

HEALTH CAPITAL, LABOUR DYNAMICS, AND AGRICULTURAL PERFORMANCE: A PANEL DATA ANALYSIS

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Abstract

Building strong health capital is essential to maintain a workforce that can sustain and boost agricultural productivity at every scale of operation. This study examines the connections between health capital, labour dynamics, and agricultural performance in sixteen West African countries, using data from 1985 to 2023. It applied a panel Two-Stage Least Squares (2SLS) method to tackle possible endogeneity. Drawing on indicators such as life expectancy, infant mortality, health spending, labour force participation rate, and gross fixed capital formation, the analysis shows that investments in health and physical capital markedly increase agricultural output, whereas idle labour and ongoing health risks limit productivity. Diagnostic tests and post-estimation checks verify the reliability of these results. The findings highlight the importance of coordinated policies that advance healthcare systems, workforce engagement, and capital investment to maximize agricultural efficiency. By connecting human and physical capital to sector-specific output, this research provides practical guidance for policymakers aiming to enhance food security, economic progress, and sustainable development in West Africa.

Keywords: human capital; health capital; physical capital; capital formation; productivity

JEL Classification: I15, I13, I120, J43, Q12

1. Introduction

Agriculture appears to be a predominant activity in the West African economic structure, serving as a critical driver of growth, employment, and food security across the subregion. It contributes substantially to gross domestic product (GDP), provides livelihoods for over 60% of the labour force, and underpins the subsistence and nutritional well-being of most households (African Development Bank [AfDB], 2022; Food and Agriculture Organization [FAO], 2023). Beyond its economic contribution, agriculture serves as a social stabilizer, absorbing a large share of the region's rapidly expanding labour force, particularly among rural youth and women, and thereby mitigating the risks of unemployment and social exclusion

(International Labour Organization [ILO], 2024; Anowor, Ichoku, Onodugo, Ochinanwata, & Uzomba, 2023). The sector's centrality to food security is equally profound, as it ensures the availability and accessibility of staple foods (essential to combating hunger and malnutrition) in a region that remains vulnerable to climatic shocks and global supply disruptions (United Nations Development Programme [UNDP], 2022). However, despite its vast potential, West Africa's agricultural sector continues to be constrained by low productivity, inadequate investment in health and other human capital determinants, limited access to modern technology, and fragile infrastructure, which hinder its capacity to drive inclusive and sustainable economic transformation (World Bank, 2023).

Despite strides in regional integration and policy reforms, agricultural productivity in West Africa continues to contend with profound impediments arising from deficient health infrastructures and erratic labour movements, which collectively undermine the sector's capacity for sustainable output and economic contributions (Anowor, Ichoku, & Onodugo, 2020; Grossman, 1972). Fragile health systems, plagued by chronic underfunding (evidenced by Sub-Saharan Africa's receipt of less than 1% of global health expenditures despite bearing 24% of the world's disease burden) coupled with severe shortages of trained personnel and frequent essential drug stock-outs, heighten vulnerability to endemic illnesses like malaria, Ebola, and HIV/AIDS (Ochinanwata, Uzoba, Onodugo, & Anowor, 2020; Azevedo, 2017), resulting in elevated morbidity that precipitates workforce absenteeism, diminished physical endurance (Yasin, Nadeem, Fiaz, & Radoi, 2024), and diverted household labour toward caregiving, thereby eroding farm-level efficiency and exacerbating poverty cycles (Ayanwale, & Alabi, 2020). Simultaneously, volatile labour dynamics manifest through widespread rural out-migration fueled by climatic disruptions and non-farm wage attractions (World Bank, 2023), pronounced gender inequities that limit women's resource access and amplify their dual burdens in production and domestic roles, alongside pervasive underemployment (often exceeding 50% when accounting for vulnerable and invisible forms) and informal employment dominating over 70% of jobs (ILOSTAT, 2025), which collectively foster seasonal labour scarcities, skill mismatches, and resistance to technological uptake, further constraining yield improvements and sector resilience. These enduring hurdles, interwoven with demographic pressures and environmental stressors, not only perpetuate suboptimal agricultural performance but also highlight the urgent need for holistic strategies that fortify health endowments and labour stability to propel inclusive growth in the region.

Theoretically, health capital constitutes a pivotal determinant of agricultural productivity, as it embodies the stock of physical and mental well-being that enhances labour efficiency, resilience, and innovation within the agricultural sector. From a human capital perspective, pioneered by Becker (1964) and later expanded by Grossman (1972), health is both a consumption and an investment good; one that directly influences an individual's capacity to supply productive labour. In the agricultural context, improved life expectancy signifies a healthier, more experienced, and enduring workforce capable of sustained engagement in

labour-intensive activities, thereby enhancing overall productivity. Conversely, high infant mortality rates often reflect systemic deficiencies in health infrastructure and household wellbeing, which constrain future labour supply and human capital formation (Bloom, Canning, & Fink, 2014). Similarly, increased public and private (out of pocket) health expenditure strengthen health outcomes by reducing disease incidence, minimizing work absenteeism, and improving nutritional status (Anowo, Ichoku, & Onodugo, 2020), all of which translate into higher labour efficiency and farm output (World Health Organization [WHO], 2023; Weil, 2014). This suggests that robust health capital not only enhances the quality and longevity of the labour force but also could foster technological adoption, adaptive capacity, and the sustainability of agricultural growth in West Africa.

Unfortunately, agriculture still grapples with entrenched research problems in West Africa's socioeconomic landscape. This has perpetuated suboptimal performance, including chronically low productivity yields (averaging merely 1.5 tons per hectare for staple cereals compared to global benchmarks of over 4 tons) stemming from pervasive health vulnerabilities and unstable labour patterns, which collectively hinder sustainable output and exacerbate food insecurity (Anowor, Kalu, Odo, & Okorie, 2025) for a population exceeding 400 million. High infant mortality rates, hovering around 52 per 1,000 live births across the region, coupled with average life expectancy at approximately 60 years and health expenditures constituting less than 5% of GDP, underscore how endemic diseases such as malaria and nutritional deficiencies erode health capital, leading to heightened morbidity that curtails labour participation and diverts resources from productive farming activities to healthcare needs (UNICEF, 2023; Azevedo, 2017; World Health Organization, 2024). Concurrently, labour dynamics reveal stark inefficiencies, with agriculture employing roughly 50% of the workforce yet plagued by seasonal underemployment, rural exodus driven by urban pull factors, and gender disparities that limit women's productivity despite their comprising over 40% of agricultural laborers, resulting in employment gaps that stifle technological adoption and capital intensification (McCullough, 2017; Bassie et al., 2024; Doss et al., 2015). These challenges illuminate profound knowledge gaps in the nexus between health capital (encompassing life expectancy, health expenditures, and infant mortality) and agricultural performance within West Africa; while extant literature explores health burdens' impact on labour productivity in broader Sub-Saharan contexts or economic growth linkages, few investigations employ panel data methodologies to dissect the interplay with labour force dynamics and gross fixed capital formation, particularly in dissecting heterogeneous effects across income strata or quantifying bidirectional causalities amid rapid demographic shifts and climate vulnerabilities (Okunade & Osmani, 2020; Piabuo & Tieguhong, 2017; Ogunniyi et al., 2020; Christiaensen & Maertens, 2022). Addressing these lacunae through rigorous panel analysis is imperative to inform targeted policies that enhance health endowments, stabilize labour inputs, and bolster capital investments for resilient agricultural advancement.

Anchored in the overarching goal of elucidating how health capital and labour dynamics jointly shape agricultural productivity across West Africa, this study pursues three interrelated objectives. First, it seeks to empirically evaluate the effects of health capital indicators, namely life expectancy, total health expenditure, and infant mortality rate, on agricultural output among sixteen West African economies from 1985 to 2023. Second, it investigates how labour force participation and gross fixed capital formation interact with these health measures to influence productivity outcomes within the agricultural sector. Third, the research aims to generate robust empirical evidence capable of informing integrated policy frameworks that align public health investment with agricultural transformation and human development priorities. These objectives give rise to the following research questions: (i) What is the magnitude and direction of the influence of health capital on agricultural output in West Africa? (ii) In what ways do labour market conditions and physical capital accumulation mediate or reinforce the relationship between health and agricultural productivity? and (iii) How do distinct health indicators, particularly life expectancy, infant mortality, and health expenditure, affect productivity across countries and time? The study's anticipated contributions are threefold. Conceptually, it deepens the theoretical discourse on endogenous growth and human capital models by embedding health dynamics into the agricultural production framework (Becker, 1964; Grossman, 1972). Empirically, it provides one of the most comprehensive region-specific analyses of the health–agriculture nexus. Practically, the study contributes to evidence-based policymaking by demonstrating that strengthening health systems and improving population wellbeing are essential levers for raising agricultural productivity, advancing food security, and accelerating inclusive and sustainable economic growth across West Africa (African Development Bank [AfDB], 2022; World Bank, 2023).

2. Literature review

From a classical economic standpoint, health capital is fundamentally a component of human capital, constituting a durable stock that enhances labour productivity and earnings potential over a lifetime (Becker, 1964; Grossman, 1972). A contemporary perspective refines this to encompass the broader cultural health capital that influences health-seeking behaviours and outcomes through social and institutional structures (Shim, 2010). Labour dynamics, classically understood as the supply and qualitative input of labour as a primary factor of production (Smith, 1776), are now analyzed through the lens of intra-household allocation, gendered productivity gaps, and the structural transformation of labour from manual tasks to mechanized and off-farm activities. Finally, agricultural performance, classically measured by land and labour productivity (Ricardo, 1817), is contemporarily assessed through a more holistic framework of agricultural transformation, which includes a shift from subsistence to commercial, high-value production and its concomitant effects on rural employment and capital intensity (Timmer, 1988).

The theoretical linkage between health, labour quality, and agricultural productivity is rigorously established within the New Household Economics and the Health-Productivity Nexus literature, positing that health functions as a crucial form of human capital (Becker, 1962). Specifically, enhancements in health capital, evidenced by increased life expectancy and greater total health expenditure, coupled with reductions in adverse health outcomes like the infant mortality rate, directly improve the quality of the labour force (Strauss & Thomas, 1998). This quality improvement manifests through several channels, like better physical stamina and cognitive function, resulting in reduced days lost to illness (less absenteeism), higher intensity of effort (greater work output per hour), and an extended productive lifespan, thereby increasing the effective stock of labour and the returns to skill accumulation (Fogel, 1994). For the agricultural sector, where physically demanding tasks are prevalent, this robust relationship implies that healthier workers are more efficient in utilizing both land and existing gross fixed capital formation (GFCF), leading directly to higher yields and ultimately greater agricultural output (World Bank, 2024). Therefore, investment in health is not merely a consumption expenditure but an essential investment that enhances the marginal product of agricultural labour, driving overall economic performance.

Human capital theory provides the principal theoretical foundation linking health, labour, and agricultural productivity, emphasizing that investments in human wellbeing and skills yield measurable economic returns through enhanced productivity and efficiency. Originating from the seminal works of Schultz (1961) and Becker (1964), the theory posits that education, training, and health constitute productive forms of capital that increase an individual's economic value and contribution to output. Within this framework, Grossman (1972) extended the concept to incorporate health capital, arguing that health is both a consumption and investment good, improving not only quality of life but also labour effectiveness and longevity. In the agricultural context, this perspective implies that healthier farmers possess greater physical endurance, cognitive ability, and adaptive capacity, thereby facilitating higher productivity and better adoption of technology (Weil, 2014; Bloom, Canning, & Fink, 2014). Moreover, the theory underscores that societies with higher life expectancy, lower infant mortality, and greater health expenditure tend to experience more stable labour dynamics and sustained economic transformation (World Bank, 2023; Nwonye et al, 2023; African Development Bank [AfDB], 2022). Thus, the human capital theory provides a compelling framework for understanding how health improvements and labour quality jointly enhance agricultural performance in West Africa, where health deficits continue to constrain productivity and development potential.

The endogenous growth theories (EGT), pioneered by Romer (1986) and Lucas (1988), fundamentally evolved from the static framework of traditional human capital theory by endogenizing the process of technological progress, thereby demonstrating how sustained long-run growth can be driven from within the economic system, escaping the diminishing returns to capital assumed by the Solow-Swan model. This pivotal shift is accomplished by

broadening the concept of capital to include human capital (the stock of skills and knowledge embodied in individuals, crucially including health) and knowledge capital (ideas and innovation). In EGT models, investment in health capital (proxied by total health expenditure and improved life expectancy) enhances the quality of the labour force, not merely its quantity, leading to positive externalities or knowledge spillovers, where one person's accumulation of knowledge benefits the entire economy (Lucas, 1988). Critically, this non-rivalrous nature of ideas and human capital accumulation allows for increasing returns to scale at the aggregate level, meaning sustained investment in health and education perpetually enhances productivity, including agricultural output, making long-term growth self-sustaining rather than dependent on exogenous technological shocks.

The theoretical foundations linking health capital and agricultural output in this study draw significantly from classical and contemporary agricultural productivity models, which emphasize the interplay between factor inputs and output efficiency. Rooted in the Cobb–Douglas production function developed by Cobb and Douglas (1928), agricultural productivity is traditionally modeled as a function of land, labour, and capital, where output depends on the efficient utilization of these factors under given technological conditions. However, subsequent extensions, particularly the endogenous growth models of Romer (1990) and Lucas (1988), incorporated human capital accumulation as a driver of productivity, positing that health, education, and innovation jointly enhance the effectiveness of traditional inputs. In the context of West Africa, this expanded model becomes particularly relevant, as empirical evidence shows that labour productivity in agriculture remains constrained by poor health outcomes, low capital intensity, and limited technological adoption (African Development Bank [AfDB], 2022; World Bank, 2023). The inclusion of health capital indicators such as life expectancy, infant mortality, and health expenditure aligns with Grossman's (1972) framework, which conceptualizes health as a productive asset influencing labour efficiency. Similarly, gross fixed capital formation (GFCF) represents the physical investment component that complements human capital and health improvements in driving agricultural output. Therefore, integrating these dimensions within an augmented agricultural productivity model provides a more comprehensive analytical framework for understanding how health and labour dynamics interact with capital formation to shape agricultural performance in West Africa.

In theoretical growth and productivity frameworks, health capital and labour inputs enter the production function as fundamental determinants of output through their influence on human efficiency, adaptability, and productive capacity. Building on the classical Cobb–Douglas production function (Cobb & Douglas, 1928), which models output as a function of capital and labour, contemporary extensions, particularly within the endogenous growth theory, incorporate health as a vital form of human capital that enhances the productivity of labour (Lucas, 1988; Romer, 1990). Grossman's (1972) health capital model formalizes this by positing that individuals invest in health to increase their available time for productive work, thereby improving labour supply and efficiency. In this context, health capital enters the

production function either directly—as a productive input augmenting efficiency, or indirectly, through its effects on labour quality, work capacity, and cognitive performance (Weil, 2014; Bloom, Canning, & Fink, 2014). Empirically, higher life expectancy and health expenditure are associated with improved physical vitality and reduced absenteeism, while lower infant mortality signals healthier population dynamics that sustain a robust workforce (World Bank, 2023; WHO, 2023; Onodugo, Nwonye, Anowor, & Ofoegbu, 2019). Thus, in an augmented agricultural production framework, output depends not only on physical capital (measured by gross fixed capital formation) and labour quantity, but also on the quality of labour embedded in health status, positioning health capital as a productive asset central to agricultural performance and economic transformation in West Africa.

A critical synthesis of empirical studies reveals a complex, multi-scalar relationship between health, labour, and agricultural productivity. At the global level, meta-analyses firmly establish that health investments are significant determinants of labour market outcomes, with a comprehensive review by Grote and Lasser (2024) concluding that evidence firmly establishes the co-benefits of health for labour market outcomes, including productivity and wages. This is often operationalized through health expenditures' impact on population-level health metrics; a panel study of 38 OECD countries by Khan et al. (2023) found that health spending has negative impact on infant mortality, whereas positive on life expectancy" (Khan et al., 2023). However, the efficacy of this conversion from spending to human capital is highly contextual, as research by Farahani et al. (2018) indicates that the returns on public versus private health expenditure vary significantly based on a country's existing health system architecture. Regionally in Sub-Saharan Africa, the agricultural sector's struggle is quantified by a pronounced productivity gap, with the 2025 Global Agricultural Productivity Report highlighting that growth in total factor productivity (TFP) has stagnated well below global targets (Virginia Tech CALS, 2025). Country-specific analyses, such as a study on Pakistan by Yasin et al. (2024), provide direct empirical support for the variables in the proposed model, confirming that both the labour force and gross fixed capital formation are statistically significant drivers of agricultural output. Collaboratively, this empirical landscape confirms the theoretical pathways but underscores a critical gap in targeted panel data analyses for West Africa, where unique institutional and climatic factors may alter the strength and significance of these established relationships.

Despite growing global evidence linking health and labour to agricultural productivity, empirical research in West Africa remains fragmented, sparse, and largely inconclusive regarding their joint influence on agricultural outcomes. Most regional studies have focused narrowly on agricultural inputs such as land, capital, and technology (Ayanwale & Alabi, 2020; Uneze, 2013), while neglecting the synergistic interaction between health capital and labour dynamics as co-determinants of productivity. Existing analyses often treat labour as homogeneous, overlooking how health shocks, morbidity, and demographic shifts alter labour efficiency and farm decision-making (Barrett et al., 2021; Onodugo, Anowor, Ifediora, &

Aliyu, 2019). Moreover, the few available cross-country investigations are limited by short time spans, poor data harmonization, and the exclusion of critical health indicators such as life expectancy and infant mortality (UNDP, 2022; ILOSTAT, 2025). This has constrained nuanced understanding of how improvements in health capital, via enhanced life expectancy or health expenditure, translate into sustained agricultural growth through their effects on labour availability and productivity. Hence, there remains a significant empirical gap in capturing the interdependent mechanisms through which health and labour jointly drive agricultural performance in West Africa.

Empirical research exploring the determinants of agricultural performance in West Africa has predominantly emphasized physical capital and climatic factors, with limited attention to the multidimensional roles of health and labour dynamics (Iyoha, 2004; Uneze, 2013; Onodugo, Anowor, Ofoegbu, 2018). Existing studies often rely on single health indicators, typically health expenditure or life expectancy, thus failing to capture the composite nature of health capital and its indirect effects on labour productivity and agricultural efficiency (Wang, 2011; Batrancea et al., 2021). Moreover, methodological weaknesses, such as short time horizons, inadequate control for endogeneity, and the use of static models, have restricted causal inference and regional generalizability (Doces, 2020). This study bridges these empirical and methodological gaps by integrating multiple health proxies (life expectancy, health expenditure, and infant mortality rate) while explicitly modeling labour dynamics and capital formation. Employing robust panel two-stage least squares across sixteen West African countries (1985–2023), it provides a more comprehensive and causally sound understanding of how health capital and labour jointly shape agricultural performance in the region.

3 Methodology

The theoretical background of this study is derived from the human capital and endogenous growth theories, which hold that investments in education and health augment labour productivity and long-run output growth (Lucas, 1988; Romer, 1990). Within agricultural contexts, improved health capital (proxied by life expectancy, health expenditure, and lower infant mortality) enhances workers' physical capacity, cognitive efficiency, and endurance, thereby increasing productivity on farms (Bloom et al., 2019). Labour dynamics, encompassing both the quantity and quality of the workforce, interact with physical capital accumulation to determine agricultural output (Schultz, 1961). The inclusion of gross fixed capital formation aligns with neoclassical production theory, emphasizing the complementary role of capital in reinforcing human and health-driven productivity gains (Solow, 1956). Thus, this framework integrates health capital, labour efficiency, and physical investment as co-determinants of agricultural performance within a dynamic production structure.

Model specification

The Solow-Swan growth model (Solow 1956) determines that the steady state output per worker is a function of capital intensity and exogenous technological progress, but its agricultural extensions incorporate human capital, particularly health, as a critical augmenting factor to reflect labour quality in low-income agrarian economies. Starting from the baseline augmented Cobb-Douglas form:

$$Y = AK^\alpha L^\beta H^\gamma \text{ -----}$$

(1)

Where Y represents agricultural output, K denotes gross fixed capital formation (e.g., machinery and infrastructure), L signifies labour force inputs, and H captures health capital proxies such as life expectancy (LEXP) and reduced infant mortality rates (INFMR), and A embodies total factor productivity (TFP) influenced by both public and private (out of pocket) health expenditures (HE) as a flow variable that builds H over time; this augmentation accounts for endogenous growth by treating health as an investable stock that enhances labour efficiency and mitigates morbidity-induced losses (Grossman, 1972; Zepeda, 2001).

To operationalize H , we adopted a composite index approach grounded in weighted averaging, but for econometric tractability in panel settings, H is disaggregated into observable indicators:

$$H = f(LEXP, INFMR, HE) \text{ -----}$$

(2)

Substituting and taking natural logarithms to address skewness and enable elasticity interpretation transforms Equation (1) into:

$$\ln Y_{it} = \ln A_{it} + \alpha \ln K_{it} + \beta \ln L_{it} + \gamma \ln H_{it} + \epsilon_{it} \text{ -----}$$

(3)

where the subscripts i and t denote country-specific and year-specific, respectively, ϵ is the stochastic error.

Given West Africa’s average life expectancy of 61.2 years, infant mortality of 49.5 per 1,000 live births, and health expenditure at 4.8% of GDP (World Bank, 2023), this log-linear form accommodates heterogeneity and non-constant returns. To align precisely with the study’s variables and control, the specified model explains the influence of health capital and labour dynamics on agricultural performance across West African countries. Drawing inspiration from the methodological and empirical approaches of several prominent scholars, such as Dauda

(2011), Acemoglu and Johnson (2007), Anowor, Nwonye, Okorie, and Ojiogu (2019), and Eggoh, Houeninvo, and Sossou (2015), the functional form of the model is specified to capture the dynamic interlinkages between health investment, labour productivity, and agricultural output. These studies collectively underscore that health capital, measured through indicators such as life expectancy, total health expenditure, and infant mortality rate, plays a critical role in enhancing labour efficiency and productivity within the agricultural sector. Consequently, the present model provides a framework for examining how improvements in population health and labour dynamics stimulate agricultural performance in West African economies, where agricultural activities remain central to livelihood and growth. Invoking Equation (1):

$$\text{Agric Output} = f(\text{Health capital}, \text{Labour dynamics}, \text{Physical capital}) \text{ -----}$$

(4)

Therefore:

$$\text{AGRQ} = f(\text{LEXP}, \text{INFMR}, \text{HE}, \text{LBF}, \text{GFCF}) \text{ -----}$$

(5)

Where *AGRQ* represents agricultural output; *LEXP*, *INFMR*, and *HE*, capture life expectancy, infant mortality rates, and health expenditures, respectively; *LBF* denotes labour force participation rate, and *GFCF* is gross fixed capital formation.

To fulfill the objectives of this study, and given the linearity assumption underlying the functional relationships among variables, we transform the theoretical production function into an estimable econometric specification, expressed as follows:

$$\ln \text{AGRQ}_{it} = \hat{\omega}_0 + \hat{\omega}_1 \ln \text{LEXP}_{it} + \hat{\omega}_2 \ln \text{INFMR}_{it} + \hat{\omega}_3 \ln \text{HE}_{it} + \hat{\omega}_4 \ln \text{LBF}_{it} + \hat{\omega}_5 \ln \text{GFCF}_{it} + \mu_{it} \text{ -----}$$

- (6)

μ is the stochastic error; $\hat{\omega}_0$ is the intercept of the function, $\hat{\omega}_1$, $\hat{\omega}_2$, $\hat{\omega}_3$, $\hat{\omega}_4$, and $\hat{\omega}_5$ are the slopes.

To empirically estimate the relationship between health capital, labour dynamics, and agricultural performance in West Africa, this study adopts a panel two-stage least squares (2SLS) estimation technique. The choice of this method is premised on its robustness in addressing potential endogeneity, simultaneity bias, and omitted variable problems that are prevalent in cross-country growth and productivity models (Wooldridge, 2019). Health indicators such as life expectancy, infant mortality rate, and total health expenditure are often endogenous to agricultural output, given that agricultural income can, in turn, influence health investment. The 2SLS approach mitigates this reverse causality by employing valid instruments that isolate exogenous variations in the explanatory variables (Baum, Schaffer, &

Stillman, 2003). Moreover, the panel structure of the data (1985–2023) allows the model to capture both within-country dynamics and cross-country heterogeneity across the 16 West African nations, enhancing statistical efficiency and inferential reliability (Hsiao, 2014). Compared to ordinary least squares (OLS) or fixed-effects estimators, panel 2SLS yields more consistent and unbiased estimates when explanatory variables are correlated with the error term. This approach makes it the most appropriate technique for the study’s objective of discerning the causal linkages between health capital accumulation, labour input, and agricultural productivity in the region.

Data Sources and Coverage

The study employs an unbalanced panel dataset covering 16 West African countries over the period 1985–2023, drawing from globally recognized databases to ensure reliability and comparability. Data on agricultural output (measured as the value added in constant 2015 US dollars) are obtained from the World Development Indicators (WDI) of the World Bank (2024). Health capital variables, including life expectancy at birth, total health expenditure (% of GDP), and infant mortality rate (per 1,000 live births), are sourced from the World Health Organization (WHO, 2024) and WDI (World Bank, 2023). Labour force participation rate and gross fixed capital formation are drawn from ILOSTAT (International Labour Organization, 2025) and World Bank (2024), respectively. The use of these sources aligns with prior empirical studies examining macro–micro linkages in development and health productivity (Dauda, 2011; Eggoh et al., 2015; Grossman, 1972). The dataset provides a robust empirical foundation for the application of Panel Two-Stage Least Squares (2SLS) estimation across diverse health and labour contexts in West Africa. To mitigate multicollinearity and endogeneity risks, potential instruments were verified through correlation diagnostics and variance inflation factors (VIFs) prior to the application of the panel Two-Stage Least Squares (2SLS) estimation technique. This rigorous preprocessing ensures the reliability and econometric soundness of subsequent estimations.

The 16 West African countries are Benin, Burkina Faso, Cape Verde, Côte d’Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, and Togo. These countries represent a subregion in Africa, ensuring both linguistic and structural diversity for the empirical estimation of health–labour–agriculture linkages.

4. Results and Discussion

Table 1: Descriptive Statistics

VARIABLE	OBS	MEAN	STD. DEV	MINIMUM	MAXIMUM
AGRQ	194	21.38249	1.642045	19.12713	25.45634
LEXP	190	54.33673	4.736132	45.33300	63.46300

<i>INFMR</i>	195	81.28359	24.61806	34.90000	127.1000
<i>HE</i>	85	5.859420	2.617948	1.701465	12.37359
<i>LBF</i>	145	15.25569	1.509398	12.64000	17.92143
<i>GFCF</i>	189	21.17867	2.337584	13.44459	25.71376

Source: Authors' computation (2025)

The descriptive statistics in Table 1 reveal significant variations in the key variables influencing agricultural performance in West Africa. The infant mortality rate (mean = 81.28) is notably high, reflecting persistent health challenges and weak human capital formation across the region, while life expectancy (mean = 54.34) indicates limited health outcomes that may constrain labour productivity. Agricultural output (mean = 21.38) and gross fixed capital formation (mean = 21.18) suggest moderate investment and production levels, whereas the low mean health expenditure (5.86) highlights chronic underfunding of health systems. The high standard deviation of infant mortality (24.62) and moderate dispersion in life expectancy (4.74) point to wide cross-country disparities in health conditions, in contrast to the relatively stable labour force participation (SD = 1.51) and agricultural output (SD = 1.64). The wide ranges in infant mortality (34.9–127.1) and life expectancy (13.44–63.46) further underscore inequality in social and economic development. Economically, these patterns suggest that disparities in health capital and uneven investment structures are likely to influence labour efficiency and agricultural productivity, validating the use of panel econometric techniques to capture heterogeneity and country-specific effects in the analysis.

Table 2: Panel Unit Roots Test Result

Variable	Level form		First difference	
	Statistic	Prob	Statistic	Prob
<i>AGRQ</i>	-0.91813	0.1793	-13.6956	0.0000
<i>LEXP</i>	-0.05680	0.4774	-3.69014	0.0000
<i>INFMR</i>	-3.50651	0.0002*	-3.75737	0.0001
<i>HE</i>	0.92064	0.8214	-1.49564	0.0274
<i>LBF</i>	-0.69922	0.2422	-8.37173	0.0000
<i>GFCF</i>	-2.41990	0.0078*	-9.32867	0.0000

Source: Authors' computation (2025)

The panel unit root test is justified in this study to ensure the stationarity of variables across the 16 West African countries, given the time-series nature of the dataset spanning 1985–2023. Testing for unit roots prevents spurious regression results and confirms the integration order of the series, which is critical for establishing valid long-run relationships among agricultural output, health_capital, labour-dynamics, and capital formation within a panel framework.

The unit root test results indicate that all variables, except gross fixed capital formation (GFCF) and infant mortality rate (INFMR), were non-stationary at level but became stationary after

first differencing, implying they are integrated of order one, $I(1)$. The labour force variable (LBF), however, remained non-stationary even after first differencing, suggesting potential structural or measurement inconsistencies in labour data across countries. Statistically, the stationarity of variables at first difference, confirmed by probability values below the 0.05 significance threshold, eliminates concerns of spurious regression. Economically, the $I(1)$ nature of most variables suggests that short-run fluctuations in agricultural output, health capital, and investment dynamics may be temporary, while a long-run equilibrium relationship among them is expected. This justifies proceeding with cointegration and panel-based estimation techniques such as the Two-Stage Least Squares (2SLS) approach to capture both short- and long-term linkages between health capital, labour dynamics, and agricultural performance in West Africa.

Panel Johansen-Fisher Cointegration Test

The results of the Panel Johansen-Fisher Cointegration test confirm the presence of a statistically significant long-run relationship among the variables, as indicated by probability values below the 0.05 significance level. This implies that health capital indicators, labour dynamics, and agricultural output in West African countries move together over time toward a stable equilibrium. Economically, this suggests that changes in health expenditure, life expectancy, labour force participation, and capital formation have enduring effects on agricultural performance rather than merely short-term fluctuations, validating the inclusion of these variables in a long-run growth framework.

Long-Run Analysis

Table 3: Long Run Result

Variable	Coefficient	Std. Error	t-Statistic
<i>C</i>	76.81458	8.382509	9.163674
<i>LEXP</i>	-0.191987	0.059309	-3.237076
<i>INFMR</i>	-0.117755	0.014201	-8.292017
<i>HE</i>	0.033650	0.013721	2.452445
<i>LBF</i>	-2.582792	0.566793	-4.556852
<i>GFCF</i>	0.141123	0.045465	3.104011

Source: Authors' computation (2025)

Evidence from the long-run result demonstrates a positive and statistically significant association between gross fixed capital formation (GFCF) and agricultural output in West Africa. This aligns with endogenous growth theory, which posits that private investment in physical capital enhances productivity by facilitating mechanization, irrigation, and storage infrastructure (Romer, 1990). The finding implies that increased capital inflows directly bolster agricultural yields, consistent with panel data analyses in sub-Saharan Africa showing that a

1% rise in GFCF correlates with 0.2–0.4% growth in crop production (Diao et al., 2008). Policymakers should prioritize investment incentives to sustain this momentum.

Conversely, life expectancy exhibits an inverse and significant relationship with agricultural output, contradicting human capital theory, which anticipates healthier populations driving labour efficiency (Becker, 1962). Statistically, this suggests diminishing marginal returns from longevity amid persistent disease burdens, potentially reducing effective workforce participation. The implication underscores the urgency for enhanced medical infrastructure; for instance, vector control and vaccination programs could reverse this by improving worker stamina. Related studies in ECOWAS nations link low life expectancy to malaria prevalence, estimating a 1.2% annual output loss per year of reduced expectancy (Asenso-Okyere et al., 2011).

The labour force participation rate also displays a negative and significant linkage to agricultural output, deviating from neoclassical models predicting positive contributions from labour inputs (Solow, 1956). This indicates underutilization, with excess labour trapped in subsistence activities or urban migration, yielding an elasticity of -0.15 to -0.30 in similar fixed-effects regressions (FAO, 2020). Economically, it highlights structural inefficiencies, skill mismatches, and youth unemployment limiting full employment in high-value agriculture. Interventions like vocational training could optimize labor allocation, mirroring successes in East Africa where participation reforms boosted output by 8–12% (ILO, 2019).

Total health expenditure maintains a positive and significant relationship with agricultural output, supporting the Grossman model of health as productive capital (Grossman, 1972). This reflects moderate fiscal commitments yielding proportional gains, with a 1% expenditure increase linked to 0.3% output rise in pooled OLS estimates for West Africa (World Bank, 2021). It implies sustained but targeted funding (prioritizing rural clinics) could amplify returns, akin to findings in Nigeria where health budgets correlated with 15% productivity uplift (Anyanwu & Erhijakpor, 2009).

Finally, infant mortality rate shows a negative and significant association with agricultural output, consistent with intergenerational human capital transmission theories (Strauss & Thomas, 1998). High rates signal nutritional deficits and maternal health gaps, eroding future labour quality; vector autoregression models estimate a 10-per-1,000 decline in mortality raises long-term output by 0.5–1% (WHO, 2018). This necessitates integrated nutrition-agriculture policies to mitigate demographic drags.

Panel Two-Stage Least Squares

In ensuring the robustness and credibility of the panel Two-Stage Least Squares (2SLS) estimation, several diagnostic and validity tests were conducted to assess the appropriateness of the instruments and the overall model specification. The essence of these diagnostics lies in

addressing the potential endogeneity bias that arises when explanatory variables correlate with the error term, which can distort the consistency of parameter estimates (Wooldridge, 2010; Greene, 2018).

First, Hausman test was conducted to make a case for the use of 2SLS instead of the traditional fixed or random effects estimators. The importance statistics for the tests confirmed the existence of endogeneity as a justification for the need of instrumental variable estimation. Second, Instrument Relevance Test was tested by the first stage of the regression results. The F-statistics in the first stage regression were larger than the rule of the thumb threshold value of 10, indicating adequate lagging of the selected instruments with values of the endogenous regressors and other theoretically justified variables are correlated with the endogenous regressors and thus eliminating weak-instrument bias (Staiger & Stock, 1997).

In addition, the Sargan-Hansen overidentification test was used to determine the validity of the instruments. The very insignificant p-values of this test are the indicators that the instruments are exogenous, i.e., there are no correlations with the error term, and they are suitable for consistent estimation (Baum, Schaffer, & Stillman 2007). Additionally, Wooldridge serial correlation and Breusch-Pagan test against heteroskedasticity were performed to make sure that the residuals were reliable. The absence of serial correlation and heteroskedasticity was observed in the results indicating that the residuals of the model indicate that the model is well behaved and that the estimated coefficients are efficient and unbiased.

Succinctly, these diagnostic outcomes validate the appropriateness of the 2SLS technique in addressing endogeneity concerns and confirm the statistical soundness of the empirical results. Thus, the adopted estimation framework is robust, consistent, and theoretically justified for analyzing the interplay between health capital, labour dynamics, and agricultural performance in West Africa.

Post-Estimation Tests and Model Robustness Checks

Following the estimation of the panel Two-Stage Least Squares (2SLS) model, post-estimation diagnostics and robustness checks were conducted to ensure stability, reliability, and internal consistency of the results. The Wald test was first employed to examine the joint significance of the estimated coefficients. The significant Wald statistic ($p < 0.05$) confirmed that the explanatory variables jointly exert a meaningful influence on agricultural output, thereby reinforcing the validity of the model's structural specification (Gujarati & Porter, 2009). In addition, the Ramsey RESET test was conducted to verify functional form adequacy and model specification errors. The statistically insignificant result of the test suggests that the model is correctly specified, free from omitted variable bias and non-linearity, ensuring that the relationships among health capital, labour dynamics, and agricultural productivity are properly captured (Wooldridge, 2010). To further verify model stability, robustness checks were

performed through alternative model estimations, including fixed and random effects regressions, which yielded consistent coefficient signs and significance levels. This consistency underscores the robustness of the 2SLS results to alternative specifications and estimation techniques (Baltagi, 2021). Additionally, the use of heteroskedasticity-robust standard errors mitigated potential bias in statistical inference, confirming the efficiency and reliability of the results. Evidently, the convergence of confirmation from these post-estimation and robustness tests validates the empirical strength of the model, affirming that the estimated parameters are both economically and statistically sound for policy interpretation within the West African agricultural context.

Model Stability and Sensitivity Analysis

The robustness of the 2SLS estimates was assessed through model stability and sensitivity analyses to ensure the reliability of the relationships between health capital, labour dynamics, and agricultural output. CUSUM and CUSUMSQ tests confirmed the constancy of coefficients over time, indicating the absence of structural breaks and validating parameter stability (Brown, Durbin, & Evans, 1975). Additionally, sensitivity checks, including alternative model specifications and the substitution of health proxies such as child mortality for infant mortality, yielded consistent coefficient signs and significance levels, demonstrating that the results are not driven by outliers or variable definitions (Baltagi, 2021; Wooldridge, 2010). In line with economic interpretations, these analyses underscore that gross fixed capital formation and health expenditure consistently enhance agricultural productivity, while underutilized labour and adverse health outcomes constrain output in West Africa. All things considered, stability and sensitivity assessments reinforce the credibility of the empirical findings and their policy relevance for regional agricultural development.

5. Policy Implications

The findings of this study carry profound policy implications for enhancing agricultural productivity and economic development in West Africa. The positive and significant impact of gross fixed capital formation and health expenditure on agricultural output underscores the need for targeted investment in agricultural infrastructure, mechanization, and healthcare systems to improve labour efficiency and reduce morbidity-related productivity losses (Grossman, 1972; Zepeda, 2001). Conversely, the negative and significant associations of life expectancy, labour force participation rate, and infant mortality with agricultural output highlight systemic underutilization of human capital and persisting health vulnerabilities, signaling the urgency for policies that enhance labour market engagement, access to quality healthcare, and preventative interventions to reduce infant and child mortality (Acemoglu & Johnson, 2007; Dauda, 2011; Eggoh, Houeninvo, & Sossou, 2015). Policymakers should therefore adopt an integrated framework that simultaneously invests in health, capital formation, and labour mobilization, ensuring that human and physical capital complement each

other to optimize agricultural productivity. Additionally, the study emphasizes the importance of evidence-based health and labour policies tailored to country-specific dynamics, including enhanced health financing, skill development programs for agricultural labour, and incentives for private-sector participation in agriculture, thereby fostering sustained economic growth and food security in the region (Anowor, Nwonye, Okorie, & Ojiogu, 2019; World Bank, 2022). In essence, these findings advocate for a holistic policy approach, recognizing that agricultural performance is contingent not only on capital investments but also on the effective deployment of healthy and productive labour.

6. Conclusion and Policy Recommendations

This study employs a robust panel Two-Stage Least Squares (2SLS) estimation framework covering sixteen West African countries from 1985 to 2023 to provide rigorous empirical evidence on the interconnections among health capital, labour dynamics, and agricultural performance. The choice of this econometric approach ensures the correction of potential endogeneity and enhances the reliability of causal inferences, producing consistent and unbiased estimates of the determinants of agricultural productivity. The empirical findings reveal that gross fixed capital formation and total health expenditure exert positive and statistically significant effects on agricultural output. This outcome underscores the crucial role of both physical and health capital accumulation in driving productivity, in alignment with the augmented Solow-Swan growth model and the human capital theory (Grossman, 1972; Zepeda, 2001). Conversely, life expectancy, labour force participation rate, and infant mortality exhibit negative yet significant associations with agricultural performance, implying that structural inefficiencies in labour utilization and persistent health challenges undermine the sector's productive capacity. These findings correspond with prior evidence emphasizing the complementary roles of health and labour quality in enhancing economic growth and agricultural efficiency (Acemoglu & Johnson, 2007; Dauda, 2011; Eggoh, Houeninvo, & Sossou, 2015).

The policy implications of these results are profound. They call for an integrated development agenda that simultaneously strengthens healthcare systems, promotes inclusive labour market participation, and fosters sustained capital deepening in agriculture. West African policymakers should prioritize targeted investments in healthcare infrastructure, agricultural mechanization, and skill development for rural labour forces. Equally, strategic interventions to reduce infant and child mortality can generate long-term productivity gains by improving labour quality and demographic resilience. Supported by rigorous diagnostic checks and model stability assessments, the study's findings offer credible, data-driven insights that can inform evidence-based policymaking. Ultimately, this study advocates for a holistic policy framework that recognizes agricultural transformation as a cumulative outcome of synergistic investments in health, labour, and physical capital, forming the foundation for sustained productivity growth, food security, and inclusive economic advancement across West Africa.

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