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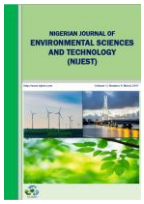

Analysis of Household Energy Use and CO_2 Emission using Environmental Kuznets Curve

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ABSTRACT

This study examined the environmental Kuznet's curve based on the household energy use and pollution of carbon dioxide in Nigeria as a means of identifying efficient energy for a sustainable environment. Secondary data sets obtained from National Bureau of Statistics on the General Household Survey (2010-11, 2012-13, 2015-16 and 2018-19) were utilized. The study employed descriptive statistics, Consumer Lifestyle Approach and the Econometric specification for income-pollution models. The result showed that the use of diesel and kerosene were declining over the years while Liquefied Petroleum Gas (LPG), electricity and petrol recorded an increasing pattern. However, charcoal and fuelwood usage experienced some decline for the first three years of the survey and rose in 2019. The results also revealed that the total of 105674, 76329, 70006 and 47586 kg of carbon dioxide were emitted monthly based on the four data sets used respectively. With a total of 296064 and 303037 kg for rural and urban households respectively and on the average a household emits a total of 19 kg of carbon dioxide. With regards to the pollution-income relationship, the coefficients of income(y), (y^2) and (y^3) were all negative, although significant at 1% levels. Indicating that the Kuznets hypothesis was partially applicable to the Nigerian households, while educational level and sex were found to be negative but significant at 1% levels. On the contrary, the family size was positive and significant at 1% level but age of the household head was insignificant determinant of carbon dioxide emission. The paper recommended that the Nigeria government should improve electricity supply, LPG and the income of the households.

Keywords: Environmental Kuznets, Household, Energy Use, Pollution, Nigeria

1.0. Introduction

Energy is an essential element for the existence of every society. It is one of the most critical commodities considered to be the lifeline of an economy. It is indeed an essential factor of production in all economies. Thus, household energy use is a necessity; it is vital for household welfare, public investments and environmental considerations. Moreover, efficient exploitation and development of a nation's energy resources are indeed of great importance to the progress and wellbeing of the people (Olaleye and Akinbode 2012).

In Nigeria, the pattern of energy demand shows that the household sector is characterized by various energy sources with records of high use of dirty fuels. About 86% of rural households depend on inefficient energy sources. This is because they have little access to clean energy sources such as electricity and Liquefied Petroleum Gas (LPG) due to lack of connectivity to the National Electricity Grid and also due to absence of functional road networks. Moreover, LPG attracts a higher installation cost. Similarly, the rural populace and the low-income urban households whose needs are often basic due to supply/demand imbalance of clean energy depend in no small extent on dirty energy sources (Maina *et al.*, 2019).

The widespread use of inefficient energy sources such as fuelwood, charcoal and kerosene for cooking and petrol and diesel for lighting homes is a significant cause of pollution which adds to the

total emission present in the atmosphere, thus influencing the environment locally and globally (WHO, 2015). Also, it causes other environmental problems such as soil erosion, desertification and loss of biodiversity. Moreover, most of these impacts are already evident in different ecological zones in the country amounting to substantial economic losses (Ogunniyi *et al*., 2012).

The relationship between household energy use and pollution is explained through the concept of Environmental Kuznets Hypothesis (EKH) which posits that a rise in income results to an increase in pollution and consequently affects the environment negatively. As income rises, pollution also rises until it reaches a particular income level where it starts to decline, thus resulting in improvement in the quality of the environment (Kuznets, 1955). This assumption empirically holds in the middle-income group because poor households spend a more significant fraction of their income on dirty fuels by buying more as income rises. Thus, as income rises from low to middle levels, a U shape can result. However, an N shape might eventually result, as wealthier households spend all income on clean inputs (Kavi and Brinda, 2007).

Undoubtedly the use of various energy sources by households generates pollution in the form of the carbon dioxide (CO_2) emission. In fact, in the developing countries, the sector alone contributes to the emission of about 59% of CO_2 into the atmosphere with solid biomass used for cooking and space heating contributing about 25% of the global emissions of CO_2 and about 50% of the anthropogenic emissions of black carbon. These high concentrations of greenhouse gases (GHG) are the causes of Climate Change (CC) (USEPA, 2015). Thus, these inefficient energy uses have far-reaching consequences for the environment. It is with this background that this study seeks to look at the pattern of household fuels use and their impact on the environment in Nigeria.

Although there are much research works on household energy use to mention but a few Bello (2011) was on the impact of fuelwood consumption in Gombe state using multinomial regression However, the study only assessed energy consumption. Olaleye and Akinbode (2012) on the other hand analyzed the demand for alternative energy sources in Lagos using Ordinary least square regression and Tobit model. The study did not consider the impact of such energy on the environment. However the few studies that analyzed CO_2 emission from energy consumption such as (Olanrewaju *et al.*, 2018; Maina *et al.*, 2020).These studies either considered one data set or a few energy sources. Therefore, this study considers the pattern of energy use and CO_2 emission from four different data sets from the same households in order to provide information for an efficient policy formulation and implementation. This study, therefore, examines the pattern of household fuel use, determines the impact of such fuel used to the environment and assesses the EKH for pollution-income relationship.

2.0. Methodology

2.1. Study area

The study was conducted in Nigeria. It lies between latitudes 4º 12′ 40.37″ N to 13º51′ 36.50 ″ N of the equator and longitudes 2º 45′ 47.735″ E to 14º42′ 55.123″ E of the Greenwich meridian. Located at the extreme inner corner of the Gulf of Guinea on the west coast of Africa, Nigeria occupies an area of 923,768 sq. km (356,669 sq mi), extending 1,127 km (700 mi) East to West and 1,046 km (650 mi) North to South. The country has 36 States and a projected population of 214, 312, 387at the end of 2019 (NPC, 2006). Various energy sources characterize the household sector in the study area; the most commonly used ones include charcoal, diesel, electricity, fuelwood, gas, kerosene and petrol (NBS, 2011).

2.2. Sources of data

Secondary data sets were used for the study, obtained from the database of the National Bureau of Statistics (NBS) on General Household Survey, Panel 2010-11, 2012-2013, 2015-2016 and 2018-2019. The data sets were based on various surveys conducted over these periods on the same households, which gives a total of 5000 across the country. The relevant information collected in the survey includes household socio-economic characteristics, food consumption, expenditure, and other non-food expenditure, among others.

2.3 Methods

2.3.1. Descriptive statistics

Descriptive statistics were used to describe the characteristics of the data sets in a way that would be well understood through the use of frequencies and graphs. These were achieved through the use of Stata Statistical Package Version 14. Thus, it was used to present the pattern of household energy use and the pollution- income relationship in Nigeria.

2.3.2. Consumer lifestyle approach

Calculating the CO_2 emissions required a couple of activities. First and foremost, the monthly household expenditure on the various energy sources as provided by the data sets were divided by the consumer price indices for the years under survey and were further converted into quantities. Then the estimated quantities were converted into different types of an equivalent unit/litre or kg of direct CO_2 emissions based on the conversion factors given by the US Environmental Protection Agency (clean energy) (2013) as modified by (Maina, 2018) presented in Table 1. The direct CO_2 emissions by households were calculated focusing on the seven major energy sources used by households in Nigeria. Hence, the direct CO_2 emission was estimated using the Consumer Lifestyle approach (CLA) given as follows:

$$\mathrm{CO_2\ direct} = \mathrm{F_m} \times \mathrm{CO_2\ coefficient} \quad (1)$$

Where: F_m is matrix of energy consumption (firewood, charcoal, kerosene, petroleum, diesel and LPG). Thus, F_m is a 1×7 vector-matrix. CO_2 coefficient is a 1×7 matrix of CO_2 coefficients for fuels.

Table 1: Conversion factor by energy type

Fuel type	Unit	CO_2 emission per unit
Petrol	1 litre	2.4kg
LPG	1 litre	0.16 kg
Diesel	1 litre	2.7 kg
Kerosene	1 litre	2.6kg
Charcoal	1kg	3.67Kg
Firewood	1kg	1.73kg
Electricity	Wh converted to kg	0.48kg

Source: (US, EPA, 2013) Note: 1kg is equivalent to 1 litre.

2.3.3. EKH for pollution income relationship estimation

The household-level information on fuel use, income and other characteristics were obtained from the data sets and considered for this analysis. The econometric specification for the estimation of the pollution-income relationship is based on the following equation;

$$CO_2 e_h = a_1 + a_2 y_h + a_3 y_h^2 + a_3 y_h^3 \sum b_j C_{ij} + e_h \quad (2)$$

where;

CO_2e_h is the carbon dioxide CO_2

e_h equivalent emissions per month from household "h".

a and b are constants

y_h is the per-capita monthly expenditure of household "h" used as proxy for household income.

C_{hj} are control variables including household size, educational level of household head, age, including dummy variables that capture differences between households such as sex.

3.0. Results and Discussion

3.1. Pattern of household energy use in Nigeria

Figure 1 presents the distribution of households based on energy types over the years of the surveys. The *x* axis represents the types of fuel used for the four panel data sets. While the *y* axis represents the expenditure share in percentage. It can be seen that they were some transitions as well as rise and

decline in the use of the various energy sources. The use of diesel, electricity and kerosene were found to have declined over the years while an increasing pattern was recorded for LPG and petrol in both the two areas. However, charcoal and fuelwood use experienced some decline in the first three years of the survey, and they increased in 2019. In general, the total energy used for all the sources experienced a decline in 2015/16 financial year. The reason could be linked to oil price volatility and its collapse between 2014-2016, which led to the drop of Gross Domestic Product (GDP) growth rate to 2.7% in 2015 and a recession. These resulted in a contraction of the economy by 1.6% (World Bank, 2018). While all these economic crises were unfolding the government's anti-corruption crusade was also taken place at the same time, which kind of ended the era for free money for so many jobless Nigerians. All these could have contributed in one way or the other to the unexplained fall in the quantity of energy use in 2015-2016 due to low total expenditure.

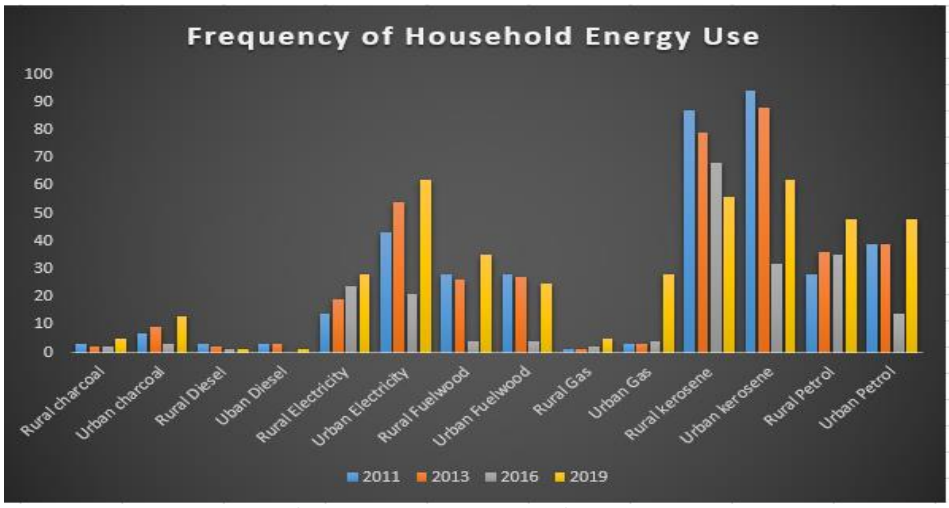

Figure 1: Distribution of households based on fuel usage

3.2 The Impact of Energy Use Pattern to the Environment

On the impact of household energy use to the environment, the consumer lifestyle approach was used to determine the direct CO_2 emission as pollution for the various energy sources and the results obtained are presented in Figure 2a, 2b, 2c and 2d respectively.

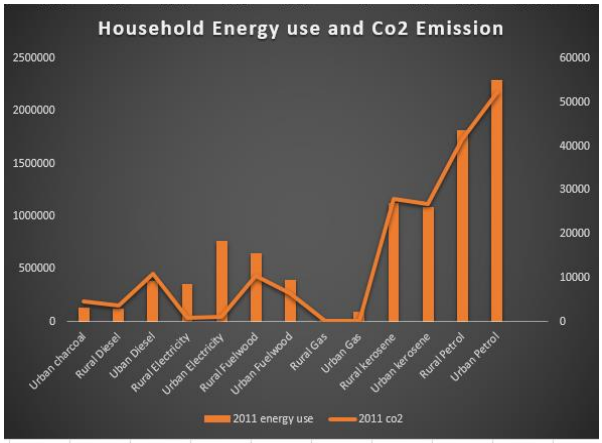

Figure 2a: Household energy use and CO_2 emission for 2010-2011

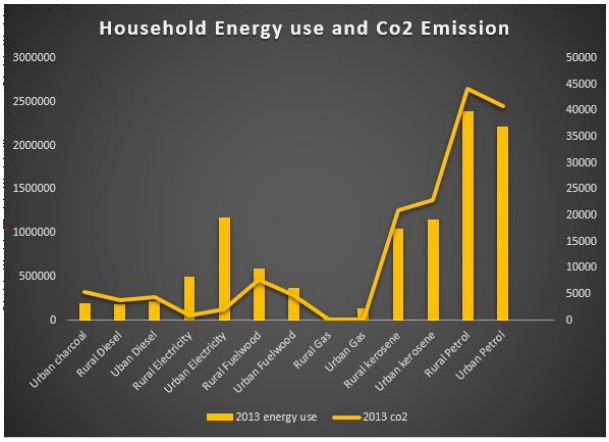

Figure 2b: Household energy use and CO_2 emission for 2012-2013

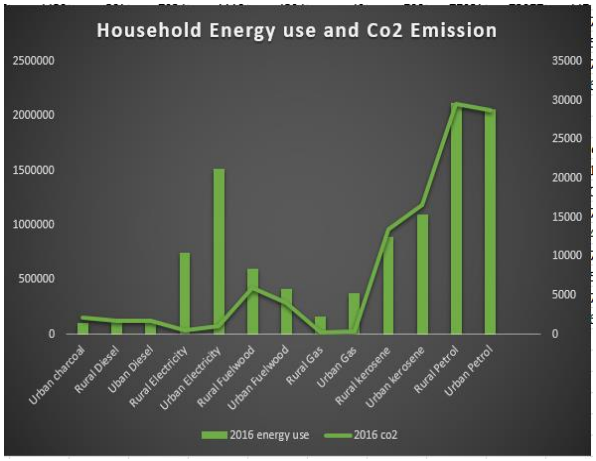

Figure 2c: Household energy use and CO_2 emission for 2015-2016

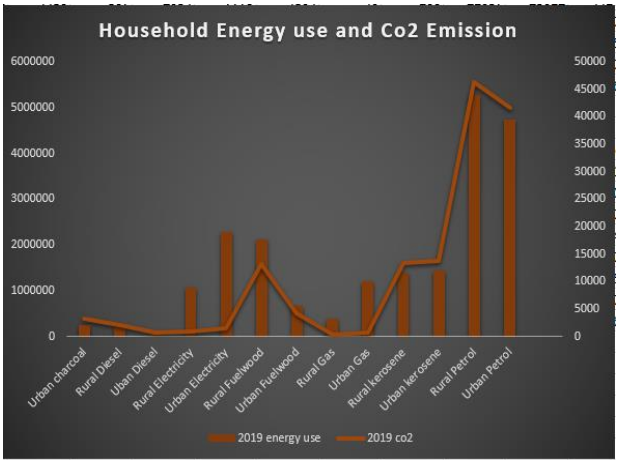

Figure 2d: Household energy use and CO_2 emission for 2018-2019

The bars in Figures 2a to 2d represent household energy use for the years of the survey, and the lines indicate the pollution via CO_2 emission. The vertical axis represents the energy sources used in both rural and urban households. While the *x* axis by the left side is the expenditure of the energy sources and the right side is the CO_2 emitted. It is observed that charcoal and diesel use were less, but they emitted a significant amount of CO_2, just like fuelwood kerosene and petrol that were highly used. However, electricity and LPG emitted less CO_2, and these further reconfirm their status as clean energy sources in line with the earlier findings of (Maina, 2018).

In total, about 105674, 76329, 70006 and 47586 kg of CO_2 were emitted in a month for the four surveys respectively. With a total of 296064 and 303037 kg for rural and urban households respectively, on average a household emits a total of 19 kg in a month. This finding is lower than the 38 kg of CO_2 reported by Maina *et al*. (2019) for Nigeria in the year 2015 to 2016. It is also lower than the average CO_2 emission of 20 tons for the households in the USA (USEPA, 2015). However, one can say without prejudice that the impact of climate change would be felt more by developing countries, including Nigeria, than even the major emitters. Thus, all hands must be on deck to mitigate it.

Furthermore, there are two noticeable patterns identified here, the use of electricity despite its epileptic supply and LPG showed increasing pattern over the years. The fact that they emit less pollution means less impact on the environment. Similarly, petrol usage for lighting homes in power generators was also found to be increasing among both rural and urban households. The implication of this is that the more use of this energy source the more the level of emission as observed in Figures 2a to 2d. This result is in agreement with the works of Maina *et al*. (2017) in which it was observed that petrol is a dirty fuel that emits high concentration of pollutants. Moreover, there is an interesting discovery about total household energy use and CO_2 emission over the years as presented in Figure 3 for better understanding.

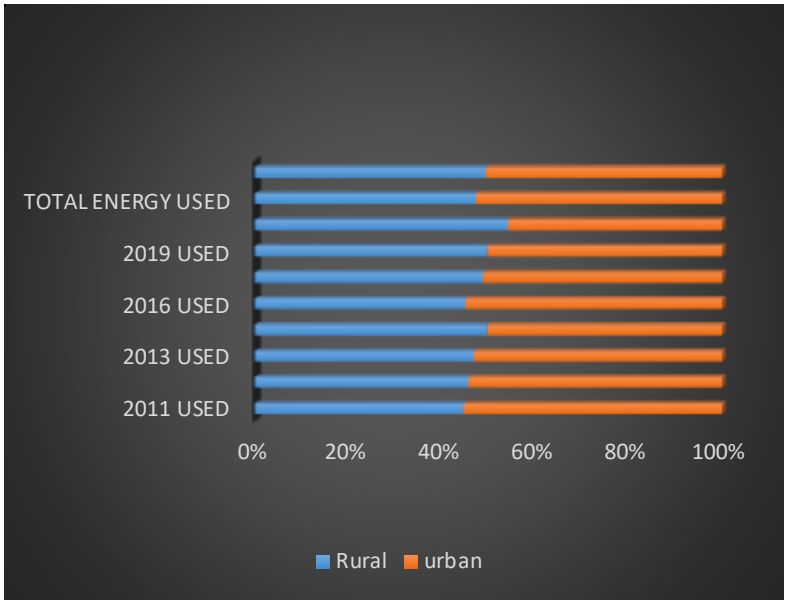

Figure 3: Total energy use in Nigeria by years and their resulting CO_2 emission

The total energy used by urban was higher than that of the rural households, likewise the pollution via CO_2 emission. Hence, the urban sector emitted more than the rural households; this is in line with the result of (Zheng *et al.*, 2009). In general, pollution was found to be decreasing over the years even as expenditure was increasing; this could mean that the households are tilting towards the use of clean energy sources; thus, less pollution. The fact that pollution is reducing over the years can be justified by the decreasing pattern of diesel and kerosene usage and an increasing pattern for LPG and electricity, as shown in Figure 1.

3.3. EKH for pollution-income relationship

The result of the econometric model on income-pollution relation is presented in Table 2.

Table 2: Regression estimate of EKH for pollution-income relationship

Variable	Coefficient	Standard error	T value	p>[t]	R^2
Constant	14.74371	4.157065	3.55	0.000***	63%
Educational level	-0.935763	0.1397525	-6.7	0.001***	
Monthly Income(y)	-4.91E-06	8.60E-07	-5.7	0.000***	
y2	-3.81E-13	1.14E-13	-3.35	0.001***	
y3	-4.51E-21	1.53E-21	-2.84	0.005***	
Household size	0.900623	0.2608413	3.45	0.001***	
Sex	-6.752242	2.377314	-2.84	0.001***	
Age	0.119355	0.037714	0.32	0.752 NS	

It can be seen that the coefficients of income (y), (y^2) and (y^3) were all negative, although significant at 1% levels. Moreover, the magnitudes of the t values were found to be decreasing. This proves that the EKF hypothesis is relevant to the study. The negativity of the coefficients implies that *Ceteris parabus* the higher the income levels, the more the CO_2 emission declines. This agrees with the finding of Kumar and Viswanthem, (2011). To justify these findings, Figure 4 is presented.

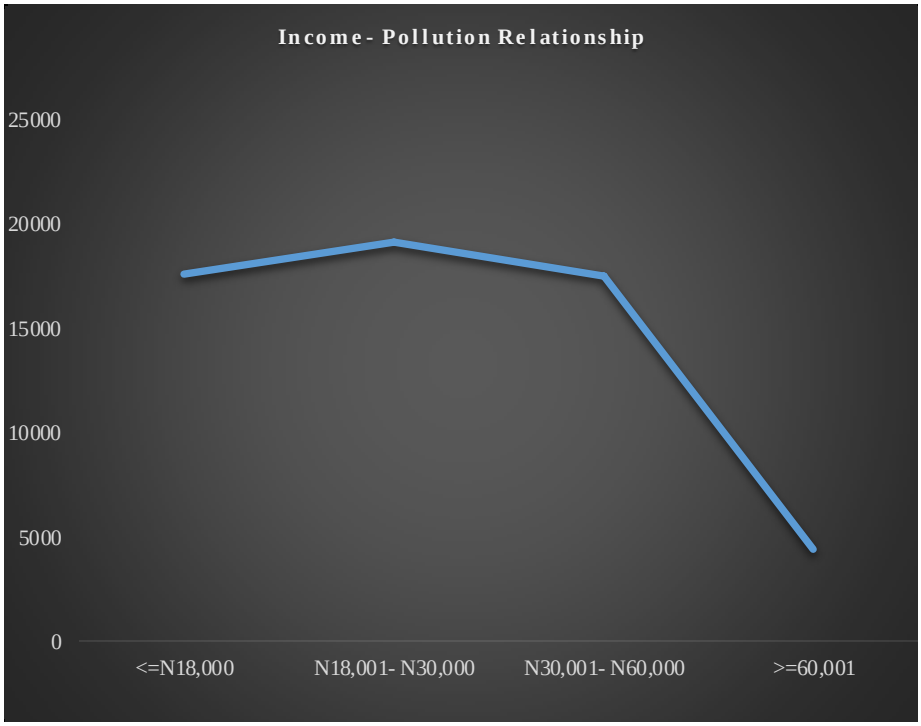

Figure 4: Income-pollution relationships

It can be observed that there is some sort of rising and falling movement more like a V-shaped relationship between income and pollution in Nigeria. Although it was not exactly like the U shape postulated by the Kuznet's hypothesis nevertheless, the income-pollution relation is still in line with the theoretical assumption. The established shape shows more of a decline and a less increase than what was postulated by Kuznet, which shows a significant rising and falling relationship. Thus, the general decline in pollution implies that the household sector is switching to the use of cleaner energy sources as income improves; this is in line with the finding of (Bello, 2011).

With regards to the socio-economic variables considered for this study, the educational level of the household head was found to be negative but significant with the highest magnitude among all the variables studied. This implies that *ceteris parabus*, increase in the educational level of the household head would make him decrease his CO_2 emission through the use of less polluting energy. The reason could be that an educated household head is perhaps well informed on the importance of the use of less polluting energy sources. Also, his lifestyle such as his interaction with his office colleagues, social media platforms and the use of another medium such as radio, television and print media could be the most influencing factors on his energy choices. Thus, he could be aware of the environmental train and is conscious about the link between his household energy usage and environmental effects, and this result is contrary to the finding of (Olanrewaju *et al.*, 2018).

The coefficient of family size was positively related to CO_2 emission at 1% level of significance. This shows that the higher the family size, the higher the CO_2 emission. This agrees with the finding of (Hargreaves *et al.*, 2013). This means that *Ceteris parabus* an increase in family size would be accompanied by a proportionate increase in the use of energy that creates more pollution. Hence, the more the increase in the family size without a corresponding increase in income the more the household resorts to the use of affordable energy such as charcoal which is dirty energy and the more the pollution increases.

The household head was found to be negatively related to CO_2 emission but significant at 1%. This shows that with all things being equal, a household headed by a male would emit less CO_2. This agrees with the finding of (Busola and Olaniyi, 2012). The reason could be the study area is mostly patrilineal where the household decisions including the expenditure are taken by the man of the house hence more financial support for less-polluting energy sources unlike a household headed by a female. She could be a widow, retired or a lone parent with so many responsibilities to handle. Hence, more stay at home and greater use of dirty energy sources. So a household headed by a man, having his wife could support him financially, thereby sharing the burden.

On the contrary, the age of the household head was found to be an insignificant determinant of CO_2 emission, although, the coefficient was low but negative. The reason for the insignificance could be because choosing to use clean or dirty energy source has nothing to do with one's age as a household head but other factors such as income and level of awareness. If a household head is well informed about environmental sustainability and have the means to actualize his age would not matter.

4.0. Conclusions

This study examined the environmental Kuznets curve based on household energy use and pollution of CO_2 in Nigeria. The result showed a rise and decline in the use of various energy sources. Diesel and kerosene were found to have declined over the years. While an increasing pattern was recorded for LPG, electricity and petrol in both the two areas. However, charcoal and fuelwood use experienced some decline in the first three years of the survey but rose in 2019. On the impact of energy use to the environment, in total about 105674, 76329, 70006 and 47586 kg of CO_2 were emitted monthly in the four years of the survey, respectively. With a total of 296064 and 303037 kg for rural and urban households respectively, on average a household emits a total of 19 kg of CO_2.

With regards to the pollution-income relationship, the coefficients of income (y), (y^2) and (y^3) were all negative but significant at 1% levels indicating that EKF hypothesis is relevant for the study. While the educational level and sex were found to be negative but significant at 1% levels. On the contrary, the family size was positive and significant at 1% while the age of the household head was found to be an insignificant determinant of CO_2 emission.

Based on the findings of the study, it was recommended that:

i. Nigeria government should improve electricity supply through the investment in renewable energy sources. Thereby reducing the use of petrol for lighting homes which is a dirty fuel in order to improve the air quality of the environment.
ii. There is the need to improve the income of the household because the higher the income level, the lesser the pollution as shown by the EKC. It can be achieved through skills acquisition programmes, issuing of soft loans.
iii. Finally, LPG use should be encouraged by making the start-up cost less expensive; such can be achieved by making the importation of cylinders and other equipment into the country duty-free.

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