Fossil Energy Consumption, Carbon Dioxide Emissions and Adult Mortality Rate in Nigeria

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The health implications of fossil energy consumption and carbon dioxide (CO_2) emissions remain a global concern. This study examines the effect of fossil energy consumption and CO_2 emissions on adult mortality rate in Nigeria. The study relies on the Health Production Function and utilises the Autoregressive Distributed Lag technique to analyse time series data from 1980 to 2019. The results of the estimated model show that fossil energy consumption reduces adult mortality rates in the short run, while CO_2 emissions increase adult mortality rates both in the short and long run. In addition, government health expenditure follows an inverted U-shape relationship in explaining adult mortality while foreign direct investment has a U-shape relationship with adult mortality in Nigeria. Trade openness and monetary policy are insignificant in the short and long run. It is recommended that the government should substitute clean energy for fossil fuel energy to improve the quality of life, strengthen CO_2 emissions tax and ensure health funds are used for the improvement of healthcare service delivery in Nigeria.

Key Words: adult mortality rate, CO_2 emissions, fossil energy consumption, Nigeria
JEL *Classification:* I15, I18, I12

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Introduction

Globally, the health sector has been recognised as an important force in any nation's growth and development process (Benjamin and Foye 2022).

This is because healthy living is a prerequisite for economic growth and development, and the quality of the healthcare system is linked directly to the people's quality of life. A healthy workforce enhances productivity, and the health of young adults is as vital as that of adults since they develop and become a more productive workforce in the future (Shobande 2020). Despite the general knowledge about the importance of healthy living, health issues remain a major challenge in Nigeria.

Nigerian health indicators are among the worst in Africa. Many people lose their livelihoods or die from different health conditions. At the same time, some suffer from disease burdens, including malaria, lower respiratory infection, neonatal disorders, diarrheal diseases, HIV/AIDS, ischemic heart disease, stroke, congenital defects, tuberculosis, and meningitis (Centers for Disease Control and Prevention N.d.; Oladosu, Chanimbe, and Anaduaka 2022). Malaria and other disease burdens, especially lower respiratory infection, the third major cause of death in developing countries (Akinyemi and Morakinyo 2018), significantly impact Nigerians as these affect their daily lives by increasing the cost of living and reducing productivity and income.

Efforts have been put in place by the government and international organisations, including the World Health Organisation (WHO), Centers for Disease Control, United States Agency for International Development (USAID), and United Nations Children's Fund (UNICEF) to address the diverse health challenges in Nigeria, some of which are related to fossil fuel use and CO_2 emissions. In 2019, the Nigerian government designs a National short-lived climate pollutants action plan highlighting 22 mitigation measures to reduce black carbon and methane emissions and co-emitted long-lived greenhouse gases, including CO_2 and other air pollutants from the transport, residential, industry, waste management, and agriculture sectors, among others. The policy aims to eliminate gas flaring by 100 percent and reduce emissions from oil production and processing, transportation, and distribution by 50 percent (International Energy Agency 2022).

The government is also committed to reducing greenhouse gas emissions through signing the Paris Agreement in September 2016. As noted in the current policy in the Nationally Determined Contribution, the government's vision is to transition from fossil fuels to clean energy and eliminate or reduce gas flaring and methane emissions. Moreover, the energy policy of the country aims to reduce the country's dependence on fossil fuels and use clean energy for rural electrification (Federal Ministry of

Environment 2021). Furthermore, USAID is collaborating with the Nigerian government to increase the health budget and strengthen the Nigerian primary health system to deal with different health challenges, including those resulting from CO_2 emissions and fossil fuels. In addition, the international body provides health inputs such as insecticide-treated bed nets and other kits to reduce the malaria burden, strongly linked to climate and environmental conditions (United States Agency for International Development N.d.). Moreover, WHO equips health centres with different facilities and trains healthcare professionals on disease prevention strategies to reduce disease-related deaths, including deaths resulting from the illnesses associated with carbon emissions and fossil fuels in Nigeria (World Health Organization N.d.).

Despite the efforts of the government and international organisations in addressing health challenges, little to no improvement has been recorded, as Nigeria remains one of the top disease burden countries worldwide (Pona et al. 2021). Climatic change and environmental conditions resulting from fossil energy consumption are common causes of health issues and high mortality rates in Nigeria (Effiong et al. 2022). Studies have linked the malaria burden to climate and environmental conditions, including stagnated water bodies, bad sewage disposal, and land pollution that favours mosquito breeding (Effiong et al. 2022; Ugwu and Zewotir 2020). Also, carbon dioxide (CO_2) emissions and other airborne particles from fossil energy consumption are negatively connected with public health, increasing respiratory and cardiovascular diseases and mortality rates (Shah et al. 2022; Urhie et al. 2020).

Fossil energy consumption is a force that drives economic growth, especially in resource-rich nations like Nigeria (Foye and Benjamin 2021a; Urhie et al. 2020). Fossil energy increases economic prosperity by creating jobs and value through the extraction, transformation, and distribution of energy products and services. There are two crucial channels through which energy contributes to the economic growth of any nation. These are the direct and indirect channels (World Economic Forum 2012). For the indirect channel, energy, most notably fossil energy, serves as input for the sectors of the economy. The manufacturing industry, for instance, uses fossil energy to produce plastic and petrochemical products, among others. Also, the agricultural sector relies on fossil energy for crop management and indirectly for fertilizer, pesticides, and machinery production (Woods et al. 2010; Center for International Environmental Law 2022). Moreover, energy is used to power the transportation, manufacturing, construction, and service sectors. Consequently, boosting economic growth and development, especially in developing countries, will spur energy consumption in various sectors of the economy (Foye and Benjamin 2021a; Urhie et al. 2020).

Meanwhile, an increase in fossil energy consumption not only boosts growth and development but also affects public health. Though fossil fuel consumption's primary effect differs from its secondary effect, both forms affect health outcomes (Foye 2022). Specifically, fossil energy consumption generates carbon emissions, which contribute significantly to outdoor or ambient air pollution, primarily when fossil fuel is used for industrial and automobile operations. These emissions advance into the atmosphere and become well mixed such that about the same amount is in the atmosphere everywhere (Foye 2022). While there are other greenhouse gas emissions such as nitrogen oxide, sulphur dioxide, methane and polyaromatic hydrocarbons, CO_2 emissions are the most dominant, causing global warming and deterioration of human health, especially in urban areas (Chen and Guo 2019; Foye 2018; World Health Organization 2021; Environmental Protection Agency N.d.). Carbon emissions pollute the air and increase atmospheric temperature levels (global warming/climate change) resulting in scarcity of water, rise in sea level, flooding, drought, and alternation in the patterns of infectious and vector-borne diseases. Air pollution also contributes to respiratory tract infections and poses a significant danger to human health. The result is high infant, under-5, and adult mortality and low life expectancy (Foye and Benjamin 2021b; Perera 2017; Weil 2014).

A critical review of the existing studies shows that limited or no existing studies examine the effect of fossil energy consumption and CO_2 emissions on adult mortality rate in Nigeria. In view of this, there is a need to investigate the effect of fossil energy consumption and CO_2 emissions on adult mortality rate in Nigeria. A precise knowledge of the relationship will enable the government to formulate appropriate policies to improve health quality and boost economic performance. Though the literature on the impact of fossil energy consumption and CO_2 emissions on health outcome indicators is replete, most of the studies focus on cross-country analysis which does not control for country-specific peculiarities; more so, their findings are contradictory (Adeleye, Azam, and Bekun 2023; Oyelade et al. 2020; Shobande 2020; Xing et al. 2019; Arawomo, Oyebamiji, and Adegboye 2018). The limited country-specific studies (Oyedele 2022; Urhie et al. 2020; Nkalu and Edeme 2019; Afolayan and Aderemi 2019) use either life expectancy, infant or under-5 mortality rates as health outcome indicators.

In addition, recent studies claim that government health expenditure (Oladosu, Chanimbe, and Anaduaka 2022; Onofrei et al. 2021), income (Adeleye et al. 2023; Oladosu, Chanimbe, and Anaduaka 2022), foreign direct investment (Immurana et al. 2023; Shah et al. 2022), trade openness (Byaro, Nkonoki, and Mayaya 2021), and monetary policy (Peter and Adediyan 2020) affect mortality rates. However, no available studies analyse their effects on adult mortality in Nigeria within a single model. This study, therefore, contributes to the growing literature by addressing these two gaps in Nigeria from 1980 to 2019 using the Autoregressive Distributed Lag (ARDL) technique. The outcome of this study is of immense benefit to the Sustainable Development Goals (SDGS), WHO, the government, and other relevant organisations that focus on promoting healthy living and well-being. Also, the study provides important information that helps the government and relevant organisations develop strategies to address environmental hazards and boost the quality of life of the people in the country.

The paper is organised as follows: Section two presents the literature review. Section three discusses the methodological issues, while the results are presented and discussed in Section four. Finally, Section five concludes and provides policy recommendations.

Literature Review

Economic theories have been widely applied to energy, health, and environmental issues. These theories include the Gary production theory, Grossman model, conservative hypothesis, Environmental Kuznets Curve (EKC), and Ramsey-Cass-Koopmans infinitely-lived agent framework. The Gary production theory explains the implications of the interaction between energy consumption and production on infant health-related risks. This theory distinguished between two forms of health and revealed that the first form of health serves as an output in the utility function while the second form enters into the production function as an input (Galama and Kapteyn 2011; Hartwig and Sturm 2018).

The Grossman model considered individuals as consumers and producers of health and argued that health investment would continue until the marginal benefit of health equates to marginal cost. At this equilibrium point, Grossman asserted that the longevity of an individual would be endogenously determined. The model was later integrated into cost analysis to advance collective decision making, and Welfare Theorists demonstrated that societal gains associated with health preservation go a long way in determining the welfare cost for an individual to partake in a collective decision (Shobande and Etukomeni 2018). So, the level of energy consumption coupled with the different policies targeted at improving the living standard of the people is crucial in any nation.

Furthermore, the conservative hypothesis asserted that conservative energy policies boost health outcomes when energy consumption is considered a factor in the health outcomes model (Shobande 2020). The EKC was propounded by Kuznets (1955) to explain the relationship between income inequality and income per capita. The theory was later employed to analyse the different aspects of economic activities. For instance, Grossman and Krueger (1991) used EKC to clarify the relationship between income per capita and two different types of pollution (sulphur dioxide and smoke). Their findings demonstrated that the EKC is an inverted U-shape such that air pollution increases with income per capita at the pre-industrial economies stage through to the industrial economies stage before declining with the income per capita at the post-industrial economies stage. This theory also predicts improvement in environmental conditions as a nation records an increase in the level of economic growth, after which the peak is recorded (Urhie et al. 2020). In summary, health outcomes deteriorate as air pollution increases with income per capita increases but improve after the post-industrial stage.

Empirically, there is still an evolving literature on the relationship among energy consumption, CO_2 emissions and health outcome indicators. The existing empirical studies are divided into cross-countries studies and country-specific studies. For the cross-sectional studies, Adeleye, Azam, and Bekun (2023) employed the structural equation modelling approach to analyse the mediation effect of CO_2 emissions on the nonrenewable energy and infant mortality rate nexus in 42 Asian and Pacific countries between 2005 and 2015. The empirical evidence for the full sample showed that infant mortality rate increases with nonrenewable energy consumption through rising CO_2 emissions. Meanwhile, the results of the different income groups indicated that mediation effects of CO_2 emissions vary.

Using unbalanced panel data on 46 European countries over the period 2005 to 2015, Adeleye et al. (2023) also made an attempt to analyse the effect of CO_2 emissions and non-renewable energy on infant and under-5 mortality rates. The results of their static and dynamic analyses revealed a positive relationship between CO_2 emission and mortality rate and a negative relationship between non-renewable energy and mortality rate. Moreover, the study reported a decline in the absolute value of the positive association of emissions at higher distributions of mortality rates and an increase in the absolute value of the negative association of non-renewable energy at higher distributions of mortality rates.

Sial et al. (2022) used the generalised least square method to analyse the relationship between fossil fuel energy consumption and infant mortality rate in 15 Asian countries from 1996 to 2019. The study established a U-shaped relationship between the consumption of fossil fuel energy and infant mortality in Asian countries. Also, the study submitted that excess fossil fuel energy consumption worsens the standard of living in the Asian countries because of the low air quality levels.

Bouchoucha (2021) assessed the nexus between environmental degradation, health, and institutional quality in 17 Middle East and North African (MENA) countries during 1996 and 2018. Using fully modified ordinary least squares and dynamic ordinary least squares methods, Bouchoucha (2021) reported a negative relationship between health status and environmental degradation in the long run in MENA countries.

Anser et al. (2020) examined the long-run and short-run impact of energy utilisation, greenhouse gasses emissions, and economic activities on mortality rate and incidence of respiratory diseases in emerging Asian economies between 1995 and 2018. This study demonstrated that emissions, fossil fuel consumption, and natural resources depletion have an adverse effect on mortality rate and incidence of respiratory diseases in the long-run while clean energy use and per capita economic growth enhanced households' health status. In the short run, however, the study reported that mortality rate and incidence of respiratory diseases are only affected by greenhouse gasses emission.

Oyelade et al. (2020) employed a quantile regression technique to analyse the effect of environmental quality on people's health in West African Anglophone countries from 1990 to 2013. It is obvious from the results of their study that CO_2 emissions from gaseous and liquid fuel consumption, residential buildings and commercial and public services, solid fuel consumption, and transport negatively affect human health in the region.

In a related study, Shobande (2020) analysed the relationship between energy use and infant mortality rates in 23 African countries between 1999 and 2014. Using the Baseline Pooled Regression and System General Method of Moment, the study specifically examined the impact of energy variables on infant mortality rate and under-5 mortality rates. The results of the study showed that the indicators of energy use have a negative effect on the 23 African countries' infant mortality rates. Also, the empirical evidence suggested that mortality rates increased proportionately with a higher degree of pollution in the countries.

Applying a robust panel fixed effect model, Xing et al. (2019) investigated the impact of fossil energy use and pollutant emissions on public health in 33 countries. Using panel data spanning 1995 to 2015, the results of the analysis showed that fossil energy consumption has a positive impact on life expectancy, while pollutant emissions have a negative relationship with life expectancy.

Osakede and Sanusi (2018) utilised ARDL to analyse the impact of fossil fuel and electricity consumption on life expectancy and infant mortality in Nigeria and South Africa from 1960 to 2014. The study submitted that fossil fuel use and electricity consumption adversely affected life expectancy and infant mortality rates in Nigeria and South Africa. Specifically, the study reported that fossil fuel use and electricity consumption negatively affect infant deaths in Nigeria in the short and long run. Meanwhile, fossil fuel use and electricity consumption only have an adverse effect on health outcomes in the short run for South Africa.

Arawomo, Oyebamiji, and Adegboye (2018) probed the relationship between energy consumption, economic growth, and health outcomes in sub-Saharan Africa (SSA) from 1990 to 2014. The results obtained from the Panel Vector Autoregressive Estimate indicated that economic growth and energy consumption did not significantly impact health outcomes in the selected sub-Saharan African countries. Meanwhile, there was evidence supporting the argument that health care expenditure enhances health outcomes in SSA, while CO_2 emission worsens it. Similarly, Balan (2016) examined the relationship between environmental quality and health outcomes for 25 European Union (EU) member countries from 1995 to 2013. The study established a significant negative relationship between CO_2 emission and health outcomes in the 25 EU countries.

Country-specific studies have also examined the effect of energy consumption and environmental quality on health outcome indicators. For instance, Oyedele (2022) conducted an empirical investigation of the impact of whole and disaggregated CO_2 emission on infant and under-5 mortality rates in Nigeria from 1980 to 2016. It is obvious from the result of the autoregressive distributed lag model and sensitivity analysis that total CO_2 emission has significant impact on both infant mortality and under-5 mortality rates. In addition, the results of the disaggregated analysis showed that CO_2 emissions from solid fuel contributed more to poor health outcomes in Nigeria.

Faizan and Thakur (2019) estimated the impact of household energy consumption on respiratory disease prevalence in India. The study relied on the data obtained from 117,752 respondents diagnosed with different chronic diseases from the 2012 to 2013 District Level Household Survey (DLHS-4). The findings of the study indicated that energy consumption has a very strong impact on respiratory disease prevalence in India, which prompted the conclusion that households using solid fuels are likely to suffer from respiratory diseases.

Using the Dynamic Ordinary Least Square and Granger causality approaches, Afolayan and Aderemi (2019) analysed the impact of environmental quality on the under-5 mortality rate in Nigeria from 1980 to 2016. The study reported an insignificant negative relationship between CO_2 emission and mortality rate. In contrast, the empirical findings revealed that electric power consumption and fossil fuel combustion significantly impact the under-5 mortality rate in Nigeria. Furthermore, the Granger causality test results showed that CO_2 emission Granger causes electric power consumption and government health expenditure; life expectancy Granger causes electric power consumption and government health expenditure; and fossil fuel consumption Granger causes mortality rate.

Matthew et al. (2019) investigated the subject matter using a different approach. They distinguished between various sources of CO_2 emissions and examined their separate effect on health outcomes. Specifically, they utilised an Auto-regressive Distribution Lag model to analyse the impact of CO_2 emissions from construction and manufacturing industries on Nigerians' health conditions from 1985 to 2017. The study submitted that CO_2 emissions from the manufacturing and construction sectors have adverse effects on Nigerians' health conditions.

In a similar study, Nkalu and Edeme (2019) examined the impact of environmental hazards on life expectancy in Nigeria from 1960 to 2017 using Generalised Autoregressive Conditional Heteroscedasticity. The results of the study showed that life expectancy declined with an increase in environmental hazard measured by CO_2 emissions from solid fuel consumption. In other words, an increase in environmental hazards brings about a decrease in the Nigerians' life expectancy.

Just like Nkalu and Edeme (2019) and Matthew et al. (2019), Matthew et al. (2018) probed the long-run relationship between greenhouse gas emissions and health outcomes in Nigeria from 1985 to 2016. The study employed the Auto-regressive Distribution Lag model, and the empirical evidence showed that an increase in greenhouse gas emissions decreases life expectancy. Furthermore, the study demonstrated that the resulting greenhouse gas emissions emanate from the combustion of fossil fuels and CO_2, which are attributable to human activities.

Using a moderated mediation model of economic growth, Urhie, Odebiyi, and Popoola (2017) analysed the relationship between economic growth, air pollution, and health outcomes in Nigeria from 1980 to 2015. The empirical results of the regression path analysis for SPSS-PROCESS showed that government spending and air pollution significantly influenced health performance in Nigeria. In addition, the study reported a significant and plausible relationship between Nigerian economic growth and air pollution, supporting the first stage of the Environmental Kuznets Curve.

Wang (2010) looked at the effect of energy consumption, economic growth, population, and technology progress on China's environment and public health. Wang's model was used to analyse different scenarios between 2010 and 2020. The findings of the study revealed that health damage increases with an increase in particulate matter 10 micrometres (PM-10) and CO_2 emissions in China. Furthermore, the study submitted that energy efficiency, population, economy, and urbanisation are the important drivers.

A detailed review of the relevant studies shows that some issues are unresolved. First, most existing studies conduct cross-country analysis (Adeleye, Azam, and Bekun 2023; Oyelade et al. 2020; Shobande 2020; Xing et al. 2019; Arawomo, Oyebamiji, and Adegboye 2018). Second, mixed results have been reported on the impact of fossil energy consumption on health outcome indicators (Sial et al. 2022; Nkalu and Edeme 2019; Afolayan and Aderemi 2019; Matthew et al. 2019; Xing et al. 2019; Shobande 2020; Arawomo, Oyebamiji, and Adegboye 2018). Third, the studies reviewed analyse the impact of fossil energy consumption and CO_2 emission on different health indicators, including life expectancy, infant mortality rate, and under-5 mortality rate, but the literature is scarce on the impact of these variables on adult mortality rate in Nigeria. This study, therefore, departs from the existing studies by analysing the impact of fossil energy consumption and CO_2 emissions on adult mortality rate in Nigeria. The study chooses these two core independent variables (fossil energy consumption and CO_2 emissions) because they are the key contributors to mortality rate and disease burden globally (Vohra et al. 2021; Farhidi and Mawi 2022; Foye 2022).

Methodology

THEORETICAL FRAMEWORK

The theoretical foundation of this study can be traced to the Health Production Function (HPF), which was first used by Grossman (1972). Or (2000) developed the model to analyse the effect of medical and non-medical inputs, including physical condition and socio-economic factors, on health outcomes. This model has also been used in the existing literature (Arawomo, Oyebamiji, and Adegboye 2018) to investigate the effects of medical and non-medical factors on health outcomes. The baseline function of the health production function is specified as follows:

$$h = f(m, e), \tag{1}$$

where h, m, and e denote health outcomes, medical input, and vector of non-medical indicators, respectively. The HPF predicts a positive relationship between health outcomes and medical inputs or resources. This implies that an increase in health care resources will enhance people's quality of life. However, diminishing returns to scale may also set in after a certain level of resources has been used to support the health care system. On the impact of non-medical input, Or (2000) began his argument by distinguishing between the various non-medical indicators and showed the dissimilarities in the effect of non-medical input such as physical environment, including pollution and socio-economic environment. While water and soil quality may improve health, Or demonstrated that noise and air pollution harm human health.

MODEL SPECIFICATION

This study relies on the health production function in equation (1) to analyse the impact of fossil energy consumption and CO_2 emissions on adult mortality rates in Nigeria. Adult mortality rate is the probability per 1,000 that a 15-year-old will not survive until age sixty. The relationship between fossil energy consumption and mortality rate remains an empirical issue. Vohra et al. (2021) and Anser et al. (2020) claim that fossil energy consumption is associated with high mortality via the air pollution channel. These authors argue that airborne particles and ground-level ozone from fossil energy consumption escalate the mortality and disease burden globally. This is because people that breathe in the polluted air suffer health-wise. Meanwhile, Sial et al. (2022) claim that fossil energy consumption directly and indirectly impacts mortality rates.

The impact of CO_2 emissions on health is well documented in the literature (Oyedele 2022; Vohra et al. 2021; Xing et al. 2016; Du et al. 2016). Jacobson (2008) claims that ozone and airborne particles emanating from higher temperature levels caused by increased CO_2 emissions pose a significant threat to human health and increase mortality rates. Ozone and airborne particles cause and worsen health conditions, including respiratory and cardiovascular illnesses, emphysema, and asthma, among others. This is because airborne particles, even at lower levels of exposure, escape the body's defence, penetrate the respiratory and circulatory system, and damage the lungs, heart, and brain (United Nations 2018).

The study incorporates some control variables into the model. Government expenditure on health is employed to examine the effect of health expenditure on adult mortality rates. Government health expenditure on health facilities and maintenance, as well as health issues, including coronavirus disease (COVID-19), enables healthcare to deliver quality services to the public, prevent the spread of diseases and improve the public health system. Thus, government expenditure is expected to reduce mortality rates (Oladosu, Chanimbe, and Anaduaka 2022; Onofrei et al. 2021; Dhrifi 2018).

Onofrei et al. (2021) and Shobande (2020) point out that high income will enable people to access quality healthcare services and reduce mortality. Moreover, secondary school enrolment is expected to indirectly impact the adult mortality rate because a society populated with educated people records higher income and maintains a decent living standard (Adeleye et al. 2023; Oladosu, Chanimbe, and Anaduaka 2022). Foreign direct investment mortality rate anticipates a direct or indirect relationship. According to Immurana et al. (2023), foreign direct investment brings about technological progress, enabling the receiving country to boost its growth and income level. This, in turn, allows the citizens to access healthcare services and reduce mortality. On the other hand, an inflow of foreign investment may reduce economic growth and lower people's capacity to access quality healthcare. Also, foreign direct investment is associated with air pollution that may affect human mortality in the receiving country (Shah et al. 2022).

The impact of trade openness on mortality rates may be positive or negative. Trade openness can worsen public health and increase mortality when trade policy prevents importing health inputs or boosters, including nutritional goods, beverages, and pharmaceutical drugs. Also, the coming together of businesspeople across the globe may lead to the spread of contagious diseases such as COVID-19 and increase mortality rates. On the other hand, trade openness can reduce mortality when trade policy prevents the import of low-quality products, hazardous materials, and technologies (Byaro, Nkonoki, and Mayaya 2021). Monetary policy may also enhance or impede health outcomes depending on whether the apex bank is pursuing an expansionary or contractionary monetary policy. An expansionary monetary policy enables people to take loans due to lower interest rates and purchase quality medical inputs or services. On the other hand, contractionary monetary policy impedes people's ability to access quality healthcare services (Peter and Adediyan 2020). Based on these augments, the augmented health production function is presented below:

$$amr_t = f(ffc_t, co2_t, gdp_t, geh_t, sse_t, fdi_t, opn_t, mnp_t). \tag{2}$$

Equation (2) is the adult mortality rate model. The econometrics specification of equation (2) with white noise term (μ) is presented in equation (3) as follows:

$$\begin{aligned} \ln amr_t = \beta_0 + \beta_1 ffc_t + \beta_2 \ln co2_t + \beta_3 gdp_t + \beta 4 \ln geh_t + \beta_5 sse_t \\ + \beta_6 fdi_t + \beta_7 opn_t + \beta_8 mnp_t + \mu, \end{aligned} \tag{3}$$

where ln *amr* is the natural logarithm of adult mortality rate. The medical input is ln *geh* and it stands for the natural logarithm of government expenditure on health. Non-medical indicators include *ffc*, *lnco2*, *gdp*, *sse*, *fdi*, *opn* and *mnp*, which denote fossil energy consumption, natural logarithm of CO_2 emissions, Gross Domestic Product (GDP) per capita growth, school enrolment, foreign direct investment, trade openness, and monetary policy. Since *ffc*, *gdp*, *sse*, *fdi*, *opn* and *mnp* are already in percentage, the study transforms amr, co2 and geh so that all the variables can have the same unit. β_0 denote intercepts and $\beta_1, \beta_2, \ldots, \beta_8$ are the parameters of fossil energy consumption, CO_2 emissions, gross domestic product per capita growth, government expenditure on health school enrolment, foreign direct investment, trade openness, and monetary policy, respectively.

The a priori expectations are expressed mathematically as follows:

$$ffc > 0;\ co2 > 0; gdp < 0;\ geh < 0;\ sse < 0;$$

$fdi </> 0;\ opn </> 0;\ mnp </> 0.$

ESTIMATION TECHNIQUES

The study examines the descriptive statistics of the variables and conducts a multicollinearity test using a correlation matrix. To establish the order stationarity of the variables, the study uses the Augmented Dickey-Fuller (ADF) unit root test and authenticates the results using the Philip-Perron unit root test. Moreover, the study utilises the Autoregressive Distributed Lag (ARDL) Bounds test to ascertain the long-run equilibrium property of the variables in the model. Also, it estimates the adult mortality model using the ARDL technique developed by Pesaran, Shin, and Smith (2001). ARDL is suitable for a model with order one variables or combinations of order zero and order one. Also, it performs better with a small sample size of data (Romilly, Song, and Liu 2001). It is also suitable for estimating the speed of adjustment from the short-run disequilibrium to the long-run equilibrium (Foye 2023) and the dependent variable must not be I(2) to satisfy the assumption of ARDL (De Vita, Klaus, and Lester 2006; McNown, Sam, and Goh 2018). The ARDL representation $(p, q, r, s, t, u, v, w, x)$ of equation (3) is presented below:

$$\begin{aligned}\Delta \ln amr_t = \beta_0 &+ \sum_{i=1}^{p} \beta_1 \Delta \ln amr_{t-1} + \sum_{i=1}^{q} \beta_2 \Delta ffc_{t-1} \\ &+ \sum_{i=1}^{r} \beta_3 \Delta \ln co2_{t-1} + \sum_{i=1}^{s} \beta_4 \Delta gdp_{t-1} \\ &+ \sum_{i=1}^{t} \beta_5 \Delta \ln geh_{t-1} + \sum_{i=1}^{u} \beta_6 \Delta sse_{t-1} \\ &+ \sum_{i=1}^{v} \beta_7 \Delta fdi_{t-1} + \sum_{i=1}^{w} \beta_8 \Delta opn_{t-1} \\ &+ \sum_{i=1}^{x} \beta_9 \Delta mnp_{t-1} + \alpha_1 \ln amr_{t-1} + \alpha_2 ffc_{t-1} \\ &+ \alpha_3 \ln co2_{t-1} + \alpha_4 gdp_{t-1} + \alpha_5 \ln geh_{t-1} + \alpha_6 sse_{t-1} \\ &+ \alpha_7 fdi_{t-1} + \alpha_8 opn_{t-1} + \alpha_9 mnp_{t-1} + \mu_t. \end{aligned} \tag{4}$$

Equation (4) is the unrestricted intercept and no trend. The first difference operator is represented by Δ, β_0 is the drift component of the model and μ is the error term. The error term is expected to behave well, that is, be serially independent, homoscedastic and normally distributed. $\beta_1, \beta_2, \ldots, \beta_9$ are the short run parameters while $\alpha_1, \alpha_2, \ldots, \alpha_9$ are the long-run coefficients.

To estimate the long-run relationship, the study normalises (Alsamara et al. 2019) the long-run coefficients by dividing them by the coefficient of the first lag of *logamr* (α_1). The long-run model can be written as follows:

$$\begin{aligned}\ln amr_t = &+\alpha_0 + \alpha_1 ffc_{t-1} + \alpha_2 \ln co2_{t-1} + \alpha_3 gdp_{t-1} + \alpha_4 \ln geh_{t-1} \\ &+ \alpha_5 sse_{t-1} + \alpha_6 fdi_{t-1} + \alpha_7 opn_{t-1} + \alpha_8 mnp_{t-1} + \mu_t, \end{aligned} \tag{5}$$

where $\alpha_1, \alpha_2, \ldots, \alpha_8$ are the long-run parameters, α_0 is constant, and μ is the white noise. The study specifies the following error correction model to estimate the short-run relationship:

$$\begin{aligned}\Delta \ln amr_t = \beta_0 &+ \sum_{i=1}^{p} \beta_1 \Delta \ln amr_{t-1} + \sum_{i=1}^{q} \beta_2 \Delta ffc_{t-1} \\ &+ \sum_{i=1}^{r} \beta_3 \Delta \ln co2_{t-1} + \sum_{i=1}^{s} \beta_4 \Delta gdp_{t-1} \\ &+ \sum_{i=1}^{t} \beta_5 \Delta \ln geh_{t-1} + \sum_{i=1}^{u} \beta_6 \Delta sse_{t-1} \\ &+ \sum_{i=1}^{v} \beta_7 \Delta fdi_{t-1} + \sum_{i=1}^{w} \beta_8 \Delta opn_{t-1} \\ &+ \sum_{i=1}^{x} \beta_9 \Delta mnp_{t-1} + \varphi ecm_{t-1} + \mu, \end{aligned} \tag{6}$$

where Δ is the first difference operator, β_0 is the intercept, $\beta_1, \beta_2, \ldots, \beta_9$ are the short run estimates, φ is the speed of adjustment from short-run disequilibrium to long-run equilibrium, ecm_{t-1} is the error correction term lagged one time and μ is the white error term. Moreover, the study conducts post estimation tests, including the Breusch-Godfrey Serial Correlation LM test, Breusch-Pagan-Godfrey Heteroscedasticity test, Jarque-Bera Normality test, Cumulative Sum of Recursive Residual (CUSUM) and Cumulative Sum of Squares (CUSMSQ) to check the robustness of the model.

SOURCES AND MEASUREMENT OF DATA

The study investigates the effect of fossil energy consumption and CO_2 emissions on adult mortality rate in Nigeria using time series data from

TABLE 1 Definition and Measurement of Variables, Data Sources, and A Priori Expectations

Variables	Symbol	Definition and Measurements	Sources
Adult mortality rate (per 1,000 adults)	*amr*	This is the probability per 1,000 that 15-year-old persons will not survive till age sixty.	WDI
Fossil fuel energy consumption (% of total)	*ffc*	This is the sum of all oil, petroleum, natural gas, and coal products and it is measured as a percentage of total energy use.	WDI
CO_2 emissions (kt)	*co2*	This occurs as a result of the burning of fossil fuels and the manufacture of cement. It is the sum of all the emissions produced during consumption of solid, liquid, and gas fuels and gas flaring. This is measured in kilotons.	WDI
GDP per capita growth (annual %)	*gdp*	Gross domestic product per capita growth is gross domestic product divided by midyear population. It is the annual percentage growth rate of GDP per capita based on constant local currency.	WDI
Health expenditure	*ghe*	This is the government expenditure on health facilities and it is measured in billion naira. It is proxied by total recurrent expenditure on health.	CBN
School enrolment (% gross)	*sse*	School enrolment is the ratio of total enrolment, regardless of age, to the population of the age group that officially corresponds to the level of education. It is the percentage of gross enrolment.	WDI

Continued on the next page

1980 to 2019. The variables, definition and measurement, symbol, and data sources are presented in table 1.

Empirical Results

PRELIMINARY ANALYSIS

Table 2 reports the summary statistics of the adult mortality rate (*amr*), fossil energy consumption (*ffc*), CO_2 emissions (*co2*), gross domestic product per capita growth (*gdp*), government health expenditure (*ghe*), secondary school enrolment (*sse*), foreign direct investment (*fdi*), trade openness (*opn*) and monetary policy (*mnp*). The average adult mortality rate (per 1,000 live births) is 389.43. This is bigger than the mean value of 287.5 for Sub-Saharan African (SSA) countries' adult mortality by 101.93 (World Bank N.d.). The implication of this result is that 389.43 deaths of

TABLE 1 *Continued from the previous page*

Variables	Symbol	Definition and Measurements	Sources
Foreign direct investment, net inflows (% of GDP)	*fdi*	Foreign direct investment combines all equity capital, reinvestment of earnings, and other capital flowing into Nigeria and it is measured as a percentage of gross domestic product.	WDI
Openness (% of GDP)	*opn*	This is the sum of exports and imports of goods and services measured as a share of gross domestic product.	WDI
Monetary policy (money supply (annual %))	*mnp*	This is also called broad money and it is the annual growth rate of the currency outside banks.	WDI

NOTES WDI stands for World Development Indicators (https://data.worldbank.org/country/nigeria) and CBN is the Central Bank of Nigeria (https://www.cbn.gov.ng/documents/statbulletin.asp).

TABLE 2 Descriptive Statistics

Item	*amr*	*ffc*	*co2*	*gdp*	*ghe*	*sse*	*fdi*	*opn*	*mnp*
Mean	389.43	19.52	87407.53	0.49	73.59	31.076	0.33	32.71	23.85
Max	413.20	22.84	115280.0	12.28	388.37	56.21	1.92	53.28	87.76
Min	363.72	15.85	42441.86	−15.70	0.04	10.97	−0.02	9.14	−0.79
SD	13.60	1.55	17192.89	5.25	103.17	10.08	0.45	12.51	18.23
Obs	40	40	40	40	40	40	40	40	40

NOTES The mean is also known as average, max stands for maximum, min is minimum, SD represents standard deviation and obs stands for observation.

adults occur for every 1,000 live births in Nigeria. This is alarming compared to the SSA countries, where only 287.5 deaths occur for every 1,000 live births. This supports the argument in the literature that Nigeria has high mortality rates.

A close look at table 2 shows the mean value of fossil energy consumption is 19.52. Compared to the average consumption of 39.8 in SSA, this implies that Nigeria contributes about 20 percent to the 39.8 percent of fossil energy consumption in SSA. This is not unexpected as Nigerian sectors and households rely on oil, natural gas, and other forms of fossil fuel for daily production and consumption activities. The mean value of CO_2 emissions is 87,407.53 kilotons, while CO_2 emissions in SSA revolve around 823,770 kilotons. The average mean value of CO_2 emissions is high for Nigeria compared to SSA, suggesting that Nigeria is one of

TABLE 3 Multicollinearity Results

Variables	*logamr*	*ffc*	*logco2*	*gdp*	*logghe*	*sse*	*fdi*	*opn*	*mnp*
logamr	1								
ffc	0.09	1							
logco2	−0.21	−0.25	1						
gdp	0.06	−0.22	0.34	1					
logghe	−0.46	−0.49	0.77	0.44	1				
sse	−0.72	−0.39	0.59	0.32	0.77	1			
fdi	0.33	0.20	−0.24	0.00	−0.10	−0.15	1		
opn	0.23	−0.22	0.46	0.50	0.55	0.16	0.21	1	
mnp	0.33	0.06	−0.01	0.17	−0.002	−0.20	0.28	0.32	1

NOTES The highest correlation coefficient between two independent variables is 0.77, which suggests that the independent variables are free from the problem of multicollinearity.

the high-emitting countries in SSA. This is corroborated by the high gas flaring and CO_2 emissions in Nigeria. This finding is in line with the submission of Adesete, Olanubi, and Dauda (2022) that Nigeria is the second highest gas-emitting country in SSA. Moreover, the mean value of GDP per capita growth in Nigeria is 0.49 percent, which is very low compared to the average value of 1.6 percent recorded in SSA. The implication is that economic growth does not translate to higher income in Nigeria. This cannot be far from the truth because Nigeria is the most populous country in Africa and characterised by income inequality. Government health expenditure prints a mean of 73.59 billion. This result implies that the Nigerian government spent an average of 73.59 billion on maintaining healthcare centres in Nigeria between 1980 and 2019. The mean of secondary school enrolment of 31.076 percent is close to the 44 percent recorded in SSA. This places Nigeria as one of the countries with a high secondary school enrolment rate in SSA. Furthermore, the mean values of foreign direct investment, trade openness, and monetary policy are 0.33, 32.71, and 23.85 percent, respectively. Moreover, table 3 shows that each of the correlation coefficients is less than 0.80, the rule of thumb (Kim 2019), suggesting that the variables are not collinear.

STATIONARY TEST

Macroeconomic time series are susceptible to nonstationarity, causing regression results to suffer from spurious regression problems (Gu-

TABLE 4 Unit Root Test

Variable	ADF		PP		Order of integ.
	(1)	(2)	(1)	(2)	
logamr	−1.11 (0.92)	−4.89 (0.00)***	−1.15 (0.91)	−4.83 (0.00)***	I(1)
ffc	−3.39 (0.07)*	–	−3.5 (0.05)*	–	I(0)
logco2	−4.12 (0.01)**	–	−4.06 (0.01)**	–	I(0)
gdp	−2.45 (0.35)	−11.73 (0.00)***	−4.13 ((0.01)**	−21.29 (0.00)***	I(1)
logghe	−0.01 (0.99)	−5.40 (0.00)***	−3.78 (0.03)**	−22.22 (0.00)***	I(1)
sse	−2.43 (0.36)	−7.65 (0.00)***	−2.45 (0.35)	−7.65 (0.00)***	I(1)
fdi	−7.96 (0.00)***	–	−4.03 (0.02)**	–	I(0)
opn	−3.28 (0.08)*	–	−3.55 (0.05)**	–	I(0)
mnp	−3.73 (0.03)**	–	−3.74 (0.03)**	–	I(0)

NOTES Cpulumn headings are as follows: (1) level, (2) first difference. ADF is Augmented Dickey-Fuller and PP stands for Phillips-Perron. The two unit root test were conducted using constant & trend and Schwarz Info Criterion. *, ** and *** denote significance at 10%, 5% and 1%, respectively. Probability values in parentheses.

jarati 2004). The study utilises the Augmented Dickey-Fuller (ADF) and Phillip-Perron (PP) unit root tests to avert this problem. Two unit root tests are chosen to obtain robust results since the stationarity property of the variables is a prerequisite for the ARDL estimation.

A variable is stationary at level, that is, I(0) if the ADF/PP test statistic is bigger than the critical values. Otherwise, it is I(d), where d represents the number of times the series is differenced before it becomes stationary. The results presented in table 4 indicate that *logamr*, *gdp*, and *logghe* are stationary at the first difference, that is, I(1), while *ffc*, *logco2fdi*, *opn*, and *mnp* are stationary at level, that is, I(0). This mixed stationary justifies the use of the ARDL technique.

ARDL BOUNDS CO-INTEGRATION TEST

Having established the stationary properties, the study estimates the ARDL Bounds model to show the long-run relationship between the variables. The ARDL bounds test is based on the *F*-statistics value with the null hypothesis of no long-run relationship and an alternate hypothesis of cointegration. The null hypothesis of no cointegration is rejected if the calculated *F*-statistic is greater than the lower and upper bound critical value. However, the result will be inconclusive if the calculated *F*-statistic is bigger than the lower bound and less than the upper bound critical

TABLE 5 ARDL Bounds Test Result

F-Bounds Test		Null Hypothesis: No levels relationship		
t-statistic	Value	Significance	I(0)	I(1)
F-statistic	6.45	10%	1.95	3.06
K	8	5%	2.22	3.39
		2.5%	2.48	3.70
		1%	2.79	4.10

NOTES ARDL Bounds test reveals that the variables are co-integrated in the long-run. I(0) denotes lower bound and I(1) denotes upper bound. Lag length is 2.

values (Pesaran, Shin, and Smith 2001). The result of the ARDL bounds test presented in table 5 indicates that the value of the *F*-statistic is bigger than the values of the Lower I(0) and Upper bounds I(1). This result indicates a long-run relationship between the variables. In other words, the variables are co-integrated in the long run.

INTERPRETATION OF THE SHORT-RUN AND LONG-RUN RESULTS

The results presented in table 6 show that fossil energy consumption has an insignificant negative impact on adult mortality rates in the short run. However, a one percent increase in the first lag of fossil energy consumption significantly decreases adult mortality rates by 0.00256 percent in the short-run, ceteris paribus. CO_2 emissions exert a positive and significant relationship with adult mortality rates. Holding other variables constant, a one percent increase in CO_2 emissions increases the number of adult deaths per 1,000 people in Nigeria by 0.02642 percent in the short run. GDP per capita growth and government health expenditure exert no significant impact on adult mortality. The first lag of government health expenditure increases adult mortality rates. Given that all other predictor variables in the model remain at a fixed value, adult mortality rates increase by 0.00491 for every one percent increase in the first lag of government health expenditure in the short-run.

Moreover, the short-run results reveal that secondary school enrolment has no significant impact on adult mortality. Likewise, there is no significant relationship between foreign direct investment and adult mortality rates. Meanwhile, the first lag of foreign direct investment is positive and significant in the short run. This implies that a one percent increase in foreign direct investment lagged one time reduces deaths of adults per

TABLE 6 Short-Run and Long-Run Results

Group	Variable	Coefficient	t-Statistics	Probability
Short run estimates	*d(ffc)*	−0.00110	−0.92120	0.3691
	d(ffc(−1))	−0.00256	−2.68771	0.0150**
	d(logco2)	0.02642	2.49829	0.0224**
	d(gdp)	0.00020	0.74977	0.4631
	d(logghe)	−0.00178	−1.08891	0.2906
	d(logghe(−1))	0.00491	2.74249	0.0134**
	d(sse)	−0.00023	−0.81777	0.4242
	d(fdi)	−0.00067	−0.22019	0.8282
	d(fdi(−1))	−0.00797	−2.79046	0.0121**
	d(opn)	−0.00024	−1.42592	0.1710
	d(opn(−1))	0.00021	1.35978	0.1907
	d(mnp)	−0.00005	−0.80376	0.4320
	cointeq(−1)	−0.18288	−2.34622	0.0306**
Long run estimates	*ffc*	0.00210	0.32715	0.7473
	logco2	0.14445	2.67043	0.0156**
	gdp	0.00445	2.06100	0.0541*
	logghe	−0.01938	−2.93211	0.0089***
	sse	−0.00123	−1.04263	0.3109
	fdi	0.05704	1.84123	0.0821*
	opn	−0.00024	−0.20008	0.8437
	mnp	−0.00025	−0.75983	0.4572
	C	4.33923	6.76430	0.0000***

NOTES 1%, 5% and 10% significant levels are denoted by ***, **, and *, respectively.

TABLE 7 Robustness Checks

Item	*F*-statistics	Probability
Heteroscedasticity Test: Breusch-Pagan-Godfrey	0.61734	0.8424
Breusch-Godfrey Serial Correlation LM Test	1.26751	0.3083
Jarque-Bera Stat	0.12276	0.9405

1,000 persons by 0.00797 percent in Nigeria, provided all other predictors are fixed.

Furthermore, the results show that trade openness and monetary policy exert an insignificant negative impact on adult mortality rates in Nigeria. Also, there is no significant relationship between the first lag of trade openness and adult mortality rates in Nigeria.

In the long-run, fossil energy consumption is positive and insignificant. CO_2 emissions and GDP per capita growth have a significant positive impact on adult mortality rates. Holding other variables constant, a one percent increase in CO_2 emissions and GDP per capita growth lead to a 0.14445 and 0.00445 percent increase in adult mortality rates in Nigeria, respectively. Also, there is a significant negative relationship between government health expenditure and adult mortality. This implies that adult mortality decreases by 0.01938 percent for every one percent increase in government health expenditure in Nigeria, based on the condition that all other predictor variables in the model remain the same. Moreover, foreign direct investment has a significant positive impact on adult mortality rates. By implication, a one percent increase in foreign direct investment increases adult mortality rates by 0.05704 percent, after controlling for the other predictors in the model. Secondary school enrolment, trade openness, and monetary policy are negative and insignificant in the long run.

The value of the error correction term is less than one, negative, and significant. This supports the earlier conclusion that the variables are co-integrated in the long run (Foye 2023). Also, the coefficients suggest that a temporary disequilibrium in the system will be corrected annually at a speed of 0.18288 percent until the steady-state is attained. Finally, the post estimation results reveal that the residual of the model is normally distributed and free from the problems of serial correction and heteroscedasticity.

DISCUSSION OF THE EMPIRICAL RESULTS

It is obvious from the results presented in table 6 that the fossil energy consumption (first lag) has a significant negative impact on adult mortality rate in the short run, though it is positive and insignificant in the long run. The negative short run relationship negates the a priori expectation and the submission of Vohra et al. (2021) and Anser et al. (2020), who report that fossil energy consumption contributes to higher mortality. Meanwhile, the result conforms to the work of Sial et al. (2022), who find a U-relationship between fossil energy consumption and mortality rates. Although the coefficient is quite small (0.00256), the implication is that fossil energy consumption reduces adult mortality rate in the short run in Nigeria. This means the economic benefits associated with fossil energy consumption outweigh its adverse effect on adult mortality in the short run. In other words, fossil energy consumption does not immediately contribute to higher adult mortality in Nigeria. The airborne particulate matter and ground-level ozone from fossil energy consumption do not immediately escape the adult body's defence as with new-borns and young children. Also, these results could be attributed to the fact that adults do not breathe quickly and absorb more pollutants emanating from fossil energy consumption more rapidly, as with children (United Nations 2018). Meanwhile, as fossil energy consumption grows, the adverse effects become more apparent on adults as shown by the positive relationship in the long run.

CO_2 emissions increase the adult mortality rates in Nigeria both in the short and long run. These findings agree with the a priori expectation and also lend credence to Oyedele (2022), Vohra et al. (2021), Oyelade et al. (2020), and Shobande (2020), who submit that CO_2 worsens human health in Nigeria. CO_2 emissions contribute greatly to outdoor air pollution, a significant threat to human health, and increase adult mortality rates in Nigeria. In addition, the findings strengthen the position of international organisations such as the World Health Organisation and climate-based organisations that often promote the consumption of clean energy to enhance the quality of life of Nigerians.

Onofrei et al. (2021) and Shobande (2020) assert that income, also known as GDP per capita growth, will enable people to afford healthcare services and improve their standard of living. But the case is not the same for Nigeria as the study establishes a significant positive relationship between GDP per capita growth and mortality rates in the long run. Though this finding contradicts the a priori expectation and substantial part of the literature, it conforms to the submission of Rasoulinezhad, Taghizadeh-Hesary, and Taghizadeh-Hesary (2020) and Farooq, Yusop, and Chaudhry (2019), who also report that income increases mortality rate. The implication of this finding is that a higher GDP per capita growth does not translate to public health improvement in Nigeria. One possible explanation for this is income inequality. This suggests that as GDP per capita increases, the gap between the rich and the poor may increase, leading to a rise in relative poverty for some of the population. This, in turn, could lead to a rise in mortality rates, as people living in poverty tend to have poorer health outcomes due to limited access to healthcare. Nigeria is an energy-oriented country, relying heavily on fossil fuels as its major source of income (Foye 2023). Fossil fuels, which constitute the larger part of the total energy consumption, are a major source of air pollution that harms human health globally.

In the short run, the behaviour of the first lag of government health expenditure contracts the theoretical prediction. Also, the finding disagrees with the conclusion of Oladosu, Chanimbe, and Anaduaka (2022) that an increase in heath expenditure improves public health. However, the finding is in line with Azuh et al. (2020), who prove that government health expenditure increases mortality rate in Nigeria. The adverse effect of government health expenditure can be attributed to mismanagement, a nonchalant government attitude toward the health sector and high level of corruption that has bedevilled the Nigerian economy (Azuh et al. 2020; Olaifa and Benjamin 2019). Though government health expenditure adversely affects human health in the short run, there is evidence that the government adjusts and addresses the factors limiting the effectiveness of the health fund in the long run. As reported in table 6, government health expenditure has a significant negative effect on adult mortality rates in Nigeria. This implies that the government health fund improves human health. This finding conforms to a priori expectation and supports the findings of Onofrei et al. (2021) and Dhrifi (2018). This long-run result is not a surprise considering the renewed efforts of the international organisations, including USAID, to ensure that the Nigerian government pays important attention to the health sector.

Foreign direct investment has a U-shape relationship with adult mortality in Nigeria. In the short run, the one lag of foreign direct investment reduces adult mortality rates in Nigeria. This finding is corroborated by Immurana et al. (2023), who submit that foreign direct investment improves human health. Inflow of foreign direct investment to Nigeria brings about technology progress, improve firms' productivity, and enables people to earn a higher income and improve their standard of living (Immurana et al. 2023). In the long run, foreign direct investment increases adult mortality in Nigeria. This finding is in line with the result of Shah et al. (2022), who claim that foreign investment harms human health. Inflow of foreign investment directly results in an increase in firms' production capacity. Given the fact that Nigeria is an energy-oriented country, the consumption of fossil energy increases with the increase in production and this affects the air quality. The poor air quality leads to different diseases and increases the adult mortality rates in Nigeria.

Trade openness and monetary policy are insignificant in the short and

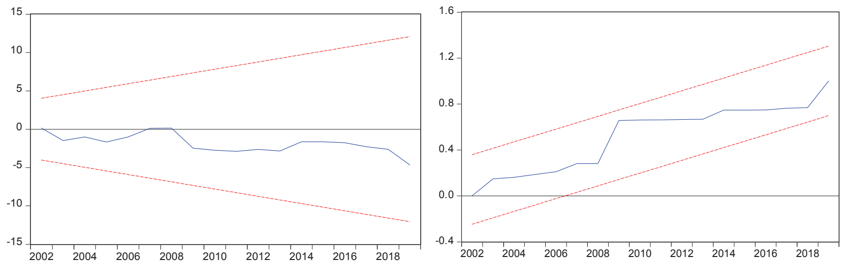

FIGURE 1 CUSUM (left) and CUSUMSQ (right) of Adult Mortality Rates (blue – CUSUM/CUSUMQ, red – 5% significance)

long run. The implication is that there is insufficient evidence to suggest that trade openness and monetary policy affect adult mortality rates in Nigeria between 1980 and 2019. These findings are incongruous to the submission of Byaro, Nkonoki, and Mayaya (2021) and Peter and Adediyan (2020), who claim that trade openness and monetary policy have significant impact on adult mortality rates. To establish the relative impact of fossil energy consumption and CO_2 emissions, the study follows Olofin et al. (2014) by examining the magnitude of the estimated model. It is obvious from the results that the magnitude of CO_2 emissions is greater than the magnitude of energy consumption. This implies that effort should be channelled towards decreasing fossil energy usage or encouraging consumption of environmentally friendly energy to improve health quality in Nigeria. Finally, the study assesses the constancy of the parameters using the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ). As shown in figure 1, the plots of the CUSUM and CUSUMSQ of the model are within the 5 percent critical bounds of parameter stability. Hence, the study concludes that the parameters are stable.

Conclusion and Policy Implications

This study analyses the short-run and long-run impact of fossil energy consumption and CO_2 emission on adult mortality rates in Nigeria from 1980 to 2019. The study controls for government health expenditure, gross domestic product per capita growth, school enrolment, foreign direct investment, trade openness, and monetary policy and utilises ADF and PP unit root tests to establish their stationary property. The ARDL technique is used for the analysis, and the results of the estimated model show that fossil energy consumption reduces adult mortality rates in the short run, suggesting that the economic benefit associated with fossil energy consumption outweighs its adverse effect on adult mortality in Nigeria. On the other hand, CO_2 emissions increase the adult mortality rate in the short and long run. This proves that outdoor air pollution associated with CO_2 emissions poses a significant threat to healthy living in Nigeria.

Moreover, the study finds that GDP per capita growth harms human health in the long run. This is justified by the heavy reliance of Nigeria on fossil energy as a major income source. Government health expenditure follows an inverted U-shape relationship in explaining adult mortality while foreign direct investment has a U-shape relationship with adult mortality in Nigeria. Trade openness and monetary policy are insignificant in the short and long run. The relative analysis indicates that CO_2 emissions have more impact on adult mortality compared to fossil energy consumption.

Overall, it is recommended that the government should substitute clean energy for fossil fuel energy to improve the quality of life in Nigeria since the magnitude of CO_2 emissions on adult mortality is greater than the magnitude of fossil energy consumption in the estimated models. Also, fossil energy consumption should be controlled by strengthening CO_2 emissions tax and channelling the funds to the health sector. Moreover, the government should increase the health fund and ensure the funds are used for the improvement of healthcare service delivery in Nigeria. Considering the impact of income and foreign direct investment, further policy initiatives should encourage the consumption of clean energy in Nigeria.

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