Academic Scholars Publishing League (ASPL)
International Journal of Natural Resources and Environmental Studies
ISSN: 2360-915X | Volume 11, Issue 10 | February, 2024| pages 15 – 23
DOI: 277-513-69-0-11102
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https://arcnjournals.org

Nigerian Road Transport: A Causal Examination of Energy Consumption, Economic Growth, and Environmental Impacts

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Abstract: *The transportation sector plays a pivotal role in human activity, fostering mobility, socioeconomic interaction, and contributing significantly to economic growth. In Nigeria, road transport constitutes the predominant mode, accounting for a substantial share of energy consumption. This study is aimed at investigating the relationship between road transport energy consumption, economic growth, and resulting emissions in Nigeria. The methodology involves utilizing secondary data to analyse road transport energy consumption, GDP per capita, and projected vehicle population from 2000 to 2021. The Granger causality test is employed to examine the directional causality between road transport energy consumption and economic growth. Additionally, a regression model is developed to estimate future road transport energy consumption based on GDP values. The projected energy consumption is further used to simulate CO_2 emissions and air pollutant emissions using the EnergyPLAN simulation software. The results indicate a unidirectional causality, suggesting that changes in road transport energy consumption do not lead to corresponding changes in GDP per capita. However, there is evidence supporting the hypothesis that changes in GDP per capita cause changes in road transport energy consumption. The regression analysis yields a polynomial equation linking road transport energy consumption to GDP per capita, explaining 60.0% of the variation. The projected fuel consumption and emissions highlight potential environmental impacts, urging proactive measures. Mitigation strategies, such as promoting cleaner transportation modes and improving fuel efficiency, are recommended to address the growing environmental footprint associated with road transport in Nigeria.*

Keywords: *Road transport, air pollutant, granger causality, energy consumption, EnergyPLAN*

1. INTRODUCTION

The transport system forms an integral part of human activity; it necessitates mobility, enhances socioeconomic interaction and contributes greatly to economic growth and development (Otuoze, et al., 2021). Nigeria's transportation sector in 2017 accounts for about 13% of the total final energy consumption and about 92% of the total final oil product consumption (IEA, 2019). Of all the modes of transportation, road transport is the most commonly used in Nigeria (Badmus, et al., 2012) and it accounts for about 98 % of the total fossil fuel consumption in the transport sector (IEA, 2019). The demand for energy in this sector is expected to rapidly increase due to many factors, including but not limited to an increase in population, urbanization and household income and the resulting increase in the number of vehicles and movement of people (Dioha & Kumar, 2020).

The debate is still heated in the energy economics literature as to whether economic growth precedes energy consumption or vice versa. According to Bekun and Agboola (2019), this discussion was first introduced to the energy economics literature by the seminal studies in the 1970s, where the investigation of the causal nexus between energy consumption and economic growth for the United States was the main discourse. Since then, there have been several other studies (Damette & Seghir, 2013; Akadiri & Akadiri, 2018; Akadiri, et al., 2018; Emir & Bekun, 2018). These literatures can be classified into four strands, namely: those that claim that energy consumption drives economic growth (Damette & Seghir, 2013); those that asserts that economic activities translate into higher energy consumption, what is called in the literature conservative hypotheses (Baranzini, et al., 2013); the third group called the feedback hypothesis in the literature in which there exists a bi-directional causal relationship seen from both energy consumption and economic growth (Tang & Tan, 2013); and finally the fourth group is known as the neutrality hypothesis where there is no causal interaction between energy consumption and economic growth (Halicioglu, 2009).

There also have been numerous studies in Nigeria on the nexus between the energy consumption and economic growth. Iyke (2015) examines the dynamic causal linkages between electricity consumption and economic growth in Nigeria within a trivariate vector error correction model (VECM), for the period 1971–2011. The results show that there is a distinct causal flow from electricity consumption to economic growth, both in the short run and in the long run. Adewuyi and Awodumi (2017) investigate the relationship among biomass energy consumption, economic growth and carbon emissions in West Africa during 1980-2010 using a simultaneous equation model estimated with three stage-least squares (3SLS). Their results show that a complete significant interactive relationship (feedback effects) exists among GDP, biomass consumption and carbon emission in Nigeria. Several other studies follow the same line (Vasylieva, et al., 2019; Ali, et al., 2016).

However, alongside the growth of the transportation sector, there are concerns regarding its environmental impact, particularly in terms of emissions. These trends raise important questions about the relationship between economic growth, road transport energy consumption, and the resulting emissions. As the demand for transportation continues to grow and concerns about energy security increases, understanding this relationship is becoming increasingly important. Most previous studies have shown that economic growth would likely lead to changes in energy consumption. However, there has not been enough literature on the nexus between road transport energy consumption and economic growth. As road transport remains the dominant mode of transportation, accounting for a substantial portion of fossil fuel consumption, it is crucial to understand the dynamics between economic growth, energy consumption, and the resulting emissions, including greenhouse gas (carbon dioxide [CO_2]), and air pollutant emissions (carbon monoxide [CO] particulate matter [PM] and nitrogen oxides [NOx]). The problem at hand is to investigate the nature of these relationships and the potential implications for sustainable development and environmental management in Nigeria's road transport sector. Therefore, this study intends to investigate the relationship between road transport energy consumption and economic growth and the resulting emissions.

2. METHODOLOGY

2.1 Data sources

The IEA Energy Statistics records were used to obtain the energy usage in the road transport sector between 2000 and 2021 as shown in Figure 1. The amount of energy consumed per capita increased significantly from 2256.8 MJ in 2000 to 3389.7 MJ in 2021, representing a 301.6% rise. It is important to note that the data appears to be presented in a random, fluctuating pattern. For instance, road energy consumption was 2194.2 MJ in 2008, 1795.4 MJ in 2015, and 3414.7 MJ in 2022.

In this study, gross domestic product is used as the measure of economic growth and is obtained from World Bank data (World Bank, 2023). From the data, GDP increases from 565.3 USD per capita in 2000 to about 2194.2 USD in 2008, and then drops to 1883.9 in 2009. From thence, it falls steadily to 2965.7 USD in 2022.

Projected vehicle population data from 2022 to 2031 was obtained from Amulah, *et al.* (2022). The vehicles are categorized into passenger car, light commercial vehicle and heavy vehicle. The categorization of the type of fuel used by the vehicle is obtained from Cervigni, *et al* (2013).

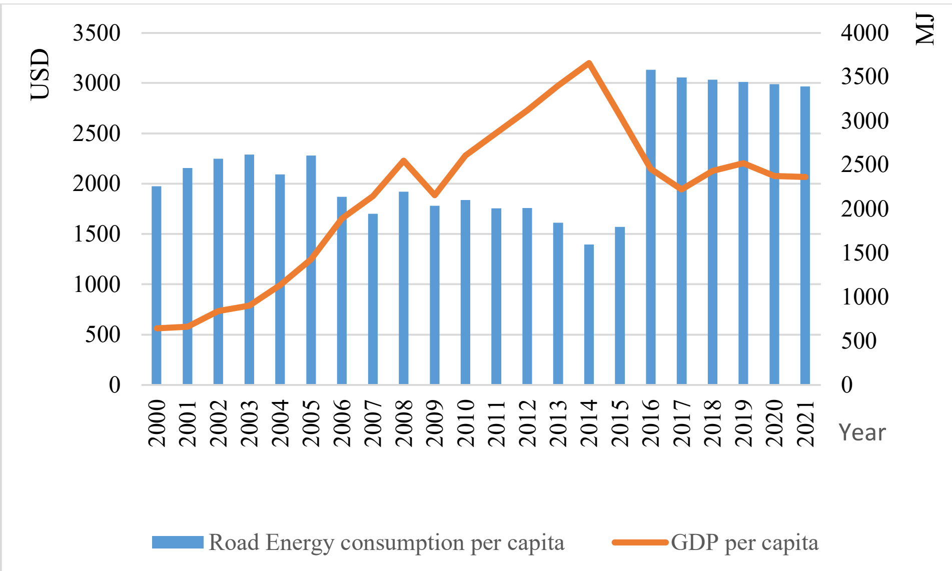


Figure 1: GDP per capita and road transport energy consumption per capita between 2000-2021

2.2 Granger Causality

The study used the Granger causality test to examine the relationship between road transport energy consumption and economic growth. This test differs from correlation because it focuses on the predictability of variables rather than just their association. Granger causality determines if a variable's past value can accurately predict the present value of another variable. If it can, the first variable is considered to Granger cause the second variable. There can be cases where two variables exhibit feedback causality, meaning they mutually influence each other. In such instances, they are said to Granger cause each other, resulting in a bidirectional causality. Alternatively, if the causality only flows from one variable to another, the direction of causality is considered unidirectional. This method has been utilized in many studies (Friston, et al., 2013; Seth & Barrett, 2015; Akomolafe, 2019; Pirgaip & Dinçergök, 2020; Alola, et al., 2022; Adebayo, 2022).

In the case of road transport energy consumption and economic growth, if road transport energy consumption Granger causes economic growth, and not the other way round, there exists a unidirectional causality from energy consumption to economic growth. On the other hand, if road transport energy consumption Granger causes economic growth and vice-versa, there exists a bidirectional causality between economic growth and road transport energy consumption.

2.2.1 Model Specification

Let *y* and *x* be stationary time series. To test the null hypothesis that *x* does not Granger-cause *y*, one first finds the proper lagged values of *y* to include in a univariate autoregression of *y*:

$$y_t = a_0 + a_1 y_{t-1} + a_2 y_{t-2} + \cdots + a_m y_{t-m} + error_t \qquad (1)$$

where y_t is the road transport energy consumption per capita in year t. Next, the autoregression is augmented by including lagged values of *x*:

$$y_t = a_0 + a_1 y_{t-1} + a_2 y_{t-2} + \cdots + a_m y_{t-m} + b_p x_{t-p} + \cdots + b_q x_{t-q} + error_t \quad (2)$$

One retains in this regression all lagged values of *x* that are individually significant according to their t-statistics, provided that collectively they add explanatory power to the regression according to an F-test (whose null hypothesis is no explanatory power jointly added by the *x*'s). In the notation of the above augmented regression, *p* is the shortest, and *q* is the longest lag length for which the lagged value of *x* is significant. The null hypothesis that *x* does not Granger-cause *y* is accepted if and only if no lagged values of *x* are retained in the regression.

2.3 GHG and Air Pollutant Emissions Computation

The hypothesized relationship between road transport energy consumption and economic growth is modelled and estimates of the parameter values are used to develop an estimated regression equation of the form:

$$y = a_0 + a_1 x + a_2 x^2 + a_3 x^3 + a_4 x^4 + a_5 x^5 + a_6 x^6 \quad (3)$$

where y is the road transport energy consumption, x is the GDP per capita and $a_0 \ldots, a_6$ are constants. This equation provides a unique relationship that can be used to identify and predict future outcomes. This model is used to project road transport energy consumption from 2022 to 2031. The projected road transport energy consumption data was inputted into the EnergyPLAN simulation software to simulate CO_2 emissions (Lund, et al., 2021). Air pollutant emissions (CO, NO_x, and PM) are considered to be a function of energy consumption and fuel-specific emission factors. These emissions are estimated using equation (3). The emission factors are given in Table 1.

$$E_i = \textstyle\sum_j (\sum_m (FC_{j,m} \,.\, EF_{i,j,m})) \quad (3)$$

Where E_i= emission of pollutant *i* [g], $FC_{j,m}$ = fuel consumption of vehicle category *j* using fuel *m* [kg], $EF_{i,j,m}$ = fuel consumption-specific emission factor of pollutant *i* for vehicle category *j* and fuel *m* [g/kg].

Table 1: Emission standards for air pollutants (Ntziachristos & Samaras, 2021)

Vehicle Category	Fuel	CO (g/kg fuel)		NO_x (g/kg fuel)		PM (g/kg fuel)	
		Min.	**Max.**[a]	**Min.**	**Max.**[a]	**Min.**	**Max.**[a]
Passenger Car	Petrol	49.0	269.5	4.48	29.89	0.02	0.04
	Diesel	2.05	8.19	11.20	13.88	0.80	2.64
Light Commercial Vehicle	Petrol	68.7	238.3	3.24	25.46	0.02	0.03
	Diesel	6.37	11.71	13.36	18.43	1.10	2.99
Heavy-Duty Vehicle	Diesel	2.20	15.00	28.34	38.29	0.61	1.57

[a]The maximum values were used for the estimation because vehicle technology and fuel standards were considered to be uncontrolled.

3. RESULTS AND DISCUSSION

Table 2 presents the descriptive statistics of the variables. Road transport energy consumption per capita has a mean of 2324.21 MJ while GDP has the mean of 1885.16 USD. The standard deviation is utilized to identify which variables have the highest level of consistency. Road transport energy consumption the lowest value which illustrates that the data are less spread out from the mean. Therefore, the data for road transport energy consumption is more consistent. The skewness value shows that energy consumption is skewed to the left (positive skewness) and GDP is skewed negatively to the right.

Table 2: Descriptive statistics of the variables

Descriptive statistics	Energy Consumption	GDP
Mean	2515.293	1885.155
Standard Error	138.3059	164.2251
Median	2324.209	2070.181
Mode	N/A	N/A
Standard Deviation	648.7121	770.2842
Sample Variance	420827.4	593337.8
Skewness	0.571648	-0.37516
Range	1984.675	2635.649
Minimum	1593.924	565.3043
Maximum	3578.599	3200.953

Table 3 shows the result of causality tests between road transport energy consumption and GDP per capita. The significance level chosen for the analysis was 5%. The first aspect of interest is the determination of the directionality of causality. The table reveals that a unidirectional causality relationship exists between road transport energy consumption and GDP per capita. Specifically, it indicates that changes in road transport energy consumption do not lead to a corresponding change in GDP per capita. This conclusion is based on the p-value associated with the first hypothesis test, which is greater than 0.05. Therefore, the null hypothesis suggesting that alterations in road transport energy consumption do not cause changes in GDP per capita is accepted.

Table 3: Pairwise Granger causality test results

Sample:2000-2021			
Null hypothesis	**Observations**	**F-statistic**	**Prob.**
Road transport energy consumption does not Granger cause GDP	21	0.41805	0.6658
GDP does not Granger cause road transport energy consumption		7.22235	0.0064

However, the analysis does uncover a noteworthy finding regarding the second hypothesis. The p-value associated with this test is less than 0.05, indicating that there is sufficient evidence to reject the null hypothesis. This implies that changes in GDP per capita do Granger cause changes in road transport energy consumption. In other words, fluctuations in economic output, as measured by GDP per capita, have a causal influence on road transport energy consumption.

The regression analysis conducted on the relationship between road transport energy consumption and GDP (Figure 2) yielded a polynomial equation of the 6th degree as shown in equation (4). This equation can be used to estimate road transport energy consumption based on GDP values.

$$y = -8 \times 10^{-16}x^6 + 1 \times 10^{-11}x^5 - 5 \times 10^{-8}x^4 + 4 \times 10^{-4}x^3 - 0.154x^2 + 95.605x - 19804 \quad (4)$$

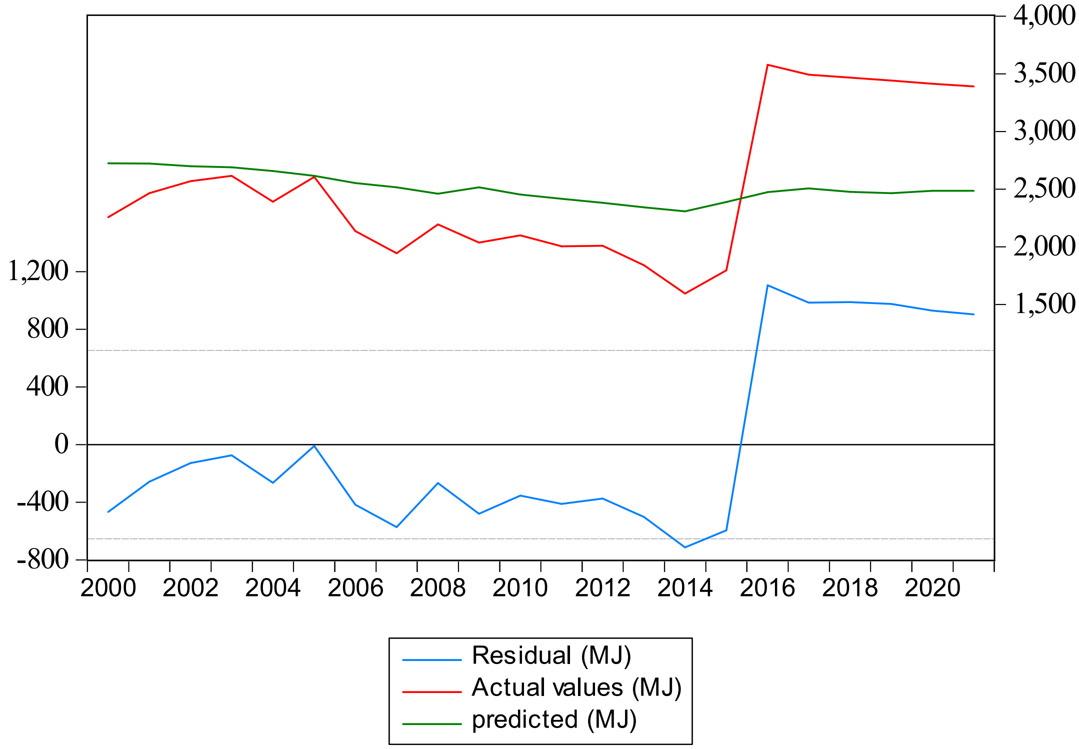
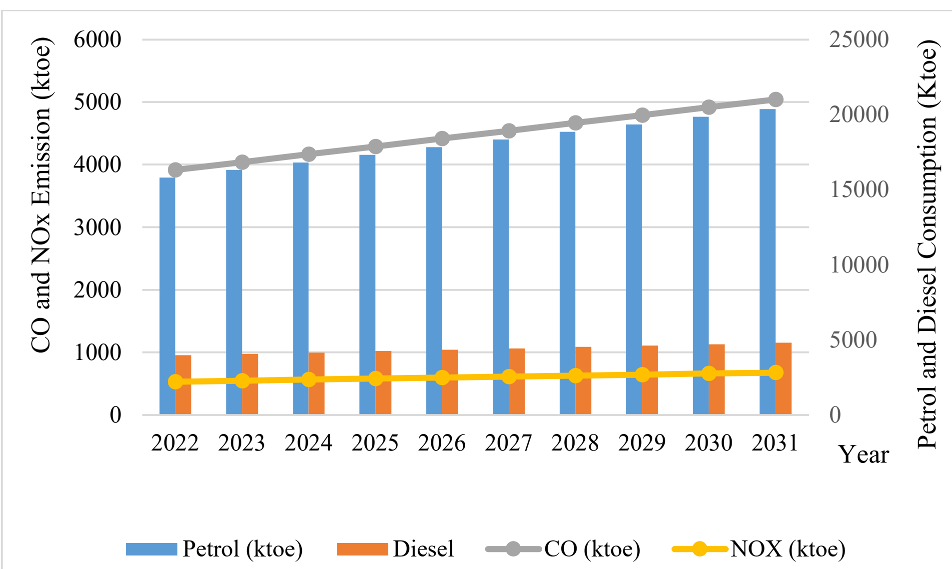


Figure 2: Road transport energy consumption expressed in terms of GDP

From equation (4), y represents the road transport energy consumption per capita and x represents GDP per capita. In this case, the r^2 value obtained from the regression analysis is 0.60. This suggests that approximately 60.0% of the variation in road transport energy consumption can be explained by changes in GDP using the polynomial equation. The remaining 40% of the variation may be attributed to other factors not accounted for in the model.

The projected fuel consumption and the resulting CO_2 and air pollutant emissions are presented in Figure 3.



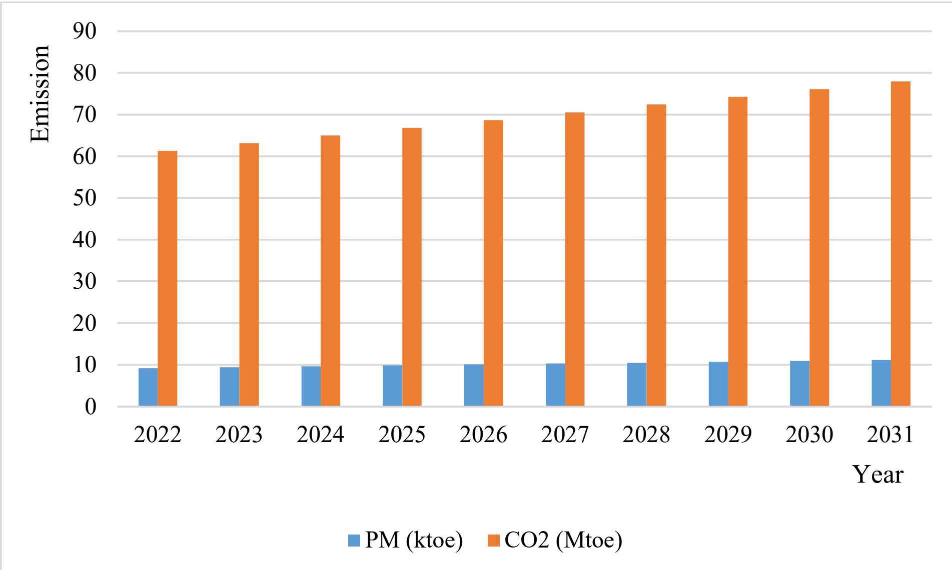


Figure 3: Projected road transport energy consumption and the resulting emissions

The average projected petrol and diesel fuel consumption is 18081.68 ktoe and 4388.09 ktoe respectively. The projected road transport CO_2 emissions in 2031 are 77.97 Mtoe. This compares to the United Kingdom's 2018 value (113.20 Mtoe) (Tiseo, 2022). Although Nigeria emits less than 1% of global emissions, an increase in economic activity and standard of living beyond the historical trend will result in higher emissions.

CO emissions for continue to increase from 3915.60 ktoe in 2022 to about 5041.09 ktoe in 2031 (28.74% increase). For the same period, NO_x emissions increase from 523.38 to 677.37 ktoe and total PM emissions increase from 9.18 ktoe to 11. 14 ktoe. The implication of these emissions trends is that Nigeria needs to address its growing environmental impact resulting from road transport. The projected increases in CO, NOx, and PM emissions suggest a higher level of air pollution, which can have adverse effects on public health and the environment. To mitigate these implications, Nigeria may need to implement policies and initiatives that promote cleaner and more sustainable modes of transportation, such as the adoption of electric vehicles or the improvement of public transportation systems. Additionally, efforts to improve fuel efficiency and promote alternative fuels could contribute to reducing emissions and minimizing the negative consequences associated with increased economic activity and higher living standards.

4. Conclusion and Recommendations

This study examines the relationship between electricity consumption and economic growth in Nigeria. The following can be concluded from the study:

i. The Granger causality test results indicate a unidirectional causality relationship between road transport energy consumption and GDP per capita in Nigeria. Changes in road transport energy consumption do not lead to a corresponding change in GDP per capita, suggesting that road transport energy consumption alone may not be a significant driver of economic growth. However, there is evidence to support the hypothesis that changes in GDP per capita do cause changes in road transport energy consumption, highlighting the influence of economic output on energy demand in the road transport sector.

ii. The regression analysis demonstrates a polynomial equation that links road transport energy consumption to GDP per capita. Approximately 60.0% of the variation in road transport energy consumption can be explained by changes in GDP using this equation. The remaining 40% of the variation may be attributed to other factors not accounted for in the model. This finding underscores the importance of considering additional variables and factors beyond GDP in understanding the complex relationship between energy consumption and economic growth in the road transport sector.

iii. The projected fuel consumption and resulting emissions in Nigeria highlight the potential environmental impact of road transport. The projected increase in CO_2 emissions and other air pollutants such as CO, NOx, and PM indicate a growing environmental footprint associated with road transport. This implies a need for proactive measures to address the growing environmental impact, including the adoption of cleaner and more sustainable transportation practices. Implementing policies that promote fuel efficiency, alternative fuels, and improved public transportation systems can contribute to mitigating the adverse implications of increased emissions and safeguarding public health and the environment.

REFERENCES

Adebayo, T. S. (2022). Environmental consequences of fossil fuel in Spain amidst renewable energy consumption: a new insight from the wavelet-based Granger causality approach. *International Journal of Sustainable Development & World Ecology, 29*(7), 579-592.

Akadiri, S. S., & Akadiri, A. C. (2018). Interaction between CO2 emissions, energy consumption and economic growth in the Middle East: Panel causality evidence. *International Journal of Energy Technology and Policy*.

Akadiri, S. S., Bekun, V. F., Taheri, E., & Akadiri, A. C. (2018). Carbon emissions, energy consumption and economic growth: A causality evidence. *International Journal of Energy Technology and Policy*.

Akomolafe, K. J. (2019). Electricity consumption and economic growth in Nigeria: a sectoral analysis. *World Journal of Business and Management, 5*(1), 45-63.

Ali, H., Law, S., & Zannah, T. (2016). Dynamic impact of urbanization, economic growth, energy consumption, and trade openness on CO2 emissions in Nigeria. *Environmental Science and Pollution Research*, 12435–12443.

Alola, A. A., Adebayo, T. S., & Onifade, S. T. (2022). Examining the dynamics of ecological footprint in CHina with spectral Granger causality and quantile-on-quantile approaches. *International Journal of Sustainable Development & World Ecology, 29*(3), 263-276.

Amulah, C. N., Ekwe, B. E., Ishaq, M. I., & Fasiu, A. O. (2022). Grey Model Analysis of Vehicle Population, Road Transport Energy Consumption, and vehicular Emissions. *Communications-Scientific Letters of the University of Zilina, 25*(1), A1-A14.

Badmus, I., Osunleke, A. S., Fagbenle, R. O., & Oyewola, M. O. (2012). Energy and exergy analyses of the Nigerian transportation sector from 1980 to 2010. *International Journal of Energy and Environmental Engineering, 3*(23).

Baranzini, A., Weber, S., Bareit, M., & Mathys, N. A. (2013). The causal relationship between energy use and economic growth in Switzerland. *Energy Economics, 36*, 464–470.

Cervigni, R., Rogers, J. A., & Dvorak, I. (Eds.). (2013). *Assessing Low-Carbon Development in Nigeria: An Analysis of four Sectors. World Bank Study.* Washington, DC: World Bank. doi:https://doi.org/10.1596/978-0-8213-9973-6

Damette, O., & Seghir, M. (2013). Energy as a driver of growth in oil exporting countries? *Energy Economics, 37*, 193–199.

Dioha, M. O., & Kumar, A. (2020). Sustainable energy pathways for land transport in Nigeria. *Utilities Policy, 64*, 101034.

Emir, F., & Bekun, F. V. (2018). Energy intensity, carbon emissions, renewable energy, and economic growth nexus: New insights from Romania. *Energy & Environment*, 1–17.

Friston, K., Moran, R., & Seth, A. K. (2013). Analysing connectivity with Granger causality and dynamic causal modelling. *Current Opinion in Neurobiology, 23*(2), 172–178.

Halicioglu, F. (2009). An econometric study of CO2 emissions, energy consumption, income and foreign trade in Turkey. *Energy Policy, 37*, 1156–1164.

Lund, H., Thellufsen, J. Z., Østergaard, P. A., Sorknæs, P., Skov, I. R., & Vad Mathiesen, B. (2021). EnergyPLAN-Advanced Analysis of Smart Energy Systems. *Smart Energy, 1*. doi:https://doi.org/10.1016/j.segy.2021.100007

Ntziachristos, L., & Samaras, Z. (2021, October). *EMEP/EEA air pollutant emission inventory guidebook 2019.* Retrieved May 22, 2022, from https://www.eea.europa.eu/themes/air/air-pollution-sources-1/emep-eea-air-pollutant-emission-inventory-guiedbook/emep

Otuoze, S., Hunt, D., & Jefferson, I. (2021). Neural network approach to modelling transport system resilience for major cities: case studies of Lagos and Kano (Nigeria). *Sustainability, 13*(3), 1371.

Pirgaip, B., & Dinçergök, B. (2020). Economic policy uncertainty, energy consumption and carbon emissions in G7 countries: evidence from a panel Granger causality analysis. *Environmental Science and Pollution Research, 27*(24), 30050-30066.

Seth, A. K., & Barrett, A. B. (2015). Granger causality analysis in neuroscience and neuroimaging. *Journal of Neuroscience, 35*(8), 3293-3297.

Tang, C. F., & Tan, E. C. (2013). Exploring the nexus of electricity consumption, economic growth, energy prices and technology innovation in Malaysia. *Applied Energy, 104*, 297–305.

Tiseo, I. (2022, July 2020). *Road transportation carbon dioxide emissions worldwide in 2018, by country*. Retrieved June 18, 2022, from https://www.statista.com/statistics/1201189/road-transport-sector-co2-emissions-worldwide-by-country/

Vasylieva, T., Lyulyov, O., Bilan, Y., & Streimikiene, D. (2019). Sustainable Economic Development and Greenhouse Gas Emissions: The Dynamic Impact of Renewable Energy Consumption, GDP, and Corruption. *Energies, 12*(17), 3289.

World Bank. (2023). *GDP growth (annual %)-Nigeria*. Retrieved May 17, 2023, from https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?end=2021&locations=NG&start=1961&view=chart