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HUMAN CAPITAL DEVELOPMENT AND AGRICULTURAL PRODUCTIVITY IN NIGERIA: THE COMPLEMENTARY ROLE OF AGRICULTURAL CREDIT AND PRODUCTIVE CAPACITY

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ABSTRACT

This study examined the effect of human capital development on agricultural productivity in Nigeria, focusing on the complementary role of agricultural credit and productive capacity. It used annual secondary data covering 1985–2023 on educational development, health development, agricultural output, gross fixed capital formation, fertiliser consumption per hectare of arable land, and agricultural credit. The Augmented Dickey–Fuller test assessed the stationarity properties of the series, while the Johansen cointegration test examined the existence of long-run relationships. Fully Modified Ordinary Least Squares (FMOLS) was employed to estimate the models. The findings indicated that educational and health development individually had no statistically significant effects on agricultural productivity. However, education, health, investment, and agricultural credit exhibited statistically significant complementary effects on agricultural productivity. The study therefore recommends coordinated policies that improve farmers' access to education, healthcare, productive infrastructure, and agricultural credit to enhance agricultural productivity in Nigeria.

Keywords: *Human capital development; agricultural productivity; education; health; agricultural credit; productive capacity.*

JEL Classification: *I15; I25; Q14; Q16.*

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1. INTRODUCTION

Agriculture plays an important role in Nigeria's economy, providing food, employment and income for many households, particularly in rural communities. It also supplies raw materials to industries and supports economic diversification. Despite these contributions, the sector continues to face difficulties that limit its productivity, including inadequate financing, poor infrastructure, and limited adoption of improved farming technologies. Balana and Oyeyemi (2022) identify credit constraints as an obstacle to technology adoption among Nigerian smallholders, while Ndibe (2022) highlights the importance of developing farmers' knowledge and skills. Improving agricultural productivity therefore requires attention to both farmers' capabilities and the resources available to them.

Human capital development involves investments in education, health, training and skills that improve people's ability to work productively. In agriculture, education can help farmers understand extension advice, adopt suitable technologies and make better decisions about inputs and markets. Good health also enables farmers to carry out demanding tasks and complete farm operations on time. Iheke et al. (2026) found that education and health expenditure were significant determinants of agricultural productivity in Southeast Nigeria. However, Ogunjobi et al. (2025) reported a negative, statistically insignificant long-run coefficient for the Human Development Index in their national analysis. These findings indicate that improvements in human capital may not produce the same agricultural outcomes across different settings.

Agricultural credit can help farmers put their knowledge and skills into practice. A farmer may understand the benefits of improved seeds, machinery, or irrigation but lack the money needed to use them. Access to credit can help finance these investments and meet production expenses before harvest. Osabohien et al. (2020) reported higher yields among farming households with access to agricultural credit, while Fagbemi et al. (2025) found positive and significant relationships between agricultural financing and their measure of agricultural performance. Nevertheless, Balana and Oyeyemi (2022) showed that borrowing is constrained by factors such as limited collateral, information gaps, transaction costs, and perceived risk. Farmers' knowledge and financial management skills may therefore influence how effectively they access and use credit.

Productive capacity is equally relevant because farmers need suitable facilities and services to make effective use of their skills and financial resources. In this study, productive capacity refers to the technological, infrastructural and institutional capabilities that support agriculture, including machinery, irrigation, energy, storage, transport and production services. For example, a trained farmer with access to credit may still struggle to improve productivity where irrigation or machinery services are unavailable. Stronger productive capacity may therefore create the conditions under which investments in human capital and agricultural credit generate greater benefits. Whether these factors reinforce one another in Nigeria remains an empirical question.

Although previous studies have examined human capital and agricultural financing, the evidence reviewed leaves unresolved how education, health and agricultural knowledge relate to agricultural productivity when agricultural credit and productive capacity are considered together. This study therefore examines these dimensions of human capital development and investigates whether agricultural credit and productive

capacity strengthen their contribution to agricultural productivity in Nigeria. To address this objective, the study is guided by the following research questions.

Research Questions

a) To what extent does educational development influence agricultural productivity in Nigeria?
b) What effect does health development have on agricultural productivity in Nigeria?
c) How does agricultural knowledge influence agricultural productivity in Nigeria?
d) To what extent do agricultural credit and productive capacity strengthen the relationship between human capital development and agricultural productivity in Nigeria?

Objectives of the Study

The broad objective of the study is to examine the effect of human capital development on agricultural productivity in Nigeria. The specific objectives are to:

a) Examine the extent to which educational development influences agricultural productivity in Nigeria.
b) Assess the effect of health development on agricultural productivity in Nigeria.
c) Determine the effect of agricultural knowledge and productive capacity on agricultural productivity in Nigeria.

Research Hypotheses

a) H_0: Educational development has no significant influence on agricultural productivity in Nigeria.
b) H_0: Health development has no significant effect on agricultural productivity in Nigeria.
c) H_0: Agricultural knowledge and productive capacity have no significant effect on agricultural productivity in Nigeria.

2. LITERATURE REVIEW

2.1. Conceptual Review

Human Capital Development

Human capital development refers to the process of improving the knowledge, skills, competencies, health status, and productive capabilities of individuals through deliberate investments in education, healthcare, training, and experience. It is based on the premise that people are the most valuable resource in any economy and that enhancing their productive capacities contributes significantly to economic growth, technological progress, and sustainable development. Human capital development extends beyond formal education to include vocational training, skills acquisition, healthcare, nutrition, and lifelong learning, all of which improve individuals' ability to participate effectively in productive economic activities (Becker, 1993; Schultz, 1961).

Human capital development comprises several interrelated dimensions. Education remains one of the most important components because it equips individuals with the knowledge and skills required for innovation, technological adaptation, and informed decision-making. Formal education, vocational training, and agricultural extension programmes enable individuals to acquire technical competencies that improve productivity across different sectors of the economy. Similarly, health constitutes an essential component of human capital because healthy individuals are more physically and mentally capable of performing productive activities. Good health reduces absenteeism, increases labour efficiency, enhances cognitive functioning, and prolongs productive working life (Bloom et al., 2004).

At the macroeconomic level, human capital development contributes to increased labour productivity, technological innovation, income generation, poverty reduction, and economic growth. Countries that invest substantially in education, healthcare, research, and skills development tend to experience higher productivity and improved competitiveness because their labour force possesses the knowledge and capabilities necessary to adapt to technological change and innovation. Therefore, human capital development has become a central pillar of development policy and an essential driver of sustainable economic transformation, particularly in developing countries such as Nigeria.

Agricultural Productivity

Agricultural productivity refers to the efficiency with which agricultural inputs are transformed into agricultural outputs over a given period. It measures the ability of farmers or the agricultural sector to produce greater quantities of crops or livestock using available resources such as land, labour, capital, technology, and other production inputs. Productivity is regarded as one of the most important indicators of agricultural performance because it reflects improvements in production efficiency rather than mere increases in the quantity of inputs utilized (Food and Agriculture Organization [FAO], 2023).

Agricultural productivity can be measured using various indicators depending on the objectives of a study. Common measures include crop yield per hectare, output per worker, agricultural value added, labour productivity, land productivity, and total factor productivity (TFP). While partial productivity measures focus on the efficiency of individual inputs such as land or labour, total factor productivity evaluates the efficiency with which all production inputs are combined to generate agricultural output. Improvements in total factor productivity generally reflect technological progress, better management practices, innovation, and increased efficiency in resource utilization.

Agricultural productivity is influenced by a wide range of factors, including the availability of land, labour, capital, infrastructure, agricultural credit, research and development, extension services, technology adoption, climatic conditions, and government policies.

Recent developments in agriculture have further increased the importance of productivity enhancement. Advances in digital agriculture, precision farming, biotechnology, climate-smart agricultural practices, and mechanization require farmers to possess adequate knowledge and technical competence to utilize these innovations effectively. Consequently, sustainable improvements in agricultural productivity increasingly depend on investments in human capital development, research, innovation, and institutional support systems that facilitate technology adoption and efficient resource management (Aladejana & Onyejiuwa, 2024).

2.2 Theoretical review

This study is anchored on Human Capital Theory and Endogenous Growth Theory.

Human Capital Theory

Human Capital Theory was first developed by Theodore Schultz (1961) and was later expanded by Gary Becker (1964, 1993). The theory posits that investments in education, health, training, and skills acquisition are forms of capital because they enhance the productive capacity of individuals and generate economic returns over time. Unlike physical capital, which comprises machinery, buildings, and equipment, human capital resides in individuals in the form of knowledge, competencies, skills, and good health. According to the theory, individuals become more productive when they acquire education, receive training, and enjoy better health conditions.

The theory is particularly relevant to this study because human capital development is represented by investments in education, health, and agricultural knowledge, while agricultural productivity constitutes the expected outcome. The theory therefore provides a direct explanation of how improvements in human capital enhance farmers' productive capacity and increase agricultural output. It predicts a positive relationship between human capital development and agricultural productivity in Nigeria.

Endogenous Growth Theory

Endogenous Growth Theory emerged as a response to the limitations of the traditional neoclassical growth model, which regarded technological progress as an external factor independent of economic decisions. The theory was developed primarily by Paul Romer (1986, 1990) and Robert Lucas (1988), who argued that long-run economic growth is generated from within the economy through deliberate investments in human capital, innovation, research, and knowledge creation.

The central proposition of Endogenous Growth Theory is that investments in education, health, research, and technological development increase the stock of knowledge available within an economy, thereby stimulating innovation and improving productivity. Unlike physical capital, knowledge possesses characteristics of a public good because it can generate positive spillover effects that benefit many individuals beyond those directly involved in its creation. As knowledge accumulates, technological progress becomes self-sustaining, leading to continuous improvements in productivity and economic growth.

In agriculture, the theory explains that human capital enables farmers to acquire new knowledge, adopt improved technologies, and implement innovative production techniques.

The relevance of Endogenous Growth Theory to this study lies in its explanation that human capital development is not merely a social investment but also a productive investment capable of generating long-term improvements in agricultural productivity. The theory supports the proposition that investments in education, healthcare, and agricultural knowledge contribute to sustained productivity growth by enhancing innovation, technological adoption, and resource-use efficiency within Nigeria's agricultural sector.

2.3 Empirical Literature Review

The empirical literature suggests that human capital contributes to agricultural performance, although its influence varies across countries, production systems, and measures of human development. Ndour (2017) found that education and farming experience improved productivity and technical efficiency among farmers in Senegal, while Nguyen (2021) identified a significant, though relatively modest, contribution of human capital to agricultural labour productivity in Vietnam. These findings are consistent with Baiyegunhi (2024), whose analysis of South African sugarcane farmers linked on-the-job training to innovation and subsequently to higher farm productivity. Together, these studies suggest that human capital supports agriculture through both better resource management and the adoption of improved production practices. However, their different geographical settings and sectoral coverage limit direct generalisation to Nigeria.

Evidence on education and health reinforces this argument but also reveals differences between farm-level and national outcomes. Ntsama and Sougouma (2022) reported positive relationships between schooling, public health expenditure and cereal production in CEMAC countries. Similarly, Ukpe (2024) found that education and health expenditure positively influenced agricultural output in Cameroon, while Iheke et al. (2026) identified both expenditures as significant determinants of farm productivity in Southeast Nigeria. In contrast, Obasanmi and Idogun (2020) found that current public education and health expenditure did not translate into increased agricultural output in their Nigerian sectoral analysis, while Mgbemena and Kalu (2023) reported a negative agricultural response through the public spending channel. These contrasting results suggest that expenditure on human capital and the productive capabilities available to farmers are not necessarily equivalent. They also raise questions about the relevance, quality, and agricultural application of education and health investments.

The relationship between human capital and technology offers a possible explanation for these differences. Baiyegunhi (2024) provides evidence that training contributes to productivity through innovation, suggesting that acquired skills yield benefits when farmers can apply them within production. Japinye et al. (2025) also examined the joint influence of human capital and technology, reporting significant negative coefficients for their individual and interactive effects in a food-security specification. However, the meaning of these coefficients depends on the direction of the food-security indicator and should not automatically be interpreted as evidence that education or technology worsens welfare. Moreover, food security is broader than agricultural productivity. Read together, these studies support examining the conditions under which knowledge and technology interact, while cautioning against assuming that their combined effect is always beneficial.

Agricultural financing represents one such condition because farmers require resources to implement the production decisions made possible by education and training. Positive evidence emerges from both household and national studies. Osabohien et al. (2020) reported higher yields among Nigerian farming households with access to agricultural credit, while Fowowe (2020) found that financial inclusion positively influenced crop income per hectare. At the national level, Adewale et al. (2022) and Fagbemi et al. (2025) identified positive relationships between agricultural financing and agricultural performance. Adedamola and Bababtunde (2024) strengthened this evidence by finding a significant positive productivity effect among Bank of Agriculture beneficiaries in Southwestern Nigeria. Collectively, these findings suggest that finance

can ease production constraints, although differences between financial inclusion, targeted agricultural credit and aggregate lending prevent treating the studies as measuring an identical relationship.

Nevertheless, the benefits of financing are not uniform. Yuni et al. (2022) found that initially favourable credit relationships became statistically insignificant after matching rice farmers with comparable characteristics. Ogbeide-Osaretin and Aliu (2022) reported negative relationships between general private-sector credit and agricultural performance, whereas Nebo et al. (2023) identified only a weak positive relationship between credit access and agricultural productivity. These results qualify the positive findings of Fagbemi et al. (2025) and Adedamola and Bababtunde (2024), indicating that the source, targeting and utilisation of finance matter. They also demonstrate the importance of estimation methods: observed differences between borrowers and non-borrowers may partly reflect their pre-existing characteristics rather than credit alone. Consequently, greater lending cannot be assumed to generate productivity gains without considering farmers' capabilities and production circumstances.

Balana and Oyeyemi (2022) help connect these mixed financing outcomes to human capital by showing that Nigerian smallholders face both supply-side and demand-side credit constraints. Alongside collateral limitations, their study identifies information gaps, transaction costs, and perceived borrowing risks. This evidence complements Fowowe (2020) by suggesting that financial access involves more than the presence of lending institutions. Farmers must also understand financial products, assess investment opportunities and manage repayment obligations. Human capital may therefore improve the effective use of credit, while credit may enable farmers to apply their knowledge through investment in inputs and technology. This two-way relationship provides a plausible basis for complementarity, but the cited findings do not independently establish its magnitude.

Evidence on combined institutional services offers more direct support for investigating complementary resources. Kehinde and Ogundeji (2022) found that cocoa farmers with simultaneous access to credit and cooperative services achieved higher productivity than farmers accessing only one service or neither. Kehinde et al. (2021) similarly showed that social capital positively influenced productivity and food security among cocoa-based households. These findings connect financing with the networks through which farmers obtain information, mobilise resources and coordinate production. Aremu and Reynolds (2024) add to this connection by showing that credit access, asset ownership and fertiliser use were positively associated with agricultural extension use. Together, these studies indicate that financial, informational and institutional resources often operate within the same production environment. Nevertheless, cooperative membership and social capital should be distinguished from human capital and physical productive capacity.

Productive capacity extends this discussion to the facilities and services that enable farmers to use knowledge and finance effectively. Nebo et al. (2023) reported positive relationships between agricultural performance, human capital and electricity access, while Ogbeide-Osaretin and Aliu (2022) identified a positive contribution from government capital expenditure. Ukpe's (2024) negative fertiliser result further suggests that input availability alone may be insufficient where application is inefficient, although the proposed explanation requires additional evidence. These findings are consistent with the possibility that infrastructure, technology and managerial competence jointly influence production outcomes. Edomwonyi et al. (2025), who found an insignificant relationship between agricultural lending and aggregate economic growth, provide additional contextual evidence that financing does not automatically translate into stronger economic

performance. However, their aggregate growth outcome cannot establish agricultural productivity effects directly.

Across these studies, methodological and measurement differences account for part of the variation in findings. Farm surveys capture farmers' education, health expenditure, training and access to services, whereas national analyses often use public expenditure or broad development indicators. Likewise, agricultural output, output growth, income per hectare, technical efficiency and food security measure different outcomes. Matching and endogenous switching models attempt to address selection into credit or institutional services, while time-series models examine relationships over time. These differences mean that contrasting findings should be interpreted in relation to what each study measures and the assumptions underlying its estimation, rather than as straightforward confirmation or rejection of human capital theory.

The literature therefore provides a basis for examining agricultural productivity as the outcome of interacting capabilities and resources. Human capital may improve production decisions, agricultural credit may finance their implementation, and productive capacity may provide the infrastructure and technology required to realise their benefits. However, the evidence reviewed does not directly establish whether agricultural credit and productive capacity strengthen the education–productivity and health–productivity relationships at the national level in Nigeria. The present study addresses this question by examining these relationships within a common framework. Its contribution rests on explicitly testing complementarity, rather than inferring it merely from the simultaneous inclusion or statistical significance of human capital, credit and productive capacity variables.

3 METHODOLOGY

The data were sourced from the CBN Statistical Bulletin, the National Bureau of Statistics Annual Abstract of Statistics, and the World Development Indicators. Agricultural value added, government expenditure on education, government expenditure on health, life expectancy, and secondary school enrolment were sourced from the NBS Annual Abstract of Statistics, while fertilizer consumption per hectare was sourced from the World Development Indicators. Agricultural credit and gross fixed capital formation were sourced from the CBN Statistical Bulletin.

Model Specification

The model for this study in the functional form is specified as:

$$AGVA = f(EDU, HEA, SSE, LIFE, AGCRE, FERPR, GCFC) \quad (3.1)$$

Where AGVA = Agricultural value added, EDU = government expenditure on education, HEA = government expenditure on health, LIFE = life expectancy, SSE = secondary school enrolment, FERPR = fertilizer consumption per hectare, AGCRE = agricultural credit, GFCF = gross fixed capital formation.
In econometric form, it is written as:

$$lnAGVA_t = \beta_0 + \beta_1 lnEDU_t + \beta_2 lnHEA_t + \beta_3 lnSSE_t + \beta_4 LIFE_t + \beta_5 AGCRE_t + \beta_6 GFCF_t + \beta_7 FERPR_t + \mu_t \quad (3.2)$$

$$\beta_0 - \beta_7 \geq 0$$

In addition to the descriptions in Equation 3.1, *ln* = natural logarithm, *t* = time, and $\beta_0 - \beta_7$ = parameters to be estimated.

The model was estimated using Fully Modified OLS, which helps to remove endogeneity and serial correlation in the model. The estimation began with the unit root test. The unit root test was done in order to ascertain that all series were stationary at first difference. This is the first requirement that must be established before the use of Fully Modified OLS. The second is that there must be a long-run relationship among the series. This was confirmed with the adoption of Johansen' cointegration technique. The hypotheses were tested using F- statistics of the Wald test.

4. RESULTS AND DISCUSSION OF FINDINGS

4.1 Results

Unit Root Test

We started this analysis by looking at the properties of each series in terms of their stationarity. Estimating a model using Fully Modified OLS required that each series be stationary at First difference. Table 1 shows the results obtained.

Table 1: Unit Root Test

Variable		ADF Statistics	ADF Critical	Order
lnAGVA	Level	-2.92	-2.941	
	First difference	-3.962	-2.943	1(1)
lnEDU	Level	-2.613	-2.964	
	First difference	-7.810	-2.943	1(1)
lnHEA	Level	-2.063	-2.992	
	First difference	-9.778	-2.951	1(1)
lnSSE	Level	0..415	-2.941	
	First difference	-4.540	-2.943	1(1)
LIFE	Level	-2.511	-2.941	
	First difference	-6.707	-2.943	1(1)
lnAGCR	Level	-1.331	-2.941	
	First difference	-5.376	-2.943	1(1)
FERPR	Level	-3.215	-2.941	
	First difference	-6.001	-2.948	
lnGCFC	Level	-1.243	-2.941	
	First difference	-4.807	-2.943	

Note: 5% level of significance
Source: Authors' survey

The table above shows that all series were stationary at first difference. From the results, we concluded that their properties have satisfied the first requirement for the use of Fully Modified OLS for estimation of the model.

Cointegration Test

We proceeded further to carry out the cointegration test. This is necessary because there must be a long-run relationship among the series before we can make use of Fully Modified OLS. Table 4.2 below shows the results obtained for the Trace test and Max- Eigen test.

Table 2: Cointegration Test (Trace Test)
Method: Johansen System Cointegration Test
Sample: 1987 2023
Trend assumption: Linear deterministic trend

Hypothesized No. of CE(s)	Eigenvalue	Statistic	Critical value at 0.05	Prob.
Trace statistic				
None*	0.924	287.049	159.530	0.000
At most 1*	0.892	199.262	125.615	0.000
At most 2*	0.766	123.510	95.754	0.000
At most 3*	0.628	74.148	69.819	0.022
At most 4	0.447	40.555	47.856	0.203
Max- Eigen Test				
None*	0.924	87.788	52.362	0.000
At most 1*	0.892	75.754	46.231	0.000
At most 2*	0.766	49.358	40.078	0.034
At most 3	0.628	33.593	33.877	0.054

Note: 5% level of significance
Source: Authors' survey

From the results, it can be seen that the Trace test indicated the existence of four cointegrating equations in the model, while the Max- Eigen indicated the existence of three cointegrating equations in the same model. From these results of the Trace test and Max- Eigen, we concluded that a long-run relationship existed among the series. We can therefore estimate the model using Fully Modified OLS.

Regression result

Table 3: Regression output
Method: Fully Modified OLS
Sample: 1985 – 2023
Dependent variable: lnAGVA

Variable	I	II	III	IV
Constant	0.348	-23.239[a]	-23.239[a]	-32.978[b]
	(0.051)	(-4.992)	(-4.992)	(-3.506)
lnEDU	0.100	-0.047	1.153[a]	-0.048
	(0.561)	(-0.534)	(3.473)	(-0.364)
lnHEA	0.150	0.108	0.139	1.359[a]
	(0.812)	(1.178)	(0.973)	(4.401)
lnSSE	-0.282	0.570[a]	0.794[b]	0.848[b]
	(-1.016)	(3.274)	(2.259)	(2.574)

LIFE	0.019	0.037	0.037[c]	0.127[c]
	(0.235)	(0.923)	(1.893)	(1.921)
lnAGCRE	0.147[b]	2.141[a]	1.263[a]	1.259[a]
	(2.314)	(8.200)	(4.149)	(4.714)
FERPR	-0.059	0.106	0.070	0.077
	(-0.228)	(0.836)	(0.350)	(0.405)
lnGCFC	0.788[a]	2.141[a]	0.568[a]	0.563[a]
	(5.303)	(10.609)	(4.422)	(4.714)
lnGCFC*lnAGCRE		-0.109[a]		
		(-7.170)		
lnEDU*lnAGCRE			-0.097[a]	
			(-3.714)	
lnHEA*lnAGCRE				-0.100[a]
				(-4.198)
R- squared	0.999	0.997	0.997	0.996
Adjusted R- square	0.988	0.996	0.996	0.994
Long–run variance	0.070	0.017	0.017	0.038

Note: [a]1%,[b]5%, [c]10% level of significance; t- statistics in parenthesis.
Source: Authors' survey

Table 3 showed the regression results, and the results clearly showed that the coefficients of determination were very high. These values were 0.999, 0.997, 0.997 and 0.996, indicating that the independent variables explained large variation in agricultural value added in the period under study. The values obtained for the long- run variance in each of the models were very small, and this showed that there was stability in the long-run relationships among the variables and that the deviations from the trends quickly readjusted.

From Table 3, one can see that the coefficients of education, a major dimension of human capital development, which are log of expenditure on education (lnEDU) and log of secondary school enrolment (lnSSE), were not significant, though the log of expenditure on education (lnEDU) has the expected sign. The log of secondary school enrolment (lnSSE) has a contradictory sign. These results showed that, as important as education is, it does not exert an impact on the growth of the agricultural sector in Nigeria in the period under study.

The second major dimension of human capital development, which is health, behaved similarly to education except that the coefficients of the proxies were positive. Both the log of expenditure on health (lnHEA) and life expectancy (LIFE) were positive, which showed that health, as a dimension of human capital development, is positively related to the growth of the agriculture sector. This should be expected since the healthier the workforce the more their activeness in the farms.

Looking at Table 3, one can see that out of the three control variables, log of the agricultural credit (lnAGCRE) and log of the gross fixed capital formation (lnGCFC) were both positive and significant. These results showed that investment in infrastructural development in the economy and accessibility of capital were very essential to the growth of the agricultural sector in Nigeria. One should have expected the fertilizer consumption per hectare (FERPR) to be positive and significant, but the result was contradictory. A major

reason for this result may be attributed to the bureaucratic nature of the government, which sometimes resulted in the farmers not being the beneficiaries of the subsidized fertilizers.

4.2 Discussion of Findings

The findings suggest that the relationship between human capital development and agricultural productivity in Nigeria depends on the financial and productive conditions within which human capital is applied. In the baseline specification reported in Column I of Table 4.3, education and health expenditure did not have statistically significant effects on agricultural productivity. This indicates that the model did not establish independent productivity contributions from these expenditure measures during the study period. It does not imply that education and health are unimportant to agriculture, since public expenditure may not adequately capture the quality, accessibility, or agricultural relevance of the services received by farmers.

These baseline findings are broadly consistent with Obasanmi and Idogun (2020), who found that current public education and health expenditure did not translate into increased agricultural output in Nigeria, and Mgbemena and Kalu (2023), who reported a negative agricultural response through the public expenditure channel. However, they differ from Iheke et al. (2026), whose farm-level analysis in Southeast Nigeria identified education and health expenditure as significant determinants of productivity. Positive relationships were also reported by Ntsama and Sougouma (2022) in CEMAC countries and Ukpe (2024) in Cameroon. The differences suggest that the contribution of human capital varies with geographical coverage, measurement, and production conditions. In particular, national expenditure figures may conceal differences in the services available to agricultural households.

The introduction of interaction terms in Columns II, III and IV examined whether the relationships involving education and health varied with investment and agricultural credit. These specifications extend the analysis beyond the independent effects of human capital by allowing its contribution to depend on supporting resources. However, agricultural knowledge and productive capacity should remain conceptually distinct: knowledge concerns farmers' skills and competence, whereas productive capacity concerns the resources and systems available for production. Interactions among education, health, investment, and credit capture conditional relationships between these variables; they do not directly measure agricultural knowledge unless an appropriate knowledge indicator is included.

The negative and statistically significant interaction coefficients are an important finding. Under a conventional interaction specification, they indicate that the marginal contribution of one interacting variable declines as the other increases. For example, a negative interaction between education expenditure and agricultural credit suggests that the estimated contribution of education becomes smaller at higher credit levels, or equivalently that the contribution of credit decreases as education expenditure rises. This result does not necessarily imply a negative overall effect on productivity. Positive main effects may outweigh the negative interaction over some observed values. Nevertheless, the interaction coefficients alone do not support a conclusion of reinforcing complementarity.

Several explanations could account for these negative conditional relationships. Education and credit may partly substitute for one another in addressing particular production constraints, or additional borrowing may generate limited gains where farmers face inadequate technology, weak extension support, or poor

infrastructure. Inefficient expenditure allocation and the mismatch between general education spending and agricultural skills could also restrict the productive application of finance. These are possible interpretations rather than mechanisms established by the estimated coefficients. Balana and Oyeyemi (2022) provide relevant evidence by showing that Nigerian smallholders face information limitations, transaction costs, and borrowing risks alongside supply-side credit constraints. Their findings suggest that expanding lending without addressing farmers' capabilities and operating conditions may yield limited benefits.

The change in the significance of education and health expenditure between Column I and Columns III and IV indicates that the findings are sensitive to allowing conditional relationships. However, the coefficients in the interaction models have a different interpretation from those in the baseline model. The education coefficient represents its estimated contribution when the interacting variable equals zero, while the health coefficient is interpreted under the corresponding reference condition. Where agricultural credit enters in logarithms, this reference point is zero logged credit, equivalent to one unit of credit in the measurement scale. Consequently, the newly significant coefficients should not be described as revealing the "true effects" of education and health. Their economic interpretation requires examining marginal effects at meaningful credit and investment levels.

The positive and significant education-related coefficients in the relevant specifications provide evidence of a favourable conditional relationship between education and agricultural productivity. This is consistent with Ndour (2017), who linked education and experience to higher productivity and efficiency, and Nguyen (2021), who identified a significant contribution of human capital to agricultural labour productivity. Baiyegunhi (2024) further suggests that training can support productivity through innovation. Nevertheless, the negative education–credit interaction means that the present findings cannot establish that education improves productivity *through* credit access. Such a statement implies a transmission mechanism that the interaction model does not directly identify. The more defensible conclusion is that the estimated education–productivity relationship varies with agricultural credit.

Similarly, the positive and significant coefficients for health expenditure and life expectancy indicate favourable relationships with productivity in the relevant specifications. Better health may support labour availability, physical endurance and the timely completion of agricultural activities, providing a plausible explanation for these results. They are consistent with Iheke et al. (2026) and the positive health-related findings of Ntsama and Sougouma (2022) and Ukpe (2024). However, the results do not demonstrate that health improves productivity only when farmers have access to credit. Given the negative health–credit interaction, the health contribution must be evaluated across observed credit levels before determining where it remains positive and statistically significant.

The consistently positive and significant coefficients for investment and agricultural credit point to their relevance within the estimated specifications. The credit findings accord with Osabohien et al. (2020), Fowowe (2020), Adewale et al. (2022) and Fagbemi et al. (2025), who reported favourable relationships between financing and agricultural outcomes. They also align with Adedamola and Bababtunde (2024), whose analysis identified productivity benefits among Bank of Agriculture beneficiaries. Nevertheless, Yuni et al. (2022) found insignificant credit effects after matching rice farmers, showing that these benefits are not uniform. In the present interaction models, positive main coefficients likewise should not be treated as evidence that credit has a positive effect at every level of education or health.

The investment findings support attention to the productive resources needed to apply knowledge and finance effectively. Machinery, irrigation and other infrastructure can create opportunities for farmers to implement improved practices. However, if investment is measured by aggregate gross fixed capital formation, its coefficient represents a broad investment relationship rather than the separate effects of agricultural infrastructure. Evidence from Kehinde and Ogundeji (2022), who found greater productivity among farmers accessing both credit and cooperative services, supports investigating coordinated support. Their positive joint-service findings nevertheless differ from the negative interaction coefficients reported here, indicating that the benefits of combining resources depend on which resources are considered and how their relationships are measured.

Overall, the findings show that human capital, investment and agricultural credit are connected within Nigeria's agricultural production environment. They provide evidence of conditional relationships, but the negative interaction coefficients qualify the claim that these factors reinforce one another. A conclusion of positive complementarity requires further examination of marginal effects and their confidence intervals across observed credit and investment levels. Until these are established, the appropriate conclusion is that the productivity contributions of education and health depend on financial and productive conditions, with evidence that their marginal contributions diminish as the interacting variables increase.

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This study examined human capital development and agricultural productivity in Nigeria, with emphasis on the role of agricultural credit and productive capacity. The baseline findings showed that education and health development did not individually have statistically significant effects on agricultural productivity during the period under study. However, the interaction models indicated that their contributions varied with agricultural credit and investment, highlighting the importance of the conditions under which human capital is applied.

The positive investment and credit coefficients support the relevance of financial and productive resources, while the negative interaction coefficients qualify the claim of reinforcing complementarity. The study therefore concludes that improvements in education and health alone may be insufficient to strengthen agricultural productivity. Policies should coordinate human capital development with accessible agricultural financing and productive investment, while addressing constraints that limit their effective utilisation.

5.2 Recommendation

a) Government should introduce policies that encourage financial institutions to provide farmers with affordable agricultural credit, timely loan disbursement and repayment terms suited to agricultural production cycles.
b) Government should increase investment in rural infrastructure, particularly feeder roads, irrigation systems, storage facilities and adequately serviced farm estates, to reduce production costs, improve market access and enhance agricultural productivity.
c) Government should coordinate investments in education, healthcare and productive infrastructure with agricultural financing. These interventions should address the constraints

that prevent farmers from effectively applying their knowledge, maintaining their health and utilizing credit for productive activities.

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