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An investigation of the relationship between human capital development and economic growth in Nigeria: A principal component analysis based human capital development index

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Abstract

The Nigerian government has, over the years, invested significantly and increasingly in education, vocational training, skills acquisition, and health to develop its human capital as a strategy for boosting the growth of the Nigerian economy. Consequently, we investigated the relationship between human capital development and economic growth in Nigeria using annual data from 1990 to 2023. We employed principal component analysis to generate an index for human capital development from six indicators. Our findings are based on the Toda-Yamamoto Granger causality test and the Autoregressive Distributed Lag (ARDL) techniques. Human capital development has a significant positive influence on economic growth in both the short and long run. Similarly, trade openness and fixed capital formation significantly increase economic growth in the short and long term. Financial development exhibits a negative and significant effect on economic growth in the short run, while its long-run effect is positive but statistically insignificant. In the short run, human capital development and trade openness have persistent positive effects on economic growth. The Granger causality test results reveal that economic growth exhibits a bidirectional causal relationship with human capital development, trade openness, and financial development. Additionally, human capital development has a bidirectional causal association with fixed capital formation and trade openness. Based on these findings, we provide important policy recommendations to enhance Nigeria's economic growth through targeted investments in human capital and financial sector reforms.

Keywords: ARDL, Economic growth, Granger causality, Human capital development, Nigeria, Principal component analysis.
JEL Classification: O470; C430; E510.

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Contents

Contribution of this paper to the literature
Our study contributes to the literature by constructing a PCA-based human capital development index to investigate the relationship between human capital development and economic growth. By integrating financial development, exchange rates, fixed capital formation, and trade openness, it offers robust and comprehensive insights into the nexus between human capital development and economic growth.

1. Introduction

Attaining higher, stable, and sustainable economic growth is a macroeconomic objective pursued by every country. Achieving this macroeconomic goal can potentially enable countries to improve their citizens' living standards, reduce poverty, and promote higher national development. Several factors contribute to a country's ability to attain higher, stable, and sustainable economic growth, among which human capital plays a crucial role (Asian Development Bank, 2010; Izushi & Huggins, 2004; Kasongo & Makamu, 2024). Human capital comprises the skills, knowledge, and health attributes embodied in an individual. It plays a significant role in enhancing productivity and fostering innovation within a country, both of which are essential for economic growth (Becker, 1964; Kasongo & Makamu, 2024; Kim, Loayza, & Meza-Cuadra, 2016; OECD, 2008; Schultz, 1961). Nickolas (2023) noted that human capital positively impacts economic growth and contributes to developing an economy by expanding skills and knowledge. Consistent with this (Blundell, Dearden, Meghir, & Sianesi, 1999) argue that enhancing a country's economic performance is not achieved solely by improving trained labor and machinery but also by ensuring that the country possesses an adequate stock of human skills capable of utilizing these resources. Besides its direct role in promoting economic growth, human capital is essential for the effective formulation and implementation of macroeconomic policies. Mu, Yan, and Wu (2023) provide evidence indicating that workers with high human capital levels are central to macroeconomic policy effectiveness. Hence, economic theories and empirical studies have highlighted the role of human capital as an indispensable catalyst for achieving higher economic growth.

The indispensable role of human capital in enhancing economic growth provides a compelling incentive for countries to develop their human capital through investment. This approach enables them to optimize the benefits derived from it, thereby promoting economic expansion. Mengesha and Singh (2023) observed that several countries have incorporated human capital development as a core component of their national development strategies. These nations have allocated substantial financial resources to human capital development, aiming not only to accelerate economic growth but also to achieve stable and sustainable development. Human capital development involves improving individuals' knowledge, skills, health, and abilities. A well-developed human capital base enhances labor productivity, fosters technological innovation, increases returns on capital, and contributes to sustainable economic growth (Alam & Sumon, 2020). This implies that developing human capital is essential for national and global economic prosperity. Therefore, it is necessary for countries to have a developed and robust human capital base if they are to achieve higher and sustainable economic growth.

However, current evidence indicates that the level of human capital development, especially in developing countries such as Nigeria, remains low. Among African nations, Nigeria and other countries in the continent have the lowest levels of human capital development, which impacts economic growth and social progress (African Development Bank, 1998; Ayeni & Akeju, 2023; Korres, 2010). This situation potentially inhibits these countries from catching up with their developed counterparts in terms of higher economic growth, low unemployment, low poverty, high living standards, and greater economic development. One reason for low human capital development in developing countries is insufficient investment in human capital (Rossi & Weber, 2024). Nigeria, for instance, which was formerly the largest and is now the fourth-largest economy in Africa in terms of GDP (Galal, 2025a), faces significant developmental challenges despite its abundant human and natural resources. The country has, over the years, struggled to translate its resource wealth into sustainable economic growth and to improve its people's living standards. One of the challenges Nigeria faces is human capital underdevelopment. The country ranks low on global human capital indices, with poor healthcare and education outcomes (World Bank, 2024). For instance, adult literacy in the country is currently 63% and life expectancy at birth is 54.46 years, which is below the 73.6 years global average (The Global Burden of Disease Study, 2024; World Bank, 2023). Nigeria is the 7th lowest in the world in the human capital index (World Bank, 2024). The country is the least in Africa in terms of life expectancy.

The Nigerian government has, over the years, invested increasingly in education, vocational training, and health to develop its human capital. For example, in 2010, Nigeria's annual budget showed that the government of Nigeria spent N161.8 billion on health and N249.1 billion on education sectors (Budget Office of the Federation, 2011). In 2020, the Nigerian government expenditure on these sectors increased by N396.50 billion and N575 billion, respectively (KPMG, 2020). In its 2025 budget, the Nigerian government has proposed to spend N2.52 trillion on education and N1.96 trillion on health sectors, respectively (Nwachukwu & Obuam, 2023). This demonstrates its commitment to developing human capital to achieve higher, more stable economic growth. However, Nigeria has yet to attain a higher and more stable level of economic growth, as the country's economic growth remains low when compared not only to developed countries but also to some of its African counterparts. Nigeria's GDP has not maintained high and steady growth over the years, particularly in recent years. The country, which was the largest in Africa and ranked the 26th largest economy globally in 2014 (Nigerian Economic Summit Group, 2024), has not sustained these positions. It now trails behind three countries on the continent, including South Africa, Algeria, and Morocco (Galal, 2025b), and ranks 42nd in the world economy ranking (The Global Economy, 2023). Currently, Nigeria ranks 4th in Africa in terms of gross domestic product. Perhaps, investment in human capital in Nigeria has not translated into significant improvements in the country's economic growth. While previous studies highlight the indispensable role of human capital development in boosting countries' economic growth, the empirical evidence in Nigeria requires further investigation.

The link between human capital development and economic growth is well documented in the extant literature. Education enhances the productivity of the workforce or workers, reinforces innovation, and improves a country's ability to adapt to advancements in technology (Barro, 1991). Similarly, quality healthcare access increases workforce participation and productivity since it ensures a healthier population (Bloom & Canning, 2003). These provide robust

evidence that developing human capital to achieve stable and sustainable economic growth will potentially result in achieving the goal. However, the Asian Development Bank (2010) observed that not every country that makes efforts to develop its human capital ultimately achieves higher economic growth. One potential reason for this is that developed human capital requires robust physical capital to be more productive. This necessitates a robust understanding of the association between human capital development and economic growth, accounting for capital formation. Against this backdrop, we investigated the impact of human capital development on economic growth and the causal association between the variables in the context of Nigeria, taking into account capital formation.

The association between human capital development and economic growth, in the context of Nigeria, has received attention from researchers but requires further assessment as the findings from the studies lack unanimity. Moreover, those studies failed to capture human capital development robustly. They disaggregated human capital development proxies, with many of these studies reporting inconsistencies in the effect of the different proxies on economic growth. For example, Eniekezimene, Wodu, and Anda-Owei (2023) reveal that in the long run, government expenditure on education and tertiary school enrolment impact economic growth negatively, while government health expenditure and primary school enrolment impact economic growth positively. Similarly, some studies focusing on other countries reported inconsistent findings. For instance, Taban and Kar (2006) report evidence showing that the direction of causality between human capital development and economic growth is a function of human capital development measure used. Abel, Mhaka, and Le Roux (2019) found that the effect of human capital development strongly depends on the human capital development proxy, as some proxies have a negative effect while others have a strong positive effect on economic growth. Isolating human capital development measures in assessing the impact of human capital development on economic growth potentially results in less robust insights. These findings reinforce the need for further investigation of the association between these variables. A further investigation of the nexus between human capital development and economic growth in Nigeria could potentially enhance the understanding of the relationship between these variables. All other things being equal, this improved understanding will aid in policy formulation aimed at enhancing economic growth through human capital development.

To eliminate potential omitted variable bias and, by extension, enhance the robustness of our findings, we included some key variables in our models. These are exchange rate, trade openness, fixed capital formation, and financial development. The variables impact economic growth and, hence, potentially influence how human capital development affects economic growth in a country. For instance, the new endogenous growth model posits that trade openness impacts economic growth positively since trade openness enables the diffusion of advanced technologies (Coe & Helpman, 1995; Romer, 1994). A nation with a high level of trade openness potentially has a greater ability to utilize technologies from advanced economies. Ceteris paribus, this enables them to boost their economic growth more rapidly than their counterparts with lower trade openness. Solow (1957) pointed out that the accumulation of physical capital in a country leads to increased production, thereby fostering economic growth. It suggests that physical capital accumulation determines a country's production level, which in turn influences its economic growth.

Exchange rate and economic growth are related. Changes in a country's currency value can stimulate or inhibit the export and import of technology, goods, and services, thereby affecting productivity and economic growth. A fall in the value of the currency of an export-dependent economy potentially stimulates the export of technology, goods, and services from the country since they become cheaper for other countries, and vice versa. Thus, a fall in the country's currency value increases exportation, while a rise in the currency's value stifles the export of technology, goods, and services, thereby impacting production and economic growth. For an import-dependent economy, a fall in its currency value stifles the importation of technology, goods, and services, while a rise in the currency's value boosts the importation of these, hence positively impacting production and economic growth. The financial sector plays an essential role in promoting savings and investment, facilitating capital allocation, and strengthening financial inclusion (Fengju & Wubishet, 2024), which are necessary for the economic growth of a country. Consistent with this, Beck and Demirguc-Kunt (2006) observed that the financial sector influences technological innovations, savings, and investment in a country, thereby enhancing the country's economic growth.

The remainder of our study is structured as follows: Section 2 is an empirical review, Section 3 presents the methodology, Section 4 discusses the results, and Section 5 presents the conclusion and recommendations.

2. Empirical Literature

Previous studies have evaluated the relationship between human capital development or human capital and economic growth in different regions and countries. For example, Polgan (2023) conducted a literature review on the effect of human capital development on economic growth. The results from content and systematic review approaches indicate that human capital development has a positive effect on economic growth. Jemiluyi and Jeke (2024) investigated the mediating role of human capital development in the association between urbanization and economic growth in Nigeria, using yearly data from 1991 to 2022. The findings from the Autoregressive Distributed Lag (ARDL) and the Dynamic Ordinary Least Squares (DOLS) approaches indicate that human capital development and urbanization interaction have a positive and statistically significant influence on economic growth. In eleven countries, Rahim et al. (2021) investigated the impact of human capital development, natural resources, financial development, technological progress, international trade, and industrialization on economic growth from 1990 to 2019. The findings from the Granger causality test technique show that human capital development has a positive effect on economic growth.

Fahimi, Saint Akadiri, Seraj, and Akadiri (2018) examined human capital development and the tourism sector's contribution to economic growth. The outcome of the analysis, using the Granger causality test approach and annual data from 1995 to 2015, reveals that a unidirectional causality exists from human capital development to economic growth. In emerging countries, the study also examined the impact of human capital, financial development, and the interaction of these variables on economic growth based on annual data from 2002 to 2017. The two-step system generalized method of moments (GMM) was used to perform the data analysis, and the results reveal that human capital significantly increases economic growth. The findings also show that the interaction between human capital and financial development has a positive and statistically significant impact on economic growth. Ayeni and Akeju (2023) evaluated the influence of capital goods and human capital on economic growth in 13 countries in West Africa using annual data from 1980 to 2018. The results from the Panel ARDL analysis approach show that human capital

and investment in human capital play a significant role in boosting economic growth. Haini (2019) assessed the impact of internet penetration and human capital formation on economic growth in 10 countries of the Association of Southeast Asian Nations (ASEAN). The pooled Ordinary Least Squares (OLS), first difference Generalized Method of Moments (GMM), and system Generalized Method of Moments (GMM) were applied to yearly data spanning 1999 to 2014. The findings indicate that human capital formation has a positive statistically significant effect on economic growth in these countries.

In the United States, Fan, Goetz, and Liang (2016) examined the quality of life and human capital interaction impact on economic growth, focusing on the county level using data that covered 2000-2007. The results from the fixed effects analysis approach reveal that human capital significantly raises economic growth, with the increase being greater in countries with a high quality of life. Odonkor, Asiedu-Nketiah, Brown, and Miah (2018) analyzed human capital development's influence on economic growth in the case of Ghana. The ordinary least squares (OLS) technique results indicate that human capital development significantly boosts economic growth. In Saudi Arabia, Elawady and Ahmed (2024) assessed the association between human capital development and economic growth using annual data spanning 1988 to 2018. The ARDL analysis approach result indicates that in the long run, human capital development impacts economic growth positively. Opoku, Poku, and Domeher (2024) evaluated human capital's role in the relationship between financial inclusion and economic growth in Africa. The GMM analysis technique was applied to annual data from 2005 to 2018 for 40 countries. The finding indicated that human capital development mediates the association between financial development and economic growth significantly. Mengesha and Singh (2023) examined the effects of human accumulation on economic growth in Ethiopia in the long run. The evidence based on annual data covering 1980-2020 and the ARDL analysis approach revealed that human capital accumulation has a strong effect on economic growth in the long run.

In Nigeria, Johnson (2011) evaluated the impact of human capital development on economic growth using yearly data from 1986 to 2009. The OLS analysis approach result indicates that human capital development has a positive and statistically significant impact on economic growth. Similarly, Otu and Adenuga (2006) investigated the association between human capital development and economic growth in Nigeria based on annual data from 1970 to 2003, which was analyzed using the error correction model technique. The results provide evidence that human capital development improves economic growth. Uddin, Ali, and Masih (2021) examined the impact of human development and institutions on economic growth in 120 developing countries. Analysis results using the dynamic system GMM, simultaneous quantile regression, and yearly data from 1996 to 2014 indicate that human development has a positive but weak impact on economic growth. Additionally, human development and institutional interaction diminish economic growth.

Eniekezimene et al. (2023) evaluated the effect of human capital development on economic growth in Nigeria. The findings from the ARDL analysis technique and yearly data spanning 1981-2021 indicate that human capital development components have inconsistent effects on economic growth. Government expenditure on education and tertiary school enrollment has a positive, insignificant effect on economic growth in the long run. In the short run, government spending on education diminishes economic growth, but government spending on health has a positive, significant effect on economic growth. Moreover, the effect of primary school enrollment on economic growth is negative, while that of secondary and tertiary school enrollment is positive. In Nigeria, Nwachukwu and Obuam (2023) explored how human capital development influences economic growth. The results from the critical review approach indicate that human capital development has a positive and statistically significant impact on economic growth. This suggests that human capital development is essential for Nigeria's economic growth. Keji (2021) examined the relationship between human capital and economic growth in Nigeria using annual data from 1981 to 2017. The vector error correction model (VECM) and cointegration analysis results show that student enrollment has a negative and statistically significant effect on economic growth. Similarly, the labor force participation rate has a negative and statistically significant impact on economic growth. Conversely, the total labor force has a positive and statistically significant effect on economic growth.

Keho (2017) assessed the relationship between trade openness and economic growth in Côte d'Ivoire using annual data from 1965 to 2014. The findings obtained using the ARDL approach show that trade openness has a positive and statistically significant impact on economic growth in both the short and long run. Similarly, Huchet-Bourdon, Le Mouël, and Vijil (2018) evaluated the association between trade openness and economic growth in 169 countries based on data from 1988 to 2015. The result of the estimation using the Generalized Method of Moments shows that trade openness diminishes economic growth in countries that specialize in products with low quality. Additionally, countries that increase their exports have the potential to grow faster after reaching a particular extensive export margin. In the case of China, Hye, Wizarat, and Lau (2016) used annual data from 1975 to 2009, the ARDL approach, and the rolling regression technique to investigate the effect of trade openness on economic growth. The finding reveals that trade openness has a positive effect on economic growth in the short and long run. Also, trade openness has a negative association with economic growth for some years. Hye and Lau (2015) explored the trade openness and economic growth nexus in India using data that span 1971-2009. The analysis of the data was performed using the ARDL technique, and the results indicate that trade openness has a positive influence on economic growth in the long run. However, trade openness has a negative effect on economic growth in the short run.

Guru and Yadav (2019) investigated how financial development and economic growth are related, focusing on BRICS, using yearly data covering 1993-2024. The evidence from the system GMM indicates that financial development has a positive and statistically significant impact on economic growth. Fengju and Wubishet (2024) focused on exploring the nexus between financial development and economic growth in East Africa, using yearly data from 1995 to 2021. The GMM analysis approach result reveals that financial development has a significantly positive effect on economic growth. Similarly, Bist (2018) investigated the association between financial development and economic growth in the long run in 16 low-income countries based on annual data covering 1995-2014. The results from analysis using the dynamic OLS and the fully modified OLS reveal that financial development has a significantly positive effect on economic growth in the long run. Another study by Hassan, Sanchez, and Yu (2011) assessed the impact of financial development on economic growth using annual data from 1980 to 2007 in middle-, low-, and high-income countries. The findings from the vector autoregression analysis technique show that financial development enhances economic growth.

In 39 African countries, Kong, Nketia, Antwi, and Musah (2020) evaluated the relationship between financial development, fixed capital formation, and economic growth using yearly data spanning 1999 and 2017. The correlated effects mean group and augmented mean group techniques result show that gross fixed capital formation influences economic growth positively. Besides, a bidirectional causality exists between gross fixed capital formation and economic growth. In the case of 18 Asian countries, Boamah, Adongo, Essieku, and Lewis Jr (2018) evaluated the impact of gross fixed capital formation and financial depth on economic growth based on yearly data from 1990 to 2017. The result of data analysis using the panel regression technique suggests that gross fixed capital formation has a positive, statistically significant effect on economic growth. Lach (2010) assessed the impact of fixed capital formation on economic growth in the long run in Poland using quarterly data from 2000Q1 to 2000Q4. The findings from the Granger causality test approach suggest that a bidirectional causality exists between fixed capital formation and economic growth. Focusing on 124 countries, Topcu, Altinoz, and Aslan (2020) analyzed gross capital accumulation, natural resources, and energy consumption's influence on economic growth. The panel VAR was applied to yearly data spanning from 1980 to 2018, and the results show that gross capital formation has a positive impact on economic growth. Additionally, the findings indicate evidence of one-way causality from gross capital formation to economic growth.

Missio, Jayme, Britto, and Luis Oreiro (2015) analyzed the association between the real exchange rate and output growth rate using yearly data covering 1978-2007 from 103 countries. The findings from the Panel Generalized Method of Moments (GMM), fixed effects, cross-sectional Ordinary Least Squares (OLS), and non-linear and random effects techniques indicate a non-linear relationship between the real exchange rate and output growth. Additionally, they reveal that a competitive exchange rate positively impacts output growth. In 150 countries, Habib, Mileva, and Stracca (2017) assessed the effect of the exchange rate on economic growth. The data used covered 1970-2010 and were segmented into five-year periods. The results from panel OLS and instrumental variable techniques indicate that currency appreciation reduces, while currency depreciation improves economic growth. Similarly, Razzaque, Bidisha, and Khondker (2017) assessed the effect of the exchange rate on Bangladesh's economic growth. They applied Toda-Yamamoto and Vector Error Correction Model (VECM) techniques to yearly data from 1980 to 2012, with findings indicating that unidirectional causality proceeds from the exchange rate to economic growth. In the long run, exchange rate depreciation translates into higher economic growth, but decreases economic growth in the short run. Barguellil, Ben-Salha, and Zmami (2018) focused on the effect of exchange rate volatility on economic growth in 45 emerging and developing countries using data from 1985 to 2015. The evidence from the System Generalized GMM suggests that exchange rate volatility impacts economic growth negatively, with the impact being more significant during flexible exchange rate regimes.

The evidence from our empirical literature reviews shows that the relationship between human capital development and economic growth has attracted researchers' attention in different countries, including Nigeria, as well as in some groups of countries. Nonetheless, gaps still exist in the extant literature on the association between the variables. For instance, to the best of our knowledge, no study has used the Principal Component Analysis (PCA) approach to capture human capital development in understanding the effect of human capital development on economic growth in the short and long run and in exploring the causal association between human capital development and economic growth in Nigeria. The extant literature reveals that several variables have been used to capture human capital development. The most widely used are secondary school enrolment, tertiary school enrolment, government expenditure on education, life expectancy, government expenditure on health, and primary school enrolment. Using only one or two of these variables to capture human capital development may potentially not provide a robust representation of the concept. Another potential issue is that including several variables in a model to represent human capital development may produce inconsistent effects on economic growth, making it very difficult to conclude with a high degree of precision the effect of human capital development on economic growth. Using the PCA approach, we captured human capital development more comprehensively. Naik (2017) notes that using PCA to generate an index has the advantage of computing a comprehensive relaxation between variables.

In this study, we employed the PCA approach to generate a human capital development index based on six variables: secondary school enrolment, life expectancy, expenditure on education, tertiary school enrolment, expenditure on health, and primary school enrolment. Hence, we fill the gap in the literature by presenting a better and more robust understanding of the relationship between human capital development and economic growth in Nigeria. Second, using a PCA-based human capital development index, we investigate the short- and long-run effects of human capital development on economic growth in Nigeria. Third, we use the Toda and Yamamoto (1995) technique to examine the causal association between human capital development and economic growth in Nigeria. Fourth, we account for the impact of some important variables, including trade openness, exchange rate, financial development, and fixed capital formation, in assessing the short- and long-run effect of human capital development on economic growth in Nigeria. To the best of my knowledge, no single study has controlled for the influence of those variables in investigating the relationship between human capital development and economic growth in Nigeria.

3. Methodology

3.1. Research Design

We adopted the quantitative research design in this study. The quantitative research design is concerned with collecting numerical data and analyzing the data to answer research questions or test hypotheses. This research design is consistent with the interpretivist research philosophy and deductive research approach. The qualitative research design benefits this study in several ways. For instance, this design produces generalizable research findings (Carr, 1994). Besides, studies based on a quantitative research design produce objective findings (Almeida, Faria, & Queiros, 2017).

3.2. Data Nature and Sources

Our data sources are purely secondary. The data are annual time series from 1990 to 2023, sourced from World Bank (2025) and Central Bank of Nigeria (2023). The variables used include economic growth, captured by real GDP

in Naira, and human capital development, measured with six variables: secondary school enrolment, government expenditure on education, tertiary school enrolment, government expenditure on health, life expectancy, and primary school enrolment. These variables were used to generate an index for human capital development using the PCA approach. Other variables in our models are trade openness, financial development, exchange rate, and fixed capital formation. Trade openness is represented by the ratio of the sum of real exports and imports of goods and services to real GDP in Naira. The Naira/US dollar exchange rate was used for the exchange rate, while fixed capital formation was proxied by nominal Gross Fixed Capital Formation in Naira. Financial development was measured by domestic credit provided by banks to the private sector as a percentage of GDP. Including trade openness, financial development, exchange rate, and fixed capital formation in our models allows us to control for their potential effects on the relationship between human capital development and economic growth. Their inclusion also helps to mitigate the risk of omitted variable bias.

Table 1 reports the eigenvalues. Only the first and second principal components of the eigenvalues are higher than 1, suggesting that only the first and second components explain more variance than an individual standardized variable. While the first component explained 71.22% of the total variance, the second component explained 17.82%. Given that the variance explained by the first component is larger, we used it as a composite index for human capital development, since it has the highest explanatory power.

Table 1. Eigenvalues.

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	4.27	3.20	0.71	0.71
Comp2	1.07	0.64	0.18	0.89
Comp3	0.43	0.29	0.07	0.96
Comp4	0.12	0.07	0.02	0.98
Comp5	0.07	0.05	0.01	0.99
Comp6	0.03		0.01	1.00

The scree plot of the eigenvalue in Figure 1 reveals a sharp fall from the first to the second eigenvalue. It is followed by a slow levelling off of the third component. The pattern shows that the first component captures most variance of human capital development proxies, with succeeding components contributing marginal additional explanatory power. The elbow after the first compound supports our choice of the first component as a composite index for human capital development.

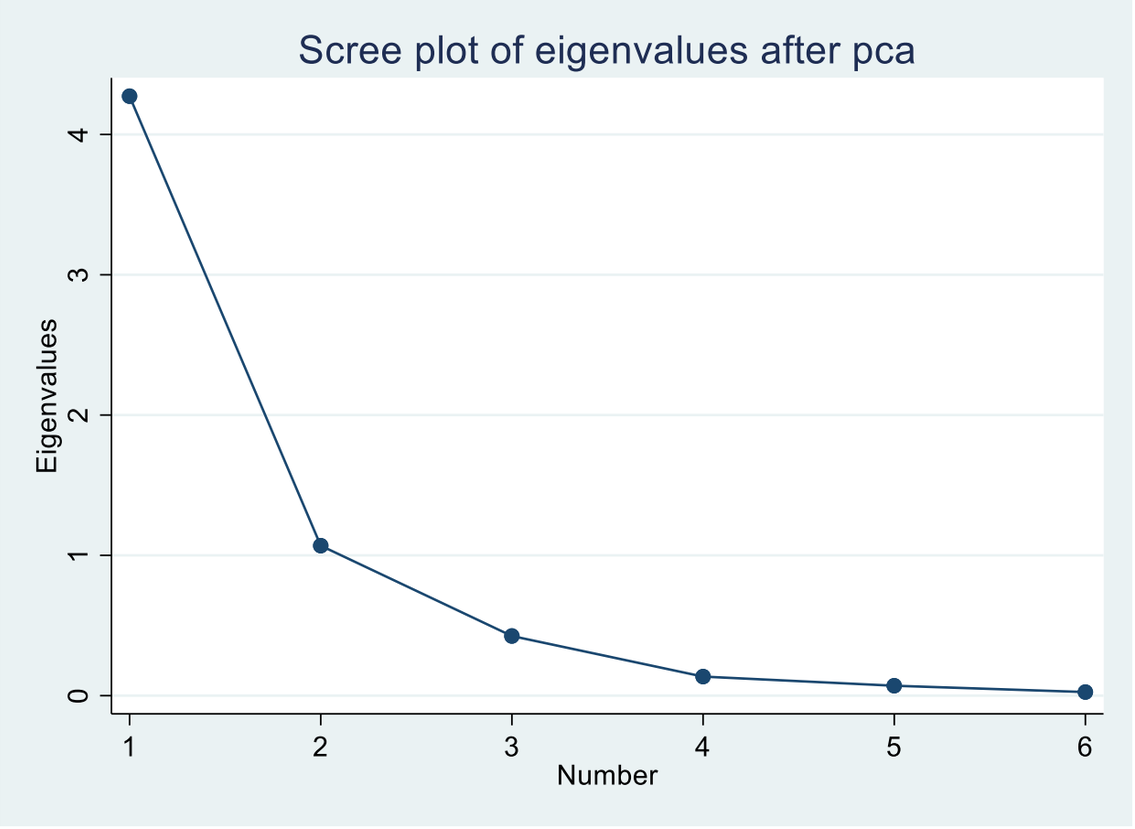

Figure 1. Scree plot of the eigenvalue.

3.3. Unit Root Test

All the variables were subjected to unit root tests to assess their stationarity status. In time series analysis, assessing variables for the presence or absence of a unit root is necessary. Estimates from series that contain a unit root are spurious, thus misguiding decisions and policy-making based on the results. We employed two tests for assessing the unit root in time series data, including Phillips and Perron (1988) and Dickey and Fuller (1981) unit root tests to examine the stationarity properties of the variables. The null hypothesis of the PP and ADF tests is that there is a unit root, while the alternative hypothesis is that there is no unit root. It therefore implies that for a series to be stationary, the null hypothesis must be rejected. Equations 1 and 2 state the PP unit root test.

$$\Delta J_t = \omega_1 + \varpi_2 J_{t-1} + \varepsilon_t \quad (1)$$

$$\Delta J_t = \omega_1 + \varpi_2 T + \varpi_3 J_{t-1} + \varepsilon_t \quad (2)$$

Equation 1 includes the constant term only while Equation 2 include the constant and trend terms. In these equations, J is the variable on which unit root was examined, ϖ_1, ϖ_2, and ϖ_3 are the constant term and parameters, Δ denotes the difference operator, ε_t denotes the error term and T in Equation 2 is the trend term. The ADF unit root test models are expressed by Equations 3 and 4.

$$\Delta J_t = \sigma_1 + \sigma_2 J_{t-1} + \sum_{f=1}^{F} \gamma_k \Delta J_{t-k} + \varepsilon_t \quad (3)$$

$$\Delta J_t = \sigma_1 + \sigma_2 t + \sigma_3 J_{t-1} + \sum_{f=1}^{F} \gamma_k \Delta J_{t-k} + \varepsilon_t \quad (4)$$

While Equation 3 is the ADF test model that captures only the constant term, Equation 4 captures the constant and trend terms. σ_1, σ_2, σ_3, and γ_k are parameters.

3.4. Models Specification

We investigate the effect of human capital development on economic growth in the short and long run in Nigeria. Besides, we assess the causal relationship between human capital development and economic growth in Nigeria. Hence, we specify two models based on these objectives. The first model investigates the short- and long-term effects of human capital development on economic growth, while the second assesses the causal association between human capital development and economic growth in Nigeria.

3.4.1. Model One

The model comprises one dependent variable and five independent variables. Economic growth is the dependent variable, while human capital development, trade openness, exchange rate, fixed capital formation, and financial development are the regressors. Equation 5 expresses economic growth as a function of the regressors used.

$$EG_t = f(HC_t, TO_t, FD_t, ER_t, FC_t) \quad (5)$$

In Equations 5, EG_t, HC_t, , TO_t, FD_t, ER_t, , and FC_t represents economic growth, human capital development, trade openness, financial development, exchange rate and fixed capital formation, respectively at time t. Taking the natural log of all the variables except human capital development, Equation 6 states the econometric form of our model.

$$ln\,E\,G_t = \varphi + \rho_1 HC_t + \rho_2\, ln\,T\,O_t + \rho_3\, ln\,F\,D_t + \rho_4\, ln\,E\,R_t + \rho_5\, ln\,F\,C_t + \upsilon_t \quad (6)$$

In Equation 6 $ln\,E\,G_t$, $ln\,T\,O_t$, $ln\,E\,R_t$, $ln\,F\,D_t$, and $ln\,F\,C_t$ represent the natural log of economic growth, traded openness, exchange rate, financial development, and fixed capital formation, all at time t. φ is the equation's slope, ρ_1, ρ_2, ρ_3, ρ_4, ρ_5 and ρ_6 are the parameters of human capital development, trade openness, financial development, exchange rate, and fixed capital formation, respectively, while υ_t is the white noise error term with zero mean and constant variance. To investigate the long and short-run impact of human capital development on economic growth, we employed the Autoregressive Distributed Lag (ARDL) model put forward by Pesaran and Shin (1998) and developed by Pesaran, Shin, and Smith (2001) approach. Equation 7 states the ARDL model.

$$\Delta\, ln\,E\,G_t = \varphi + \sum_{k=1} \tau_1\, ln\,\Delta\, EG_{t-i} + \sum_{k=0}^{K} \tau_2 \Delta HC_{t-i} + \sum_{k=0}^{K} \tau_3 \Delta\, ln\,T\,O_{t-i} + \sum_{k=0}^{K} \tau_4 \Delta\, ln\,F\,D_{t-i} + \sum_{k=0}^{K} \tau_5 \Delta\, ln\,E\,R_{t-1} + \sum_{k=0}^{K} \tau_6 \Delta\, ln\,F\,C_{t-i} + \phi_1\, ln\,E\,G_t + \phi_2 HC\phi_2 + \phi_3\, ln\,T\,O_t + \phi_4\, ln\,F\,D_t + \phi_5\, ln\,E\,R_t + \phi_6\, ln\,F\,C_t + \upsilon_t \quad (7)$$

Where τ_1, τ_2, τ_3, τ_4, τ_5 and τ_6 are the short-run parameters of economic growth, human capital development, trade openness, financial development, exchange rate and fixed capital formation, respectively. Similarly, ϕ_1, ϕ_2, ϕ_3, ϕ_4, ϕ_5, and ϕ_6 are, respectively the long run parameters of economic growth, human capital development, trade openness, financial development, exchange rate and fixed capital formation, while Δ and K, respectively denote difference operator and optimal lag. Our error correction model is expressed by Equation 8.

$$\Delta\, ln\,E\,G_t = \varphi + \sum_{k=1}^{K} \tau_1 \Delta\, ln\,E\,G_{t-i} + \sum_{k=1}^{K} \tau_2 \Delta HC_{t-i} + \sum_{k=0}^{K} \tau_3 \Delta\, ln\,T\,O_{t-i} + \sum_{k=0}^{K} \tau_4 \Delta\, ln\,F\,D_{t-i} + \sum_{k=0}^{K} \tau_5 \Delta\, ln\,E\,R_{t-1} + \sum_{k=0}^{K} \tau_6 \Delta\, ln\,F\,C_{t-i} + \pi ECT_{t-1} + \varepsilon_t \quad (8)$$

Where ECT_t represents the error correction term, π is the coefficient of the error correction term while ε_t represents the error term of the model. The coefficient of the error correction term indicates the speed at which economic growth adjusts to the equilibrium after a shock. It is instructive to state that for economic growth to return to equilibrium after a short-run deviation from its equilibrium, three conditions must be fulfilled. These conditions are: The error correction term coefficient must be greater than zero, statistically significant, and less than 1 in absolute terms (Adeshola & Zumba, 2022; Zumba, 2024). The nearer the absolute value of the error correction term coefficient is to 1, the faster economic growth returns to equilibrium after a disturbance, and vice versa.

We used the ARDL technique to estimate Equations 7 and 8. This estimation technique was employed because it is the most appropriate method for the analysis. Pesaran, Shin, and Smith (2001) noted that the techniques enable estimation of the long and short-run effects of a dependent variable or dependent variables on a dependent variable. Also, the ARDL estimation technique is suitable for estimating a model that has variables of mixed integration order (I⌈0⌉ and I⌈1⌉) (Qamruzzaman, 2024; Zestos, Jiang, Hamed, & Raymond, 2023). The integration results obtained in this study indicate that our variables are I(0) and I(1), making the ARDL estimation technique appropriate. The analysis method is also flexible regarding the integration order of variables within a model. This technique potentially reduces risks associated with degrees of freedom loss and model overfitting, as it selects the optimal lag length individually for each variable in the model. Additionally, the ARDL analysis accounts for potential variations in adjustment processes by considering the possibility of asymmetry in the coefficients of the error correction term (Chandio, Magsi, & Ozturk, 2020). Furthermore, if the dataset sample is moderately large or somewhat small, the ARDL technique is suitable because it will produce reliable and more robust results.

3.4.2. Second Model

We examined the causal relationship between human capital development and economic growth in Nigeria. Specifically, we assessed whether there is a unidirectional, bidirectional, or no causal relationship between human capital development and economic growth in Nigeria. The Toda and Yamamoto (1995) Granger causality test was employed to achieve this objective. This approach to cointegration testing makes use of augmented vector autoregression to evaluate causality relationships between variables. Several reasons informed our choice of this

model for assessing the causal association between the variables. One of these is that this approach to causality assessment addresses the challenges inherent in the traditional Granger causality test since it avoids any potential non-cointegration or stationarity between the variables used during the causality test (Paul, 2020). Besides, the approach ensures that the produced test statistics contain an asymptotic distribution for carrying out well-founded inferences (Amiri & Ventelou, 2012). Furthermore, the technique fits the vector autoregression model to variable levels, hence minimizing any potential risks linked to possible incorrect series integration order identification (Mavrotas & Kelly, 2001). Equations 9 and 10 express the Toda and Yamamoto (1995) Granger causality test models.

$$Q_t = \lambda_0 + \sum_{j=1}^{h} \lambda_{1j} Q_{t-j} + \sum_{k=h+1}^{d_{max}\Sigma} \lambda_{2k} Q_{t-k} + \sum_{j=1}^{h\Sigma} \gamma_{1j} R_{t-j} + \sum_{k=h+1}^{d_{max}\Sigma} \gamma_{2k} R_{t-k} + \xi_{it} \quad (9)$$

$$R_t = \eta_0 + \sum_{j=1}^{h} \eta_{1j} R_{t-j} + \sum_{k=h+1}^{d_{max}\Sigma} \eta_{2k} R_{t-k} + \sum_{j=1}^{h\Sigma} \delta_{1j} Q_{t-j} + \sum_{k=h+1}^{d_{max}\Sigma} \delta_{2k} Q_{t-k} + \xi_{2t} \quad (10)$$

R and Q represent the variable for which the causality relationship was assessed, d_{max} is the maximum integration order, while $\xi_{1t,}$ and ξ_{2t} are the error terms of the equations. In this study, the null hypothesis of the Granger causality test is that Q/R does not Granger cause R/Q. The decision to accept or reject the null hypothesis is a function of whether or not the chi-squared statistic value of the test is statistically significant. In particular, if the F-statistic value is statistically significant at a given significance level, the null hypothesis is rejected, indicating that causality runs from Q/R to R/Q. But if the F-statistic value is not statistically significant at a given significance level, the null hypothesis is not rejected, which means that Q/R does not Granger cause R/Q. There are three possible outcomes from the Granger causality test as follows: Granger causality from R to Q, Granger causality from Q to R, and no Granger causality between the variables.

3.5 Cointegration Test

The presence of a long-run or otherwise, relationship between economic growth and human capital development, trade openness, financial development, exchange rate and fixed capital formation was assessed using the ARDL bounds approach. The null hypothesis of this approach to testing for cointegration is that there no level relationship. That is, in Equation 7 $\phi_1 = \phi_2 = \phi_3 = \phi_4 = \phi_5 = \phi_6 = 0$. The alternative hypothesis is there is a level relationship, which means that in Equation 7$\phi_1 \neq \phi_2 \neq \phi_3 \neq \phi_4 \neq \phi_5 \neq \phi_6 \neq 0$. If there must be a long-run relationship between economic growth and human capital development, financial development, trade openness, exchange rate and fixed capital formation, we must reject the null hypothesis. The decision rule guiding this cointegration test approach is as follows: if the F-statistic value of the test is less than the lower critical bound value, we reject the null hypothesis, suggesting that there is no cointegration between economic growth and human capital development, trade openness, financial development, exchange rate and fixed capital formation. Hence, we report only the short-run estimates since the long-run estimates are not valid. However, if the test's F-statistic value is greater than the upper critical bound value, the null hypothesis is rejected, implying a level relationship exists between economic growth and its regressors in Equation 7. In such a case, we report the short- and long-run estimates since they are both valid. Another possibility is that the F-statistic value can fall between the lower and upper critical bounds, making the test inconclusive. In this case, the decision to report the long-run estimates depends on whether or not the error correction term coefficient is statistically significant (Zumba, 2024). We report the long-run estimates only if the error correction term is statistically significant.

4. Result and Discussion

Table 2 reports the descriptive statistics of the variables. The mean and median values of each variable fall between their respective minimum and maximum values, suggesting that all the variables are consistent. The variables' standard deviation values indicate that the least and highest values are 0.32 and 1.96, respectively, implying that each variable exhibits less variability. That is, the observations of each variable lie close to the variable's respective mean values. None of the variables exhibits normal skewness. Specifically, economic growth, trade openness, and fixed capital formation are right-tailed, while human capital development, exchange rate, and financial development are left-tailed. Similarly, none of the variables exhibits evidence of normal peakedness. This is evident in the kurtosis statistics of the variables, which indicate that while economic growth and trade openness are leptokurtic, human capital development, fixed capital formation, exchange rate, and financial development are platykurtic. For all variables except trade openness, the null hypothesis of normality is not rejected. This suggests that, apart from trade openness, which is not normally distributed, all the variables exhibit normally distributed behavior. No variable has any missing observations, since each has 34 observations.

Table 2. Summary statistic result.

Statistics	$lnEG_t$	HC_t	$lnTO_t$	$lnFC_t$	$lnER_t$	$lnFD_t$
Mean	30.0	-5.88E-09	-0.82	29.8	4.59	2.28
Median	30.1	0.1299	-0.85	29.8	4.9	2.30
Maximum	31.9	2.36	0.26	30.1	6.46	2.98
Minimum	29.2	-2.59	-1.56	29.6	2.08	1.60
Std. Dev.	0.62	1.96	0.32	0.14	1.16	0.33
Skewness	0.66	-0.11	0.86	0.15	-0.65	-0.04
Kurtosis	3.25	1.28	5.88	1.76	2.37	2.66
Jarque-Bera	2.54	4.24	15.9***	2.30	2.94	0.18
Obs.	34	34	34	34	34	34

Note: *** indicates statistically significant at 1%.

We assessed all the variables for stationarity using two tests (PP and ADF), the results of which are in Table 3. We reject the null hypothesis of the tests at the first difference for economic growth and fixed capital formation when we included only the constant term and at the level when we captured the constant and trend terms. In the case of human capital development and the exchange rate, there is no evidence to reject the tests' null hypothesis at the level when we captured only the constant term and the constant and trend terms in implementing the test. However, after

subjecting the variables to the tests at their first difference, we found evidence to reject the null hypothesis when we included only the constant term and the constant and trend terms. In the trade openness case, we reject the tests' null hypothesis at the level when we captured only the constant term and both the constant and trend terms, suggesting that the variable is stationary at the level. The ADF test result indicates that financial development is stationary at a level when only the constant term is captured and when the constant and trend terms are captured. However, the PP test result shows that the variable is stationary at the first difference when the test was carried out either with only the constant term or with constant and trend terms. The unit root test result indicates that the variables are a mixture of I(0) and I(1), hence providing strong support for our choice of the ARDL estimation technique.

Table 3. Unit root test result.

Variable	Augmented Dickey and Fuller (ADF)		Philips and Perron (PP)	
	Constant	Constant & trend	Constant	Constant & trend
$ln\,E\,G_t$	-6.44***v	-5.45***u	-5.45***v	-5.45***u
HC_t	-5.57***v	-5.45***v	-5.60***v	-5.50***v
$ln\,T\,O_t$	-4.45***u	-4.34***u	-4.46***u	-9.40***u
$ln\,F\,C_t$	-6.03***v	-10.62***u	-5.84***v	-11.3***u
$ln\,E\,R_t$	-5.29***v	-5.29***v	-5.28***v	-5.24***v
$ln\,F\,D_t$	-2.63*u	-3.28*u	-6.67***v	-9.83***v

Note: *, and *** denote statistically significant at 10%, and 1%, respectively, while u and v first difference and second difference, respectively.

Table 4 reports the correlation assessment outcome. The correlation analysis assists in detecting multicollinearity between explanatory variables. A correlation coefficient of greater than 0.9 indicates evidence of serious correlation (Asteriou & Hall, 2011). Hence, evidence in Table 4 indicates the absence of serious multicollinearity between human capital development, fixed capital formation, exchange rate, and financial development. There is evidence of a direct correlation between economic growth and all its regressors. Similarly, financial development exhibits a direct correlation with fixed capital formation, human capital development, exchange rates, and trade openness. This correlation direction is also observed between human capital development and fixed capital formation, human capital development and exchange rate, and between fixed capital formation and exchange rate. Fixed capital formation and exchange rate show inverse correlations with trade openness. Similarly, an inverse correlation exists between trade openness and human capital development.

Table 4. Correlation matrix.

Variable	$ln\,E\,G_t$	HC_t	$ln\,T\,O_t$	$ln\,F\,C_t$	$ln\,E\,R_t$	$ln\,F\,D_t$
$ln\,E\,G_t$	1.00					
HC_t	0.88	1.00				
$ln\,T\,O_t$	0.32	-0.11	1.00			
$ln\,F\,C_t$	0.78	0.79	-0.03	1.00		
$ln\,E\,R_t$	0.78	0.85	-0.02	0.74	1.00	
$ln\,F\,D_t$	0.69	0.78	0.03	0.55	0.76	1.00

Table 5 presents the ARDL bounds approach to the integration test outcome. The test's F-statistic (11.35) is greater than the upper critical value at 1%, indicating it is statistically significant at the 1% level. This provides strong evidence to reject the null hypothesis that there is no level relationship a long-run relationship exists between economic growth and the regressors. It means that not only a short-run relationship exists between economic growth and human capital development, financial development, exchange rate, fixed capital formation, and trade openness, but also a long-run relationship between the variables. Thus, we report the short- and long-run ARDL model estimates, since both are valid.

Table 5. Cointegration Test Result.

F-statistics	K	Critical bounds		
		Significance level	Lower critical bound	Upper critical bound
11.3***	5	10%	2.08	3
		5%	2.39	3.38
		1%	3.06	4.15

Note: *** indicates statistically significant at 1%.

In autoregressive models, optimal lag inclusion is essential, as it helps address potential problems associated with correlation and causation. Therefore, we used several lag selection criteria to determine the optimal lag length for our RDL model. The results are presented in Table 6. While three lag selection criteria suggest 2 as the optimal lag, two indicate 1. Specifically, sequential modified LR, final prediction errors, and the Akaike information criterion point to 2 as the optimal lag, whereas the Schwarz information criterion and Hannan-Quinn information criterion suggest 1. Consequently, we included 2 lags in estimating our ARDL model.

Table 6. Lag Selection Result.

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-36.1	NA	5.61e-07	2.63	2.91	2.72
1	84.2	188	3.01e-09	-2.63	-0.71*	-2.00*
2	128	51.9*	2.40e-09*	-3.12*	0.45	-1.94

Note: * Indicates lag order selected by the criterion, LR: sequential modified LR test statistic (each test at 5% level), FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion, HQ: Hannan-Quinn information criterion.

Table 7. The ARDL estimates.

Variable	Coefficient	Variable	Coefficient
Short run		**Long run**	
Constant	-9.32 [11.1533]	Constant	-8.13 [9.76]
ΔHC_t	0.22*** [0.06]	HC_t	0.28*** [0.02]
ΔHC_{t-1}	0.32*** [0.05]		
$\Delta \ln TO_t$	0.95*** [0.06]	$\ln TO_t$	0.70*** [0.11]
$\Delta \ln TO_{t-1}$	0.80*** [0.14]		
$\Delta \ln TO_{t-2}$	0.25** [0.10]		
$\Delta \ln FC_t$	0.36* [0.20]	$\ln FC_t$	1.32*** [0.3s]
$\Delta \ln FC_{t-1}$	1.51*** [0.41}		
$\Delta \ln FC_{t-2}$	-0.75*** [0.20]		
$\Delta \ln ER_t$	0.05 [0.06]	$\ln ER_t$	-0.13*** [0.03]
$\Delta \ln ER_{t-1}$	-0.15*** [0.04]		
$\Delta \ln ER_{t-2}$	0.19** [0.07]		
$\Delta \ln FD_t$	-0.22* [0.11]	$\ln FD$	0.01 [0.09]
$\Delta \ln FD_{t-1}$	0.01 [0.11]		
ect_{t-1}	-0.95*** [0.14]		
R^2	0.99		
Adjusted R^2	0.985		
F-statistic	155 (0.00)		

Note: *, **, *** denotes statistically significant at 10%, 5% and 1%, respectively. (.) and [.], respectively area p-value and standard error.

Table 7 presents our ARDL model estimates. The error correction term coefficient reveals strong evidence of a long-run relationship. The coefficient is -0.94 and significant at the 1% level, supporting the strong cointegration test result reported in Table 5. It suggests that any deviations of economic growth from its equilibrium in the previous year are transient, as the variable will eventually return to its equilibrium in the long run. Specifically, about 94.6% of the deviation of economic growth from the equilibrium is corrected in the current year, which is a strong indication that the variable will return to its equilibrium.

The short- and long-run coefficients of human capital development are positive and statistically significant, suggesting that in the short and long run, human capital development is an important determinant of economic growth. The respective short- and long-run coefficients of human capital development are 0.22 and 0.28, implying that a rise in human capital development by 1 unit translates into an increase in economic growth by 0.22% and 0.28% in the short and long run, respectively. That is, improvements in human capital development are necessary for the short- and long-run growth of the Nigerian economy. This finding underscores the findings reported by Hye et al. (2016), Odonkor et al. (2018), and Rahim et al. (2021), which reveal that human capital development boosts economic growth significantly. Likewise, the finding lends credence to the endogenous growth model and human capital theory that postulate that human capital is necessary for economic growth. A year lag in human capital development has a positive and statistically significant influence on economic growth in the current period. This finding implies that human capital development's positive effect on economic growth in Nigeria is persistent.

Trade openness has a positive and statistically significant impact on economic growth in the short and long run. Ceteris paribus, evidence in Table 7 indicates that a 1% rise in trade openness translates into 0.95% improvement in economic growth in the short run and 0.70% in the long run. This implies that trade openness improvements will translate into higher economic growth in the short and long run. Coe and Helpman (1995) opine that trade openness stimulates the diffusion of technology. That is, it paves the way for countries to import and export technologies and also facilitates goods and services importation and exportation, which, if carefully and effectively managed, enhances economic growth. Our finding suggests that trade openness in Nigeria has been carefully and effectively implemented since it has a strong positive impact on the country's economic growth. Hye et al. (2016); Hye and Lau (2015), and Keho (2017) report similar findings in India, China, and Côte d'Ivoire, respectively. The coefficients of the first and second lag trade openness are positive and statistically significant. This interesting finding means that the positive effect of trade openness on economic growth is consistent.

The effect of fixed capital formation on economic growth in the short and long run is positive and statistically significant, implying that fixed capital formation is indispensable for enhancing economic growth in the short and long run. The short-run coefficient of fixed capital formation is 0.36, while the long-run coefficient is 1.32. This indicates that, all other things being constant, economic growth improves by 0.36% and 1.32%, respectively, in the short and long run if fixed capital formation improves by 1%. The finding is consistent with the finding presented by Boamah et al. (2018), which shows that fixed capital formation has a positive effect on economic growth. Similarly, it lends credence to the finding reported by Topcu et al. (2020), which shows that capital formation has a positive and statistically significant effect on economic growth in 124 countries. Solow (1957) posits that the accumulation of physical capital in a country translates into a rise in production, thereby bringing about economic growth in the

country. This provides a strong reason for the short- and long-term positive effect of fixed capital formation on Nigeria's economic growth. The more Nigeria accumulates fixed capital, the more it can produce goods and services, since it is essential for the production of goods and services. All else constant, this boosts the country's economic growth. In the short run, our estimates reveal that while the first lag of fixed capital formation has a positive and significant impact, the second lag has a negative and significant effect on the current year's economic growth. This mixed result suggests that, in the short run, the positive effect of fixed capital formation on economic growth may not be sustainable.

The exchange rate's effect on economic growth is positive but not statistically significant. The short-run coefficient of the exchange rate is 0.05; that is, a fall in the value of the Naira by 1% increases economic growth weakly by 0.05% in the short run. This result supports the findings presented by Malec, Maitah, Rojik, Aragaw, and Fulnečková (2024), which shows that in the short run, the exchange rate has a positive effect on economic growth. While the first lag of the exchange rate has a significant negative effect, the second lag has a positive and significant impact on the current year's economic growth. This interesting finding suggests that, in the short run, the positive effect of the exchange rate on economic growth is inconsistent. In the long run, the exchange rate has a significant impact on economic growth, indicating that weakening the value of the Naira against other currencies reduces economic growth significantly. The coefficient of the exchange rate in the long run is -0.13, meaning that a fall in the Naira's value against other currencies by 1% significantly reduces economic growth by 0.13%, ceteris paribus. The study by Malec et al. (2024) revealed similar results.

In the short run, financial development has a negative and insignificant effect on economic growth. The short-run coefficient of this variable is -0.22. That is, all else equal, a rise in financial development by 1% weakens economic growth by 0.22% in the short run. Singh, Arya, Yadav, and Power (2023) and Loayza and Ranciere (2006) presented a similar finding. Their finding reveals that in the short run, financial development has a negative impact on economic growth. However, it contradicts the result presented by Abbas, Afshan, and Mustifa (2022). Their results indicate that financial development significantly contributes to economic growth in the short term. However, the long-term findings suggest that the influence of financial development on economic growth is positive but statistically insignificant. This implies that, over the long run, increases in economic growth resulting from financial development are minimal. Furthermore, it indicates that improvements in financial development in Nigeria have a limited impact on economic growth in the long term. A similar effect of financial development on economic growth was reported by Singh et al. (2023).

To examine the reliability of the ARDL estimates in Table 7, the estimates were subjected to post-estimation tests. These tests include normality, serial correlation, heteroskedasticity, and functional form. Table 8 presents the outcome of these tests. The p-value of each test statistic is not statistically significant; hence, the null hypothesis of all the tests is not rejected. That is, the residuals of our ARDL model are normally distributed, are not serially correlated, their variance is constant, and the functional form of the model is correctly specified. The result implies that the ARDL estimates are valid, authentic, and reliable.

Table 8. Post estimation test result.

Test	Statistic	p-value
Normality (Jarque-Bera)	0.33	0.85
Serial correlation (Breusch-Godfrey LM test)	2.53	0.11
Heteroskedasticity (ARCH)	1.14	0.29
Functional form (RAMSEY Reset)	0.37	0.55

To further ascertain the validity of our ARDL result in Table 7, we subject the estimates to Cumulative Sum (CUSUM) recursive residuals and Cumulative Sum of Squares (CUSMQ) recursive residuals. Brown, Durbin, and Evans (1975) proposed these approaches for assessing the consistency of estimates. Figures 2 and 3, respectively, are the CUSUM and CUSUMQ test results. Evidence from these Figures confirms that the parameters of the ARDL model presented in Table 7 are highly consistent and stable. That is, the estimated parameters do not exhibit structural instability, since the test statistic, as indicated by the graphs of the CUMSUM and CUSUMQ tests, remains consistently within the 5% level of significance. This result affirms that the estimates are not only valid but also reliable.

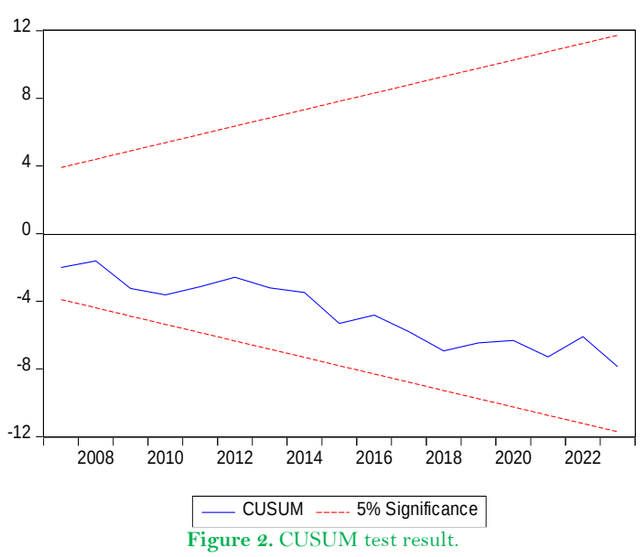

Figure 2. CUSUM test result.

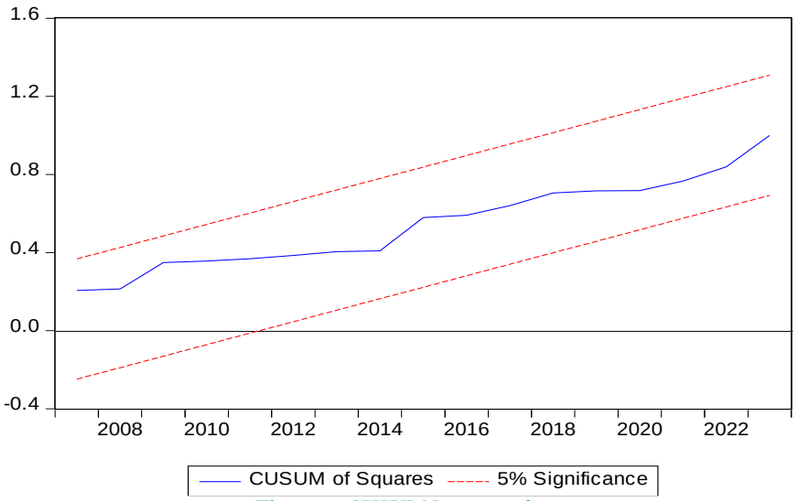

Figure 3. CUSUMQ test result.

Turning to the Granger causality test result, Table 9 shows evidence of a bidirectional causality between human capital development and economic growth. This implies that human capital development predicts economic growth, and likewise, economic growth predicts human capital development. This does not support the finding presented by Boamah et al. (2018), which reveals a unidirectional causality from human capital development to economic growth. A similar causality association is also found between trade openness and economic growth, as well as between fixed capital formation and economic growth. This implies that trade openness and fixed capital formation forecast economic growth, and likewise, economic growth forecasts trade openness and fixed capital formation. Some earlier studies present similar findings. For example, Lach (2010) observed a bidirectional causality between fixed capital formation and economic growth, while Alam and Sumon (2020) reported a bidirectional causal association between economic growth and trade openness.

Human capital development exhibits a bidirectional causal relationship with trade openness, fixed capital formation, and financial development. That is, all other factors being constant, human capital development predicts financial development, trade openness, and fixed capital formation, and vice versa. Similar findings have been presented in previous studies. For instance, Vo, Tran, and Nguyen (2021) reported a bidirectional causality between human capital development and financial development in the Asian countries. Trade openness and fixed capital formation exhibit a two-way causal relationship, suggesting they predict each other, and the finding aligns with the findings presented by other studies, such as Yeboah, Baffour, Chibalamula, and Atiso (2025). There is also compelling evidence indicating a bidirectional causality between trade openness and fixed capital formation, suggesting that the variables predict each other. This outcome underscores the finding presented by Yeboah et al. (2025) in nine economies in Europe.

There is evidence of a one-way causality from economic growth to financial development, which means that while economic growth predicts financial development, the reverse is not true. This does not support the result presented by Abbas et al. (2022), which shows evidence of a two-way causal relationship between financial development and economic growth. Similarly, the results provide strong evidence of unidirectional Granger causality from the exchange rate to fixed capital formation, financial development, and human capital development. All other factors being constant, this implies that exchange rate forecasts, fixed capital formation, human capital development, and financial development influence each other, but these variables do not predict the exchange rate. Furthermore, a unidirectional causality from trade openness to financial development is observed. Specifically, while financial development does not predict trade openness, trade openness predicts financial development. This causal relationship was also identified between fixed capital formation and financial development. The evidence indicates that fixed capital formation predicts financial development, but the reverse is not true. There is no evidence of a causal relationship between trade openness and the exchange rate; that is, the exchange rate does not predict trade openness, nor does trade openness predict the exchange rate. A similar result was observed between economic growth and the exchange rate, suggesting that neither variable predicts the other. The finding does not conform to that presented by Amoah, Nyarko, and Asare (2015).

Table 9. Results of the Granger causality test.

H_0	X^2	Causality	H_0	X^2	Causality
$HD \mapsto lnEG$ $lnEG \mapsto HD$	10.85** 15.9***	$lnEG \leftrightarrow HD$	$lnFC \leftrightarrow HD$ $HD \mapsto lnFC$	64.3*** 17.1***	$lnFC \leftrightarrow HD$
$lnTO \mapsto lnEG$ $lnEG \mapsto lnTO$	18.2** 27.4***	$lnTO \leftrightarrow lnEG$	$lnER \mapsto lnTO$ $lnTO \mapsto lnER$	6.20 1.97	No causality
$lnER \mapsto lnEG$ $lnEG \mapsto lnER$	4.20 5.52	No causality	$lnFD \mapsto lnTO$ $lnTO \mapsto lnFD$	3.42 83.2***	$lnTO \rightarrow lnFD$
$lnFD \mapsto lnEG$ $lnEG \mapsto lnFD$	4.07 60.9***	$lnEG \rightarrow lnFD$	$lnFC \mapsto lnTO$ $lnTO \mapsto lnFC$	11.8** 28.8***	$lnFC \leftrightarrow lnTO$
$lnFC \mapsto lnEG$ $lnEG \mapsto lnFC$	9.11* 13.5***	$lnFC \leftrightarrow lnEG$	$lnFD \mapsto lnER$ $lnER \mapsto lnFD$	5.07 33.2***	$lnER \rightarrow lnFD$
$lnTO \mapsto HD$ $HD \mapsto lnTO$	20.5*** 9.08*	$lnTO \leftrightarrow HD$	$lnFC \mapsto lnER$ $lnER \mapsto lnFC$	6.99 37.2***	$lnER \rightarrow lnFC$
$lnER \mapsto HD$ $HD \mapsto lnER$	161*** 2.56	$lnEX \rightarrow HD$	$lnFC \mapsto lnFD$ $lnFD \mapsto lnFC$	41.8*** 7.28	$lnFC \rightarrow lnFD$
$lnFD \mapsto HD$ $HD \mapsto lnFD$	69.8*** 42.9***	$lnFD \leftrightarrow HD$			

Note: *, **, and *** denote null hypothesis at 10%, 5%, and 1%, respectively, $\mapsto$, $\rightarrow$, $\leftrightarrow$, respectively denote does not Granger cause, unidirectional causality, and bidirectional causality.

5. Conclusion and Recommendations

In this study, we explored the short- and long-term effects of human capital development on economic growth, as well as the causal relationship between these two variables in Nigeria. To eliminate potential omitted variable bias, we included trade openness, financial development, exchange rate, and fixed capital formation as control variables. The data used span from 1992 to 2023 and were analyzed using the Autoregressive Distributed Lag (ARDL) approach and the Toda and Yamamoto (1995) Granger causality test. The findings from the ARDL technique indicate that human capital development significantly increases economic growth in both the short and long run, with the short-run effect being sustainable. Similarly, fixed capital formation and trade openness also have a significant positive impact on economic growth in both periods. Notably, the short-run influence of trade openness on economic growth is persistent, whereas the short-run impact of fixed capital formation is unsustainable. The exchange rate exhibits a mixed effect: it has a positive and insignificant impact in the short run, and a negative and significant impact in the long run on economic growth. Financial development also shows a mixed influence; it has a negative and significant effect in the short run, and a positive but insignificant effect in the long run. Additionally, the short-run effects of the previous year's financial development and exchange rate on economic growth are positive, but only the effect of the exchange rate is statistically significant.

The results from the Granger causality test indicate that economic growth exhibits a bidirectional causal relationship with human capital development, trade openness, and fixed capital formation. Additionally, there is a bidirectional causal association between trade openness and human capital development. Evidence also suggests a bidirectional causal relationship between fixed capital formation and trade openness, as well as between financial development and human capital development, fixed capital formation and human capital development, and fixed capital formation and trade openness. Furthermore, unidirectional causality exists from economic growth to financial development, and from the exchange rate to human capital development and fixed capital formation. Similarly, causality runs unidirectionally from trade openness to fixed capital formation and financial development. No evidence of causality was found between economic growth and the exchange rate, nor between the exchange rate and trade openness.

We recommend the following for policymakers and the Nigerian government. The government of Nigeria should prioritize investment in human capital development within the country. It should invest significantly in healthcare, vocational training, and education to strengthen and develop human capital. Additionally, policymakers should formulate and implement robust policies that improve access to quality healthcare and education, as this will enhance the quality of the workforce and, consequently, productivity. Given the vital role of trade openness in promoting Nigeria's short- and long-term economic growth, policymakers should develop and implement policies that facilitate trade between Nigeria and other countries. Such policies include reducing trade barriers, strengthening economic partnerships and relationships, and improving trade infrastructure. These measures will help the country maximize the benefits of trade openness, thereby boosting economic growth.

Policymakers should implement strategies that encourage investment in and the accumulation of physical infrastructure, such as industrial, energy, airport, and road facilities. The Nigerian government could provide incentives for investors in fixed capital, including tax cuts or tax breaks, to promote investment in fixed capital, which is essential for Nigeria's economic growth. Given the negative impact of financial development on economic growth in the short term, there is a need to reform Nigeria's financial sector. Greater efforts should be directed toward ensuring robust financial inclusion across the country, improving access to credit for businesses of all sizes, and reinforcing financial regulations to enhance the efficiency of the financial sector in Nigeria. All else being equal, these measures could mitigate the short-term adverse effects of financial development on economic growth and, in the long run, strengthen financial development to support sustained economic growth in Nigeria.

Furthermore, the Nigerian government, through the Central Bank of Nigeria (CBN), should formulate and implement policies that ensure the exchange rate of the Naira against other countries' currencies is neither too strong nor too weak. All else being equal, this will help address the adverse effects of a decline in the Naira's value relative to other currencies on economic growth. Such measures could include diversifying the country's economy, implementing robust monetary policies, and improving Nigeria's foreign exchange reserves. Ensuring the stability of the Naira's exchange rate will prevent it from hindering Nigeria's economic growth, thereby fostering a more resilient and sustainable economic environment.

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