Nigeria Living Standard Survey

[4] GHS: General Household Survey

Figure 1.0: Percentage of Households that Used Electricity for Lighting and Kerosene for cooking



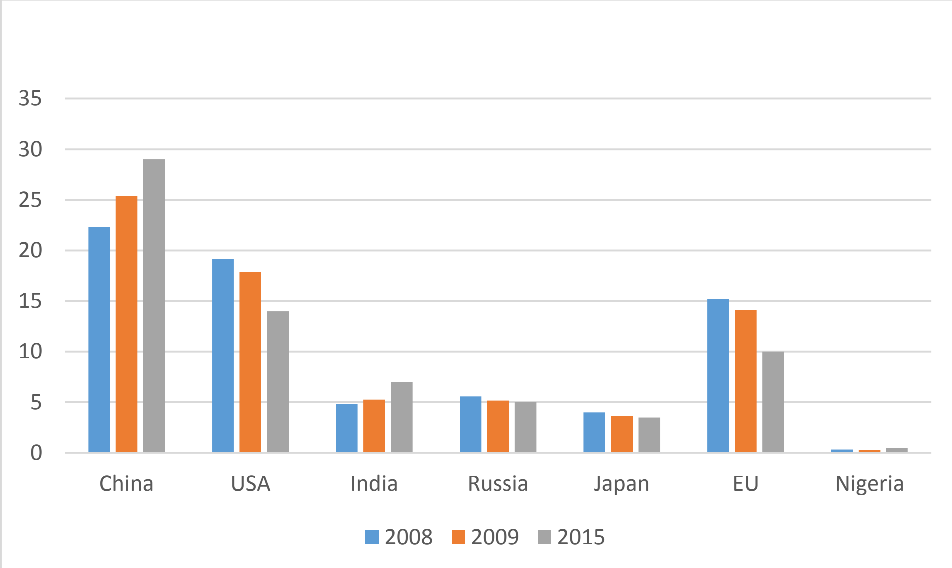
Data Source: CWIQ (2006), HNLSS (2008/2009) and GHS (2010/2011)

Chart Source: Author's Construction

In Figure 1.0 above, the percentage of Nigerian households that used electricity for lighting was 21% in 2006, 25.8% in 2008 and 34.7% in 2010. This shows households increased access to electricity overtime. Cooking is another household activity that stimulates energy demand. In 2006, 2008 and 2010, the percentage of Nigerian households that used kerosene for cooking were 26.6%, 15.8% and 47.7% respectively. Considering the fact that the carbon emission factor that is associated with electricity is low relative to that of kerosene, increasing households' access to electricity will have implication on the rate of household CO_2 emissions.

The contributions of countries in Africa to global CO_2 emissions remain low relative to the contributions of countries in Europe, America, Asia, et cetera. In year 2008, Africa's contribution to global CO_2 emissions stood at 3.8% and 3.68% in 2009. This implies a decline in the contribution of the continent to global CO_2 emissions in 2009. On the contrary, Asia continent remains the largest contributor to world CO_2 emissions, follow by North America. Statistically, Asia accounted for 40.46% and 43.6% of world CO_2 emissions in year 2008 and 2009 respectively. This implies a 3.14% rise in the continent's contribution to global CO_2 emissions in 2009. North America accounted for 22.58% and 21.09% of the world CO_2 emissions in year 2008 and 2009 respectively. By inference, the continent's contribution to global CO_2 emissions reduced by 1.49% in 2009. Comparing Africa, North America and Asia in terms of their contributions to world CO_2 emissions, it will be logically valid and sound to reach a conclusion that African continent is not the major culprit responsible for climate change. Figure 2 below shows selected countries and their shares of global CO_2 emissions.

Figure 2: Selected Countries and their Shares of World CO_2 Emissions



Data Source: IES[5] Monthly Update and Olivier et al. (2016)

Chart Source: Author's Construction

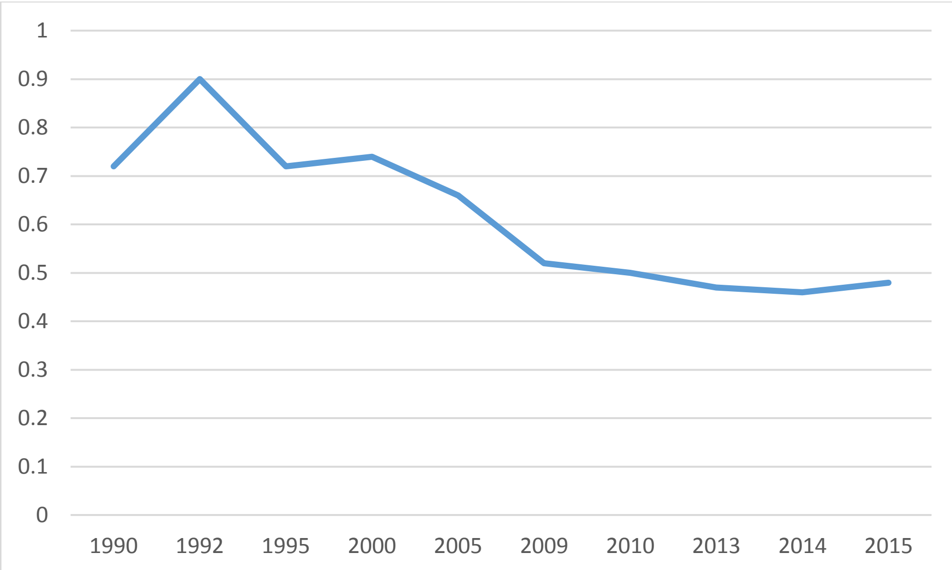
Figure 2 above reveals the five largest emitting countries, the European Union and Nigeria. In Year 2008 and 2009, China accounted for 22.31% and 25.36%, United States of America accounted for 19.13% and 17.84%, India accounted for 4.83% and 5.27%, Russia accounted for 5.57% and 5.17%, Japan accounted for 4.0% and 3.61% and countries of the European Union accounted for 15.18% and 14.1% of the global CO_2 emissions. Nigeria accounted for 0.26% and 0.33% of the global CO_2 emissions in 2008 and 2009 respectively. In year 2015, China (29%), USA (14%), India (7%), Russia (5%), Japan (3.5%) and all countries of the European Union (10%) accounted for two thirds of the total global emissions (Olivier, Janssens-Maehout, Muntean and Peters, 2016). In year 2015, Nigeria accounted for 0.48% of global CO_2 emissions. Most developing countries of the world are not major emitters of carbon dioxide, except China and India as revealed by the information. The contribution of Nigeria to global CO_2 emissions remains small relative to the contributions of developing countries like China and India. Table 1 and Figure 3 below show the values of CO_2 emissions per capita in Nigeria from 1990 to 2015.

Table 1: CO_2 Emissions Per Capita (1990 to 2015)

Variable	Years									
CO_2 Emissions Per Capita	1990	1992	1995	2000	2005	2009	2010	2013	2014	2015
	0.72	0.9	0.72	0.74	0.66	0.52	0.5	0.47	0.46	0.48

[5] IES: International Energy Statistics

Figure 3: Trend of CO_2 Emissions Per Capita (1990 to 2015)



Data Source: EDGAR[6], PRB (1997)[7] and IES (2017)

Chart Source: Author's Construction

Figure 3 above presents the behaviour of CO_2 emissions per capita (the amount of carbon dioxide (CO_2) in metric tons or kilogram equivalent released into the atmosphere per person, usually a year) of Nigeria. In year 1990, Nigeria's CO_2 emissions per capita was 0.72 metric tons. In year 1992, it jumped to 0.92 metric tons. In year 1995, it fell to 0.72 metric tons. In year 2000, the figure rose to 0.74 metric tons. In year 2005, the figure fell to 0.66 metric tons and further fell to 0.5 metric tons in year 2010. In year 2013, the figure was 0.47 metric tons and fell to 0.46 metric tons in year 2014. In year 2015, the figure increased to 0.48 metric tons. Overtime, CO_2 emissions per capita has

In 1956, it became noticeable that countries around the world started releasing more CO_2 into the atmosphere than the recommended volume required for the stability of the climate (Minx, Scott, Peters and Barret, 2008). The carbon dioxide absorption capacity of the planet has been exceeded, hence, global warming has emerged. It is an undebatable statement that the danger inherent in the continuity of global warming cum the increasing level of carbon dioxide has tickled the consciousness of stakeholders at the national, regional and international levels. Ministries and agencies in different countries, as well as non-governmental organisations, such as the United Nations, Union of Concerned Scientists, Greenpeace, World Meteorological Organisation, World Bank, et cetera have become key players in the crusade against carbon emissions. In addition, various countries within the planetary boundaries have entered into different environmental treaties to show their concern to ensuring a safe environment for all by pledging an emission reduction commitment that is to be achieved within a convenient time frame. One of the international environmental conventions entered into by countries is the Kyoto Protocol, which

[6] EDGAR: Emission Database for Global Atmospheric Research

[7] PRB: Population Reference Bureau

was adopted in Kyoto, Japan, on the 11th of December, 1997. The Kyoto Protocol was based on the premise that global warming exists and that anthropogenic (human related) activities have caused it. Hence, its principal objective is to fight global warming by reducing the level of carbon footprint in the atmosphere to a level that would prevent significant distortion of the climate system or cause climate instability.

The increasing level of carbon emissions has been identified by most scientists as the genesis of climate change. This poses a serious socio-economic risk to any economy, especially developing countries whose adaptive capabilities are weak. Results of various findings have identified anthropogenic (human related) activities such as transportation, cooking, heating, et cetera as the culprit responsible for the high level of carbon concentration in the atmosphere, thereby provoking climate change. According to the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (2013), "It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century" (as cited in Wikipedia, 2017). The Intergovernmental Panel on Climate Change (2007a) asserts that recent scientific evidence reveals that the current level of greenhouse gases is above the level of natural variability and is primarily driven by human behaviour (as cited in Underwood, 2013). From this Premise, the Intergovernmental Panel on Climate Change (2007a) concluded with **very high confidence**[8] that the global average net effect of human activities on the climate since 1750 has been one of warming (as cited in Underwood, 2013). "Continual emittance of greenhouse gases at current rates would likely cause further warming and induce additional changes in the climate that would very likely be of greater magnitude than those already observed. The risk to human civilisation of this increased carbon emissions and warming are many and varied, but are certain to impose cost: psychological, social and economic" (Underwood, 2013). According to the Intergovernmental Panel on Climate Change (2007b), the most susceptible of industries and societies are "generally those in both coastal and river flood plains, those whose economies are linked with climate sensitive resources and those in areas prone to extreme weather events, especially where rapid urbanization is occurring" (as cited in Underwood, 2013). The limited adaptive capabilities and heavy reliance on resources that are very sensitive to changes in climate, such as food and water make poor communities the most vulnerable (Underwood, 2013). The likely adverse effect carbon emissions poses to the health status of millions of people all over the world, particularly countries with low adaptive capabilities, is one of the most serious costs of climate change (Underwood, 2013). However, climate change may offer some benefits, but the negative health effects will far exceed any potential benefits (Underwood, 2013).

According to World Health Organisation (WHO) and the United Nations Framework Convention on Climate Change (UNFCC) (2015), in 2013, 95% of rural population, 49% of urban population and 75% of national population used solid fuels for cooking. This has implication on the quality of air members of household breathe in. Air pollution in and around the home is largely a result of the burning of fossil fuels for cooking, heating, et cetera.

It is crystal clear that the increasing carbon emissions from anthropogenic activities such as energy consumption for cooking, heating, transportation, et cetera could cause ecological disaster, thereby placing potential costs on Nigerians and the economy as a whole. One of the sectors that seems most vulnerable to climate change is the agricultural sector. Like in any other economy, the agricultural sector is a component of the Nigerian economy whose performance is not only

[8] According to IPCC, very high confidence is a terminology that implies that the assertion is "at least 9 out of 10 chance of being correct"

determined by monetary and fiscal factors, but also by climatic factor. The sector is estimated to be the highest employer of labour and contribute the highest to the nation's Gross Domestic Product. In period 2010-2015, the sector contributed an average of 25.3% to the country's real Gross Domestic Product (CBN[9], 2015). According to Folawewo and Olakojo (2010), in the period 1996-2000 and 2001-2007, the average contribution of agricultural sector employment to total employment was 55.2% and 53% respectively. On the basis of sectoral contribution to employment and national output, the Nigerian economy can be said to be strongly tied to climate sensitive resources. In Nigeria, more than 50% of agricultural activities take place in the rural areas and this consequently make rural households the most vulnerable to climate change.

The potential adverse health effect associated with increasing carbon emissions is another issue of serious concern. Climate change such as increased temperature, flooding, drought and displacement, et cetera negatively impact agricultural production and cause breakdown in food system. These disproportionally affect those most vulnerable to hunger and can lead to food insecurity and nutritional crisis. The deterioration of air quality associated with increasing carbon footprint may provoke different types of respiratory diseases such as cystic fibrosis, lung cancer, emphysema, asthma, bronchitis, pneumonia, influenza, et cetera and reduce labour productivity. According to World Health Organisation (2012), in Nigeria, "57% of an estimated 130,900 child deaths due to acute lower respiratory infections is attributable to household air pollution (as cited in WHO and UNFCCC[10], 2015). According to WHO (2012), "50% of total deaths from ischemic heart disease, stroke, lung cancer, chronic obstructive pulmonary disease (18-year+) and acute lower respiratory infections (under 5years) are attributed to household air pollution" (as cited in WHO & UNFCCC, 2015). The rising level of the Earth temperature is yet another outcome of rising carbon footprint. On the overall, carbon emissions has the potential to reduce the quality of life and life expectancy of Nigerians. Falling aggregate output as a result of declining labour productivity and ill health could rear their ugly heads in the scheme of things in the face of uncontrolled or rising carbon footprint.

In conclusion, the thirst for sustainable development by countries has triggered wider discussion and concentration on the concept of "environment" as well as its quality. As a matter of fact, the recently launched Sustainable Development Goals (SDGs), otherwise known as the Global Goals, directly and indirectly included environmental quality as one of the needed recipes for achieving sustainable development by any country within the planetary boundaries. On this premise, understanding the determinants of Nigerian household direct carbon dioxide emission is a necessary condition in devising policies on alleviating climate change towards the achievement of sustainable development in Nigeria. This is the focal point of the research.

The broad objective of this research is to employ econometric technique to uncover socio-economic and demographic factors that influence the level of Nigerian household direct CO_2 emissions. In addition, the following specific objectives will be achieved: to examine the factors that influence urban and rural household's CO_2 emissions; to evaluate the level of direct CO_2 emissions in each sector (rural and urban); to evaluate the level of CO_2 emissions in each geopolitical zone; and to give policy advice to the government.

Unlike advanced countries, there is dearth of empirical investigations on developing countries' household carbon footprint. As Serino and Klasen (2015) assert, the few conducted studies for developing countries are usually from the major emitters like China and India. Nigeria is not

[9] Central Bank of Nigeria
[10] United Nations Framework Convention on Climate Change

considered a major emitter of greenhouse gases as evident by its share of global CO_2 emissions. However, it is important to investigate the determinants of its household CO_2 emissions for the sake of climate change mitigation policy. Adeoti and Osho (2011) in their study estimated only the carbon dioxide emissions associated with household kerosene consumption for lighting without recourse to examining factors that influence household energy consumption patterns and its associated carbon emissions. Hence the research fill the identified gap by examining the determinants of Nigerian household direct carbon dioxide emissions.

The study focuses only on the carbon dioxide (CO_2) component of the Kyoto basket of six gases and disregard other greenhouse gases. More so, the study is limited to CO_2 emissions from household direct energy consumption. Hence kerosene, petrol, liquefied petroleum gas, firewood, charcoal, electricity and diesel are the focused energies. In conclusion, the study examines a sample of four thousand five hundred and sixty households that domiciled within the borders of Nigeria.

2. LITERATURE REVIEW

2.1 *Review of Empirical Literature*

Wei, Liu, Fan and Wu (2007) found that approximately 26% of total energy consumption and 30% of CO_2 emissions are caused by residents' lifestyle in China. The study revealed that residents' lifestyle has significant impact on energy use and related CO_2 emissions. Kerkhof, Benders and Moll (2009) found that average households in the Netherlands and United Kingdom emitted higher amounts of CO_2 relative to average households in Sweden and Norway. It is also revealed that the carbon emission intensities of households' consumption decreased with increasing income in both the Netherlands and the United Kingdom, whereas it increased in Norway and Sweden. Comparison of the national results revealed that country's characteristics like energy supply, population density and the availability of district heating influenced variations in household CO_2 emissions between and within countries. Adeoti and Osho (2011) found that average CO_2 emissions from kerosene combustion for lighting in Nigeria is about 0.06 kg per hour per lamp. The researchers also found that $3\times10W_p$ solar pv is required to replace a kerosene lamp, while about 0.124 tons of CO_2 would be avoided per lamp per year. At the national level, under the kerosene lamp replacement projection assumptions made, between 0.4 and 1.0 million tons of CO_2 would be avoided per year. Findings also revealed that the household investment required to own a solar pv including the capital cost of switching from kerosene lamp is about US$ 356, while the national capital investment outlay is between US$1,138.265 and US$2,848. They also found that assuming the CO_2 saved is to be traded, it will magnet a significant annual revenue on the order of 6.96 million to almost US$ 17.4 per annum. Liu, Wu, wang and Wei (2011) found that population, per capita household consumption and urbanization level have significant positive impact on the growth of household CO_2 emissions. However, carbon emission intensity decline reduce the growth of household carbon emissions. Wu, Liu and Tang (2012) in their study, found that family size, household income and educational level have statistically significant impact on household CO_2 emissions. However, in terms of direction of relationship, family size is positively related to household CO_2 emissions, while family income and educational level are found to be negatively related to household CO_2 emissions. The authors' argument for the negative nexus is that when household income increases, household tends to search for better energy sources as explained by the energy ladder hypothesis. Jaiswal and Shah (2013) in their study, found that households do not differ significantly in their carbon footprints due to age, education and family income. However, the research also revealed that carbon footprints of the households vary significantly with their personal income, family size, employment status and type of family. Wang and Yang (2014) found that for urban residents' indirect CO_2 emissions is on the rise. The estimated regression model revealed that urbanization level, per capita income and industrialisation level have positive effect on urban household CO_2 emissions, but negatively influenced by energy intensity and Engel coefficient. For the rural households, the indirect CO_2 emissions is on the decline. Empirical findings showed that Engel coefficient, energy intensity and industrialization level have positive impact on rural household CO_2 emissions, but negatively influenced by urbanization level and per capita income. Lee and Lee (2014) in their study, found that population-weighted density, centrality, and transit subsidy have significant negative impact on household carbon emissions, while population size has an insignificant positive impact on household GHG emissions within the study period. Also, Polycentricity is found to have significant positive impact on household carbon emissions. Han, Xu and Han (2014) found that employment has a significant negative impact on per capita HECEs (household embedded carbon emissions), unemployment has a significant negative effect on per capita HECEs, retired has a significant negative impact on per capita HECEs, beingeducated has a significant negative impact on per capita HECEs, preschool has an insignificant positive impact on per capita HECEs, marry has an insignificant negative impact on per capita HECEs, gender has an insignificant positive impact on per capita HECEs, education has a significant positive impact on per capita HECEs, net income has a significant positive impact on per capita HECEs, expected income has a significant positive impact on per capita HECEs, deposit has a significant positive impact on per capita HECEs, ownhouse has a significant negative impact on per capita HECEs and owncar has a significant positive impact on per capita HECEs. Das and Paul (2014) found that activity coefficient, structure coefficient and population are the main cause of increased CO_2 emissions from household fuel consumption. It is also revealed that energy intensity has gone down by 60% within the period of study. Sharaai, Mokhtar, Jin and Azali (2015) in their study, found that electricity consumption and transportation have significant positive impact on household CO_2 emissions, while income has an insignificant positive impact on carbon emissions. Household size has an insignificant negative impact on the dependent variable. Ahmad, Baiocchi and Creutzig (2015) in their study, divided emissions in India according to their sources: electricity use, private transport and cooking. The results revealed that income is positively correlated with all types of emissions. Household size is negatively correlated with all types of emissions except private transport. Urban density is negatively correlated with emissions except for cooking fuels emissions. Xu, Tan, Chen, Yang and Su (2015) in their study, found a significant negative correlation coefficients between household CO_2 emissions, age, age squared, male ratio and dependency ratio. While household size, employment ratio, living area, perceived measures, distance and household CO_2 emissions have significant positive correlation coefficients. The results of the conducted Analysis of Variance (ANOVA) test revealed that the mean household CO_2 emissions among different urban households vary significantly in terms of household head educational attainment, car-holdings, household income, energy saving, energy saving awareness, city location and household head occupation. The estimated model and statistical test revealed that age, male ratio, household size, dependency ratio, income, car-holdings, living area and city location have significant positive impact on household carbon emissions. On the other hand, age squared, energy saving and distance have significant negative impact on the variable of interest. All the categories of occupation except high-end occupation have insignificant negative impact on household carbon emissions. The advanced Diploma/university degrees category of education has insignificant positive impact, while junior to senior high school category has insignificant negative impact on the variable of interest. Li, Zhao, Liu and Zhao (2015) in their study, found a unidirectional causal relationship between the independent variable and the dependent variables with causation running from urbanisation to direct and indirect household carbon dioxide emissions. As revealed by the estimated models and statistical test, urbanisation is found to have significant positive effect on direct and indirect household CO_2 emissions. Qu, Maraseni, Liu, Zhang and Yusaf (2015) found that urban household emit CO_2 than rural household within the period of study. Statistically, in 1995, per capita household carbon emissions from direct sources for urban and rural households were 0.5 tCO_2 and 0.22 tCO_2 respectively. In 2011, these values had increased to 20% and 177.27% respectively. Similarly, in 1995, per capita household carbon emissions from indirect sources were 0.43 tCO_2 and 0.16 tCO_2 respectively. In 2011, these values had increased by 306% and 235% respectively. The result of the regression model showed that per capita income has positive impact on per capita urban household carbon emissions, while household size has negative impact on per capita urban household carbon emissions. On the rural side, per capita income has positive impact on per capita rural household CO_2 emissions, while household size has negative impact on per capita rural household CO_2 emissions. The negative impact of household size on both per capita urban and rural households' carbon emissions was suggested to be the implication of economies of scale of energy use within the household. The per capita income and household size are responsible for 99.7% variations in the per capita urban household carbon emissions, while per capita income and household size are responsible for 98.9% variations in the per capita rural household carbon emissions. Serino and Klasen (2015) in their study, found that on the average, households emitted 1.46 tons of CO_2 in year 2000 and it increased to 1.86 tons in year 2006. The household emissions was further disaggregated into income quintiles. The Results showed that in year 2000, households in the poorest income quintile emitted an average of 0.10 tons of CO_2 per capita, while households in the richest income quintile emitted an average of 0.77 tons of CO_2 per capita. In year 2006, households in the poorest income quintile released 0.12 tons of CO_2 per capita, while households in the richest income quintile emitted an average of 1.02 tons of CO_2 per capita. The estimated cross section regression model showed that income has significant positive impact on household CO_2 emissions, although, its elasticity coefficient is less than one. Age, year 2006, household size, urban lifestyle, educational level of the household head, married household head, electricity access and floor area have significant positive impact on household CO_2 emissions, while male headed household, widowed household head, income squared and age squared have significant negative impact on household CO_2 emissions. Li, Huang, Yang, Chuai, li and Qu (2016) found that urbanization level, carbon intensity, age structure and per capita income have significant positive impacts on per capita household CO_2 emissions. However, July average temperature, January average temperature and total household population have negative impacts on per capita household CO_2 emissions. The July average temperature does not have statistical significant impact on the dependent variable. Wang and Yang (2016) estimated total emissions to be 10.5 Mtc in year 2000, 20.12 Mtc in year 2002, 25.84 Mtc in year 2007 and 21.35 Mtc in year 2010. It was found that emission coefficient effect, intermediate demand effect, per capita GDP effect and the population size effect have positive effects on the growth of indirect household CO_2 emissions. It was also noted through the findings that per capita GDP has the highest effect, while intermediate demand effect has the lowest positive effect on indirect household CO_2 emissions. On the other hand, energy intensity effect; residential consumption rate effect; consumption structure effect and the rural and urban residential consumption rate effect have negative impacts on the growth of indirect CO_2 emissions.

It was also noted that the energy intensity effect played the dominant role in indirect household CO_2 emissions reduction.

2.2 Review of Methodology

Wei et al. (2007) employed the consumer lifestyle approach (CLA) to analyse the impact of lifestyle of urban and rural residents on the energy use and the related CO_2 emission in China. The direct CO_2 emissions from household energy consumption was calculated using the linear multiplier factor method and the indirect CO_2 emissions was calculated by multiplying the carbon emission intensity of each sector by its corresponding consumption expenditure. The study also used descriptive statistics to present data on variables that are relevant to the study. Kerkhof et al. (2009) adopted a hybrid approach of physical chemical process and economic input-output analysis to determine the country specific carbon emission intensity of each sector. The carbon emission intensity of each sector was then linked to the national data on consumption expenditures to estimate average household CO_2 emissions in each country. Descriptive statistics was also employed to present data on variables that are relevant to the study. Adeoti and Osho (2011) obtained data on household kerosene lamp fuel consumption through questionnaire survey, direct measurement and method triangulation. An emission factor of 3.15 kg CO_2 per litre of kerosene was employed to estimate the average amount of CO_2 emissions. The cost of solar pv equipment was obtained from market source, while installation cost was estimated. The annual worth cost (awc) model was specified to estimate the profitability of the replacement strategy. The awc comprises the present worth cost, the minimum attractive rate of return, the economic life and the capital recovery factor obtained from the interest rate table. Descriptive statistics were also employed to present data on variables relevant to the study. Liu et al. (2011) employed the input-output method to estimate the indirect CO_2 emission from household consumption. The direct CO_2 emission from household consumption was calculated using the Intergovernmental Panel on Climate Change. The logarithmic mean divisia index (LMDI) method was employed to decompose the effects of changes in the identified independent variables on indirect CO_2 emissions from household consumption. Jaiswal and Shah (2013) employed the service of an online standard carbon emission calculator to estimate or compute the carbon footprint of each household under study. Descriptive statistics was used to analyse the data. Wu et al. (2012) conducted their study using the stratified random sampling technique with a semi structured questionnaire as the research instrument. To obtain the CO_2 emissions of each energy source, the Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories standard emission factors were utilized. The Tukey's HSD (honest significance difference) test was used to compare the means of different parameters, and a multiple linear regression model was built to analyse the impact of identified factors on household CO_2 emission. Wang and Yang (2014) calculated the indirect CO_2 emission from household energy consumption by aggregating the product of carbon emission intensity of each sector by its corresponding consumption expenditure. The industrialisation level was measured by the ratio of the share of secondary industry output to value of Gross Domestic Product. The STIRPAT (Stochastic Impacts by Regression on Population, Affluence and technology) was employed to analyse the impacts of the identified factors on indirect household CO_2 emissions. The model was estimated using partial least square estimation technique. Descriptive statistics was also utilised to analyse data on certain variables. Lee and Lee (2014) adopted the multilevel structural equation model (SEM) to empirically analyse the effect of urban form on household greenhouse gas emissions in the United States of America. In addition to the econometric approach, the study employed descriptive statistics to present data on some variables. Han et al. (2014) calculated the embedded carbon emissions using the input-output expenditure method. Both the ordinary least squares regression model and quantile regression were employed to ascertain the determinants of per capita household embedded carbon emissions (HECEs) within the study period. Das and Paul (2014) in their study, employed the input-output approach to estimate both the direct and indirect CO_2 emissions from household energy consumption. The decomposition method proposed by Sun (1998) was utilised to evaluate the impact of each factor on household CO_2 emissions. The pollution coefficient was defined as the ratio of CO_2 emitted to the amount of energy consumed. Energy intensity coefficient was defined as the ratio of energy consumed to the household consumption expenditure. Activity coefficient was defined as the ratio of total household consumption expenditure to population. Structure coefficient was defined as the ratio of household consumption expenditure for a particular category to the total household consumption. Sharaai et al. (2015) employed the structural equation modelling (SEM) to evaluate the impact of identified independent variables on household CO_2 emission in Penang, Malaysia. Ahmad et al. (2015) employed a panel data model to evaluate the impacts of identified factors on household CO emissions among urban households within the period of study. The ordinary least squares estimation technique was used to estimate the parameters in the model. The decision of which model (fixed effects or random effects) to settle down with was influenced by the Hausman test conducted. Chow test was performed to evaluate whether city specific effects should be considered. Li et al. (2015) in their study, estimated indirect household CO_2 emissions using input-output method and the direct household CO_2 emission using Linear Multiplier Factor Method. The research employed Augmented Dickey-Fuller test (ADF) to examine the stationarity status of the series in the model. Furthermore, to know the direction of causal relationship between the variable of interest and the explanatory variables, Granger causality test was employed. The optimal lag length for the ADF test was determined using Schwarz Information Criterion (SIC) and Akaike Information Criterion. The specified time series econometric model was estimated using Ordinary Least Squares (OLS) estimation technique. Descriptive statistics was also used to present data on variables that are relevant to the study. Qu et al. (2015) in their study, decomposed household CO_2 emissions into direct and indirect CO_2 emission from household energy consumption. The direct CO_2 emission was estimated using the Intergovernmental Panel on Climate Change (IPCC's) reference approach, while the indirect CO_2 emission was estimated using the input-output analysis approach. A linear regression model was set up to analyse the impact of identified factors on urban and rural household per capita carbon emissions in China. Xu et al. (2015) estimated household carbon emissions using the IPCC reference approach. Pearson correlation analysis was employed to evaluate the degree of relationship between household carbon emissions and various household characteristics. Analysis of Variance (ANOVA) test was conducted to ascertain the statistical significance of variations in average household carbon emissions. In addition, a cross section linear regression model was employed to analyse the survey data. The parameters of the model was estimated using Ordinary Least Squares (OLS) technique. Serino and Klasen (2015) estimated carbon emissions from household consumption using input-output expenditure approach. To empirically evaluate the impacts of identified socio-economic and demographic factors on household CO_2 emissions, a cross section linear multiple regression model was specified. Ordinary Least Squares (OLS) estimation technique was used to estimate the parameters in the model. In addition to the econometric analysis, the study also employed the service of descriptive statistics to present data on variables that are relevant to the study. Li et al. (2016) decomposed household CO_2 emission into direct and indirect carbon emissions. The direct CO_2 emission was calculated using the IPCC reference method. The indirect CO_2 emission was estimated using the input-output method and consumer lifestyle approach. The spatial econometric model was employed to analyse the influence of identified factors on per capita household CO_2 emission. The akaike information criterion was adopted for model selection. The variance inflation factor (VIF) and condition index were utilised to test for the existence of multicollinearity in the model. Wang and Yang (2016) decomposed household CO_2 emissions into direct and indirect CO_2 emissions. The direct CO_2 emissions from household consumption was estimated by multiplying carbon emission factor of each energy source by its corresponding amount consumed. The indirect CO_2 emissions from household consumption was estimated using the input-output and consumer lifestyle approach. The logarithmic Mean Divisia Index (LMDI) was employed to analyse the impacts of identified factors on CO_2 emissions from household consumption within the period of study in Beijing. Descriptive statistics were also utilised in the study.

3. Methodology

3.1 Study Area

Nigeria is an agrarian economy located in the western region of Africa. It covers a total area of 923, 768 km^2. Its total area comprises land (910, 768 km^2) and water (13, 000 km^2). It is bordered by Benin republic in the west, Niger republic in the north, Gulf of Guinea in the south, and Chad and Cameroon in the east. With approximately 185 million population according to the National Population Commission (2018), the country is regarded as the 7th most populous in the world and the 1st in Africa. The country is divided into six geo-political zones, which are: south-south; south east; south-west; north-east; north-central and north-west. Each zone comprises rural and urban areas. A larger percentage of its population lives in rural areas. Its rural population (% of total population) is 51.4% in 2016 (World Bank World Development Indicators, 2016).

3.2 Estimating Direct CO_2 emissions from Household Energy Consumption

Direct CO_2 emissions can be viewed as the carbon footprint from direct consumption of energies in household activities such as cooking, lighting, transportation, et cetera. The Linear Multiplier Factor Method is employed to estimate the carbon dioxide emissions from household energy consumption. First, each energy usage amount is multiplied by its corresponding carbon emission coefficient or factor, and then added to get the total direct carbon emissions of the ith household. The estimation model for direct carbon emissions from household energy consumption is expressed as follows:

$$DC_i = \sum_{k}^{n} CF_k \cdot A_k$$

$Where$:

$CF_k = Carbon\ emission\ factor\ of\ k^{th} energy$

$A_k = Amount\ of\ the\ k^{th}\ energy\ consumed$

$DC_i = Direct\ carbon\ dioxide\ emissions\ of\ the\ i^{th}\ household$

$$\sum_{i}^{z} DC_i = Total\ direct\ carbon\ emissions$$

3.3 Theoretical Framework

The theoretical environmental Kuznets curve model adopted was developed by Andreoni, J. and Levinson, A. in 2001. The AL model approaches the EKC from a consumer standpoint and assumes increasing returns to pollution abatement.

Consider a representative agent whose utility function depends on the consumption of one private good, C, and on a bad good called pollution, P. The preferences can be expressed as:

$U = U(C, P\ ) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$ 1

Where $\frac{\delta U}{\delta C} > 0$ and $\frac{\delta U}{\delta P} < 0$, and U(C, P) is quasiconcave in C and −P and both arguments (C, −P) are normal goods. Suppose that the representative agent has a means by which he can alleviate pollution by spending resources either to clean it up or, equivalently, to prevent it from happening at all. Let environmental effort, E, be the resources available to do so. Pollution then becomes a positive function of consumption and a negative function of environmental effort.

$P = P(C, E)$ 2

Where $\frac{\delta P}{\delta c} > 0$ and $\frac{\delta P}{\delta E} < 0$. Suppose the representative agent has an endowment, Y, of resources which can be spent on C and E. For simplicity, the relative costs of consumption and environmental effort are normalized to 1. The resource constraint becomes:

$Y = C + E \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$ 3

Suppose:

$U = C - zP \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$ 4

$P = C - C^{\alpha}E^{\beta} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$ 5

Where U is the utility function and P is the pollution function. Eq. (4) is linear and additive in C and P, z > 0 is the constant marginal disutility of pollution. The first term of Eq. (5), C, is the gross pollution before abatement and is directly proportional to consumption. The second term of Eq. (5), $C^{\alpha}E^{\beta}$, represents abatement. Eq. (5) indicates that consumption causes pollution one-for-one, but resources spent on environmental efforts abate pollution with a standard concave production function.

Suppose z = 1, substituting the pollution function into the utility function implies the individual is maximizing $C^{\alpha}E^{\beta}$ subject to Y = C + E, hence consumption and environmental effort have standard Cobb-Douglas solution:

$Max.(C, E): U = \ C^{\alpha}E^{\beta} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$ 6

$Subject\ to: C + E = Y$

$Solution$:

$U = C^{\alpha}E^{\beta} - \pi(M - C - E) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$ 7

$$\frac{\delta U}{\delta C} = \ \alpha C^{\alpha-1}E^{\beta} + (-1)\pi = 0 \quad First\ Order\ Condition$$

$$\pi = \ \alpha C^{\alpha-1}E^{\beta}$$

$$\frac{\delta U}{\delta E} = \ \beta C^{\alpha}E^{\beta-1} + (-1)\pi = 0 \quad First\ Order\ Condition$$

$$\pi = \ \beta C^{\alpha}E^{\beta-1}$$

$$Setting\ \alpha C^{\alpha-1}E^{\beta} = \beta C^{\alpha}E^{\beta-1} gives\ \ C = \frac{\alpha E}{\beta}\ and\ E = \frac{C\beta}{\alpha}$$

$$Substituting\ \frac{\alpha E}{\beta}\ and\ \frac{C\beta}{\alpha}\ into\ Eq.3\ gives:$$

$$E^* = \frac{\beta}{\alpha+\beta}Y$$

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

C^* *and* E^* *are the optimal consumption and environmental effort that maxize utility*

Substituting C^**and* E^* *into Eq.* 5 *gives*:

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

The above expression gives the Environmental Kuznets Curve.

The derivative of $P^*(Y)$ represents the slope of the EKC curve:

$$\frac{\delta P^*}{\delta Y} = \frac{\alpha}{\alpha+\beta} - (\alpha+\beta)\left(\frac{\alpha}{\alpha+\beta}\right)^{\alpha}\left(\frac{\beta}{\alpha+\beta}\right)^{\beta} Y^{\alpha+\beta-1}$$

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

If $\alpha + \beta = 1$, *effort spent abating pollution has constant returns to scale, and* $\frac{\delta P^*}{\delta Y}$ *is constant. Then* P^* *rises with* Y *without a downward sloping portion of the pollution income curve.*

If $\alpha + \beta < 1$, *effort spent abating pollution exhibits decreasing returns to scale such that* $P^*(Y)$ *convex.*

If $\alpha + \beta > 1$, *effort spent abating pollution exhibit increasing returns to scale such that* $P^*(Y)$ *is concave. This is the EKC curve.*

3.4 Model Specification

According to Boulding (1966), theories without facts may be barren, but facts without theories are meaningless. In reaction to this, the environmental Kuznets curve hypothesis is the theoretical foundation of the model specified below. The EKC identifies economic progress (income) as the principal determinant of indicators of environmental degradation. However, at the household level, other socio-economic and demographic factors may play an important role in explaining the dynamics of Nigerian household carbon emissions. The introduced explanatory variables are: household size; age of household head; motorization; household male population; literacy ratio; household head gender; and polygamy status.

The model is specified explicitly as follows:

$$Ln(CE_i) = \beta_0 + \beta_1 HH\_Income_i + \beta_2 HH\_Income_i^2 + \beta_3 Age_i + \beta_4 Age_i^2 + \beta_5 Lit\_Ratio_i + \beta_6 Motorisation_i + \beta_7 Male\_Pop_i + \beta_8 HH\_Gender_i + \beta_9 HH\_Size_i + \beta_{10} Polygamy_i + U_i$$

$Where$:

$(CE_i) = Carbon\ emissions\ \ of\ the\ i^{th}\ household$

$HH\_Income_i = \ Income\ of\ the\ i^{th} household$

$HH\_Size_i = Number\ of\ individuals\ in\ the\ i^{th} household$

$Age\ _i = \ Age\ of\ the\ i^{th}\ household\ head$

$Male\_Pop_i \ = \ Male\ population\ of\ the\ i^{th}\ household$

$HH\_Gender_i \ = \ Gender\ of\ the\ i^{th}\ household\ head$

$Polygamy_i \ = \ Polygamous\ status\ of\ the\ i^{th}\ household$

$Lit\_Ratio_i = \ Literacy\ ratio\ of\ the\ i^{th}\ household$

$Motorisation_i \ = \ Number\ of\ vehicles\ owned\ by\ the\ i^{th}\ household$

$ln \ = \ Natural\ logarithm\ (log_e)$

$U_i \ = \ Error\ term\ of\ the\ i^{th}\ household$

3.5 Description of variables

Variables	Definitions
Household size	The number of individuals that make up the household
Household income	Household's total income in naira
Age	Age of household head
Male population	Total number of males in the household
Literacy ratio	The ratio of household members that can read and write in any language to total number of household members (0, 1)
Motorisation	Total number of vehicles owned by the household **Note:** A vehicle is a mobile machine that transports people or cargo. Pollution intensive vehicles used other than bicycle are the focus
Polygamy	The state of household head having more than one wife. Assign 1= if household head is polygamous and 0 = if otherwise
Household head gender	The sex of household head. Assign 1 = if household head is male and 0 = if otherwise

Note: (0, 1) implies that the value lies within 0 to 1

3.6 A priori Expectation

Sequel to the explicitly specified cross section log-linear econometric model, the parameters in the model are expected to behave as follows:

$\beta_0 >$[11] $0, \beta_1 > 0, \beta_2 <$[12] $0, \beta_3 > 0, \beta_4 < 0, \beta_5 < 0, \beta_6 > 0, \beta_7 > 0, \beta_8 > 0$, $\beta_9 > 0$ and $\beta_{10} > 0$

3.7 Data Requirements and Sources

For this research, data on household socio-economic and demographic characteristics were obtained from the 2015 National Bureau of Statistics General Household Survey and data utilised for the trend analysis were obtained from the 2017 International Energy Statistics (IES) monthly update and Olivier et al. (2016). For the estimation of household direct carbon footprint using the Linear Multiplier Factor Method, the required carbon emission factors were obtained from the United States of America Environmental Protection Agency (EPA) website as well as related journal articles. In conclusion, the kilogram price of firewood was obtained from the Cocoa Research Institute of Nigeria (CRIN[13]) website and that of charcoal through interview from its sellers.

4. RESULTS AND DISCUSSION

4.1 Demographic Characteristics of Nigerian Household

Table A below shows the demographic characteristics of Nigerian household across sectors, regions and at the National level. The demographic characteristics under consideration are household size, male population, female population and age of household head.

Table 2: Demographic Characteristics of Nigerian Household across Zones

Region/Sector/National	Household Size		Male Population		Female Population		Age of H/Head	
	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
Rural	7.5	3.62	3.69	2.17	3.81	2.23	52.83	14.64
Urban	6.45	3.32	3.13	2.03	3.31	1.97	52.83	14.5
South-West	5.72	2.98	2.76	1.81	2.96	1.83	54.97	15.02
South-South	6.9	3.15	3.34	1.93	3.56	2.05	52.65	14.92
South-East	5.97	2.97	2.79	1.76	3.18	1.87	58.57	14.1
North-West	8.46	3.45	4.27	2.18	4.2	2.22	50.21	13.74
North-East	8.99	4.36	4.52	2.59	4.47	2.52	49.54	13.22
North-Central	7.03	3.25	3.44	1.91	3.59	2.11	50.98	14.45
National	7.16	3.56	3.51	2.14	3.65	2.17	52.83	14.59

Source: Author's Computation from 2015 General Household Survey

[11] > Implies positive relationship
[12] < Implies negative relationship
[13] CRIN Website: www.crin-ng.org/index.php/services

Note: Household expenditure is used to proxy household income. It is also squared to evaluate the validity of environmental Kuznets curve at household level in Nigeria

The above Table presents numerical information on the demographic characteristics of Nigerian household. The statistics show that the average household size of a rural household is 7.5 persons while that of an urban household is 6.45 persons. On the average, male and female population of a rural household are 3.69 and 3.81 persons respectively while that of an urban household are 3.13 and 3.31 persons respectively. The average age of a rural household head is 52.83 years while that of an urban household head is 52.83 years. At the regional level, household size, male and female population of a household in the south-west are 5.72, 2.76 and 2.96 persons respectively. In the south-west, the average age of household head is 54.97 years. On the average, household size, male and female population of a south-south household are 6.9, 3.34 and 3.56 persons respectively. In the South-South, the average age of household head is 52.65 years. On the average, household size, male and female population of a south-east household are 5.97, 2.79 and 3.18 persons respectively. In the south-east, the average age of household head is 58.57 years. In the north-west, on the average, the household size, male and female population of a household are 8.46, 4.27 and 4.2 persons respectively. The average age of a household head in the north-west is 50.21 years. In the north-east, household size, male and female population are 8.99, 4.52 and 4.49 persons respectively. In the north-east, the average age of household head is 49.54 years. In the north-central, household size, male and female population are 7.03, 3.44 and 3.59 persons respectively. In the north-central, the average age of household head is 50.98 years. At the National level, household size, male and female population are 7.16, 3.51 and 3.65 persons respectively. The average age of household head in Nigeria is 52.83 years. Comparatively, the north-east has the highest household size relative to other regions. Household head in the south-east has the highest age relative to household head in other regions.

4.2 Summary Statistics of Nigerian Household Carbon Dioxide Emissions across Zones

The Table below presents statistics of Nigerian household carbon emissions across regions, sectors and at the National level.

Table 3: National, Regional and Sectoral Mean Carbon Emissions

Region/Sector/National	Household Carbon Emissions (kg CO_2)	
	Mean	Standard Deviation
Rural	304.72	514.49
Urban	458.99	898.45
South-West	274.77	476.92
South-South	352.5	734.52
South-East	213.49	367
North-West	515.55	656.46
North-East	487.31	1111.28
North-Central	274.99	379.54
National	353.71	664.82

Source: Author’s Computation from 2015 General Household Survey

In Table 3 above, the mean carbon emissions of rural household is 304.72 kg CO_2 while that of urban household is 458.99 kg CO_2. This implies that urban household lives a more carbon intensive lifestyle relative to rural household. At the regional level, the mean carbon emissions of south-west, south-south, south-east, north-west, north-east and north-central household are 274.77 kg, 352.5 kg, 213.49 kg, 515.55 kg, 487.31 kg and 274 kg CO_2 respectively. At the national level, the household average carbon emissions is 353.71 kg CO_2. Comparatively, north-east household has the highest mean carbon emissions relative to household in other regions. This speaks volume of the differences in household energy consumption patterns across the six geo-political zones.

4.3 Summary Statistics of urban and rural households Carbon Emissions

The Table below provides information on urban and rural households mean carbon emissions across the six geo-political zones in Nigeria.

Table 4: Urban and Rural Households Mean Carbon Emissions

Regions	Sectors	
	Urban Household (Kg CO_2)	Rural Household (Kg CO_2)
South-West	291.78	236.74
South-East	283.92	187.32
South-South	566.95	250.79
North West	754.16	464.61
North-East	1059.32	377.39
North-Central	417.71	220.15

Source: Author's Computation from 2015 General Household Survey

In Table 4 above, the mean carbon emissions of urban household in the south-west is 291.78 kg CO_2 while that of rural household is 236.73 kg CO_2. In the south-east, the mean carbon emissions of urban and rural households are 283 kg CO_2 and 187.32 kg CO_2 respectively. The mean carbon emissions of urban and rural households in South-South are 566.95 kg CO_2 and 250.79 kg CO_2. In the north-west, the mean carbon emissions of urban household is 291.78 kg CO_2 while that of rural household is 464.61 kg CO_2. In the north-east, the mean carbon emissions of urban and rural households' are 1059.32 kg CO_2 and 377.39 kg CO_2 respectively. The mean carbon emissions of urban and rural households in the north-central are 417.71 kg CO_2 and 220.15 kg CO_2 respectively. In conclusion, on the average, household in urban areas live a relatively high carbon intensive lifestyle relative to households in rural areas.

4.3 National and Sectoral Determinants of Household Carbon Emissions

Table 5 below shows the determinants of household carbon emissions at the national level. The explanatory variables examined are household income, household size, household head age, literacy ratio, household head polygamous status, motorisation, household head gender and male population.

Table 5: Determinants of Nigerian Household Direct CO_2 Emissions

Variables	Coefficients		
	National	Urban[14]	Rural[15]
HH_Income	$8.84\times10^{-6***}$ (6.83×10^{-7})	$9.67\times10^{-6***}$ (1.01×10^{-6})	$1.96\times10^{-5***}$ (1.49×10^{-6})
HH_Income^2	$-1.37\times10^{-12***}$ (1.08×10^{-13})	$-1.49\times10^{-12***}$ (1.54×10^{-13})	$-1.46\times10^{-11***}$ (1.19×10^{-12})
HH_Size	0.0492^{***} (0.0107)	0.1061^{***} (0.1742)	0.0214^{*} (0.0128)
Age	0.0097 (0.0086)	0.0264^{*} (0.0139)	0.0042 (0.0104)
Age^2	$-1.28\times10^{-4*}$ (7.75×10^{-5})	-0.0003^{*} (0.0001)	-8.32×10^{-5} (9.34×10^{-5})
HH_Gender	0.2289^{***} (0.0536)	0.1622^{*} (0.0759)	0.2882^{***} (0.0687)
Polygamy	0.0202 (0.06)	0.0704 (0.1134)	0.0880 (0.0688)
Lit_Ratio	0.2133^{***} (0.0585)	-0.0037 (0.1077)	-0.0192 (0.0713)
Motorisation	0.0934^{***} (0.0272)	0.2398^{***} (0.0408)	-0.052198 (0.0344)
Male_Pop	0.001 (0.0167)	-0.0207 (0.0291)	0.018 (0.0199)
Constant	3.9992^{***} (0.2308)	3.6216^{***} (0.3606)	4.1684^{***} (0.2808)
Observations	4560	1448	3112
R-squared	0.0988	0.2506	0.0913
F_cal	49.85 {0.0000}	48.06 {0.0000}	31.16 {0.0000}

Note: Standard errors are presented in round brackets
Probability values are presented in curly brackets
$^{***}p < 0.01$; $*p < 0.05$; $^{*}p < 0.10$

The results of the estimated econometric model presented in Table 5 above are analysed sequentially below:

- ❖ Household Carbon Emissions and Household Income

The regression results show that household income has statistically significant positive impact on household carbon emissions ($\beta = 8.84\times10^{-6}$, $p < 0.01$). The positive sign of the interaction term

[14] Note: Coefficients of urban household econometric model are not explained but only presented

[15] Note: Coefficients of rural household econometric model are not explained but only presented

implies that household carbon emission is an increasing function of household income. Holding other factors constant, a naira increase in household income will cause 8.84×10^{-4} percent increase in household carbon emissions. This result is reported in similar studies conducted by Serino and Klasen (2015), Xu et al. (2015), Sharaai et al. (2015), Han et al. (2014) and Li et al. (2016).

- Household Carbon Emissions and Household Size

The regression results show that household size has statistically significant positive impact on household carbon emissions ($\beta = 0.0492$, $p < 0.01$). The positive sign of the coefficient implies that household carbon emissions level is an increasing function of household size. Assuming other factors remain unchanged, a one person increase in household size will cause 4.92 percent increase in household CO_2 emissions. This result is reported in similar studies conducted by Serino and Klasen (2015) and Xu et al. (2015), but in contrast to Sharaai et al. (2015) and Li et al. (2016).

- Household Carbon Emissions and Age of Household Head

The regression results reveal that age of the household head has statistically insignificant positive effect on household carbon emissions ($\beta = 0.0097$, $p > 0.1$). The positive sign of the interaction term implies that household carbon emissions level is an increasing function of household head age. Holding other factors constant, a one year increase in age of household head will cause 0.97 percent increase in household CO_2 emissions. Since the probability value is greater than the level of significance (10%), it is concluded that the effect of the increase on household carbon emissions is not statistically different from zero.

- Household Carbon Emissions and Household Head Gender

The regression results show that gender of household head has statistically significant positive impact on household carbon emissions ($\beta = 0.2289$, $p < 0.01$). The positive sign of the interaction term implies that the level of household carbon emissions is being raised by the gender of household head. Holding other factors constant, the movement of household head gender from 0 to 1 will cause 25.72 percent increase in household carbon emissions. This result is consistent with similar study conducted by Han et al. (2014) but in contrast to study conducted by Serino and Klasen (2015).

- Household Carbon Emissions and Polygamy

Surprisingly, the regression results show that polygamous status of household head has statistically insignificant positive impact on household carbon emissions ($\beta = 0.0202$, $p > 0.1$). The positive sign of the coefficient implies that household carbon emissions level is being raised by polygamous status of the household head. Holding other factors constant, the movement of household head polygamous status from 0 to 1 will cause household carbon emissions to increase by 2.04 percent. Since the probability value is greater than the level of significance (10%), it is concluded that the impact of the increase on household carbon emissions is not statistically different from zero.

- Household Carbon Emissions and Literacy Ratio

The regression results show that literacy ratio of household has statistically significant positive impact on household carbon emissions ($\beta = 0.2133$, $p < 0.01$). Paradoxically, household carbon emissions level is an increasing function of household literacy ratio. Holding other factors constant, a one unit increase in literacy ratio will cause 21.33 percent increase in household carbon emissions. This result is in contrast with similar study conducted by Han et al. (2014).

❖ Household Carbon Emissions and Motorisation

The regression results show that motorisation has statistically significant positive impact on household carbon emissions ($\beta = 0.0934$, $p < 0.01$). The positive sign of the interaction term implies that household carbon emissions level is an increasing function of motorisation. Holding other factors constant, a one unit increase in household vehicle stock will cause house carbon emissions to increase by 9.34 percent. This result is consistent with similar studies conducted by Han et al. (2014).

❖ Household Carbon Emissions and Male Population

The regression results show that male population has statistically insignificant positive impact on household carbon emissions ($\beta = 0.001$, $p > 0.1$). The positive sign of the interaction term implies that household carbon emissions level is an increasing function of household male population. Holding other factors constant, increase in household population by one male will cause 0.1 percent increase in household carbon emissions. Since the probability value is greater than the level of significance (10%), it is concluded that the effect of the increase on household carbon emissions is not statistically different from zero. This result is consistent with similar study conducted by Xu et al. (2015).

❖ Household Carbon Emissions and Household Income-squared

The regression results show that household income has statistically significant nonlinear effect on household carbon emissions ($\beta = -1.37\times10^{-12}$, $p < 0.01$). The negative sign of the coefficient denotes inverted U-shaped relationship between household carbon emissions and household income. By implication, household carbon emissions level will increase with household income to a maximum point (turning point), beyond which further increase in income will lead to significant decline in household carbon emissions. This result confirms the validity of environmental Kuznets curve (EKC) hypothesis at the household level. Be that as it may, this result is consistent with similar study conducted by Serino and Klasen (2015).

❖ Household Carbon Emissions and Age-squared

The regression results show that age of household head has statistically significant nonlinear impact on household carbon emissions ($\beta = -1.28\times10^{-4}$, $p < 0.01$). The negative sign of the interaction term denotes inverted U-shaped relationship between household carbon emissions and household head age. By implication, household carbon emissions level will increase with age of household head to a particular point (turning point), beyond which further increase in age will lead to significant decline in household carbon emissions. Preferences and consumption patterns of household members do not only change with income, but with age as well. This result is consistent with similar studies conducted by Serino and Klasen (2015) and Xu et al. (2015).

❖ Household Carbon Emissions and Intercept Coefficient

The results show that the intercept coefficient of the model is statistically significant and positive ($\beta = 3.9992$, $p < 0.01$). This implies that if all the explanatory factors are zero, household carbon emissions will be 54.55 kg CO_2.

In conclusion, the predictors accounted for 9.88 percent variations in household carbon emissions ($R^2 = 0.0988$, $F = 49.85$, $p < 0.01$).

4.4 Summary of Findings

The results of the estimated log-linear econometric model x-ray the socio-economic and demographic factors that determined the behaviour of Nigerian household carbon emissions at the national level. As revealed by the findings, household income, household size, gender of household head, literacy ratio of household and motorisation have statistically significant positive effects on household carbon emissions. Surprisingly, literacy ratio of household contradicts a priori expectation. In addition, age of household head, polygamous status of household head and household male population have statistically insignificant positive impacts on household carbon emissions. The coefficients of income-square and age-square are negative and significant at one percent. These confirm the non-linear effect of income and age on Nigerian household carbon emissions.

The second regression results focused on households in urban areas and the determinants of their carbon dioxide emissions. As revealed by the findings, household income, household size, age of household head, household head gender and motorisation have statistically significant positive impacts on urban household carbon emissions. Polygamy, literacy ratio and male population failed the test of statistical significance at 1%, 5% and 10%. The coefficients of income-square and age-square are negative and significant at one percent. These confirm the non-linear effect of income and age on urban household carbon emissions.

The third regression results mirror the determinants of Nigerian rural household carbon emissions. As revealed by the empirical findings, household income, household size and gender of household head have statistically significant positive impacts on rural household carbon emissions. Paradoxically, motorisation contradicts a priori expectation. Age of household head, polygamy, literacy ratio, motorisation and male population failed the test of statistical significance at 1%, 5% and 10%. The coefficient of income-square is negative and statistically significant at one percent. This confirms the non-linear effect of income on rural household carbon emissions. The coefficient of age-squared is found to be negative and statistically insignificant.

4.5 Conclusion

Based on the results of the empirical investigation, household income, literacy ratio, household size and motorisation appear to be the key quantitative factors that positively influence the behaviour of household carbon emissions in Nigeria. This implies that carbon emissions from household activities will continue to rise as household become more affluent, educated and large in size. If handled with kid gloves, the potential ecological disaster associated with high carbon footprint may derail the sustainable development mission of the country. This, however, does not translate to preventing income, literacy ratio and household size from being on the rise. Alternative options that are capable of ameliorating household carbon emissions should be looked into.

4.6 Policy Recommendations

Considering the fact that Nigeria is a country with large reserve of people living below the poverty line, the huge cost associated with renewable energy use may hinder household large scale movement away from the consumption of fossil fuels. However, the following policy options, if adhered to by the government and policymakers will prevent Nigerian household carbon emissions level from going worse.

- Government should ensure regular supply of electricity (an energy with relatively low carbon emission factor) in order to discourage low and medium income households from using energies with high carbon emission factors, e.g. firewood, kerosene, et cetera.
- Government should combine improvements in the public transportation system with regulations and incentives to encourage the use of less polluting or non-polluting transportation alternatives such as walking, cycling, et cetera.
- Government should tailor policies by socio-economic group and gender to combat specific polluting behaviour.
- Government should embark on adequate sensitisation of the public on the need to be conscious of the environmental consequence of their transportation choices.
- Government should prioritize technical schools in Nigeria so that technical students can be equipped with the required knowledge to produce renewable energy gadgets for households and firms at relatively affordable prices.
- There is need for government to breathe life into its environmental regulatory agencies. If this is achieved, less environmental friendly lifestyle in the country can be reduced to the least level.

4.7 Limitations of the Study

It is desired by the researcher to look beyond the number of households, variables and energy options considered in this study, but the inability to do so is enrooted in the scope of the household survey data used.

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