International Journal of Social Science, Management and Economics Research
Volume 4 Issue 5 Sep-Oct 2026
ISSN: 2583-9853| www.ijssmer.com

FRACTIONAL PERSISTENCE AND DYNAMIC INTERDEPENDENCE OF CLIMATE CHANGE, HEALTH OUTCOMES AND ECONOMIC GROWTH IN NIGERIA: EVIDENCE FROM FRACTIONAL CO-INTEGRATION VECTOR AUTOREGRESSIVE (FCVAR) MODEL

SALIU Mojeed Olanrewaju
Ekiti State University, Ado-Ekiti, Ekiti State, **Nigeria**

&

ARIYO Bukola Mary
Ekiti State University, Ado-Ekiti, Ekiti State, **Nigeria**

Received: 05/09/2026 Accepted: 15/09/2026 Published: 20/09/2026

DOI - https://doi.org/10.61421/IJSSMER.2026.4504

ABSTRACT

This study investigates the persistence and dynamic interdependence of climate change, health outcomes and economic growth in Nigeria, contributing to the literature by jointly modelling fractional persistence and long-run relationships within a climate-health-growth framework. Using annual data on real GDP growth, climate change, life expectancy, infant mortality, labour-force participation and gross fixed capital formation, the study applies Gaussian semi-parametric (GSP) and Geweke-Porter-Hudak (GPH) fractional integration estimators alongside the Fractionally Cointegrated Vector Autoregressive (FCVAR) model, which accommodates fractional orders of integration and cointegration. The results reveal heterogeneous persistence: economic growth, climate change and capital formation are predominantly non-stationary but mean-reverting, whereas life expectancy, infant mortality and labour-force participation exhibit stronger, largely non-mean-reverting persistence. The FCVAR bootstrap rank tests further reveal selective rather than pervasive long-run interdependence, with fractional cointegration identified only for economic growth-life expectancy, economic growth-infant mortality and climate change-life expectancy. The findings establish health outcomes as an important long-run linkage between climatic conditions and economic performance in Nigeria. The study concludes that persistent shocks and long-run adjustment are heterogeneous across the climate-health-growth nexus. Consequently, policy should integrate climate adaptation with sustained healthcare investment, disease prevention, climate-resilient infrastructure and green productive investment, while strengthening institutional coordination to mitigate persistent health and economic vulnerabilities.

Keywords: Climate Change, Health Outcomes, Economic Growth, Fractional Integration, Fractional Co-integration.

1. INTRODUCTION

Economic growth remains a central objective of macroeconomic policy because of its fundamental role in employment creation, poverty reduction, improvements in living standards, and overall socioeconomic development. Sustained economic growth expands the productive capacity of an economy, enhances household welfare, and strengthens the fiscal capacity of governments to provide essential public goods and services (Arogundade et al., 2024; Prall et al., 2023). Although conventional growth analysis has largely emphasized domestic factors such as capital accumulation, human capital development, institutional quality, and productivity, alongside external factors such as trade, foreign investment, and global economic conditions, increasing attention has been directed towards environmental conditions as an important determinant of economic performance (Nasir et al., 2019; Ngoma et al., 2024; Raza et al., 2023). Climate change, in particular, represents an increasingly important external shock capable of altering both the productive and welfare foundations upon which sustainable economic growth depends.

The economic consequences of climate change operate through multiple and mutually reinforcing channels. Variations in temperature and precipitation, together with increasing exposure to droughts, floods, heat waves, and other extreme climatic events, can affect agricultural productivity, food security, energy demand, water availability, infrastructure, labour productivity, and the allocation of public resources. These consequences are particularly important in developing economies where agriculture and other climate-sensitive activities account for substantial proportions of employment and livelihoods (Wang & Lewis, 2024; Sponagel et al., 2024). Climate-related disasters can additionally damage productive infrastructure, interrupt supply chains and market activities, and compel governments to redirect resources from productive investment towards reconstruction and adaptation. At the broader macroeconomic level, climate change may contribute to inflation variability, migration, financial-market stress, changes in energy markets, widening income disparities, and increasing public debt (Tao et al., 2023). Its economic implications therefore extend considerably beyond environmental deterioration.

The severity of these consequences is not uniform across economies. Geographical exposure, economic structure, income levels, technological capabilities, institutional quality, infrastructure, and adaptive capacity determine the ability of individual countries to withstand and recover from climatic shocks. Developed economies generally possess greater financial and technological resources for climate adaptation and tend to have more diversified productive structures, whereas developing countries frequently combine high exposure to climate-sensitive sectors with limited adaptive capacity (Bilal, 2024; Roy, 2024). This vulnerability is particularly pronounced in sub-Saharan Africa, where dependence on agriculture, infrastructural deficiencies, poverty, limited access to technology, and existing public-health challenges can intensify the economic consequences of climatic disturbances (Rocco et al., 2021).

An important but sometimes insufficiently integrated dimension of this relationship is the health transmission channel. Climate change can influence population health through rising temperatures, changing precipitation patterns, deteriorating air and water quality, altered patterns of vector-borne and infectious diseases, food insecurity, malnutrition, and exposure to extreme weather events. Heat stress and unfavourable climatic conditions may also impair workers' physical and cognitive capacity, thereby reducing labour productivity (Song et al., 2023; Arogundade et al., 2024). Consequently, climatic shocks may affect economic performance not only directly through agriculture, infrastructure, energy, and other productive activities, but also indirectly through their effects on human health and productive capacity.

Health itself constitutes a fundamental component of human capital and an important determinant of long-term economic performance. Healthy individuals are generally better positioned to participate effectively in productive activities, while improvements in child health can facilitate cognitive development, educational attainment, and productivity in adulthood (Rahman et al., 2022). Improvements in population health can therefore increase labour productivity, prolong economically productive lives, reduce productivity losses associated with morbidity and premature mortality, and generate wider social and economic benefits (Okunade & Osanami, 2020). The importance of health to sustainable development is equally reflected in the global development agenda, particularly Sustainable Development Goal 3, which seeks to ensure healthy lives and promote well-being across populations (Akinbode et al., 2020). Thus, climate change, health outcomes, and economic growth should not necessarily be regarded as isolated processes; rather, they constitute potentially interconnected dimensions of sustainable development.

These interrelationships are particularly important for Nigeria. The Nigerian economy is substantially exposed to climatic risks because several important sectors, including agriculture, forestry, energy, tourism, water resources, and coastal activities, are sensitive to climatic conditions (Ogunbadejo et al., 2020). Nigeria is susceptible to rising temperatures, changing precipitation patterns, flooding, droughts, heat waves, and other climatic hazards capable of disrupting agricultural production, infrastructure, livelihoods, population health, and aggregate economic activity. Rapid population growth, poverty, infrastructural deficiencies, and limited adaptive capacity may further amplify the socioeconomic consequences of these climatic disturbances.

The challenge is particularly significant because climatic vulnerability has coincided with relatively weak economic and health outcomes. Nigeria recorded relatively strong economic growth during much of 2000–2014, averaging above 7% annually, but growth subsequently weakened considerably, while rapid population expansion contributed to declining per capita income (Central Bank of Nigeria, 2023; World Bank, 2024). At the same time, notwithstanding Nigeria's participation in international climate frameworks and the adoption of national measures, including the National Adaptation Strategy and Plan of Action on Climate Change, National Adaptation Plan Framework, Climate Change Act 2021, updated Nationally Determined Contribution, and long-term low-emission development initiatives, the country continues to face substantial climate vulnerability. The original evidence motivating this study further indicates that Nigeria's life expectancy at birth was approximately 53.6 years in 2022, while infant mortality remained considerably above desirable regional and international benchmarks. The coexistence of climate vulnerability, relatively poor health indicators, and unstable economic performance raises an important empirical question concerning whether these phenomena share persistent and dynamic long-run relationships.

Although an expanding empirical literature has investigated these issues, important limitations remain. One strand has examined the relationship between climate change and economic growth (Bilal, 2024; Atchade & Nougbode, 2024; Arogundade et al., 2024; Abid et al., 2023). However, climate conditions have frequently been represented by temperature or precipitation separately. Such individual measures provide useful information but may not adequately capture the multidimensional nature of climatic conditions confronting an economy. This creates a measurement gap, particularly for country-specific studies where variations in temperature and precipitation may jointly determine climatic exposure. The present study addresses this limitation by employing a Climate Change Index constructed from average annual temperature change and average annual precipitation, thereby providing a composite representation of climatic conditions.

A related limitation characterizes the health-growth literature. Existing studies have examined the effects of health outcomes on economic performance (Adebanjo et al., 2023; Alwago, 2023; Eboh et al., 2022; Jemiluyi & Alao-Owunna, 2020), but individual indicators are frequently used to represent population health. Relying exclusively on either longevity or mortality may provide an incomplete representation of health conditions. This study therefore considers life expectancy at birth and infant mortality rate simultaneously. While life expectancy reflects longevity and broader population health conditions, infant mortality captures early-life health vulnerability and the effectiveness of the socioeconomic and healthcare environment.

More fundamentally, the literature remains fragmented across the climate-health-growth nexus. Studies examining climate change and economic growth, health and economic growth, and climate change and health outcomes have largely evolved as separate empirical strands. For instance, Bressler et al. (2021), and Herrnstadt and Dinan (2020) provide evidence concerning climate change and health outcomes, yet comparatively limited attention has been devoted to jointly examining climate change, health outcomes, and economic growth within an integrated country-specific framework. Such fragmentation makes it difficult to determine whether climatic disturbances are dynamically associated with health conditions and whether these relationships coexist with long-run movements in economic performance.

Beyond these measurement and empirical limitations lies a more fundamental methodological gap concerning persistence and long-memory dynamics. Much of the conventional time-series literature evaluates macroeconomic, environmental, and health variables within an integer-order integration framework, under which a variable is generally classified as stationary, (I(0)), or as possessing a unit root, (I(1)). Such a dichotomous classification can be overly restrictive when the effects of shocks decay slowly over time. Climate variables may exhibit persistent behaviour because changes in climatic conditions evolve gradually; health indicators such as life expectancy and infant mortality similarly tend to adjust slowly because they reflect accumulated demographic, socioeconomic, environmental, and healthcare conditions. Macroeconomic variables may likewise retain the effects of shocks for extended periods. Consequently, imposing integer orders of integration may conceal important information concerning the actual magnitude and duration of persistence.

This distinction has important economic and policy implications. A shock to climate conditions, population health, or economic growth may be short-lived, highly persistent but ultimately mean-reverting, or effectively permanent. These possibilities require different policy responses. Conventional unit-root procedures may classify a highly persistent but mean-reverting process as non-stationary and thereby fail to reveal the speed at which shocks dissipate. Fractional integration provides a more flexible alternative by allowing the differencing parameter d to assume fractional values and thereby permitting direct estimation of the degree of persistence. It can therefore distinguish between stationary short-memory behaviour, stationary long-memory behaviour, non-stationary but mean-reverting processes, and non-mean-reverting dynamics. This distinction is particularly relevant for climate and health policy because the effectiveness, intensity, and duration of policy intervention should depend partly on whether shocks naturally dissipate or exert enduring effects.

An analogous limitation arises in the analysis of long-run relationships. Conventional cointegration techniques generally rely on integer-order representations and may therefore inadequately characterize relationships among variables whose individual and equilibrium-adjustment processes exhibit fractional dynamics. Fractional cointegration relaxes this restriction by permitting long-run equilibrium relationships in which deviations from equilibrium follow a fractional order of integration. It consequently provides richer information concerning the extent and speed of long-run adjustment. Despite these advantages, the application of fractional integration, particularly fractional cointegration, to the joint relationship among climate change, health outcomes, and economic growth remains scarce, while evidence for Nigeria is especially limited. The methodological gap is therefore not simply the absence of another econometric technique; rather, it concerns the limited understanding of how persistent climate, health, and growth shocks are and whether their long-run interdependence exhibits fractional mean-reverting behaviour.

Against this background, this study investigates the fractional persistence and dynamic interdependence of climate change, health outcomes, and economic growth in Nigeria. Climate change is represented by a Climate Change Index incorporating average annual temperature change and average annual precipitation; health outcomes are captured by life expectancy at birth and infant mortality rate; while economic growth is represented by the real GDP growth rate. The study employs fractional integration to estimate the degree of persistence inherent in the individual variables and fractional cointegration to determine whether they share persistent but mean-reverting long-run equilibrium relationships.

The study contributes to the literature in three principal respects. First, it provides a more encompassing measurement of climate conditions by combining temperature and precipitation information within a climate change index rather than relying exclusively on either climatic indicator. Second, it integrates two complementary dimensions of population health-life expectancy and infant mortality, with climate change and economic growth within a unified Nigerian framework. Third, and most importantly, it moves beyond the conventional (I(0)/I(1)) paradigm by employing fractional integration and fractional cointegration to identify the degree of persistence, mean-reverting properties, and long-run adjustment dynamics underlying the climate-health-growth nexus. The resulting evidence is expected to provide a more nuanced basis for determining whether climatic and health shocks in Nigeria are temporary, persistent but reversible, or permanent, with corresponding implications for the design and duration of climate adaptation, public-health, and sustainable-growth policies.

2. EMPIRICAL LITERATURE REVIEW

Recent empirical literature has increasingly acknowledged that climate change, population health, and economic performance are dynamically interconnected, although the three strands have largely been investigated separately and with conventional econometric techniques. Arogundade et al (2024) examined the effects of climate change on economic growth in Nigeria using annual observations spanning 1961–2022. The study employed the Autoregressive Distributed Lag (ARDL) model, Fully Modified Ordinary Least Squares (FMOLS), Quantile ARDL (QARDL), and time-varying Granger causality techniques, with average temperature and precipitation serving as separate measures of climate change. The findings revealed that temperature and precipitation exerted adverse and statistically significant effects on economic performance in the long run, whereas their short-run impacts were generally positive. The QARDL estimates further established heterogeneous climate effects across different quantiles of economic growth, while time-varying causality supported causation running from climate conditions to economic performance. Notwithstanding its methodological richness, the study treated temperature and precipitation separately and remained within the conventional integer-order integration framework. It therefore did not establish the precise fractional persistence of climatic and macroeconomic shocks or whether their long-run relationship was fractionally cointegrated. The present study extends this evidence by constructing a composite climate change index from temperature change and precipitation and applying fractional integration and fractional cointegration to the Nigerian climate–health–growth nexus.

Atchadé and Nougbodé (2024) investigated the relationship among climate change, food availability, agricultural productivity, and economic growth in Benin over the period 1961–2021. Using ARDL, Vector Autoregression and Toda–Yamamoto Granger causality procedures, they found that agricultural productivity and food production promoted economic expansion, whereas temperature fluctuations adversely affected economic growth. Their causality results showed a unidirectional relationship from temperature variation to agricultural value added, although no direct causality was established between temperature variation and aggregate economic growth. While the study provided useful evidence on an indirect climate–growth transmission mechanism through agriculture, it concentrated predominantly on the agricultural channel and represented climate change mainly through temperature variation. Moreover, the ARDL framework imposed the conventional distinction between (I(0)) and (I(1)) processes and did not account for long-memory behaviour. The present study broadens this perspective by incorporating the health channel, combining temperature and precipitation in a climate index, and allowing the orders of integration and cointegration to take fractional values.

Bressler (2021) investigated the mortality consequences of climate change globally by extending the Dynamic Integrated Climate-Economy model to incorporate a temperature-related mortality damage function. The resulting DICE-EMR framework introduced the "mortality cost of carbon" and showed that incorporating temperature-related deaths substantially increased the estimated social cost of carbon. Under the study's baseline scenario, additional carbon emissions were associated with sizeable cumulative excess mortality during 2020–2100, thereby demonstrating that excluding health damages substantially understates the welfare cost of climate change. The analysis, however, was a global integrated-assessment exercise and concentrated primarily on temperature-related mortality rather than country-specific historical relationships involving precipitation, life expectancy, infant mortality and actual economic growth. Bressler also acknowledged that several non-temperature mortality pathways were omitted. The present study responds by examining observed Nigerian time-series data and simultaneously incorporating temperature, precipitation, life expectancy, infant mortality and real GDP growth within a fractional persistence framework.

Alwago (2023) investigated the nexus among health expenditure, life expectancy and economic growth in Kenya using an ARDL modelling framework. The study found evidence that increased health expenditure contributes positively to economic activity and that improved population health constitutes an important channel through which health investment can generate economic benefits. The country-specific time-series orientation is relevant to the present investigation because Kenya, like Nigeria, is a developing African economy with considerable health and development constraints. However, the emphasis was on health financing rather than climatic determinants of health, and the ARDL specification did not permit the integration parameter to assume fractional values. Consequently, it could not distinguish between weakly persistent, highly persistent but mean-reverting, and permanent health or growth shocks. The current study responds by focusing directly on health outcomes and climatic exposure while estimating their fractional persistence and long-run interdependence.

Abid et al (2023) examined whether climate-change mitigation promotes economic, environmental and social development across 18 European countries over 1981–2018. The study employed panel quantile regression, incorporating trade openness, foreign direct investment, renewable and non-renewable energy consumption, population growth and life expectancy as controls. The findings showed that climate-mitigation efforts did not uniformly promote economic growth; positive growth effects were concentrated in countries with moderate or high environmental performance, whereas countries with low environmental performance derived little growth benefit. Climate mitigation nevertheless improved environmental performance across the sample. The authors concluded that the growth consequences of climate policy are heterogeneous and dependent on institutional and environmental conditions. This supports the present study's recognition of heterogeneous climate–growth interactions, but differs because it focuses on European panel data and climate-mitigation policies rather than the persistence and long-run climate–growth dynamics of a single developing economy.

Bilal and Känzig (2024) investigated the macroeconomic consequences of global climate change by distinguishing between global and local temperature shocks. Their empirical framework estimated the dynamic effects of temperature variations on macroeconomic activity across countries. The study showed that increases in global temperature generate sizeable and persistent reductions in economic output, indicating that the macroeconomic costs of climate change may be considerably larger than estimates based solely on local temperature variations. The authors concluded that global temperature shocks have economically important growth consequences and that conventional country-specific temperature models may understate climate damages. The study strengthens the climate–growth argument underlying the present research but does not jointly examine climate, health outcomes and growth within a fractional persistence and cointegration framework.

Adebanjo et al (2023) investigated the relationship between infant mortality and economic growth in Nigeria using annual World Development Indicators data covering 1970–2022. The study focused particularly on the response of economic growth to shocks in infant mortality. Its findings indicate that infant mortality and macroeconomic performance are dynamically interrelated, reinforcing the importance of improvements in child survival for Nigeria's development prospects. The study concluded that adequate healthcare provision and reductions in infant mortality are necessary for improving economic performance. Its Nigerian focus and use of infant mortality make it directly relevant to the present study; however, it does not jointly model life expectancy, climate change and economic growth or allow for fractional persistence.

Herrnstadt and Dinan (2020) estimated the expected effect of climate change on long-run U.S. economic output for the Congressional Budget Office. Their modelling projected that climate change would reduce average annual U.S. real GDP growth by approximately 0.03 percentage points during 2020–2050, accumulating to roughly a 1% reduction in the level of real GDP by 2050 relative to a counterfactual without additional climate change. The study therefore provides strong evidence on the climate–growth nexus, but it does not directly model health outcomes as an intermediary

Jemiluyi and Alao-Owunna (2020) investigated the gender dimension of the health status–economic growth nexus in Nigeria using annual data for 1981–2018 and dynamic ordinary least squares (DOLS). Health status was represented through gender-disaggregated life expectancy. Their results demonstrated that the contribution of longevity to economic growth differs between males and females, showing that aggregation can conceal important health–growth heterogeneity. The authors concluded that gender-specific health improvements should form part of growth-enhancing policies. The present study extends this Nigerian evidence by incorporating both life expectancy and infant mortality, climate change and fractional dynamic interdependence rather than concentrating on gender-disaggregated longevity.

Eboh et al (2022) examined health expenditure, child mortality and economic growth in Nigeria using annual time-series data for 1980-2020 and the ordinary least squares technique. The findings showed that government health expenditure and capital health expenditure reduced under-five mortality, although their effects were statistically insignificant, whereas recurrent health expenditure had a significant mortality-reducing effect. Gross fixed capital formation was found to have a positive and significant relationship with child mortality. The authors emphasized improved and appropriately structured healthcare expenditure as necessary for better health outcomes and sustainable development. Although directly relevant to Nigeria, the study primarily uses conventional OLS and does not investigate persistence, fractional integration or long-run fractional cointegration among health, climate and growth variables.

Taken together, the reviewed evidence reveals several important regularities but also substantial unresolved issues. First, recent studies overwhelmingly confirm that climatic conditions can influence economic activity through agricultural productivity, infrastructure, labour productivity and other channels, although the magnitude and direction of the effects vary across countries and time horizons. Second, the health–growth literature generally supports the proposition that improvements in longevity and reductions in mortality can enhance economic performance, while environmental studies increasingly demonstrate that climate-related pressures can themselves deteriorate health outcomes. Third, these strands remain remarkably fragmented: studies of climate and growth rarely incorporate health outcomes; studies of health and growth generally omit direct climatic exposure; and studies of climate and health seldom embed economic growth within the same dynamic framework.

A further gap relates to measurement. Temperature and precipitation are frequently introduced separately into empirical models even though actual climatic exposure reflects their combined behaviour. Similarly, population health is often represented by a single indicator, particularly life expectancy, despite the complementary information contained in mortality indicators. The present study responds by constructing a Climate Change Index from average annual temperature change and average annual precipitation and by jointly incorporating life expectancy and infant mortality as alternative but complementary dimensions of health outcomes.

Most importantly, the reviewed empirical literature shows that the predominant methodologies remain ARDL, QARDL, VAR, VECM, conventional panel cointegration, FMOLS, fixed-effects models and causality procedures. These techniques have generated valuable evidence but largely maintain the standard (I(0)/I(1)) distinction. Such a restriction may be consequential for climate, health and macroeconomic variables whose shocks can persist for extended periods without necessarily being permanent. Yet applications of fractional integration and fractional cointegration to the joint climate change–health outcomes–economic growth relationship remain extremely scarce, particularly for Nigeria.

Accordingly, the present study advances the literature by estimating the fractional orders of integration of Nigeria's climate change index, life expectancy, infant mortality and real GDP growth and subsequently testing their fractional cointegration. This makes it possible to distinguish shocks that are stationary and rapidly mean-reverting from those that are long-memory and slowly mean-reverting, as well as those that may be effectively permanent. Beyond establishing whether a long-run relationship exists, the fractional cointegration framework further permits examination of whether deviations from equilibrium exhibit gradual long-memory adjustment. The study therefore addresses the principal measurement, integration and methodological shortcomings identified in the recent literature and provides a unified framework for understanding the persistence and dynamic interdependence of climate change, population health and economic growth in Nigeria.

3. DATA SET AND METHODS

This study employs annual time-series data for Nigeria to investigate the persistence and dynamic interdependence among climate change, health outcomes and economic growth. The empirical framework comprises six variables: real gross domestic product growth rate (RGDPGR), climate change index (CCI), life expectancy at birth (LEB), infant mortality rate (IMR), labour force participation rate (LFP), and gross fixed capital formation (GFCF). The selection of these variables reflects the multidimensional channels through which climatic conditions and population health may interact with economic performance. In particular, RGDPGR represents economic performance, while GFCF and LFP account for capital accumulation and labour-market participation. Health outcomes are captured by LEB and IMR, thereby incorporating both longevity and early-life mortality dimensions.

Rather than relying exclusively on the two climatic indicators (temperature and precipitation change), the climate change index (CCI) is constructed from the annual temperature and precipitation change using the Principal Component Analysis (PCA) method. This composite specification is intended to capture broader variations in climatic conditions and reduce the limitation associated with representing climate change through a single meteorological variable. Data on economic performance (RGDPGR) and Health Outcomes (LEB and IMR) are sourced from the World Development Index (WDI), while data on GFCF and LFP are both sourced from Central Bank of Nigeria (CBN) statistical bulletin. Data on the average annual temperature and average annual precipitation, that both formed the climate change index, are sourced from the World Bank Climate Change Knowledge Portal (CCKP).

In order to effectively examine the persistence and dynamic interdependence among climate change, health outcomes and economic growth in Nigeria, this study therefore employs a two-phase modelling framework. First are the two semi-parametric fractional integration estimators, namely, Log-periodogram estimator, also called Geweke and Porter-Hudak (GPH) and the Gaussian Semi-Parametric (GSP), which are both used to estimate long-memory properties in the climate-health-growth nexus. Second, having established the persistence characteristics of the individual series, their long-run dynamic interdependence is investigated using the Fractionally Cointegrated Vector Autoregressive (FCVAR) model of Johansen and Nielsen (2012). This sequential procedure is preferable to relying exclusively on conventional unit-root and cointegration methods because economic, climatic and health variables may exhibit long memory, whereby shocks decay gradually at rates that cannot adequately be represented by integer orders of integration. Fractional integration permits d to assume non-integer values and therefore provides a richer characterization of persistence.

i. Semi-Parametric Fractional Integration

In a bid to estimate the memory parameter d of the time-series, this research incorporates two semi-parametric estimators, namely, the log-periodogram (GPH) estimator by Geweke and Porter-Hudak (1982) and the Gaussian Semi-Parametric (GSP) by Robinson (1995). Let X_t connotes the time-series variable, which is designed to follow a fractionally integrated process as follows:

$$(1-L)^d X_t = U_t, t = 1, 2, \dots\dots\dots\dots.., T \qquad eq\ 1$$

Where d is the long-memory parameter and U_t is a short-memory disturbance term. The Log-periodogram (GPH) estimator, utilizes the features of spectral density at low frequencies. The estimator is obtained from the regression as follows:

$$logI(\lambda j) = \alpha - dlog\left[4sin^2\left(\frac{\lambda j}{2}\right)\right] + vj, j = 1, 2, \dots\dots\dots\dots\dots\dots, m \qquad eq\ 2$$

Where $I(\lambda j)$ is the periodogram and $\lambda j = \frac{2\pi j}{T}$ represents the Fourier frequencies. The value of d is expressed by the slope coefficient from this regression using the lowest m frequencies.

In order to compliment the GPH model, this study equally adopts the Gaussian Semi-Parametric estimator, which estimates d by minimizing a frequency-domain objective function based on low-frequency ordinates as follows:

$$Qm^{(d)} = log\left(\frac{1}{m}\sum_{j=1}^{m} \lambda j^{2d} I(\lambda j)\right) - \frac{2d}{m}\sum_{j=1}^{m} log\lambda j \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.. eq\ 3$$

For both estimators (GPH and GSP), if $d < 0.5$, then the parameter d is termed to be stationary and mean-reverting (fast convergence). If $0.5 \leq d < 1$, parameter d is interpreted to be nonstationary but mean-reverting (slow convergence). If $d \geq 1$, the d is non-convergent (persistent divergence).

ii. Fractionally Cointegrated Vector Autoregressive Model

Although the fractional integration estimates establish the persistence of individual variables, they do not determine whether persistent variables share common long-run equilibrium relationships. The second stage therefore applies the FCVAR framework developed by Johansen (2008) and Johansen and Nielsen (2012). The model generalizes the conventional cointegrated VAR by allowing the variables and their equilibrium errors to possess fractional orders of integration. For a P-dimensional vector X_t, the conventional CVAR representation is given as:

$$\Delta X_t = \alpha\beta' X_{t-1} + \sum_{i=1}^{k} \Gamma_i \Delta X_{t-1} + \varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. eq\ 4$$

Introducing fractional differencing yields the FCVAR specification as:

$$\Delta^d X_t = \alpha\beta' L_b \Delta^{d-b} X_t + \sum_{i=1}^{k} \Gamma_i L_b^i \Delta^d X_t + \varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. eq\ 5$$

Where

$$\Delta^d = (1-L)^d, L_b = 1 - \Delta^b \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. eq\ 6$$

Here, d denotes the fractional integration order of the system, b represents the reduction in persistence generated by cointegration, β contains the long-run cointegrating vectors, α contains the corresponding adjustment coefficients, Γ_i captures short-run dynamics, k is the lag order, and ε_t is an innovation vector. If $X_t \sim I(d)$ and a non-zero linear combination exists such that: $\beta' X_t \sim I(d-b), b > 0$, the variables are fractionally cointegrated. Thus, b measures the extent to which the equilibrium relationship reduces the memory of the original series. The conventional $I(1)/I(0)$ cointegration framework is therefore nested within the more general fractional specification.

Given the objective of identifying precisely where long-run interdependence occurs within the climate-health-growth system, the FCVAR analysis is implemented using 15 bivariate systems generated from the six variables. The systems are: (RGDPGR, CCI), (RGDPGR, LEB), (RGDPGR, IMR), (RGDPGR, LFP), (RGDPGR, GFCF), (CCI, LEB), (CCI, IMR), (CCI, LFP), (CCI, GFCF), (LEB, IMR), (LEB, LFP), (LEB, GFCF), (IMR, LFP), (IMR, GFCF), (LFP, GFCF). The bivariate specification permits the long-run relationship between each pair to be identified directly without imposing the assumption that all six variables necessarily belong to a single cointegrating system. This is particularly appropriate where the objective is to determine whether long-run interdependence is pervasive or concentrated in specific climate, health and economic relationships.

4. EMPIRICAL FINDINGS

This particular part of the research first shows the trend analysis of the economic growth, health outcomes and climate change in figures 1. The time plot in figure 1 reveals heterogeneous temporal patterns across Nigeria’s climate, health and macroeconomic indicators. RGDPGR exhibits pronounced cyclical fluctuations with recurrent expansionary and contractionary episodes, while CCI combines substantial variability with a discernible upward tendency. In contrast, the health indicators display relatively smooth but persistent trajectories: IMR declines markedly over most of the sample, whereas LEB trends upward, reflecting an apparent inverse movement between mortality and longevity. LFP follows a nonlinear trajectory characterized by an initial increase, prolonged decline and a sharp late-period reversal, while GFCF records relatively moderate movement initially before accelerating substantially toward the end of the sample.

Overall, the graphical patterns indicate considerable heterogeneity in volatility, persistence and possible structural changes across the variables. The simultaneous evolution of CCI with health, labour-market, investment and growth indicators suggests potential dynamic interdependence; however, such visual co-movement neither establishes causality nor confirms long-run equilibrium relationships. Rather, the observed persistence and nonlinear trajectories provide preliminary justification for the fractional econometric framework. Accordingly, the subsequent GPH and GSP estimates formally determine the degree and mean-reverting properties of individual-series persistence, while the FCVAR analysis establishes whether the variables share fractional long-run equilibrium relationships and identifies their associated adjustment dynamics.

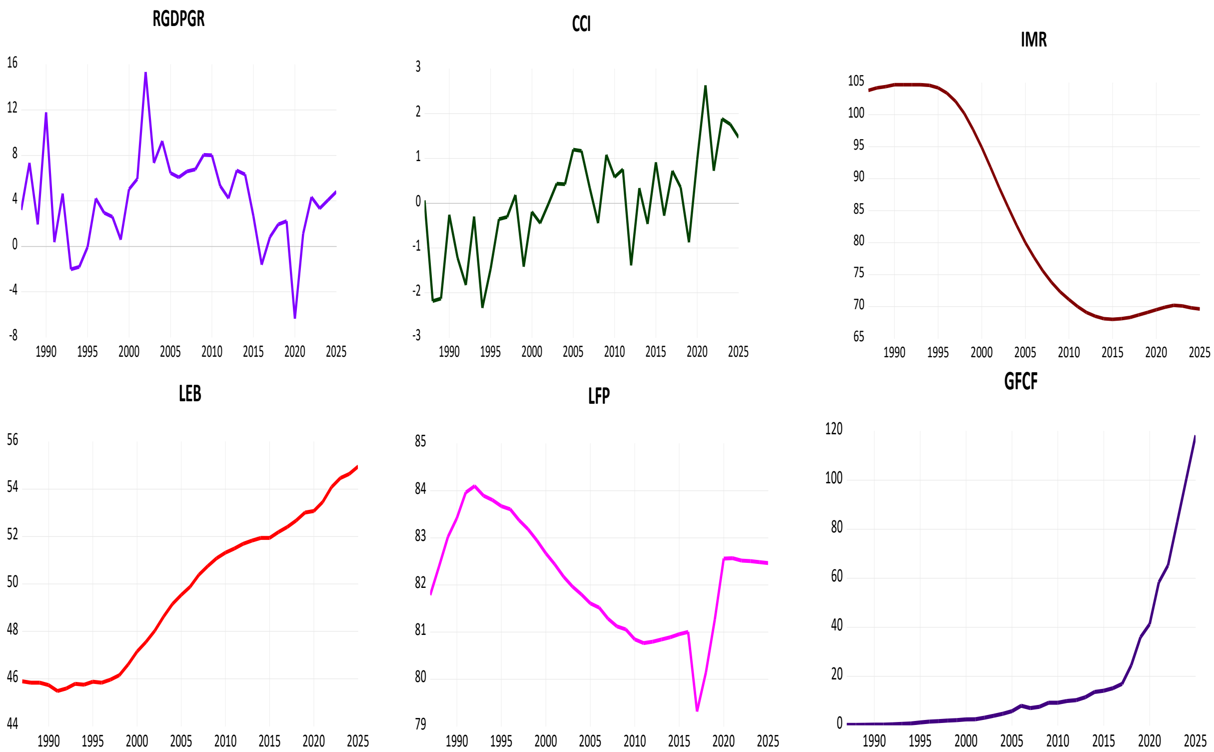

Figure 1: Trend Analysis of Selected Variables

Table 1: Fractional Integration Estimation, GSP/GPH Log-Periodogram Regression

Variables	GSP		GPH	
	dm = $T^{0.4}$	dm = $T^{0.5}$	dm = $T^{0.4}$	dm = $T^{0.5}$
RGDPGR	0.7806***[0.2500]	0.6263***[0.2041]	0.9766[0.6227]	0.8764**[0.4415]
CCI	0.6409***[0.2500]	0.5712***[0.2041]	0.6185[0.6227]	0.6032[0.4415]
LEB	1.1246***[0.2500]	1.1006***[0.2041]	1.1362*[0.6227]	1.1173***[0.4415]
IMR	1.4364***[0.2500]	1.2790***[0.2041]	1.4621**[0.6227]	1.2776***[0.4415]
LFP	1.0983***[0.2500]	1.0205***[0.2041]	1.0013[0.6227]	0.7808*[0.4415]
GFCF	0.5723*[0.2500]	0.7343***[0.2041]	0.5807[0.6227]	0.7414*[0.4415]

NOTE: (***), (**), (*) represent the 1%, 5%, 10% significance levels respectively. Standard errors are given in squared brackets.

Table 1 presents the GSP and GPH semi-parametric estimates of the fractional differencing parameter d under the m=T^0.4 and m= T^0.4 bandwidths. The estimates reveal substantial but heterogeneous long-memory behaviour across the climate-health-growth variables, while their broad consistency across alternative estimators and bandwidths reinforces the robustness of the persistence evidence. A clear distinction emerges between mean-reverting and non-mean-reverting persistence. RGDPGR, CCI and GFCF predominantly exhibit $0.5 < d < 1$, particularly under the GSP estimator, indicating non-stationary but mean-reverting long-memory processes. Thus, shocks to economic growth, climate conditions and capital formation are highly persistent but tend eventually to dissipate rather than exert permanent effects. The persistence and mean-reverting tendency of economic activity broadly accords with Awe et al (2021), who document a high degree of persistence in Nigerian economic activity and find evidence of mean reversion when nonlinearities are accommodated. Similarly, the long-memory behaviour of CCI is consistent with the climate literature of Gil-Alana (2003, 2005) and Gil-Alana and Sauci (2019), which demonstrates that temperature and other climatic series can exhibit fractional integration and substantial persistence rather than conforming neatly to conventional integer integration.

In contrast, LEB, IMR and LFP exhibit considerably stronger persistence. The GSP estimates exceed unity under both bandwidths, LEB (1.1006-1.1246), IMR (1.2790-1.4364) and LFP (1.0205–1.0983), while the GPH estimates broadly reinforce this pattern, especially for LEB and IMR. These estimates indicate predominantly non-stationary and non-mean-reverting behaviour, implying that shocks to health outcomes and labour-force participation can have exceptionally persistent effects and may require deliberate policy intervention rather than reliance on automatic adjustment. IMR exhibits the highest d estimates and therefore represents the most persistent variable in the system. Overall, the findings establish heterogeneous fractional persistence within Nigeria's climate-health-growth nexus: economic growth, climate conditions and capital formation are predominantly non-stationary but mean-reverting, whereas health outcomes and labour-force participation display stronger, largely non-mean-reverting persistence. This reinforces the usefulness of fractional integration over the restrictive I(0)/I(1) dichotomy and provides the empirical basis for the subsequent FCVAR analysis, which determines whether these individually persistent processes nevertheless share lower-memory long-run equilibrium relationships.

Table 2. Lag Selection and Bootstrap Cointegrating-Rank Tests

Variable pair	Selected lag (k)	LR: r=0 vs 1	Bootstrap p-value	LR: r=1 vs 2	Bootstrap p-value	Selected rank (r)
RGDPGR, CCI	3	9.520	0.609	—	—	0
RGDPGR, LEB	3	36.181	0.023	1.023	0.448	1
RGDPGR, IMR	1	22.510	0.014	0.275	0.685	1
RGDPGR, LFP	3	0.218	0.894	—	—	0
RGDPGR, GFCF	2	5.197	0.762	—	—	0
CCI, LEB	1	21.034	0.025	0.191	0.794	1
CCI, IMR	2	9.541	0.578	—	—	0
CCI, LFP	3	2.608	0.915	—	—	0
CCI, GFCF	2	10.575	0.392	—	—	0
LEB, IMR	2	13.735	0.281	—	—	0
LEB, LFP	3	2.988	0.915	—	—	0
LEB, GFCF	1	17.598	0.184	—	—	0

IMR, LFP	2	11.917	0.247	—	—	0
IMR, GFCF	1	17.170	0.075	—	—	0
LFP, GFCF	1	19.919	0.334	—	—	0

Note. The reported lag order is the selected positive lag in the FCVAR output. Bootstrap inference is based on 999 replications. The r = 1 versus r = 2 test is reported only where the null of r = 0 is rejected at the 5% level; otherwise dash indicates that the sequential rank procedure stopped at r = 0. Sample size is 39 observations for each bivariate system.

Table 3. FCVAR Fractional-Parameter Estimates and Model Fit

Variable pair	r	k	d (SE)	b (SE)	Log-likelihood	AIC	BIC
RGDPGR, CCI	0	3	0.010 (0.211)	0.010 (0.001)	-144.692	321.383	348.000
RGDPGR, LEB	1	3	0.010 (0.124)	0.010 (0.000)	-62.619	163.237	194.845
RGDPGR, IMR	1	1	1.305 (1.144)	1.305 (0.338)	-82.451	186.903	205.202
RGDPGR, LFP	0	3	0.083 (0.345)	0.083 (0.102)	-120.092	272.184	298.801
RGDPGR, GFCF	0	2	0.010 (0.280)	0.010 (0.004)	-187.621	399.242	419.204
CCI, LEB	1	1	0.873 (0.264)	0.873 (0.233)	-22.382	66.765	85.064
CCI, IMR	0	2	0.901 (NaN)	0.901 (NaN)	-34.545	93.090	113.053
CCI, LFP	0	3	1.016 (NaN)	1.016 (NaN)	-69.949	171.898	198.515
CCI, GFCF	0	2	0.741 (0.671)	0.741 (0.725)	-134.495	292.991	312.953
LEB, IMR	0	2	0.859 (NaN)	0.859 (NaN)	37.594	-51.187	-31.225
LEB, LFP	0	3	1.210 (0.535)	1.131 (0.260)	3.715	24.571	51.188
LEB, GFCF	0	1	0.691 (NaN)	0.691 (NaN)	-76.382	168.764	182.072
IMR, LFP	0	2	0.906 (1.327)	0.906 (0.796)	-6.779	37.558	57.520
IMR, GFCF	0	1	2.000 (0.147)	1.031 (0.257)	-78.973	173.947	187.255
LFP, GFCF	0	1	0.428 (NaN)	0.428 (NaN)	-113.783	243.567	256.875

Note. d denotes the fractional integration/persistence parameter and b the fractional cointegration parameter as reported by the FCVAR estimation. Standard errors are in parentheses. “NaN” reproduces cases in which the numerical Hessian did not yield a finite standard error. Parameter space: 0.010 to 2.000, with d ≥ b imposed

Table 4. Cointegrating Vectors, Adjustment Coefficients and Long-Run Matrices for Rank-One FCVAR Systems.

Panel A. Fractional Parameters, Cointegrating Vectors and Adjustment Coefficients

Variable pair	Var 1	Var 2	k	d	b	β_1	β_2	α_1 (SE)	α_2 (SE)
RGDPGR, LEB	RGDPGR	LEB	3	0.010	0.010	1.000	4.109	8569336.985 (1.421)	-1603371.792 (0.626)
RGDPGR, IMR	RGDPGR	IMR	1	1.305	1.305	1.000	-0.016	-0.607 (1.270)	0.011 (0.030)
CCI, LEB	CCI	LEB	1	0.873	0.873	1.000	-0.183	-1.257 (0.753)	0.153 (0.100)

Panel B. Long-run Matrix $\Pi = \alpha\beta'$

Variable pair	Π_{11}	Π_{12}	Π_{21}	Π_{22}
RGDPGR, LEB	8569336.985	35212868.044	-1603371.792	-6588528.310
RGDPGR, IMR	-0.607	0.010	0.011	-0.000
CCI, LEB	-1.257	0.230	0.153	-0.028

Note: Only systems for which the bootstrap rank procedure selected r = 1 are reported. The cointegrating vector β is normalized on Var 1 (β_1 = 1.000), consistent with the identifying restriction in the FCVAR output. α contains the corresponding adjustment coefficients, with standard errors in parentheses. $\Pi = \alpha\beta'$ is the reported long-run matrix.

Table 5. Level Parameters and Short-Run Dynamic Matrices for Rank-One FCVAR Systems

Variable pair	μ_1 (SE)	μ_2 (SE)	Γ_1 estimate [SE]	Γ_2 estimate [SE]	Γ_3 estimate [SE]
RGDPGR-LEB	4.247 (0.079)	45.885 (0.082)	[-8569336.278, -35213001.749; 1603369.595, 6588616.776] [NaN, 4.946; 0.808, 2.424]	[-8568015.567, -35178101.543; 1603208.108, 6582319.986] [46.630, 5.121; NaN, 4.155]	[-8796125.462, -37258935.036; 1605622.423, 6918153.446] [23.806, NaN; NaN, NaN]
RGDPGR-IMR	4.242 (1.250)	103.615 (0.080)	[-0.212, -1.357; -0.010, 0.948] [0.264, 3.531; 0.011, 0.160]	—	—
CCI-LEB	-1.295 (0.173)	45.947 (0.122)	[0.186, 2.284; -0.076, 0.756] [0.330, 0.633; 0.078, 0.132]	—	—

Note. μ contains the level parameters. Γj denotes the short-run coefficient matrix at lag j. Within each Γ cell, the first 2×2 matrix contains coefficient estimates and the second bracketed 2×2 matrix contains the corresponding standard errors in the same row-column order (Var 1, Var 2). "NaN" is retained exactly where the FCVAR output reports a non-finite standard error. Dash indicates that the selected model contains no such lag.

The FCVAR results provide evidence of selective rather than pervasive long-run interdependence within Nigeria's climate-health-growth nexus. The bootstrap rank tests reject the null of no fractional cointegration at the 5% level for only (RGDPGR, LEB) (LR=36.181, P=0.023), (RGDPGR, IMR) (LR=22.510, P=0.014), and (CCI, LEB) (LR=21.034, P=0.025); the subsequent $r = 1$ versus $r = 2$ tests are insignificant, confirming a single cointegrating vector in each case. The remaining twelve pairs retain $r = 2$, implying no statistically supported fractional long-run equilibrium relationship at the 5% level. This selective cointegration is consistent with the flexibility of Johansen and Nielsen's (2010, 2012) FCVAR framework, which permits highly persistent variables to share a lower-memory equilibrium without imposing the conventional integer-order restriction. Similar evidence that fractional cointegration can characterize persistent economic and environmental systems has been documented by Tule et al. (2020) for Nigeria and Gil-Alana et al. (2021) for the emissions-output nexus.

Among the rank-one systems, (RGDPGR, IMR) records $d = b = 1.305$, implying $d - b = 0$, while (CCI, LEB) yields $d = b = 0.873$, likewise producing an I(0) equilibrium error. Thus, despite substantial individual persistence, deviations from their identified long-run relations are reduced to short-memory processes. This finding is broadly comparable to Gil-Alana and Monge (2020), who found that persistent environmental and economic variables can form a lower-order, stable long-run equilibrium, and to long-memory climate evidence showing that persistent climatic series can nevertheless be cointegrated (Gil-Alana et al., 2023). The (CCI, LEB) relationship is particularly relevant to the study's central hypothesis, indicating a long-run linkage between climatic conditions and population health, while the RGDPGR relationships with both LEB and IMR suggest that economic performance and health outcomes are dynamically connected over the long horizon. These findings broadly complement earlier conventional cointegration evidence linking economic development, environmental conditions and health indicators.

The normalized long-run coefficients further reveal heterogeneous equilibrium relationships. For (RGDPGR, IMR) and (CCI, LEB), the estimated vectors are β = (1, -0.016)′ and (1, -0.183)′, respectively, while their adjustment vectors are α = (-0.607, 0.011)′ and (-1.257, 0.153)′. The negative adjustment coefficients on RGDPGR and CCI indicate that these variables provide the principal corrective response to disequilibrium in their respective systems, although the statistical precision of individual adjustment coefficients should be interpreted cautiously given their reported standard errors. The short-run Γ matrices additionally indicate that long-run equilibrium adjustment coexists with dynamic interactions at shorter horizons.

Two qualifications are particularly important. First, the (RGDPGR, LEB) rank-one result should be treated cautiously: although its bootstrap rank evidence supports cointegration, the FCVAR estimates lie at the lower parameter boundary ($d = b = 0.010$) and the reported α and Π coefficients are extraordinarily large. This points to numerical instability and makes the existence of the rank-one relation more defensible than a strong economic interpretation of its coefficient magnitudes. Second, for the $r = 0$ systems, the reported b estimates should not be interpreted as evidence of cointegration, since no cointegrating vector is identified; similarly, the non-finite Hessian standard errors reported for several models warrant caution in interpreting their fractional parameters.

5. CONCLUSION AND POLICY RECOMMENDATIONS

This study establishes substantial heterogeneity in the persistence and long-run interdependence of climate change, health outcomes and economic growth in Nigeria. The GSP/GPH estimates indicate that RGDPGR, CCI and GFCF are predominantly non-stationary but mean-reverting, whereas LEB, IMR and LFP exhibit stronger, largely non-mean-reverting persistence. More importantly, the FCVAR results reveal selective fractional cointegration: long-run equilibrium relationships exist only between (RGDPGR, LEB), (RGDPGR, IMR) and (CCI, LEB), positioning health outcomes as a critical linkage between climatic conditions and economic performance. The findings therefore demonstrate that persistent shocks do not uniformly translate into long-run interdependence across the system.

Policy should consequently prioritize an integrated climate-health-growth framework, with sustained investment in climate-resilient healthcare, disease prevention, clean water, sanitation and protection against climate-related health risks. Given the strong persistence of health and labour-market shocks, interventions should be preventive and sustained rather than temporary. Climate-resilient infrastructure, renewable energy and green productive investment should also be strengthened, alongside institutional coordination of climate, health and macroeconomic policies.

REFERENCE

1) Abid, N., Ahmad, F., Aftab, J., & Razzaq, A. (2023). A blessing or a burden? Assessing the impact of climate change mitigation efforts in Europe using quantile regression models. *Energy Policy, 178*, 113589. https://doi.org/10.1016/j.enpol.2023.113589
2) Adebanjo, S., Banchani, E., Adejumo, B., & Mishiwo, S. H. (2023). Infant mortality rate and economic growth in Nigeria: An empirical analysis. *International Journal of Innovative Finance and Economics Research, 11*(3), 175–186.
3) Akinbode, S. O., Dipeolu, A. O., Bolarinwa, T. M., & Olukowi, O. B. (2021). Effect of health outcome on economic growth in Sub-Saharan Africa: A system generalized method of moment approach. *Journal of Economics and Development, 23*(3), 254–269. https://doi.org/10.1108/JED-06-2020-0078
4) Alege, P. O., & Ogundipe, A. A. (2013). Environmental quality and economic growth in Nigeria: A fractional cointegration analysis. *International Journal of Development and Sustainability, 2*(2), 580–596.
5) Alwago, W. O. (2023). The nexus between health expenditure, life expectancy, and economic growth: ARDL model analysis for Kenya. *Regional Science Policy & Practice, 15*(5), 1064-1085. https://doi.org/10.1111/rsp3.12588
6) Arogundade, S., Hassan, A. S., & Mduduzi, B. (2024). Is climate change hindering the economic progress of Nigerian economy? Insights from dynamic models. *Heliyon, 10* (20), e39288. https://doi.org/10.1016/j.heliyon.2024.e39288.
7) Atchadé, M. N., & Nougbodé, H. (2024). Statistical investigation on the relationship between climate change, food availability, agricultural productivity, and economic expansion. *Heliyon, 10*(12), e32520. https://doi.org/10.1016/j.heliyon.2024.e32520
8) Awe, O. O., Mudida, R., & Gil-Alana, L. A. (2021). Comparative analysis of economic growth in Nigeria and Kenya: A fractional integration approach. *International Journal of Finance & Economics, 26*(1), 1197–1205. https://doi.org/10.1002/ijfe.1845
9) Bilal, A., & Känzig, D. R. (2024). The macroeconomic impact of climate change: Global vs. local temperature (NBER Working Paper No. 32450). *National Bureau of Economic Research*. https://doi.org/10.3386/w32450
10) Bressler, R. D. (2021). The mortality cost of carbon. *Nature Communications, 12*, 4467. https://doi.org/10.1038/s41467-021-24487-w
11) Central Bank of Nigeria. (2023). *Annual report 2023*. Central Bank of Nigeria.
12) Eboh, I. A., Aduku, E. B., & Onwughalu, U. B. (2022). Health expenditure, child mortality and economic growth in Nigeria. *International Journal of Economics Development Research, 3*(3), 198–216. https://doi.org/10.37385/ijedr.v3i3.461

13) Geweke, J. & Porter-Hudak, S. (1983). The estimation and application of long memory time series models. *Journal of Time Series Analysis*, 4(4), 221–238. https://doi.org/10.1111/j.1467-9892.1983.tb00371.x
14) Gil-Alana, L. A. (2003). An application of fractional integration to a long temperature series. *International Journal of Climatology, 23*(14), 1699–1710. https://doi.org/10.1002/joc.968
15) Gil-Alana, L. A. (2005). Statistical modelling of the temperatures in the Northern Hemisphere using fractional integration techniques. *Journal of Climate, 18*(24), 5357–5369. https://doi.org/10.1175/JCLI3543.1
16) Gil-Alana, L. A., Martin-Valmayor, M. A., & Hube-Antoine, C. (2023). An analysis of temperature anomalies in Chile using fractional integration. *Stochastic Environmental Research and Risk Assessment, 37*, 2713–2724. https://doi.org/10.1007/s00477-023-02414-3
17) Gil-Alana, L. A., & Monge, M. (2020). Global CO_2 emissions and global temperatures: Are they related? *International Journal of Climatology, 40*(15), 6603–6611. https://doi.org/10.1002/joc.6601
18) Gil-Alana, L. A., & Sauci, L. (2019). US temperatures: Time trends and persistence. *International Journal of Climatology, 39*(13), 5091–5103. https://doi.org/10.1002/joc.6128
19) Herrnstadt, E., & Dinan, T. (2020). *CBO's projection of the effect of climate change on U.S. economic output* (Working Paper 2020-06). Congressional Budget Office.
20) Jemiluyi, O. O., & Alao-Owunna, I. (2020). A reconsideration of the health status–economic growth nexus: Evaluation of the gender differential effect in Nigeria. *Eurasian Journal of Economics and Finance, 8*(4), 217–230. https://doi.org/10.15604/ejef.2020.08.04.003
21) Johansen, S. (2008). A representation theory for a class of vector autoregressive models for fractional processes. *Econometric Theory, 24*(3), 651–676. https://doi.org/10.1017/S0266466608080274
22) Johansen, S., & Nielsen, M. Ø. (2012). Likelihood inference for a fractionally cointegrated vector autoregressive model. *Econometrica, 80*(6), 2667–2732. https://doi.org/10.3982/ECTA9299
23) Nasir, M. A., Huynh, T. L. D., & Tram, H. T. X. (2019). Role of financial development, economic growth and foreign direct investment in driving climate change: A case of emerging ASEAN. *Journal of Enviroment Management, 242*, 131–141. https://doi.org/10.1016/j.jenvman.2019.03.112.
24) Ngoma, R. G. T. M., Wang, X., Meng, X. R., Tsoni, C. G. A. M., Danwana, S. B., & Ndombi, B. T. (2024). Achieving climate sustainability in the Republic of Congo: The role of economic growth, biomass energy consumption, rule of law and government effectiveness-A NARDL approach. *Heliyon, 10*(15), e34256. https://doi.org/10.1016/j.heliyon.2024.e34256.
25) Ogunbadejo, H. K., Lawal, J. S. O., & Zubair, A. (2020). Effect of health on economic growth in Nigeria: An application of the ARDL model. *International Journal of Development Research, 10*(12), 42875–42883. https://doi.org/10.37118/ijdr.20207.12.2020
26) Okunade, A. A., & Osmani, A. R. (2020). Effects of life expectancy on economic growth: New results using the flexible Box–Cox power transformation model. *Applied Economics Letters, 27*(20), 1681–1684. https://doi.org/10.1080/13504851.2020.1713976
27) Prall, M., Olazabal, M., & Lehmann, M. (2023). Socio-economic projections in urban climate change adaptation planning: Practices and prospects for just adaptation. *Habitat International*, *142*, 102946. https://doi.org/10.1016/j.habitatint.2023.102946

28) Rahman, M., Alam, K. & Khanam, R. (2022). Carried out a research on socio-economic factors affecting high infant and child mortality rates in selected African countries. *Rahman et al. Globalization and Health* 1-13.
29) Raza, M. Y., Hasan, M. M., & Chen, Y. (2023). Role of economic growth, urbanization and energy consumption on climate change in Bangladesh. *Energy Strategy Reviews, 47*, 101088. https://doi.org/10.1016/j.esr.2023.101088.
30) Robinson, P. M. (1995). Gaussian semiparametric estimation of long range dependence. *The Annals of Statistics, 23*(5), 1630–1661. https://doi.org/10.1214/aos/1176324317
31) Rocco, L., Fumagalli, E., Mirelman, A. J., & Suhrcke, M. (2021). Mortality, morbidity and economic growth. *PLOS ONE, 16*(5), e0251424. https://doi.org/10.1371/journal.pone.0251424
32) Roy, A. (2024). A panel data study on the effect of climate change on life expectancy. *PLOS Climate, 3*(1), e0000339. https://doi.org/10.1371/journal.pclm.0000339.
33) Song, Y., Pan, Z., Lun, F., Long, B., Liu, S., Han, G., Wang, J., Huang, N., Zhang, Z., Ma, S., Sun, G., & Liu, C. (2023). Temperature impact on the economic growth effect: Method development and model performance evaluation with subnational data in China. *EPJ Data Science*, *12*(1), 51. https://doi.org/10.1140/epjds/s13688-023-00425-2
34) Sponagel, C., Weik, J., Feuerbacher, A., & Bahrs, E. (2024). Exploring the climate change mitigation potential and regional distribution of agrivoltaics with geodata-based farm economic modelling and life cycle assessment. *Journal of Environmental Management*, *359*, 121021. https://doi.org/10.1016/j.jenvman.2024.121021.
35) Tao, Z., Ren, Z., Chen, Y., Huang, X., & Liu, X. (2023). Pathway to sustainable economic growth: Linkage among energy consumption, carbon emissions, climate change and technological innovation. *Energy Strategy Reviews*, *50*, 101253. https://doi.org/10.1016/j.esr.2023.101253
36) Tule, M. K., Salisu, A. A., & Ebuh, G. U. (2020). A test for inflation persistence in Nigeria using fractional integration & fractional cointegration techniques. *Economic Modelling, 87*, 225–237. https://doi.org/10.1016/j.econmod.2019.07.024
37) Wang, Y., & Lewis, D. J. (2024). Wildfires and climate change have lowered the economic value of western U.S. forests by altering risk expectations. *Journal of Environmental Economics and Management*, *123*, 102894. https://doi.org/10.1016/j.jeem.2023.102894
38) World Bank. (2024). *World Development Indicators*. World Bank.