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Human Capital Development and Economic Growth Nexus in Nigeria: Aggregate and Sectoral Analyses

Kenneth Onyeanuna Ahamba[1], Eucharia Leona Ekechukwu[2], Kelechi Clara Anyanwu[3], Onyinye Ogomegbunam Mgbemena[4], Aloysius Orogwu Alo[5], Obinna Augustine Anum[6], Emeka Ifeoma Ejeh[7], Angela Eze[8], Benedict Nkemdirim Igbokwe[9], Ngozi Theresa Onuora[10], Ann Onyekelu[11], Elizabeth Ngozi Patterson[12]

[1,3]Department of Economics and Development Studies, Alex Ekwueme Federal University, Ndufu-Alike, Ebonyi State, Nigeria

[2,5,7]Department of Educational Management and Foundational Studies, Alex Ekwueme Federal University, Ndufu-Alike, Ebonyi State, Nigeria

[4]Department of Economics, Michael Okpara University of Agriculture, Umudike, Nigeria

[6]Department of Social Science Education, Economics Education Unit, Prince Abubakar Audu University, Ayingba, Kogi State, Nigeria

[8,12]Department of Arts and Humanities Education, Alex Ekwueme Federal University, Ndufu Alike, Ebonyi State, Nigeria

[9]Igbo Language Unit, Directorate of General Studies, Federal University of Technology, Owerri, Imo State, Nigeria

[10]Department of Linguistics and Nigerian Languages, Alex Ekwueme Federal University, Ndufu-Alike, Ebonyi State, Nigeria

[11]Department of Igbo, African and Communication Studies, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria

Authors' emails: [1]ahamba.kenneth@funai.edu.ng or kendrys4jesus@yahoo.com; [2]ekechukwuleonaeucharia@gmail.com; [3]anyanwu.kelechi@funai.edu.ng; [4]mgbemena.onyinye@mouau.edu.ng; [5]aloysiusorogwu8@gmail.com; [6]obinna.a@ksu.edu.ng; [7]ejehifeoma@gmail.com; [8]angela.eze@funai.edu.ng; [9]benedict.igbokwe@futo.edu.ng; [10]onuora.ngozi@funai.edu.ng; [11]ac.onyekelu@unizik.edu.ng; [12]patterson.ngozi@funai.edu.ng

Corresponding author's email: ahamba.kenneth@funai.edu.ng or kendrys4jesus@yahoo.com

Abstract

Despite Nigeria's abundant human and natural resources endowments, and sustained investments in education and health, the country's growth performance remains volatile and structurally imbalanced, raising concerns about the efficacy of human capital accumulation in translating these resources into sustainable and inclusive growth across sectors. This study therefore investigates the impact of human capital development on aggregate and sectoral economic growth in Nigeria by applying the Autoregressive Distributed Lag approach and the Toda-Yamamoto modified Wald causality test to annual time series data spanning 1981-2023. Economic growth is proxy by aggregate real gross domestic product (RGDP) and its sectoral components of agricultural (AGDP), industrial (IGDP) and Services (SGDP) while human capital development is proxy by human capital index (HCI), life expectancy (LIFE) and mortality rate (MOTA). The control variables include total factor productivity, gross fixed capital formation, population growth, institutional quality and exchange rate. Findings indicate significant short-run and long-run impacts with notable sectoral asymmetries. Human capital index significantly stimulates AGDP and made positive short-run impact on RGDP, IGDP and SGDP, though its lagged impact on SGDP is negative. Life expectancy made insignificant positive impact on RGDP and negative impact on sectoral growth while mortality rate undermines aggregate and sectoral growth, highlighting persistent health constraints. Causality results reveal that HCI causes aggregate and sectoral growth, LIFE causes IGDP whereas MOTA causes aggregate and sectoral growth. These results support human-capital led growth hypothesis and underscore the need to complement uniform growth policy interventions with sector-specific growth policy strategies so as to promote sustainable and inclusive economic growth in Nigeria.

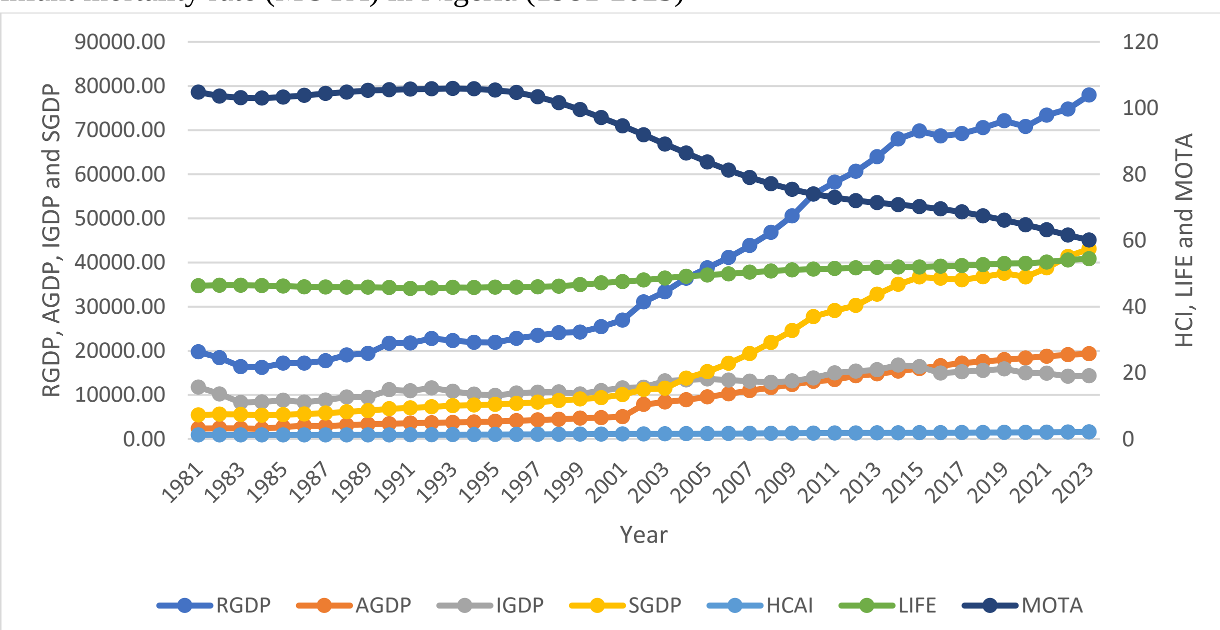
Keywords: Human Capital Development; Aggregate and Sectoral Growth; ARDL; Toda–Yamamoto Causality; Nigeria

1. Introduction

The role of human capital development in fostering economic growth has long occupied a central position in growth theory and development policy discourse. Human capital development which comprises of education, skills, health and overall capabilities of a country's workforce has been widely recognised as a key driver of economic growth and development of every nation (Schultz, 1961; Becker, 1964; Romer, 1986; Lucas, 1988; Romer, 1990a; Barro, 1991; Barro & Sala-i-Martin, 2004; Hanushek & Woessmann, 2008; Ogundari & Awokuse, 2018; Sarwar et al., 2021; Keji, 2021; Wirajing et al., 2023; Okoh, 2025). Schultz (1961) outlines six major mechanisms through which human capital is developed. These include (a) investment in health facilities and services aimed at improving life expectancy, strength, stamina, vigour and overall vitality of the population; (b) On-the-job training including firm-based arrangements like the traditional apprenticeship systems, which Arrow (1962) refers to as 'learning by doing'; (c) formally structured education at the primary, secondary and tertiary levels; (d) organized study programmes for adults who are not engaged in agriculture; (e) labour mobility in the form of migration of individuals and families in response to changing employment opportunities; and (f) transfer or importation of technical assistance, expertise and consultants. Education promotes the creation of new ideas which is a major component of human capital reflected in the accumulation of scientific knowledge (Becker, 1975). Investments in the health and education sectors contribute to the development of human capital which has the capacity to generate growth in physical capital and thus economic growth (Romer 1990b). Human capital, such as education and health, improves labour productivity, spurs innovation, promotes efficient allocation of resources thereby fostering sustainable economic prosperity of nations (Romer, 1990a). No wander, World Bank (2020) notes that sustained and inclusive growth can be actualized through accumulation of human capital which enhances progress, creates decent employment opportunities or jobs for all, and promotes standards of living. Empirically, cross-country evidence suggests that countries with higher educational attainment, better health outcomes, and stronger institutional environments record superior growth performance (Barro, 1991; Mankiw, Romer, & Weil, 1992). In developing countries, Nigeria inclusive, the role of human capital is especially crucial given the need to diversify economic structures, expand the non-oil sectors like solid minerals, agriculture, industry, as well as services, and boost productivity amid increasing rate of population growth.

In Nigeria, the human capital-economic growth nexus is particularly important given the country's large population, abundant natural resources, and persistent structural transformation challenges. Over the past four decades, Nigeria's real gross domestic product (RGDP) has exhibited a pattern of cyclical expansion and contraction (Figure 1). During the 1980s and 1990s, economic growth was heavily influenced by oil price fluctuations, and macroeconomic instability associated with structural adjustment programmes (SAP). During this period, RGDP growth was erratic, reflecting weak industrial capacity, and exchange rate volatility. The post-2000 oil price boom stimulated rapid economic growth culminating in the 2014 GDP rebasing that positioned Nigeria as Africa's largest economy. Sadly, the oil price collapse of 2014 and 2015 triggered the 2016 recession exposing structural fragilities in Nigeria's growth model. A modest recovery followed between 2017 and 2019, but the COVID-19 pandemic in 2020 induced another contraction, disrupting production, trade, and fiscal stability. Between 2021 and 2025, growth has been characterized by recovery attempts amid persistent inflationary pressures, exchange rate depreciation, subsidy reforms and structural policy adjustments (World Bank 2025).

Figure 1: Trends of economic growth, human capital index (HCI), life expectancy (LIFE) and infant mortality rate (MOTA) in Nigeria (1981-2023)



Source: CBN Statistical Bulletin (2024), Penn World Table (2025) and World Development Indicators (2025)

Sectorally, the services sector gross domestic product (SGDP) has increasingly dominated total output since the rebasing period, reflecting expansion in telecommunications, financial services, and informal trade. The agricultural sector has remained a critical source of employment, yet agricultural sector gross domestic product (AGDP) has been modest due to infrastructural deficits, climate variability, limited mechanization, and insecurity in some parts of the country. The industrial sector gross domestic product (IGDP), heavily dependent on oil and gas has exhibited significant volatility with limited manufacturing diversification despite policy interventions aimed at industrialization. Human capital indicators as shown in Figure 1 reveal gradual but insignificant improvement. Life expectancy (LIFE) improved from below 47 years in the early 1980s to 55 years in the mid-2020s reflecting improvements in immunization, disease control and primary healthcare expansion. Mortality rate (MOTA), particularly infant, declined steadily but remain high relatively to global average and emerging economies. Access to education expanded considerably following the Universal Basic Education (UBE) reforms and tertiary expansion policies, but quality adjusted measures like human capital index (HCI), based on years of schooling and returns to education indicate persistent and significant learning gaps and skills mismatches (Pen World Table, 2025, World Bank, 2025). Macroeconomic and structural conditions further complicate the growth process. Gross fixed capital formation (GFCF) has fluctuated in line with oil revenue cycles and fiscal space constraints. Exchange rate (EXRA) volatility have intensified macroeconomic uncertainty, particularly, in recent years. Population growth (POGR), consistently above 2.5% annually except from 2016 to date when it declined marginally to below 2.5%, exerts pressure on social infrastructure and labour markets. Total factor productivity (TFPR) growth has been weak, and institutional quality (ISQG) proxied by quality of government in this study reflect persistent governance and regulatory challenges. (Penn World Table, 2025; World Bank, 2025, Teorell et al., 2025).

On the whole, Figure 1 reveals an economy heavily reliant on services activities, while agriculture and industry contribute relatively modestly to overall growth since 2005, and the gap is still widening in favour of services sector gross domestic product (SGDP). Recent official data from the Nigeria's National Bureau of Statistics, NBS (2025) reveal that in the third quarter of 2025, agriculture expanded by 3.79 percent and industry showed modest gains of 3.77 percent, whereas the services sector continued to lead economic growth with a growth rate of 4.15 percent. This reflects the increasing dominance of services in Nigeria's GDP composition. Such patterns of growth raise critical questions about the role of human capital in promoting productivity across all these major sectors of the Nigerian economy. This is one of the motivations behind this study. Another motivation behind this study is the knowledge gap discovered in the empirical literature. Some studies have examined the impact of human capital development on economic growth. Applying the pooled least squares model to annual data spanning 2000 to 2012, Pelinescu (2015) examined the impact of human capital on economic growth in European Union Countries. Findings indicate that government education expenditure in GDP had significant negative impact on GDP per capita while number of employees with secondary education, and the number of patents made significant positive impact on GDP per capita. Barra and Zotti (2016) examined the human capital development-economic growth nexus in the area where 72 universities are located in Italy using panel data over the period 2003 to 2011. Findings show that human capital development proxy by university efficiency and number of graduates have a positive and significant impact on economic growth proxy by gross domestic product per capita. The same results were obtained when robustness checks were performed. Hakooma, and Venkatesh (2017) investigated the nexus between human capital development and economic growth in Zambia using the vector error correction model and time series data over the period of 1970-2013. Short-run result indicates that government expenditure on health and secondary school enrolment had positive impact on GDP per capita with the later being significant whereas government expenditure on education had significant negative impact on GDP per capita. Long-run result reveals that government expenditure on health and secondary school enrolment had significant positive impact on GDP per capita while government expenditure on education retains its significant negative impact on GDP per capita. Employing a dynamic model based on the system generalized method of moments and a panel data covering 35 sub-Saharan African countries from 1980–2008, Ogundari and Awokuse (2018) studied the contribution of human capital to economic growth. Findings show that primary, secondary, and tertiary education enrolments, average years of schooling, expenditure on education and life expectancy exerted positive effect on real GDP per capita, with all the variables being significant except tertiary education enrolments. However, the effect of health is relatively larger than the contribution of education. Wirajing et al (2023) examined the human capital-economic growth nexus in 48 African countries using system GMM and panel data covering 2000 to 2019. Findings indicate that human capital index as a gender parity index, human capital index for the male and female genders exerted significant positive effects on GDP per capita across all specifications. Also, internet penetration and foreign direct investments interaction with human capital generated positive net effects on GDP per capita. Applying the pooled mean group and panel autoregressive distributed lag approach to panel dataset of six Gulf Cooperation Council (GCC) countries covering the period 2000–2022, Bashir (2024) explored the link between human capital and economic growth. Findings indicate that school enrolment, government expenditures on education, life expectancy, government expenditure on health and employment level made significant positive impact on real gross domestic product in both short-run and long-run. Applying the augmented mean group model to panel data of 30 sub-Saharan African countries from 2000 to 2020, Bekele et al (2024) studied the effect of human capital development on economic sustainability. Findings indicate that human capital development measured based on years of schooling and returns to education exerted a statistically significant negative effect on economic sustainability across all specifications. Correa et al (2025) examined the nexus between human capital development and economic growth in Colombia by applying the dynamic stochastic general equilibrium and vector error correction to time series data spanning 1970–2019. Findings reveal that human capital has significant positive impact on economic growth in both long-run and short-run as indicated by DSGE model and vector error correction model respectively.

In Nigeria, Keji (2021) investigated the nexus between human capital and economic growth in Nigeria between 1981 and 2017 using vector error correction mechanism. Short-run result reveals that student enrolment at lags 1 and 2, labour participation rate at lags 1 and 2, and government expenditure at lag 2 made positive impact on GDP growth rate in the short-run whereas total labour force at lags 1 and 2, and government expenditure made negative impact on GDP growth. Long-run result indicates that student enrolment, labour participation rate, and government expenditure made positive impact on GDP growth rate while total labour force made negative impact on GDP growth. The study concludes that human capital development has significant impact on economic growth in Nigeria. Applying the ordinary least square (OLS) technique and Granger causality Wald test to time series data spanning 1981 to 2018, Krokeyi and Niyekpemi (2021) investigated the nexus between human capital and economic growth in Nigeria. OLS result suggests that government expenditure on education and health exerted positive effect on GDP growth rate with the education expenditure being significant, while causality test indicates a unidirectional causality from government expenditures on education and health to real GDP growth rate. Applying the autoregressive distributed lag (ARDL) to time series data of annual frequency spanning 1981 to 2021, Eniekezimene et al (2023) explored the link between human capital development and economic growth in Nigeria. Findings reveal that, in the long-run, government expenditure on education and tertiary school enrolment had insignificant negative impact on economic growth proxy by real gross domestic product growth rate whereas government expenditure on health, primary and secondary school enrolments had insignificant positive impacts on economic growth. Short-run result indicates that while government expenditure on education, primary, secondary and tertiary school enrolments made significant negative impact on economic growth, government expenditure on health had significant positive impact on economic growth. Ugbaka et al (2023) studied the effect of human capital development on economic growth in Nigeria by applying ARDL to time series data over the period of 1986 to 2020. Short-run result indicates that total government expenditure on education, primary and tertiary school enrolments, and labour force exerted positive effect on GDP with tertiary school enrolment being significant whereas total government expenditure on health and secondary school enrolment had insignificant negative impact on GDP. Long-run result shows that total government expenditures on education and health, primary and tertiary school enrolments, and labour force made positive effect on GDP with tertiary school enrolment being significant while secondary school enrolment had insignificant negative impact on GDP. Okwori and Awogbemi (2024) examined the role of human capital development in Nigeria's economic growth using vector autoregression (VAR), vector error correction model (VECM), and Granger causality tests and time series data covering 1990 to 2022. VAR long-run result shows that government expenditure on education had significant positive impact on real GDP while government expenditure on health had significant negative impact on real GDP while VECM short-run result indicates insignificant negative impact of government expenditures on education and health on real GDP. Granger causality test result suggests that government expenditures on education and health had no significant predictive power over real GDP. Okoh (2025) investigated the impact of human capital development on economic growth in Nigeria by applying the fully modified ordinary least squares (FMOLS) approach and the bound test to time series data spanning 1990 to 2022. Findings show that government spendings on education and health had a positive and significant impact on real gross domestic product in Nigeria. Adeyemo (2025) examined the impact of human capital development and economic growth in Nigeria using ARDL estimation technique and time series data spanning 1986 to 2021. The study modelled economic growth proxy by gross domestic product as a function of human capital proxy by primary school enrolment, government expenditures on education and health. Both short-run and long-run results indicate that primary school enrolment and government expenditure on education had positive impact on gross domestic product with the later being significant whereas government expenditure on health had negative impact on gross domestic product with its lags 1 and 2 being significant in the short-run. Udu (2025) investigated human capital development and economic growth nexus in Nigeria using autoregressive distributed lag technique and time series data spanning 1992 to 2024. Findings indicate that primary, secondary and tertiary school enrolments, total government expenditures on education and health had significant positive impact on GDP in both short-run and long-run. Ibrahim (2025) analysed the impact of human capital development on economic growth in Nigeria using ARDL and time series data covering the period of 1989 to 2023. Short-run finding indicates that secondary school enrolment exerted insignificant positive impact on real GDP but its lags 1 and 2 impacted significantly and negatively whereas tertiary school enrolment made significant negative impact. Long-run result indicates significant positive impact of secondary and tertiary school enrolment on real GDP.

These existing empirical studies on Nigeria predominantly focussed on aggregate economic growth alone and shorter sample periods, utilized single human capital variables like school enrolments at primary, secondary and tertiary levels, government expenditures on education and health, etc., omitted key institutional and macroeconomic variables, and structural breaks. Given Nigeria's structural transformations, recurrent economic shocks, and evolving policy environment over the full 1981 to 2023 period, there is a compelling need for a comprehensive analysis that simultaneously examines aggregate and sectoral economic growth, incorporates multidimensional human capital proxies, and controls for productivity, demographic, macroeconomic, and institutional factors. Without such rigorous empirical evidence, policy interventions aimed at education reform, health improvement, productivity enhancement, and institutional strengthening risk being inadequately designed or misaligned with sectoral growth realities. In order to fill these gaps, this study examined the impact of human capital index (HCI), life expectancy (LIFE), mortality rates (MOTA) and other growth determinants on (i) aggregate economic growth proxy by real gross domestic product; (ii) agricultural sector growth proxy by agricultural sector GDP; (iii) industrial sector growth proxy by industrial sector GDP; and (iv) services sector growth proxy by services sector GDP from 1981 to 2023 using the dynamic ARDL technique. The study also investigated the direction of causality between aggregate real GDP, agricultural sector GDP, industrial sector GDP, services sector GDP and human capital index, life expectancy, mortality rate and other growth determinants from 1981 to 2023 using the Toda-Yamamoto causality test.

2. Methods and Materials

Theoretical framework of the study

This study adopts the augmented Cobb-Douglas production function as its theoretical framework to examine the impact of human capital development on both aggregate and sectoral economic growth in Nigeria. The Cobb-Douglas production which provides a neoclassical framework for analysing the relationship between factor inputs and output explains how variations in production inputs contribute to changes in aggregate output (Cobb & Douglas, 1928; Swan, 1956, Solow. 1957); and has been widely employed in empirical growth studies. The traditional Cobb-Douglas production function is specified as:

$$Y = AK^{\alpha}L^{\beta} \qquad (1)$$

Where Y is total output or GDP (proxy for economic growth), A is total factor productivity (technology and efficiency parameter), K is physical capital, and L is labour, α and β are output elasticities of capital and labour respectively. The model assumes constant returns to scale when $\alpha+\beta = 1$.

In modern theory, labour is not treated as a homogeneous input. Instead, its productivity depends largely on the quality of labour, which is influenced by human capital development like education, training, skills and health. Following the augmented Cobb-Douglas production function of Mankiw, Romer and Weil (1992), the study extends the traditional model by incorporating human capital as a separate factor of production. The augmented Cobb-Douglas production function is expressed as:

$$Y = AK^{\alpha}L^{\beta}H^{\gamma} \qquad (2)$$

Where H is human capital (proxy by human capital index in this study), γ is output elasticity of human capital. For estimation purposes, eqn (2) is transformed into a log-linear form specified in eqn (3).

$$\ln Y = \ln A + \alpha \ln K + \beta \ln L + \gamma \ln H + \mu \qquad (3)$$

Where μ is the error term, ln means that the variables are expressed in their natural logarithm.

Empirical model specification and data

Following the augmented Cobb-Douglas production function and the modification of the empirical models of Amir et al (2012), and Siddiqui and ur Rehman (2016), the model of this study is specified in four equations to capture objectives 1, 2, 3 and 4, that is to investigate the impact of human capital development on (1) aggregate economic growth (RGDP), (2) agricultural sector growth (AGDP), (3) industrial sector growth (IGDP) and (4) services sector growth (SGDP).

$$\ln RGDP_t = \alpha_0 + \alpha_1 HCI_t + \alpha_2 LIFE_t + \alpha_3 MOTA_t + \alpha_4 TFPR_t + \alpha_5 \ln GFCF_t + \alpha_6 POGR_t + \alpha_7 ISQG_t + \alpha_8 EXRA_t + \mu_{1t} \qquad (4)$$

$$\ln AGDP_t = \beta_0 + \beta_1 HCI_t + \beta_2 LIFE_t + \beta_3 MOTA_t + \beta_4 TFPR_t + \beta_5 \ln GFCF_t + \beta_6 POGR_t + \beta_7 ISQG_t + \beta_8 EXRA_t + \mu_{2t} \qquad (5)$$

$$\ln IGDP_t = \varphi_0 + \varphi_1 HCI_t + \varphi_2 LIFE_t + \varphi_3 MOTA_t + \varphi_4 TFPR_t + \varphi_5 \ln GFCF_t + \varphi_6 POGR_t + \varphi_7 ISQG_t + \varphi_8 EXRA_t + \mu_{3t} \quad (6)$$

$$\ln SGDP_t = \psi_0 + \psi_1 HCI_t + \psi_2 LIFE_t + \psi_3 MOTA_t + \psi_4 TFPR_t + \psi_5 \ln GFCF_t + \psi_6 POGR_t + \psi_7 ISQG_t + \psi_8 EXRA_t + \mu_{4t} \quad (7)$$

Where lnRGDP is aggregate real gross domestic product in its natural logarithm (the dependent variable used to proxy aggregate economic growth in Nigeria), lnAGDP is agricultural sector gross domestic product in its natural logarithm (the dependent variable used to proxy agricultural sector growth in Nigeria), lnIGDP is industrial sector gross domestic product in its natural logarithm (the dependent variable used to proxy industrial sector growth in Nigeria), lnSGDP is services sector gross domestic product in its natural logarithm (the dependent variable used to proxy services sector growth in Nigeria), HCI is education based human capital index (the core explanatory variable used to proxy education human capital development in Nigeria), LIFE is life expectancy (another core explanatory variable used to proxy health human capital), MOTA is mortality rate (another core explanatory variable used to proxy health human capital), TFPR is total factor productivity, lnGFCF is gross fixed capital formation in its natural logarithm (a proxy for physical capital), POGR is population growth rate (a proxy for labour force), ISQG is government quality (a proxy for institutional quality which has been recognized as an important variable in the economic prosperity of nations by many growth studies like Adams-Kane & Lim, 2014; Raifu et al., 2021; Ofori et al., 2024; Sanni & Onakoya, 2025; Urama et al., 2025), EXRA is exchange rate added to open up the economy as the Nigerian economy relates with other economies of the world through international trade, foreign direct investment, technology transfer and adoption, etc., α_0, $\beta_0, \varphi_0, \psi_0$ are constants, $\alpha_1 ... \alpha_8$, $\beta_1 ... \beta_8$, $\varphi_1 ... \varphi_8$, and $\psi_1 ... \psi_8$ are parameters to be estimated. Based on theoretical expositions, $\alpha_1 > 0$, $\alpha_2 > 0$, $\alpha_3 < 0$, $\alpha_4 > 0$, $\alpha_5 > 0$, $\alpha_6 > 0$, $\alpha_7 > 0$, $\alpha_8 > 0$ or < 0; $\beta_1 > 0$, $\beta_2 > 0$, $\beta_3 < 0$, $\beta_4 > 0$, $\beta_5 > 0$, $\beta_6 > 0$, $\beta_7 > 0$, $\beta_8 > 0$ or < 0; $\varphi_1 > 0$, $\varphi_2 > 0$, $\varphi_3 < 0$, $\varphi_4 > 0$, $\varphi_5 > 0$, $\varphi_6 > 0$, $\varphi_7 > 0$, $\varphi_8 > 0$ or < 0; $\psi_1 > 0$, $\psi_2 > 0$, $\psi_3 < 0$, $\psi_4 > 0$, $\psi_5 > 0$, $\psi_6 > 0$, $\psi_7 > 0$, $\psi_8 > 0$ or < 0.

This study employed time series data of annual frequency spanning 1981 to 2023. The choice of this period of study is based on data availability on the relevant variables. All the variables are logged except those that are already in rates (or percentages) and indices. This is to eradicate the existence of any potential heteroscedasticity. The description of data used in the empirical analysis of this study and their specific sources are presented in Table 1.

Table 1: Data description and sources

Variables	Description	Source
RGDP	Gross domestic product at 2010 constant market prices (annual) in (N' Billion) Nigeria local currency	Central Bank of Nigeria Statistical Bulletin (2024)
AGDP	Agricultural sector gross domestic product at 2010 constant market prices (annual) in (N' Billion) Nigeria local currency	Central Bank of Nigeria Statistical Bulletin (2024)
IGDP	Industrial sector gross domestic product at 2010 constant market prices (annual) in (N' Billion) Nigeria local currency	Central Bank of Nigeria Statistical Bulletin (2024)
SGDP	Services sector gross domestic product at 2010 constant market prices (annual) in (N' Billion) Nigeria local currency	Central Bank of Nigeria Statistical Bulletin (2024)
HCI	Human capital index, based on years of schooling and returns to education	Penn World Table (2025)
LIFE	Life expectancy at birth, total (years)	World Development Indicators (2025)
MOTA	Mortality rate, infant (per 1,000 live births)	World Development Indicators (2025)
TFPR	Total factor productivity level at current PPPs (USA=1)	Penn World Table (2025)
GFCF	Gross fixed capital formation in (N' Billion) Nigeria local currency	Central Bank of Nigeria Statistical Bulletin (2024)
POGR	Population growth (annual %)	World Development Indicators (2025)
ISQG	Quality of government	Teorell et al (2025)
EXRA	Official exchange rate (LCU per US$, period average)	World Development Indicators, 2025

Source: Compiled by the authors

Estimation methods and procedures

To investigate the impact of human capital development on aggregate and sectoral economic growth in Nigeria, the study employed the autoregressive distributed lag (ARDL) data analysis approach developed by Pesaran, Shin and Smith (2001). The autoregressive distributed lag approach is adjudged to be superior to the ordinary least squares multiple regression analysis, the Johansen cointegration analysis and the Engle-Granger static procedures, and has become increasingly popular among researchers in recent years (Jayaraman & Choong, 2009). This is because of the capacity of the autoregressive distributed lag approach to estimate variables that are stationary at levels, at first difference and at a mixture of levels and first difference. Another merit of the ARDL over OLS multiple regression analysis, the Johansen cointegration analysis and the Engle-Granger static procedures is its ability to estimate both short-run and long-run parameters. Thus, the ARDL is the most suitable approach for this study because the variables are stationary at both levels and first difference, and are of finite sample size (1981- 2023). The ARDL bounds cointegration test incorporating other control variables and structural breaks identified in the RGDP, AGDP, IGDP and SGDP datasets is employed to examine the existence of long-run relationship between the dependent variables of the four growth equations and the independent variables. The cointegration test using the ARDL bounds approach is conducted using F-test for joint significance of the coefficients of lagged-level variables. The decision rule is to reject the null hypothesis $H_0 = 0$ (no cointegration among the variables) if the calculated F-statistics is greater than the upper critical bound and conclude that the variables are cointegrated, or accept H_0 if the calculated F-statistics is less than the lower bound, and conclude that the variables are not cointegrated, but if the calculated F-statistics remains between the lower and upper critical bounds then the decision is inconclusive (Pesaran et al., 2001). The optimal lag length k is selected based on the SIC (Schwarz Information Criterion).

To model the short-run and the long-run impacts of human capital development on the aggregate economic growth (RGDP) and the three sectoral economic growth (AGDP, IGDP, and SGDP), the following unrestricted error correction model (UECM) frameworks are implemented.

$$\begin{aligned}\Delta \ln RGDP_t = {} & \alpha_0 + \alpha_1 \ln RGDP_{t-1} + \alpha_2 HCI_{t-1} + \alpha_3 LIFE_{t-1} + \alpha_4 MOTA_{t-1} + \alpha_5 TFPR_{t-1} + \alpha_6 \ln GFCF_{t-1} + \alpha_7 POGR_{t-1} \\ & + \alpha_8 ISQG_{t-1} + \alpha_9 EXRA_{t-1} + \alpha_{10} RBK2002_{t-1} + \sum_{j=0}^{k} \varpi_{1j} \Delta \ln RGDP_{t-j} + \sum_{j=0}^{k} \varpi_{2j} \Delta HCI_{t-j} + \sum_{j=0}^{k} \varpi_{3j} \Delta LIFE_{t-j} \\ & + \sum_{j=0}^{k} \varpi_{4j} \Delta MOTA_{t-j} + \sum_{j=0}^{k} \varpi_{5j} \Delta TFPR_{t-j} + \sum_{j=0}^{k} \varpi_{6j} \Delta \ln GFCF_{t-j} + \sum_{j=0}^{k} \varpi_{7j} \Delta POGR_{t-j} + \sum_{j=0}^{k} \varpi_{8j} \Delta ISQG_{t-j} \\ & + \sum_{j=0}^{k} \varpi_{9j} \Delta EXRA_{t-j} + \sum_{j=0}^{k} \varpi_{10j} \Delta RBK2002_{t-j} + \sum_{j=0}^{k} \varpi_{11j} \Delta ECT_{1t-j} \end{aligned} \qquad (8)$$

$$\begin{aligned}\Delta \ln AGDP_t = {} & \beta_0 + \beta_1 \ln AGDP_{t-1} + \beta_2 HCI_{t-1} + \beta_3 LIFE_{t-1} + \beta_4 MOTA_{t-1} + \beta_5 TFPR_{t-1} + \beta_6 \ln GFCF_{t-1} + \beta_7 POGR_{t-1} \\ & + \beta_8 ISQG_{t-1} + \beta_9 EXRA_{t-1} + \beta_{10} ABK2002_{t-1} + \sum_{j=0}^{k} \vartheta_{1j} \Delta \ln AGDP_{t-j} + \sum_{j=0}^{k} \vartheta_{2j} \Delta HCI_{t-j} + \sum_{j=0}^{k} \vartheta_{3j} \Delta LIFE_{t-j} \\ & + \sum_{j=0}^{k} \vartheta_{4j} \Delta MOTA_{t-j} + \sum_{j=0}^{k} \vartheta_{5j} \Delta TFPR_{t-j} + \sum_{j=0}^{k} \vartheta_{6j} \Delta \ln GFCF_{t-j} + \sum_{j=0}^{k} \vartheta_{7j} \Delta POGR_{t-j} + \sum_{j=0}^{k} \vartheta_{8j} \Delta ISQG_{t-j} \\ & + \sum_{j=0}^{k} \vartheta_{9j} \Delta EXRA_{t-j} + \sum_{j=0}^{k} \vartheta_{10j} \Delta ABK2002_{t-j} + \sum_{j=0}^{k} \vartheta_{11j} \Delta ECT_{2t-j} \end{aligned} \qquad (9)$$

$$\Delta \ln IGDP_t = \varphi_0 + \varphi_1 \ln IGDP_{t-1} + \varphi_2 HCI_{t-1} + \varphi_3 LIFE_{t-1} \varphi_4 MOTA_{t-1} + \varphi_5 TFPR_{t-1} + \varphi_6 \ln GFCF_{t-1} + \varphi_7 POGR_{t-1} + \varphi_8 ISQG_{t-1} + \varphi_9 EXRA_{t-1} + \varphi_{10} IBK2003_{t-1} + \sum_{j=0}^{k} \pi_{1j} \Delta \ln IGDP_{t-j} + \sum_{j=0}^{k} \pi_{2j} \Delta HCI_{t-j} + \sum_{j=0}^{k} \pi_{3j} \Delta LIFE_{t-j} + \sum_{j=0}^{k} \pi_{4j} \Delta MOTA_{t-j} + \sum_{j=0}^{k} \pi_{5j} \Delta TFPR_{t-j} + \sum_{j=0}^{k} \pi_{6j} \Delta \ln GFCF_{t-j} + \sum_{j=0}^{k} \pi_{7j} \Delta POGR_{t-j} + \sum_{j=0}^{k} \pi_{8j} \Delta ISQG_{t-j} + \sum_{j=0}^{k} \pi_{9j} \Delta EXRA_{t-j} + \sum_{j=0}^{k} \pi_{10j} \Delta IBK2003_{t-j} + \sum_{j=0}^{k} \pi_{11j} \Delta ECT_{3t-j} \quad (10)$$

$$\Delta \ln SGDP_t = \psi_0 + \psi_1 \ln SGDP_{t-1} + \psi_2 HCI_{t-1} + \psi_3 LIFE_{t-1} + \psi_4 MOTA_{t-1} + \psi_5 TFPR_{t-1} + \psi_6 \ln GFCF_{t-1} + \psi_7 POGR_{t-1} + \psi_8 ISQG_{t-1} + \psi_9 EXRA_{t-1} + \psi_{10} SBK2004_{t-1} + \sum_{j=0}^{k} \sigma_{1j} \Delta \ln SGDP_{t-j} + \sum_{j=0}^{k} \sigma_{2j} \Delta HCI_{t-j} + \sum_{j=0}^{k} \sigma_{3j} \Delta LIFE_{t-j} + \sum_{j=0}^{k} \sigma_{4j} \Delta MOTA_{t-j} + \sum_{j=0}^{k} \sigma_{5j} \Delta TFPR_{t-j} + \sum_{j=0}^{k} \sigma_{6j} \Delta \ln GFCF_{t-j} + \sum_{j=0}^{k} \sigma_{7j} \Delta POGR_{t-j} + \sum_{j=0}^{k} \sigma_{8j} \Delta ISQG_{t-j} + \sum_{j=0}^{k} \sigma_{9j} \Delta EXRA_{t-j} + \sum_{j=0}^{k} \sigma_{10j} \Delta SBK2004_{t-j} + \sum_{j=0}^{k} \sigma_{11j} \Delta ECT_{4t-j} \quad (11)$$

where the variables remain as defined previously, $lnRGDP_{t-1}$, $lnAGDP_{t-1}$, $lnIGDP_{t-1}$, $lnSGDP_{t-1}$ are the lagged values of RGDP, AGDP, IGDP, and SGDP in their natural logarithm respectively, RBK2002, ABK2002, IBK2003 and SBK2004 are dummy variables incorporated into the ARDL specifications of equations 4, 5, 6 and 7 respectively, to capture the structural breaks identified by Zivot-Andrews breakpoint unit root test in RGDP, AGDP, IGDP and SGDP data series in 2002, 2002, 2003 and 2004 respectively, $\alpha_1 ... \alpha_{10}$, $\beta_1 ... \beta_{10}$, $\varphi_1 ... \varphi_{10}$, $\psi_1 ... \psi_{10}$ are long-run parameters to be estimated while $\varpi_1 ... \varpi_{11}$, $\vartheta_1 ... \vartheta_{11}$, $\pi_1 ... \pi_{11}$, $\sigma_1 ... \sigma_{11}$ are short-run parameters to be estimated, ECT is the error correction term, Δ is difference operator, and k is the optimal lag length. The short-run and long-run coefficients of the variables are estimated once cointegration is established among the variables. The error correction coefficient from the estimation of the short run relationship in each of the equations indicates the speed of adjustment or the rate at which the cointegration model corrects its previous period disequilibrium to restore the long-run equilibrium relationship. A significant and negative error correction coefficient means that any short-run deviation from equilibrium between the dependent and independent variables will converge back to the long-run relationship. The validity and reliability of the estimated equations and parameters, are confirmed using the following relevant diagnostic tests: Breusch–Godfrey serial correlation LM test, Breusch–Pagan-Godfrey test for heteroskedasticity, Jarque–Bera normality test, Ramsey RESET test for model specification; and CUSUM and CUSUM of Squares stability tests.

The study also examines the causal link between RGDP, AGDP, IGDP, SGDP and human capital development using the Toda-Yamamoto causality test developed by Toda and Yamamoto (1995). This is important because it aids comprehension of policy implication of findings (Salahuddin & Gow, 2019, Shahbaz et al., 2013). Toda and Yamamoto in their classic publication in 1995 solves the power and size problem associated with the traditional stationarity and cointegration tests by employing a modified Wald test (MWALD) to test for restrictions imposed on the parameters of the vector autoregressive, VAR (ρ) model making the procedure applicable irrespective of the order of integration or cointegration present in the system (Rahman et al., 2015; Kumar et al., 2015). The procedure specifies a VAR model in level, and involves the estimation of a {k + dmax} VAR model, in which the lag length k, is augmented with the maximum order of integration of the variables (dmax). The following augmented VAR {k + dmax} equations are estimated for RGDP, AGDP, IGDP and SGDP respectively:

$$W_t = \phi + \lambda_1 W_{t-1} + \lambda_2 W_{t-2} + \lambda_3 W_{t-3} + ... + \lambda_k W_{t-k} + \lambda_{k+d\max} W_{t-k+d\max} + \mu_{1t} \quad (12)$$

$$X_t = \eta + \lambda_1 X_{t-1} + \lambda_2 X_{t-2} + \lambda_3 X_{t-3} + ... + \lambda_k X_{t-k} + \lambda_{k+d\max} X_{t-k+d\max} + \mu_{2t} \quad (13)$$

$$Y_t = \omega + \lambda_1 Y_{t-1} + \lambda_2 Y_{t-2} + \lambda_3 Y_{t-3} + ... + \lambda_k Y_{t-k} + \lambda_{k+d\max} Y_{t-k+d\max} + \mu_{3t} \quad (14)$$

$$Z_t = \gamma + \lambda_1 Z_{t-1} + \lambda_2 Z_{t-2} + \lambda_3 Z_{t-3} + ... + \lambda_k Z_{t-k} + \lambda_{k+d\max} Z_{t-k+d\max} + \mu_{4t} \quad (15)$$

Where W = (lnRGDP, HCI, LIFE, MOTA, TFPR, lnGFCF, POGR, INSQG, EXRA), ϕ = (9 X 1) vector of constants, λ = (9 X 9) coefficient matrix, $\mu_{1t}...\mu_{4t}$ are the residuals which follow a white noise process and are assumed to be normally distributed. Eqns (13), (14), and (15) are explained in the same way as eqn (12) but X = (lnAGDP, HCI, LIFE, MOTA, TFPR, lnGFCF, POGR, INSQG, EXRA), Y = (lnIGDP, HCI, LIFE, MOTA, TFPR, lnGFCF, POGR, INSQG, EXRA), Z = (lnSGDP, HCI, LIFE, MOTA, TFPR, lnGFCF, POGR, INSQG, EXRA), for eqns (13), (14), and (15) respectively. All the variables are as described in Table 1, k = the optimal lag order for the VAR equations, dmax is the maximum order of integration for the variables in the four growth equations. The row i, column j element in d_k equals zero for k = 1, 2, 3, …, ρ. Note that ρ is the summation of k and dmax, i.e., [ρ = {k+dmax}]. The null hypothesis that jth element of W_t does not Granger-cause the ith element of W_t is rejected when the probability value of the standard Wald test falls within the acceptable 1 to 10 per cent level of significance. The same decision rule is applicable to eqns (13), (14), and (15).

3. Empirical Results and Discussions

Descriptive statistics

The empirical analysis of the study starts with descriptive statistics of the variables employed in the data analysis as presented in Table 2.

Table 2: Summary of descriptive statistics

Variable	RGDP	AGDP	IGDP	SGDP	HCI	LIFE
Mean	39902.54	8972.015	12311.06	18192.60	1.511628	48.87472
Median	31064.27	7817.080	11753.40	11202.68	2.000000	48.02000
Maximum	77936.10	19306.49	16742.15	43079.98	2.000000	54.46200

Minimum	16211.49	2303.510	8255.760	5352.560	1.000000	45.48300
Std. Dev.	21651.62	6016.322	2480.869	13170.01	0.505781	2.994398
Skewness	0.485004	0.423233	0.041201	0.591162	-0.046524	0.337207
Kurtosis	1.591566	1.604532	1.787895	1.684454	1.002165	1.537137
Jarque-Bera	5.239911	4.772707	2.644479	5.605322	7.166675	4.649018
Probability	0.072806	0.091964	0.266538	0.060648	0.027783	0.097831
Sum	1715809.	385796.7	529375.4	782281.9	65.00000	2101.613
Sum Sq. Dev.	1.97E+10	1.52E+09	2.58E+08	7.28E+09	10.74419	376.5895
Observations	43	43	43	43	43	43

Source: Computed by the authors using Eviews

The descriptive statistics reveals that the mean and median values of the series lie within the maximum and minimum threshold of each of the variables which is a desirable quality of data for estimation, forecasting and policy projections.

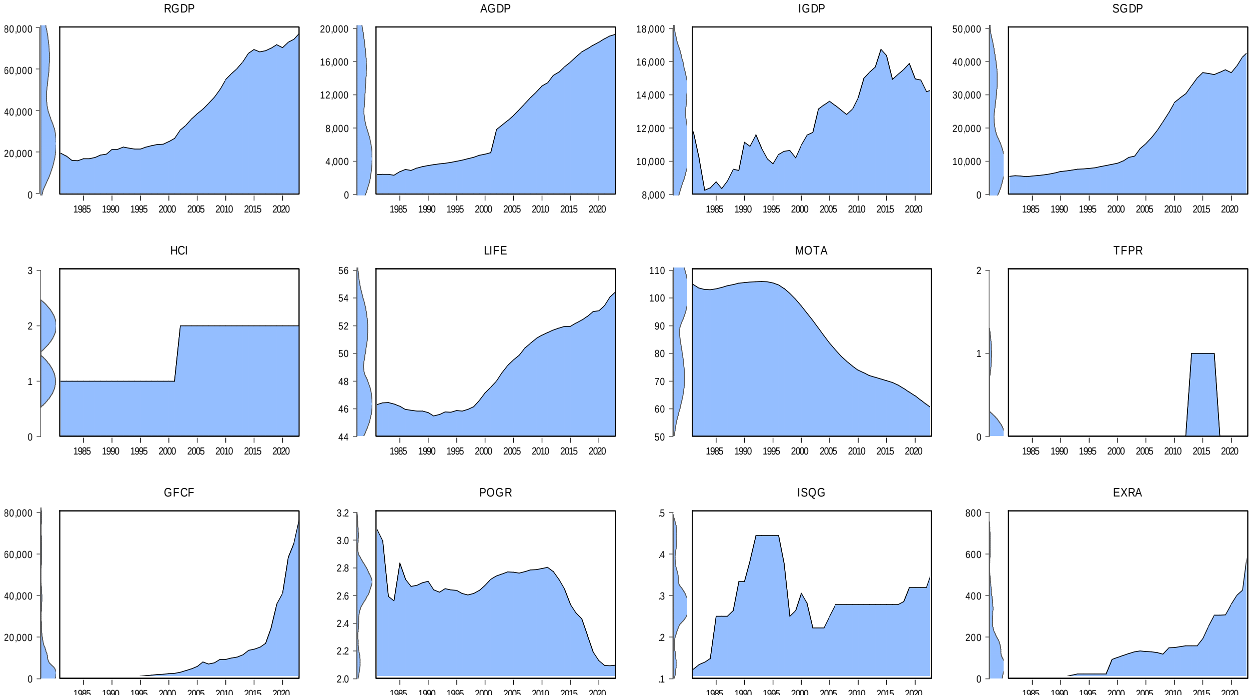
Table 2: Summary of descriptive statistics (cont'd)

Variable	MOTA	TFPR	GFCF	POGR	ISQG	EXRA
Mean	88.08140	0.116279	10914.56	2.623146	0.290254	127.9705
Median	91.90000	0.000000	3078.780	2.664631	0.277778	118.5667
Maximum	105.9000	1.000000	77834.67	3.074953	0.444444	645.1941
Minimum	60.10000	0.000000	87.14000	2.092817	0.123148	0.617708
Std. Dev.	16.48373	0.324353	18164.56	0.224355	0.079845	142.7848
Skewness	-0.267746	2.394072	2.367732	-1.035384	0.201051	1.548338
Kurtosis	1.419120	6.731579	7.905060	3.894098	3.221085	5.554952
Jarque-Bera	4.991466	66.02470	83.28427	9.115086	0.377261	28.87663
Probability	0.082436	0.000000	0.000000	0.010488	0.828092	0.000001
Sum	3787.500	5.000000	469326.2	112.7953	12.48094	5502.731
Sum Sq. Dev.	11411.97	4.418605	1.39E+10	2.114073	0.267762	856275.4
Observations	43	43	43	43	43	43

Source: Computed by the authors using Eviews

The Jarque-Bera statistics and its p-values indicate that most of variables are normally distributed as most of the p-values are above 0.05, whereas the skewness values show that all the variables are positively skewed except human capital index and population growth rate. RGDP, AGDP, IGDP, SGDP, HCI, LIFE and MOTA with kurtosis values less than 3 are platykurtic, POGR and ISQG with kurtosis values around 3 are mesokurtic, whereas TFPR, GFCF and EXRA with kurtosis values above 3 are leptokurtic. Each of the variables has 43 observations which are adequate for objective assessment of the human capital-growth nexus in Nigeria. Figure 2 reveals the movements of the variables over the period under review which expose the stochastic nature of macroeconomic variables (Nelson & Plosser, 1982). This necessitates the stationarity test presented in Tables 4 and 5 because time series data analysis requires that all the data series be stationary, as regressing non-stationary time series together leads to misleading or spurious results (Granger & Newbold, 1974).

Figure 2: Graphical trend analysis of the dependent and independent variables (1981 – 2023)



Source: Computed by the authors using Eviews

Correlation matrix

The correlation matrix presented in Table 3 shows that human capital index and life expectancy are positively correlated to both aggregate economic growth (RGDP) and sectoral economic growth (AGDP, IGDP and SGDP), whereas mortality rate correlates negatively to both aggregate and sectoral growth proxies. It is also glaring that none of the explanatory variables is correlated at above 0.80. This suggests absence of multicollinearity in the dataset.

Table 3: Correlation matrix

Correlation	RGDP	AGDP	IGDP	SGDP	HCI	LIFE	MOTA	TFPR	GFCF	POGR	ISQG	EXRA
RGDP	1.00											
AGDP	0.99	1.00										
IGDP	0.92	0.91	1.00									
SGDP	0.99	0.98	0.89	1.00								

HCI	0.76	0.79	0.77	0.73	1.00							
LIFE	0.78	0.78	0.79	0.77	0.70	1.00						
MOTA	-0.78	-0.78	-0.70	-0.77	-0.71	-0.79	1.00					
TFPR	0.47	0.42	0.51	0.47	0.35	0.39	-0.40	1.00				
GFCF	0.77	0.782	0.56	0.79	0.55	0.77	-0.75	0.06	1.00			
POGR	-0.60	-0.61	-0.37	-0.63	-0.30	-0.55	0.54	-0.10	-0.73	1.00		
ISQG	0.061	0.05	0.04	0.06	-0.12	-0.05	0.04	-0.05	0.14	-0.34	1.00	
EXRA	0.78	0.79	0.72	0.78	0.72	0.79	-0.77	0.21	0.73	-0.76	0.096	1.00

Source: Computed by the authors using Eviews

Unit root test of stationarity

The Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests in Table 4 suggest a mixed order of integration, I(0) and I(1). However, when structural breaks are present, traditional unit root tests including the ADF and PP tests tend to yield biased outcomes due to their limited power to reject the unit root null hypothesis. This limitation arises because conventional unit root testing procedures fail to account for structural breaks dates resulting from changes in the economic and political environment (Perron, 2006).

Table 4: Results of ADF and PP unit root tests of stationarity

Variable	ADF Test			PP Test		
	t- statistic I(0)	t- statistic I(1)	Result	t- statistic I(0)	t- statistic I(1)	Result
lnRGDP	-0.924905	-4.102034*	I(1)	0.358399	-3.987381*	I(1)
lnAGDP	-0.496821	-6.092143*	I(1)	-0.496436	-6.085350*	I(1)
lnIGDP	-0.850243	-6.403124*	I(1)	-5.568342	-1.017752*	I(1)
lnSGDP	0.912770	-2.872925***	I(1)	1.429873	-2.815553***	I(1)
HCI	-1.000000	-6.403124*	I(1)	-1.000000	-6.403127*	I(1)
LIFE	0.630293	-4.174132*	I(1)	-2.091612	-5.653697*	I(1)
MOTA	0.456169	-3.430262**	I(1)	-1.379310	-4.924493**	I(1)
TFPR	-2.263173	-6.244998*	I(1)	-2.421892	-6.244998*	I(1)

lnGFCF	0.605173	-4.271154*	I(1)	0.271354	-4.254667*	I(1)
POGR	-2.623112***	-5.386165*	I(0)	-1.142656	-5.386165*	I(1)
ISQG	-2.492858	-2.908539***	I(1)	-2.236456	-4.638431*	I(1)
EXRA	4.136028*	-6.066745*	I(0)	4.136028*	-6.136723*	I(0)

Source: Computed by the authors using Eviews; Note: *, **, *** implies rejection of the null hypothesis at 1%, 5%, or 10% level of significance. The test was implemented with intercept and the maximum lag length of 9 was auto-selected on SIC basis for augmented Dickey–Fuller (ADF) test and Newey–West Bandwidth employing the Bartlett–Kernel procedure for Phillips–Perron (PP).

To address this problem, the Zivot-Andrews unit root test capable of identifying an unknown single structural break in time series data is applied using Eviews data analysis software. The test which follows the basic framework outlined in Zivot and Andrews (1992) is implemented with intercept and maximum lag length of 4. The result in Table 5 identified a structural break in all the data series. For lnRGDP, lnAGDP, lnIGDP and lnSGDP, a structural break was dictated in the series in 2002, 2002, 2003 and 2004 respectively. Interestingly, a structural break was also identified in HCI, LIFE, MOTA, TFPR, lnGFCF, POGR, ISQG and EXRA in 2007, 1999, 1991, 2013, 2007, 2014, 1997 and 2016 respectively. These findings imply that the economy has witnessed significant policy shocks at the indicated breakpoint dates. For example, between 2002 and 2004, Nigeria implemented macro-fiscal, monetary and structural reforms that correspond with the structural breaks identified in RGDP(2002), AGDP(2002), IGDP(2003) and SGDP (2004). In 2002, fiscal policy emphasized budget discipline, privatization of government investments, diversification of agro-allied production, and private sector promotion, alongside the re-introduction of the Dutch Auction System to stabilize the exchange rate and improve financial intermediation (Central Bank of Nigeria, 2002; 2003). These measures affected aggregate growth and agricultural output through improved macroeconomic stability and market liberalization. In 2003, reform efforts crystallized under the National Economic Empowerment and Development Strategies (NEEDS), formerly launched in 2004, which promoted private sector led growth, governance reform, and institutional restructuring (Okonjo-Iweala & Osafo-Kwaako, 2007). Agricultural initiatives such as the Root and Tuber Expansion programme supported rural productivity. By 2004, NEEDS was embedded in fiscal operations, accelerating privatization, strengthening financial sector reforms, and redirecting expenditure toward infrastructure and services (International Monetary Fund, 2004). Collectively, these reforms altered the growth trajectory across aggregate and sectoral GDP, consistent with the Zivot-Andrews structural break results.

Table 5**:** Zivot-Andrews unit root test with unknown single structural break

Variable	Level form I(0)		First difference form I(1)		
	t-Statistic	Break Date Lag	t-Statistic	Break Date Lag	Results

lnRGDP	-9.309738*	2002	4	-5.457522*	2000	4	I(0) with break
lnAGDP	-9.309738*	2002	4	-7.227511*	2000	4	I(0) with break
lnIGDP	-3.152335	2003	4	-6.172439*	2015	4	I(1) with break
lnSGDP	-4.969143*	2004	4	-4.069865**	2016	4	I(0) with break
HCI	-3.050020	2007	4	-6.446218*	2008	4	I(1) with break
LIFE	-4.292179***	1999	4	-4.394695***	2010	4	I(0) with break
MOTA	-4.426284***	1991	4	-4.066284	1991	4	I(0) with break
TFPR	-8.221452*	2013	4	-5.197821**	2016	4	I(0) with break
lnGFCF	-4.224543	2007	4	-4.960402**	2007	4	I(1) with break
POGR	-4.468359	2014	4	4.468685***	2015	4	I(1) with break
ISQG	-3.906948	1997	4	-4.034175***	1995	4	I(1) with break
EXRA	1.231264	2016	4	-7.378590*	1989	4	I(1) with break

Source: Computed by the authors using Eviews; The break locations, i.e. intercept/trend and both are denoted by the midpoint implying rejection of the null hypothesis at 10% (*); 5% (**) and 1% (***) significance levels respectively, based on percentage points of the asymptotic distribution critical values as provided by Zivot and Andrews (1992) Table.

The Zivot-Andrews single structural breakpoint unit root test in Table 5 corroborates the ADF and PP stationarity test results of mixed order of integration, I(0) and I(1). Hence, the study adopts the ARDL bounds test in verifying whether there exists cointegration among the variables.

Cointegration test

The results of cointegration tests based on the ARDL-bounds testing method incorporating the structural breaks identified in the series for lnRGDP, lnAGDP, lnIGDP and lnSGDP equations are presented in Table 6. The results indicate existence of long-run relationships among the variables as the F-statistic values of 4.54649, 40.25231, 33.44153 and 8.06756 for lnRGDP, lnAGDP, lnIGDP and lnSGDP equations respectively are greater than the upper bounds critical value of 3.15

at 5 percent significance level. This leads to estimation of both short-run and long-run results in equations 8, 9, 10, and 11.

Table 6: Results of ARDL bounds tests to co-integration for lnRGDP, lnAGDP, lnIGDP and lnSGDP equations

Test statistic	Value	K
Eqn (8) F-statistic	4.54649	8
Eqn (9) F-statistic	40.25231	8
Eqn (10) F-statistic	33.44153	8
Eqn (11) F-statistic	8.06756	8
Critical Value Bounds		
Significant	I0 Bound	I1 Bound
10%	1.85	2.85
5%	2.11	3.15
2.5%	2.33	3.42
1%	2.62	3.77

Source: Computed by the authors using Eviews

ARDL short-run and long-run estimates

The results were estimated under ARDL(1, 1, 0, 2, 0, 2, 2, 0, 1, 0), ARDL(2, 2, 1, 2, 2, 0, 2, 1, 0, 2), ARDL(1, 2, 0, 2, 0, 0, 2, 2, 1, 2) and ARDL(1, 2, 2, 1, 2, 1, 1, 0, 0, 0) using the Akaike information criterion (AIC) and maximum dependent lag length of two, two, two, and two for lnRGDP, lnAGDP, lnIGDP and lnSGDP equations respectively. The ARDL short-run and long-run estimates for lnRGDP, lnAGDP, lnIGDP and lnSGDP equations are presented in Tables 7 and 8 respectively.

Table 7: ARDL short-run results for lnRGDP, lnAGDP, lnIGDP and lnSGDP equations

Variables	lnRGDP eqn (8)	lnAGDP eqn (9)	lnIGDP eqn (10)	lnSGDP eqn (11)
D(LNAGDP(-1)		-0.423880* [-5.226483]		
D(HCI)	0.113355* [3.113179]	0.418453* [26.175303]	0.013827 [0.233556]	0.059925*** [0.0947]
D(HCI(-1)		0.135522* [3.948386]	0.120711** [0.0243]	-0.079482** [-2.357855]
D(LIFE)	0.013067 [0.248929]	-0.036714 [-1.367348]	-0.127184 [-1.457546]	-0.028295 [-0.526000]
D(LIFE(-1)				0.079264 [0.1420]

	-0.052191	-0.051635**	0.033409	0.083992*
D(MOTA)	[-1.336129]	[-2.519142]	[0.415141]	[3.085505]
	0.072127**	0.045748*	0.115052**	
D(MOTA(-1)	[2.424896]	[2.670458]	[2.424337]	
	0.008824	0.017688***	-0.016565	-0.013679
D(TFPR)	[0.485829]	[1.840454]	[-0.503362]	[-0.578983]
		-0.019862**		-0.049148***
D(TFPR(-1)		[-2.232262]		[-2.038050]
	0.113706**	0.024610	0.191084*	0.042043
D(LNGFCF)	[2.253440]	[1.423128]	[2.780259]	[1.033693]
	0.090917**			
D(LNGFCF(-1)	[2.230551]			
	0.342366*	0.055439	0.689488*	0.071212
D(POGR)	[4.730683]	[1.660126]	[5.529040]	[0.929309]
	-0.129314***	0.355491*	-0.495682*	
D(POGR(-1)	[-1.910949]	[9.197017]	[-4.929268]	
	0.195764	0.187852**	-0.007790	-0.073474
D(ISQG)	[1.239158]	[2.344173]	[-0.024773]	[-0.477205]
			0.702033**	
D(ISQG(-1)			[2.147464]	
	0.000138	-0.000103	0.000130	0.000043
D(EXRA)	[1.042991]	[-1.593451]	[0.579021]	[0.319599]
			-0.000837***	
D(EXRA(-1)			[-1.850867]	
	-0.019816	-0.017278**		
D(R/ABK2002)	[-1.340773]	[-2.103083]		
			-0.025694	
D(IBK2003)			[-1.406142]	
				0.008026
D(SBK2004)				[0.770120]
	-0.356759*	-0.280135*	-0.462835*	-0.582535*
CointEq(-1)	[-3.176754]	[-3.667962]	[-3.630319]	[-4.846271]
R^2	0.999107	0.999926		0.999475
F-statistic	1237.217	9045.261	0.987807	1905.499
Prob.(F-statistic)	0.000000	0.000000	76.96282	0.000000
Durbin-Watson	2.281604	2.080189	0.000000	1.816614
stat.			2.208954	

Source: Computed by the authors using Eviews; Note: *, **, *** = significance at 1%, 5% and 10% respectively. t-statistics are in parentheses.

The short-run estimates in Table 7 indicate that human capital index (HCI) has a positive and statistically significant short-run impact on aggregate economic growth (lnRGDP) and sectoral economic growth (lnAGDP and lnSGDP). The coefficient of HCI suggests that 1% increase in HCI immediately generated 0.113355%, 0.418453% and 0.059925% increase in lnRGDP, lnAGDP and lnSGDP respectively. Its lagged impact on lnAGDP and lnIGDP is significantly positive and indicates 0.135522% and 0.120711% increase in agriculture and industrial growth following 1% increase in HCI(-1). This finding confirms the theoretical prediction of the endogenous growth models that human capital enhances productivity, innovation, and economic performance. It indicates that improvements in education, training, skills acquisition and health conditions increase labour efficiency and facilitate technological diffusion across sectors of the Nigerian economy, and corroborates the findings of Barra and Zotti (2016) in Italy, and Wirajing et al (2023) for 48 African countries but contradicts the result of Bekele et al (2024) in 30 sub-Saharan African countries. However, the lagged impact of human capital index on services sector growth is negative and statistically significant, implying that 1% increase in HCI(-1) reduces lnSGDP by 0.079482%. This negative impact contradicts theoretical postulation and may be attributed to the fact that the impact of education on the services sector growth may not be instantaneous as it may require some time for its positive effect to be felt, and the diversion of time, energy, and resources from production to educational pursuit reduces lnSGDP. From the coefficients, human capital index made the highest impact on agricultural sector growth (lnAGDP). In contrast, the industrial and services sectors exhibit weaker or mixed responses to human capital improvements, particularly in this short-run. This may reflect structural rigidities including technological constraints, capital intensity, and skill mismatches, which limit the immediate transmission of human capital improvements into industrial sector productivity gains. The services sector while generally human capital intensive may also be affected by labour market segmentation and the prevalence of informal employment, reducing the measurable productivity impact of aggregate human capital improvements. The Toda-Yamamoto causality result in Table 8 supports the significant positive impact of HCI by providing evidence that past values of HCI have predictive power over future values of aggregate and sectoral growth as it reveals unidirectional causality from HCI to both aggregate and sectoral growth. Thus, human capital influences economic growth through productivity enhancement, labour efficiency, technological adoption, innovation and invention, and structural transformation. This highlights the need for further improvement in the quality of human capital, especially in education through curriculum revision and increased funding to meet the productive needs of the economy across all the sectors. Life expectancy made statistically insignificant positive impact on lnRGDP and insignificant negative impact on lnAGDP, lnIGDP and lnSGDP. However, its lag one impact on lnSGDP is positive but insignificant. These results indicate that life expectancy has not significantly promoted both aggregate and sectoral economic growth in Nigeria. This highlights the need for improvement in both quality and quantity of health facilities and medical personnels so as to improve life expectancy and its impact on economic growth in Nigeria. The result may also reflect the fact that the economic benefits of improved health outcomes materialize gradually and depend on complementary factors such as skills, employment opportunities, and capital accumulation. The negative coefficients of life expectancy contradict theory and the result of Ogundari and Awokuse (2018) in 35 sub-Saharan African countries, and Bashir (2024) in six Gulf Cooperation Council (GCC) countries. Mortality rate made negative impact on lnRGDP and lnAGDP with the later being significant. The coefficient indicates 0.051635% reduction in lnAGDP as a result of 1% increase in mortality rate. This finding lends credence to a priori expectation as increase in mortality rate lowers labour supply, reduces human capital accumulation and leads to loss of potential output. Surprisingly, mortality rate exerted insignificant positive effect on lnIGDP and significant positive effect on lnSGDP. The coefficient reveals 0.083992% increase in lnSGDP following 1% increase in mortality rate. While the negative effect on agriculture aligns with theoretical expectations, the positive effect on services sector growth may appear counterintuitive. However, the outcome can be explained by Nigeria's demographic and structural characteristics. The adverse effect of mortality rate on agriculture reflects the sector's heavy dependence on manual labour and rural population dynamics. High mortality rates reduce the availability of rural labour, lower agricultural productivity, and weaken human capital accumulation in rural areas. Poor child health outcomes also reflect broader deficiencies in healthcare, nutrition, and rural infrastructure, which further constrain agricultural productivity. The positive relationship between mortality and services sector growth may also reflect structural transformation and demographic shifts rather than a direct productivity-enhancing effect of mortality. High mortality rates are typically concentrated in the rural and poor regions, contributing to rural urban migration as households seek better healthcare and economic opportunities, this migration expands the urban labour force, particularly in informal services such as retail, transport and personal services, thereby increasing measured services sector GDP. In this context, the significant positive coefficient reflects labour reallocation and structural adjustment rather than an economically desirable effect of mortality. Moreover, mortality may alter household labour supply decisions, with surviving members increasing labour force participation to compensate for lost income, particularly in urban service activities. Again, Nigeria has a very large young population with high fertility rates (Alawode & Lawal, 2025; Michael et al., 2024; Addah & Ikobho, 2022), and if infant mortality increases rather than the working age population, the immediate effect may be reduction in dependency ratios in the short-run and increase in GDP especially in per capita or sectoral growth, even if overall welfare declines. This demographic adjustment mechanism helps to explain the observed sectoral asymmetry. Therefore, the result does not imply that mortality promote economic growth, but rather that mortality influences the sectoral composition of growth through labour mobility, demographic adjustment and structural transformation. The lagged impact of mortality rate on lnRGDP, lnAGDP and lnIGDP is positive and significant with the coefficients indicating 0.072127%, 0.045748% and 0.115052% increase in lnRGDP, lnAGDP and lnIGDP respectively. These significant positive lagged effects of mortality rate contradict theory. It is imperative to note that while child mortality undermines long-run human capital and welfare, short- to medium-term macroeconomic adjustments can produce a positive statistical association. Mortality shocks may temporarily reduce dependency ratios, increase adult labour supply, and stimulate replacement fertility, particularly in labour-intensive sectors. They may also trigger public health expenditure and infrastructure investment that generate multiplier effects across the economy. Additionally, wage adjustments, capital deepening, and structural transformation dynamics can contribute to subsequent growth. Thus, these significant positive lagged effects may be attributed to transitional demographic and policy responses rather than any developmental benefit of child mortality, as sustainable growth ultimately depends on improved health outcomes and human capital accumulation among other growth determinants.

For the control variables, total factor productivity (an efficient and technology parameter) indicates positive impact on lnRGDP and lnAGDP with the later being significant whereas its impact on lnIGDP and lnSGDP is insignificantly negative. Sadly, the TFPR at lag one made significant negative impact on lnAGDP and lnSGDP with the coefficients suggesting 0.019862% and 0.049148% decline in the two sectors' GDP respectively. Gross fixed capital formation and population growth made positive impact across all specifications in the short-run with the coefficients being significant in fostering lnRGDP and lnIGDP, though population growth at lag one made significant negative impact on lnRGDP, lnAGDP and lnIGDP. Institutional quality has positive impact on lnRGDP and lnAGDP and negative impact on lnIGDP and lnSGDP with that of lnAGDP being significant. Interestingly, institutional quality at lag one made significant and positive impact on lnIGDP with the coefficient indicating 0.702033% rise in lnIGDP. Exchange rate (EXRA) made insignificant positive impact across all specifications except in lnAGDP eqn (9) with insignificant negative coefficient. Sadly, its lagged impact on lnIGDP is significantly negative, suggesting a 0.000837% reduction as a result of 1% increase in exchange rate. The structural breaks, RBK2002, ABK2002 and IBK2003 made negative impact on lnRGDP, lnAGDP and lnIGDP with that of lnAGDP being significant. SBK2004 made positive though insignificant impact on lnSGDP. Interestingly, the coefficient of ECM(-1) in all the specifications is negatively signed and significant at 1% level with about 35.67%, 28.01%, 46.28% and 58.25% disequilibrium corrected in the long-run in lnRGDP, lnAGDP, lnIGDP and lnSGDP equation respectively. This implies that services sector adjusts more rapidly to shocks whereas agriculture adjusts more gradually. Summary statistics in the lower part of Table 7 indicates high explanatory power and joint significance of the specifications and absence of autocorrelation. The ARDL long-run estimates are presented in Table 8.

Table 8: ARDL long-run results for lnRGDP, lnAGDP, lnIGDP and lnSGDP equations

Variables	lnRGDP eqn (8)	lnAGDP eqn (9)	lnIGDP eqn (10)	lnSGDP eqn (11)
HCI	0.087992 [0.861166]	0.607381* [6.186596]	0.020338 [0.149802]	0.099648 [1.202843]

	0.036628	-0.276783*	-0.274794	-0.283292*
LIFE	[0.246460]	[-2.921110]	[-1.401866]	[-2.692464]
	-0.020388	-0.073431*	-0.001039	-0.070779*
MOTA	[-0.730248]	[-4.948173]	[-0.027969]	[-3.820151]
	0.024734	0.110259*	-0.035790	0.053205
TFPR	[0.506790]	[2.834273	[-0.476215]	[1.437947]
	0.069990	0.087851***	0.412856*	0.236730*
LNGFCF	[1.088880]	[1.920612]	[2.621858]	[7.452997]
	0.733788*	-0.269017	1.722559*	0.311376*
POGR	[2.797250]	[-1.189588]	[3.120919]	[2.931524]
	0.548729	-0.003613	-1.973184***	-0.126128
ISQG	[1.266162]	[-0.012207]	[-1.826759]	[-0.476908]
	0.000388	-0.000871	0.004572*	0.000073
EXRA	[0.983062]	[-1.070512]	[2.719420]	[0.316831]
	-0.055546	-0.061678***		
R/ABK2002	[0.1731]	[-2.051168]		
			-0.055514	
IBK2003			[-1.380052]	
				0.013777
SBK2002				[0.739123]
	7.805535	28.313456*	15.633308	27.022735*
C	[0.793028]	[5.021803]	[1.268677]	[3.963612]

Source: Computed by the authors using Eviews; Note: *, **, *** = significance at 1%, 5% and 10% respectively. t-statistics are in parentheses.

The ARDL long-run estimates for equations (8) – (11) reported in Table 8 indicate substantial sectoral heterogeneity in the growth process. Human capital index made positive impact in all the specifications with the coefficient in lnAGDP equation being significant, and this corroborates its short-run significant positive impact. Precisely, the coefficient indicates that 1% increase in HCI led to 0.607381%, increase in lnAGDP. This means that HCI significantly enhanced agricultural sector GDP in both short-run and long-run which reflects the importance of education and health in improving agricultural productivity through better adoption of modern farming techniques, efficient resource allocation, and improved farm management. Life expectancy retained its positive impact on lnRGDP and negative impact on lnAGDP, lnIGDP and lnSGDP in the long-run with the coefficients being significant in lnAGDP and lnSGDP specifications. Quantitatively, the results show that 1% increase in LIFE reduced lnAGDP, and lnSGDP by 0.276783%, and 0.283292% respectively. The negative impact on lnAGDP likely reflects structural transformation and labour reallocation from agriculture to non-agricultural sectors as improved health enhances labour mobility. Similarly, the negative effect on services sector growth may reflect negative labour market absorption constraints, where increases in labour supply associated with higher life expectancy are not matched with sufficient productivity-enhancing employment opportunities. Mortality rate made negative impact on lnRGDP, lnAGDP, lnIGDP and lnSGDP with a significant coefficient in lnAGDP and lnSGDP equations. Numerically, the coefficients suggest that 1% increase in mortality rate reduces lnAGDP and lnSGDP by 0.073431% and 0.070779%. The control variables reveal that TFPR made positive impact on lnRGDP, lnAGDP and lnSGDP and negative impact on lnIGDP with the coefficient being significant in lnAGDP equation only. The coefficient indicates 0.110259%, increase in lnAGDP. GFCF and POGR exerted positive impact across all the specifications with most of the coefficients being significant in the long-run except in lnAGDP equation where POGR has insignificant negative coefficient. ISQG and EXRA produced mixed results across the specifications. Whereas the identified structural breaks, RBK2002, ABK2002 and IBK2003 made negative impact on lnRGDP, lnAGDP and lnIGDP, SBK2004 impacted positively on lnSGDP. The long-run results indicate that most of the human capital variables are insignificant, while HCI is only significant in lnAGDP equation, LIFE has positive coefficient in the lnRGDP equation only and the coefficient is insignificant, while its impact on all the three sectoral GDP is negative with two being significant. Mortality rate has negative impact on both aggregate and sectoral GDP with three of the coefficients being significant. With inclusion of the control variables, the long-run evidence shows that Nigeria's growth structure is sectorally asymmetric. Agriculture is human capital and productivity driven, industry is investment and population driven, services sector is demand and capital driven, aggregate growth is largely demographic dependent. Institutional quality indicates limited long-run effectiveness and even significant negative impact on industrial GDP, suggesting structural inefficiencies. These findings highlight the need to complement uniform growth policy interventions with sector-specific growth policy strategies so as to promote sustainable and inclusive economic growth in Nigeria.

Results of Toda-Yamamoto causality test

The Toda-Yamamoto modified Wald causality test was carried out to investigate the direction of causality between human capital variables and both aggregate (lnRGDP), and sectoral economic growth (lnAGDP, lnIGDP and lnSGDP). The results provide robust evidence on the direction of causal relationships between human capital development indicators and economic growth at aggregate and sectoral levels in Nigeria. The Toda-Yamamoto approach avoids the limitations of traditional Granger causality by allowing valid inferences irrespective of integration and cointegration properties of the variables, thereby producing reliable valid interpretations (Toda & Yamamoto, 1995). The results presented in Table 9 reveal a mixture of unidirectional, bidirectional, and no causal relationships, with clear sectoral differences.

Table 9: Toda-Yamamoto causality (modified WALD) test results

Toda-Yamamoto causality (modified WALD) test results for lnRGDP eqn (12)			
	Chi-Square (χ^2)	**Probability**	**Conclusion**

ΔHCI → ΔlnRGDP	8.561806**	0.0138	Reject
ΔlnRGDP → ΔHCI	3.228123	0.1991	Do not reject
ΔLIFE → ΔlnRGDP	3.188036	0.2031	Do not reject
ΔlnRGDP → ΔLIFE	1.606050	0.4480	Do not reject
ΔMOTA → ΔlnRGDP	6.211768**	0.0448	Reject
ΔlnRGDP → ΔMOTA	0.401814	0.8180	Do not reject
ΔTFPR → ΔlnRGDP	4.308859	0.1160	Do not reject
ΔlnRGDP → ΔTFPR	5.862068***	0.0533	Reject
ΔlnGFCF → ΔlnRGDP	11.63220*	0.0030	Reject
ΔlnRGDP → ΔlnGFCF	5.815945***	0.0546	Reject
ΔPOGR → ΔlnRGDP	8.348637**	0.0154	Reject
ΔlnRGDP → ΔPOGR	7.973066**	0.0186	Reject
ΔISQG → ΔlnRGDP	0.387519	0.8239	Do not reject
Δ lnRGDP → ΔISQG	2.244892	0.3255	Do not reject
Δ EXRA → ΔlnRGDP	0.388937	0.8233	Do not reject
Δ lnRGDP → ΔEXRA	0.876337	0.6452	Do not reject
Δ RBK2002 → ΔlnRGDP	3.190650	0.2028	Do not reject
Δ lnRGDP → ΔRBK2002	2.639873	0.2672	Do not reject

Toda-Yamamoto causality (modified WALD) test results for lnAGDP eqn (13)

	Chi-Square (χ^2)	**Probability**	**Conclusion**
ΔHCI → ΔlnAGDP	7.528351**	0.0232	Reject
ΔlnAGDP → ΔHCI	2.371925	0.3055	Do not reject
ΔLIFE → ΔlnAGDP	1.283252	0.5264	Do not reject
ΔlnAGDP → ΔLIFE	16.58855*	0.0002	Reject
ΔMOTA → ΔlnAGDP	12.73155*	0.0017	Reject
ΔlnAGDP → ΔMOTA	2.075534	0.3542	Do not reject
ΔTFPR → ΔlnAGDP	8.497394**	0.0143	Reject
ΔlnAGDP → ΔTFPR	0.459836	0.7946	Do not reject
ΔlnGFCF → ΔlnAGDP	8.183412*	0.0002	Reject
ΔlnAGDP → ΔlnGFCF	10.96635*	0.0042	Reject
ΔPOGR → ΔlnAGDP	15.59516*	0.0004	Reject
ΔlnAGDP → ΔPOGR	6.635631**	0.0362	Reject
ΔISQG → ΔlnAGDP	5.632306***	0.0598	Reject
ΔlnAGDP → ΔISQG	0.616214	0.7348	Do not reject
ΔEXRA → ΔlnAGDP	0.244412	0.8850	Do not reject
ΔlnAGDP → ΔEXRA	18.15463*	0.0001	Reject
ΔABK2002 → ΔlnAGDP	0.310152	0.8563	Do not reject
ΔlnAGDP → ΔABK2002	0.824349	0.6622	Do not reject

Toda-Yamamoto causality (modified WALD) test results for lnIGDP eqn (14)

	Chi-Square (χ^2)	**Probability**	**Conclusion**
ΔHCI → ΔlnIGDP	5.964191***	0.0507	Reject
ΔlnIGDP → ΔHCI	1.256489	0.5335	Do not reject
ΔLIFE → ΔlnIGDP	5.589160***	0.0611	Reject
ΔlnIGDP → ΔLIFE	1.894907	0.3877	Do not reject
ΔMOTA → ΔlnIGDP	9.844906*	0.0073	Reject
ΔlnIGDP → ΔMOTA	2.019494	0.3643	Do not reject
ΔTFPR → ΔlnIGDP	0.445390	0.8004	Do not reject
ΔlnIGDP → ΔTFPR	7.049337**	0.0295	Reject
ΔlnGFCF → ΔlnIGDP	15.14799*	0.0005	Reject
ΔlnIGDP → ΔlnGFCF	11.33779*	0.0035	Reject
ΔPOGR → ΔlnIGDP	7.769390**	0.0206	Reject
ΔlnIGDP → ΔPOGR	3.173298	0.2046	Do not reject
ΔISQG → ΔlnIGDP	3.548542	0.1696	Do not reject
ΔlnIGDP → ΔISQG	1.542429	0.4625	Do not reject
Δ EXRA → ΔlnIGDP	6.322078**	0.0424	Reject
ΔlnIGDP → ΔEXRA	0.905343	0.6359	Do not reject
ΔIBK2003 → ΔlnIGDP	0.568209	0.7527	Do not reject
ΔlnIGDP → ΔIBK2003	2.351033	0.3087	Do not reject

Toda-Yamamoto causality (modified WALD) test results for lnSGDP eqn (15)

	Chi-Square (χ^2)	**Probability**	**Conclusion**
ΔHCI → ΔlnSGDP	13.51050*	0.0012	Reject
ΔlnSGDP → ΔHCI	2.924375	0.2317	Do not reject
ΔLIFE → ΔlnSGDP	4.400671	0.1108	Do not reject
ΔlnSGDP → ΔLIFE	7.986082**	0.0184	Reject
MOTA → ΔlnSGDP	6.543408**	0.0379	Reject
ΔlnSGDP → ΔMOTA	3.386514	0.1839	Do not reject
ΔTFPR → ΔlnSGDP	16.27897*	0.0003	Reject
ΔlnSGDP → ΔTFPR	0.235148	0.8891	Do not reject
ΔlnGFCF → ΔlnSGDP	8.152689**	0.0170	Reject
ΔlnSGDP → ΔlnGFCF	7.383947**	0.0249	Reject
ΔPOGR → ΔlnSGDP	11.31463*	0.0035	Reject
ΔlnSGDP → ΔPOGR	7.631769**	0.0220	Reject
ΔISQG → ΔlnSGDP	8.291722**	0.0158	Reject
ΔlnSGDP → ΔISQG	0.399087	0.8191	Do not reject
ΔEXRA → ΔlnSGDP	3.202329	0.2017	Do not reject
Δ lnSGDP → ΔEXRA	1.489463	0.4749	Do not reject
Δ SBK2004 → ΔlnSGDP	2.407928	0.3000	Do not reject
Δ lnSGDP → ΔSBK2004	5.219472	0.0736	Reject

Source: Computed by the authors using Eviews; Note: *, **, *** = significance at 1%, 5% and 10% respectively.

Specifically, the results indicate strong and consistent evidence that the human capital index Granger-causes aggregate (lnRGDP) and sectoral economic growth (lnAGDP, lnIGDP, lnSGDP), while none of these growth indicators causes human capital index. This establishes a uniform unidirectional causality from HCI to lnRGDP, lnAGDP, lnIGDP and lnSGDP as the p-values of 0.0138, 0.0232, 0.0507 and 0.0012 are less than 0.10. This finding strongly supports the endogenous growth theory, which emphasizes that investments in education, knowledge and skills enhance labour productivity, technological adoption and innovation, thereby promoting economic growth (Becker, 1964; Lucas 1988; Romer, 1990). Human capital promotes the efficiency of agricultural production through improved farming techniques, strengthens industrial productivity through skilled labour and technical competence, and drives services sector growth through knowledge intensive activities like finance, telecommunications, and information technology. The absence of reverse causality indicates that economic growth alone does not automatically translate into human capital development without deliberate public investment in education, training and healthcare systems. This has important policy implications, suggesting that Nigeria's growth sustainability depends critically on proactive human capital development policies. Life expectancy has no causal effect on aggregate economic growth as the p-value of 0.2031 is greater than 0.10, but exhibits sector-specific causal relationships. It Granger-causes industrial sector growth as the p-value of 0.0611 is less than 0.10 but does not Granger-cause agricultural and services sector growth as the p-values of 0.5264 and 0.1108 are greater than 0.10. However, both agricultural and services sector growth Granger-cause life expectancy as the p-values of 0.0002 and 0.0184 are less than 0.10. This implies that while improved health conditions contribute to industrial productivity by promoting workforce efficiency and reducing absenteeism, growth in agriculture and services sectors improves life expectancy through increased income, food security, improved nutrition and enhanced access to healthcare services. This finding aligns with the health-led growth hypothesis, which emphasizes that improved health enhances worker productivity and economic performance (Bloom, Canning & Sevilla, 2004; Weil, 2007); and the nutrition-health-productivity linkage emphasized in development literature (Fogel, 1994). Mortality rate Granger-causes both aggregate and sectoral growth as the p-values of 0.0448, 0.0017, 0.0073 and 0.0379 for lnRGDP, lnAGDP, lnIGDP and lnSGDP are less than 0.10. This result should be interpreted with caution. It does not mean that increase in MOTA increases growth as causality indicates predictive power. The result implies that past variations in infant mortality rate contain predictive information about aggregate and sectoral economic growth. This can be seen from the ARDL results where MOTA impacted negatively and significantly on agricultural sector growth in the short-run, and negatively on both aggregate and sectoral growth in the long-run, though insignificantly. The finding likely reflects the role of health conditions and demographic dynamics in shaping labour productivity and sectoral output, rather than suggesting that higher mortality enhances growth. Alternatively, the finding highlights the critical importance of child health and healthcare systems in driving long-run growth. Lower infant mortality reflects improved healthcare infrastructure, better nutrition and improved maternal health, which contribute to the development of a healthier and more productive future labour force. High child mortality rates reduce human capital accumulation by lowering life expectancy, reducing educational attainment, and weakening workforce productivity. The consistent causal effect across all sectors and aggregate GDP suggests that improving child survival rates is essential for sustaining Nigeria's long-run economic growth and development.

For the control variables, total factor productivity does not Granger-cause aggregate economic growth as the p-value of 0.1160 is greater than 0.10, but Granger-causes agricultural and services sector as the p-values of 0.0143 and 0.0003 are less than 0.10, while industrial sector Granger-causes TFPR as the reverse p-value of 0.0295 is less than 0.10. this indicates that productivity improvements enhance agricultural efficiency through better technology, mechanization and improved farming practices, while also supporting services sector expansion through technological innovation and efficiency improvements (Aghion & Howitt, 2009). Conversely, industrial expansion stimulates productivity growth through learning-by-doing, technological spillovers and economies of scale (Arrow, 1962). The absence of productivity-led causality at the aggregate level suggests structural constraints in Nigeria's economy that limit the broad transmission of productivity gains across sectors. GFCF shows bidirectional causality with lnRGDP, lnAGDP, lnIGDP and lnSGDP as their respective p-values of 0.0030, 0.0002, 0.0005 and 0.0170 and their reverse p-values of 0.0546, 0.0042, 0.0035 and 0.0249 are less than 0.10. This confirms mutual reinforcement between investment and economic growth across all sectors of the Nigerian economy. Capital accumulation promotes productive capacity by improving infrastructure, machinery, and technological capability thereby stimulating output growth. At the same time, economic growth generates higher income, savings and investment, creating a virtuous cycle of growth and capital accumulation (Solow, 1956). This finding highlights the importance of investment-driven growth strategies and the need to promote infrastructure development and capital formation to sustain economic growth. The result reveals a bidirectional causality between population growth and lnRGDP, lnAGDP, and lnSGDP as their respective p-values of 0.0154, 0.0004 and 0.0035 and their reverse p-values of 0.0186, 0.0362 and 0.220 are less than 0.10; and unidirectional causality from POGR to lnIGDP as the p-value of 0.0206 is less than 0.10. This shows that POGR contributes to economic growth by increasing labour supply, expanding domestic markets, and boosting production capacity. Similarly, economic growth enhances demographic outcomes through improved standards of living, access to healthcare and reduced mortality rate (Bloom & Williamson, 1998). The bidirectional causality suggests that Nigeria's large population represents both an opportunity and a challenge, emphasizing the importance of policies that improve labour productivity through education, skills development and employment creation. Institutional quality does not Granger-cause aggregate and industrial growth as their respective p-values of 0.8239 and 0.1696 are greater than 0.10, but Granger-causes lnAGDP and lnSGDP as their respective p-values of 0.0598 and 0.0158 are less than 0.10. This denotes that governance quality plays a more direct role in sectors that rely heavily in regulatory effectiveness, policy implementation and institutional support. Effective institutions increase access to credit, improve policy stability, strengthen property rights, and promote efficient resource allocation, thereby supporting agricultural productivity and services sector growth (Acemoglu, Johnson & Robinson, 2001; Acemoglu, et al., 2005). However, weak institutional quality limits economic performance by limiting efficiency, encouraging corruption, misallocation of resources and discouraging investments. EXRA Granger-causes lnIGDP as the p-value of 0.0424 is less than 0.10, but does not cause aggregate, agricultural and services sector growth as the p-values of 0.8233, 0.8850, and 0.2017 are greater than 0.10. This implies that exchange rate movements significantly affect industrial competitiveness particularly in import-dependent manufacturing firms where exchange rate depreciation increases input costs and affects production capacity. Conversely, lnAGDP Granger-causes EXRA as the reverse p-value of 0.0001 is less than 0.10, indicating that agricultural export performance influences foreign exchange earnings and exchange rate dynamics, highlighting the importance of export diversifications. The result further reveals that structural break dummy variables, RBK2002, ABK2002, IBK2003 and SBK2004 do not Granger-cause lnRGDP, lnAGDP, lnIGDP and lnSGDP as their respective p-values of 0.2028, 0.8563, 0.7527 and 0.3000 are greater than 0.10, indicating that structural changes such as policy reforms and macroeconomic adjustments influenced economic growth indirectly rather serving as immediate causal drivers, However, lnSGDP Granger-causes the structural break dummy SBK2004, suggesting that structural reforms were influenced by developments in the services sector, particularly, telecommunications and financial sector reforms. These causality results provide strong and consistent evidence that human capital development and health indicators are fundamental drivers of economic growth across all sectors, emphasizing the importance of education, healthcare, capital formation, population management, exchange rate management, and institutional reforms in promoting economic growth in Nigeria. For Nigeria, sustained investment in human capital development, healthcare systems, infrastructure, and institutional strengthening is essential for achieving inclusive and sustainable economic growth.

Diagnostic tests of model adequacy

A comprehensive set of diagnostic tests was performed to evaluate the adequacy of the ARDL model equations, and to determine the suitability of the parameter estimates for prediction and policy projections and the outcomes are presented in Table 10.

Table 10: Residual diagnostic tests for lnRGDP, lnAGDP, lnIGDP and lnSGDP equations

lnRGDP eqn (8)	
Tests	Probability Values
Breusch-Godfrey Serial Correlation LM Test	0.7223
Breusch-Pagan-Godfrey Heteroskedasticity Test	0.6140
Jarue Bera Normality Test	0.562617

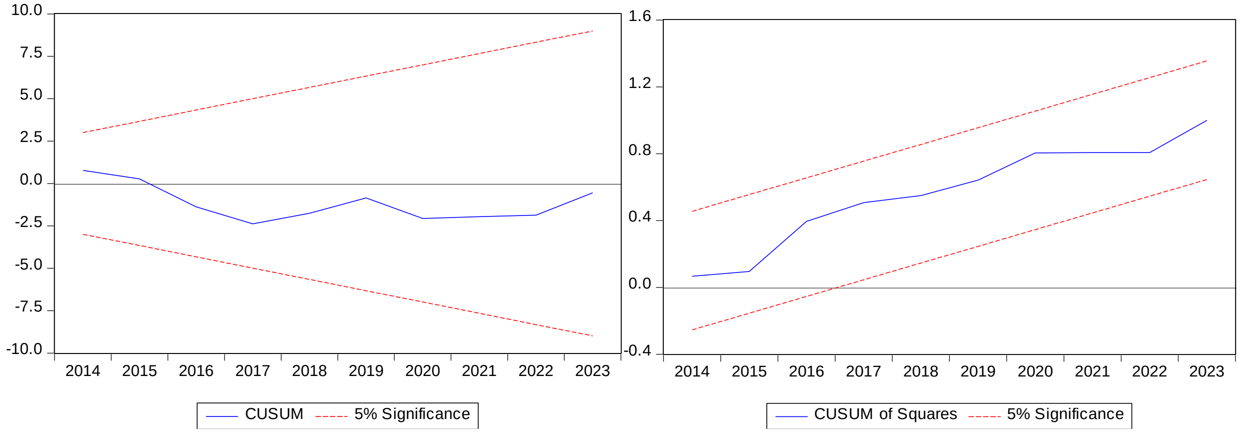
Ramsey RESET Test	0.4928
lnAGDP eqn (9)	
Tests	Probability Values
Breusch-Godfrey Serial Correlation LM Test	0.9561
Breusch-Pagan-Godfrey Heteroskedasticity Test	0.5126
Jarue Bera Normality Test	0.803291
Ramsey RESET Test	0.7632
lnIGDP eqn (10)	
Tests	Probability Values
Breusch-Godfrey Serial Correlation LM Test	0.6466
Breusch-Pagan-Godfrey Heteroskedasticity Test	0.4086
Jarue Bera Normality Test	0.737205
Ramsey RESET Test	0.5981
lnSGDP eqn (11)	
Tests	Probability Values
Breusch-Godfrey Serial Correlation LM Test	0.7853
Breusch-Pagan-Godfrey Heteroskedasticity Test	0.8823
Jarue Bera Normality Test	0.631160
Ramsey RESET Test	0.7491

Source: Computed by the authors using Eviews

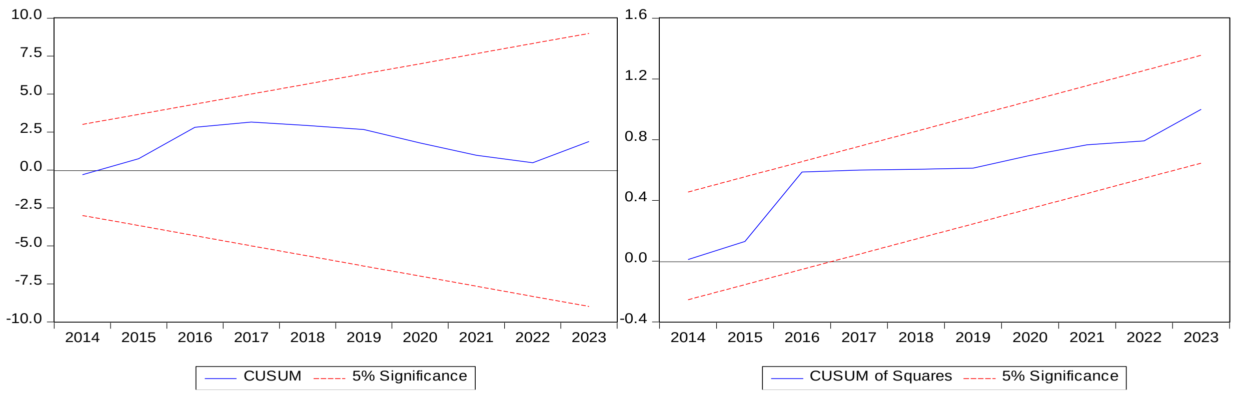
From the residual diagnostic tests of model adequacy presented in Table 10, the probability values in all the specifications are greater than 0.05. Thus, the Breusch-Godfrey LM test for serial correlation confirms the absence of autocorrelation in the residuals across the aggregate and sectoral specifications, indicating that the selected lag structures adequately capture the dynamic relationships among the variables. Similarly, the Breusch-Pagan-Godfrey heteroskedasticity indicates that the residuals are homoscedastic, confirming constant error variance and ensuring the efficiency of the estimated coefficients. The Jarque-Bera normality test indicates that the residuals are normally distributed, validating the reliability of statistical inference based on standard t-statistics and F-statistics. Moreover, the Ramsey RESET test confirms that the models are correctly specified and do not suffer from functional form misspecification or omitted variable bias. Hence, these diagnostic tests collectively demonstrate that the estimated ARDL models are econometrically sound and the estimated parameters are suitable for policy inferences. To assess parameter stability, the cumulative sum CUSUM) and the cumulative sum of squares (CUSUMQ) stability tests were conducted. The plots presented in Figure 3 show that the test statistics remain within the 5 percent critical bounds, confirming the stability of the estimated coefficients over the sample period.

Figure 3. CUSUM and CUSUM of squares graphs for the ARDL specifications. 1. CUSUM and CUSUM of squares for the lnRGDP eqn (8). 2. CUSUM and CUSUM of squares for the lnAGDP eqn (9). 3. CUSUM and CUSUM of squares for the lnIGDP eqn (10). 4. CUSUM and CUSUM of squares for the lnSGDP eqn (11)

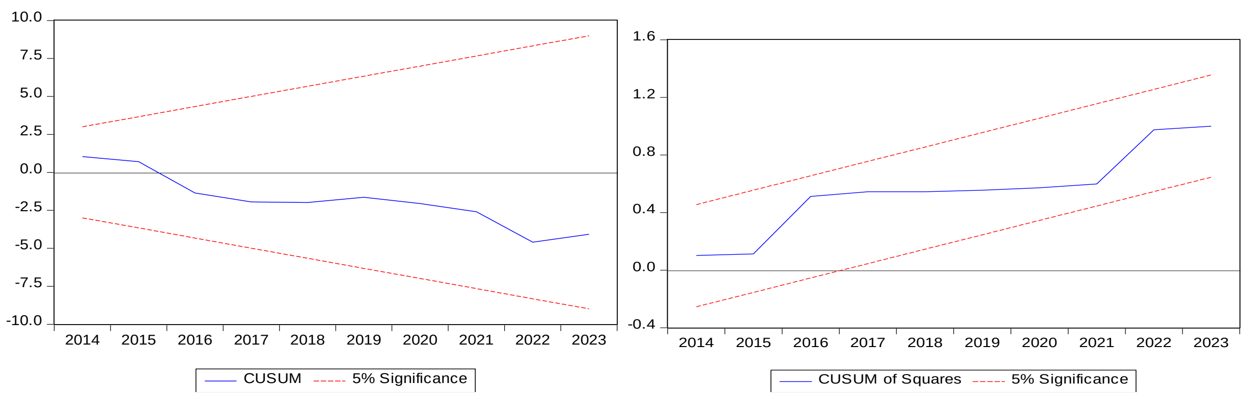
1.



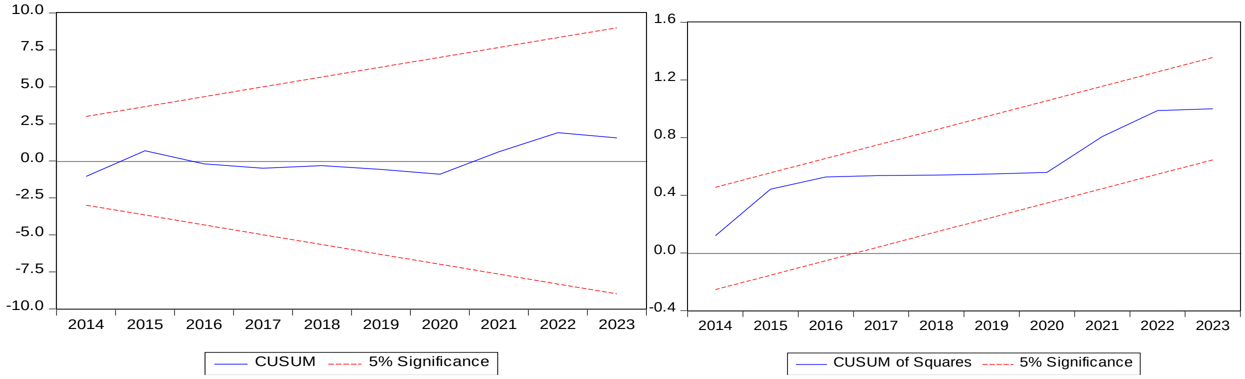
2.



3.



4.



Source: Computed by the authors using Eviews

The inclusion of structural break dummy variables, RBK2002, ABK2002 IBK2003 and SBK2004 further strengthens model robustness by explicitly accounting for structural shifts identified through the Zivot-Andrews breakpoint unit root test. These breaks correspond to major macroeconomic and institutional changes in Nigeria, including banking sector reforms, policy liberalizations, and structural adjustments. The Toda-Yamamoto causality approach itself provides a robustness advantage, as it avoids biases associated with pre-testing for cointegration and allows for valid inference regardless of the integration order of the variables. This strengthens confidence in the direction of causality identified in the study. Furthermore, the consistency between causality results and ARDL long-run estimates provides additional confirmation of the underlying relationships. For example, the observed causal linkage between human capital and agricultural growth aligns with the significant ARDL long-run estimate, reinforcing the validity of the findings.

4. Conclusion, Policy Implications and Recommendations

This study investigated the nexus between human capital development and economic growth in Nigeria using time series data of annual frequency spanning 1981 to 2023. The analysis employed the Autoregressive Distributed Lag (ARDL) framework and the Toda-Yamamoto causality test technique within the augmented Cobb-Douglas production structure proposed by Mankiw, Romer and Weil (1992). Human capital was proxied by the Human capital index (HCI), life expectancy (LIFE) and mortality rate (MOTA), while economic growth was measured at both aggregate (real gross domestic product, RGDP) and sectoral levels (agricultural sector gross domestic product, AGDP, industrial sector gross domestic product, IGDP, and services sector gross domestic product, SGDP). The model incorporated additional growth determinants such as total factor productivity (TFPR), gross fixed capital formation (GFCF), population growth (POGR), institutional quality (ISQG), exchange rate (EXRA), and structural break dummies.

The short-run estimates reveal that human capital index exerts a significant positive effect on both aggregate and sectoral outputs, although its lagged effect on the services sector output is significantly negative. Life expectancy displays weak and largely insignificant effects across sectors, while mortality rate exerts negative effects on aggregate output and agricultural output but positive effects on other sectors, although its lagged effects on aggregate and most sectoral GDPs are significantly positive. Gross fixed capital formation and population growth (at level) generally support growth, whereas other control variables yield mixed outcomes. Structural break dummies largely exert negative effects, suggesting disruptive policy or structural shifts. The long-run estimates indicate that human capital index maintains a positive impact on aggregate output and across all sectors, with a significant impact on agriculture, confirming its growth enhancing role. Mortality rate consistently undermines aggregate and sectoral growth, particularly in agriculture, while life expectancy indicates limited and, in some cases, negative sectoral effects. GFCF remains positively associated with both aggregate and sectoral outputs, reinforcing the complementarity between human and physical capital in fostering economic growth in Nigeria. The Toda-Yamamoto causality results further strengthen these conclusions by revealing unidirectional causality from human capital to aggregate and sectoral growth, and from mortality rate to economic growth. Collectively, the evidence demonstrates that human capital is a fundamental driver of economic growth in Nigeria. However, inefficiencies in health outcomes, structural rigidities, and institutional weaknesses constrain the full productivity potential of human capital.

These findings infer several important policy implications for maximising the growth dividends of human capital in Nigeria. Hence, the following policy recommendations and transmission pathways.

From the empirical findings human capital development represents one of the most powerful and consistent drivers of growth across all sectors. The primary transmission pathway operates through improved labour productivity, technological adoption, and sectoral efficiency. In agriculture, skilled farmers adopt mechanization, improved inputs, and climate resilient techniques more effectively, increasing output and strengthening food supply chains. In industry, technical skills improve machinery utilization, reduce operational inefficiencies, and enhance manufacturing productivity. In services, human capital strengthens financial intermediation, digital services, logistics efficiency, and managerial performance. Policy must therefore prioritize education quality improvements and relevance, expansion of technical and vocational training, modernization of agricultural extension services, and industry linked skill development programmes. Aligning education systems with sectoral labour market demands will promote workforce productivity and generate sustained aggregate and sectoral growth. Life expectancy requires particularly strong and targeted policy attention because the empirical findings show weak or negative effects on agriculture and services sectors growth, whereas causality evidence reveals that sectoral growth itself drives life expectancy improvements. This suggests that longevity gains in Nigeria have not yet been effectively translated into productive economic contributions. The critical policy objectives are therefore to transform increased longevity into productive and economically active years. The growth fostering pathway of life expectancy operates through increased healthy labour supply, retention of human capital and demographic productivity gains. Higher life expectancy increases the size and experience level of the workforce, promotes knowledge accumulation, and boosts productivity, but only if individuals remain healthy and economically active. To activate this pathway, health policy must shift from focusing solely on survival to promoting healthy and productive longevity. Preventive healthcare investments like nutrition programmes, chronic disease prevention, occupational health services, and early health interventions will ensure that additional years of life translate into productive labour force participation. Integrating healthcare policy with labour market policy is also essential. Re-skilling programmes, adult education, and workforce health programmes will allow older workers to remain productive contributors to agriculture, industry, and services. In agriculture, healthier farmers sustain longer productive cycles and adopt labour intensive and mechanized technologies more efficiently. In industry, healthier workers reduce absenteeism and improve operational productivity. In services, longer healthy working lives promote experience-based productivity, innovation, and managerial effectiveness. Strengthening child and adolescent health is equally critical because healthier early-life populations achieve higher educational attainment and productivity later in life, reinforcing the life expectancy human capital growth transmission mechanism. Thus, healthcare reform must be explicitly linked to productivity enhancement to convert longevity gains into sustained economic growth. Mortality reduction complements life expectancy improvements by strengthening labour force stability and protecting accumulated human capital. The empirical findings indicate that mortality rate significantly reduces agricultural and services sector growth and exerts causal influence on aggregate and sectoral GDP. The transmission mechanism operates through labour supply contraction, productivity loss, and disruption of economic activity. High mortality reduces workforce availability, weakens human capital accumulation, and increases dependency burdens, thereby constraining production, policy should therefore prioritize expanding primary healthcare access, strengthening disease prevention programmes, improving maternal and child healthcare, and investing in healthcare infrastructure, particularly in rural areas where agricultural productivity depends heavily on labour availability. Reducing mortality will stabilize the labour force, protect productivity, and promote sectoral GDP. For the control variables, capital formation plays a central role in stimulating growth through productive capacity expansion, technological upgrading, and infrastructure development. The empirical results show strong positive effects of GFCF on industrial and services sectors GDP, as well as bidirectional causality between GFCF and growth, indicating mutually reinforcing dynamics. Investment in infrastructure including electricity, transport, irrigation, and digital networks reduces production costs, improves efficiency, and fosters productivity across all sectors. Industrial investment strengthens manufacturing capacity and technological adoption whereas agricultural investment enhances mechanization, storage and irrigation systems. Policy should therefore promote capital formation through infrastructure expansion, improved access to credit, investment incentives, and financial sector reforms that facilitate private sector investment. These interventions will improve productive capacity and support sustained aggregate and sectoral growth. Population growth contributes positively to growth through labour supply expansion and market size effects, particularly in industry and services. The empirical result reveals significant long-run and causal influence on sectoral growth. The transmission pathway operates through increased availability and expanded domestic demand, which stimulate production and investment. However, the growth benefits of population growth depend on productive labour absorption. Policy should therefore promote employment intensive industrialization, expand skills development programmes, and strengthen labour market integration to ensure that population growth promotes productivity rather increasing unemployment. Transforming demographic expansion into a productive workforce will maximize the demographic dividend and support long-run growth. Total factor productivity improvement represents another key growth pathway, especially in agriculture and services sectors. The results indicate that TFPR increases lnAGDP and causes sectoral growth. Policies promoting mechanization, technological innovation, research and development, and extension services will promote production efficiency and resource utilization. Improving productivity reduces costs, increases output per worker, and strengthens sectoral competitiveness. Exchange rate stability is particularly important for industrial growth because it affects the cost of imported capital goods and intermediate inputs. Stable exchange rate reduces uncertainty, lower production costs, and improve industrial competitiveness. Policy should therefore prioritize exchange rate stability through prudent monetary management and export diversification strategies that strengthen foreign exchange earnings. Institutional quality provides the enabling environment through which all other growth drivers operate. Strong institutions improve regulatory efficiency, enhance investor confidence, reduce uncertainty, and strengthen resource allocation. Governance reforms that improve transparency, reduce bureaucratic inefficiencies, and ensure policy consistency will facilitate investment, productivity growth and sectoral expansion.

Suggestions for further studies

Although this study provides robust evidence on the human capital-economic growth nexus in Nigeria using aggregate and sectoral time series data (1981-2023), there is need for further investigation due to some limitations of this study. First, future research should employ alternative and disaggregated health indicators, including adult and maternal mortality, age-specific mortality, and rural-urban health data. Since this study used infant mortality which reflects child survival and health system quality rather than working-age mortality as a proxy, more granular measures would allow clearer identification of labour force and demographic effects. Second, subnational and panel data analyses are recommended to address potential aggregation bias and over-parameterization concerns inherent in national time-series models. State level panels would permit the use of dynamic estimators to better control for endogeneity and reduce overfitting risks. Third, additional robustness checks such as multiple-testing corrections, nonlinear and frequency-domain causality tests, and time-varying parameter models would strengthen causal inference and address ambiguity in causality findings. Fourth, future research should explicitly model transmission mechanisms using structural frameworks like structural vector autoregression (SVAR) and computable general equilibrium (CGE) models to decompose direct and indirect channels linking human capital, fiscal responses, and sectoral growth. Finally, integrating institutional quality, governance efficiency, demographic structure, environmental factors, and digital human capital variables would enhance understanding of sector-specific dynamics and improve policy relevance. Governance effectiveness, ICT penetration, dependency ratios, and climate variability may significantly condition sectoral growth outcomes in Nigeria.

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