The Causal Linkage between Agriculture, Industry, and Service Sectors in Sub-Saharan Africa: Application of Panel CS-ARDL

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Abstract
This study examines the relationships among agriculture, service, and industry sectors in Sub-Saharan Africa (SSA) using panel data from 49 countries, drawn from the UNECA database for the period 1980–2023. The CS-ARDL model was employed to assess both short- and long-run linkages. The findings revealed that all sectors experience significant short-run shocks, with negative effects from contemporaneous and early lagged values. In contrast, the significant error correction terms indicate a strong adjustment toward the long-run equilibrium. Agriculture benefits positively and significantly from services and industry in the long run, whereas the long-run effects on these sectors are largely insignificant. Lagged effects reveal delayed intersectoral spillovers, highlighting the potential for sectoral complementarities. At the same time, weak long-run integration underscores the need for policies to strengthen intersectoral linkages and support sustainable structural transformation. The study recommends that policies should focus on strengthening linkages between agriculture, services, and industry, while promoting sectoral diversification and agricultural productivity through technology, infrastructure, and human capital development. Furthermore, short-run shock mitigation measures such as safety nets and market stabilisation are essential to maintain stability and support sustainable long-term growth.

Keywords: *Intersectoral Linkages, Sub-Saharan Africa, Panel CS-ARDL*

INTRODUCTION

The relationship between the agricultural sector and industrial growth has long been a central theme in development literature. Integrating agricultural and industrial processes enhances productivity by strengthening value chains and fostering backward and forward linkages (Ye, 2023). In many developing countries, however, incentives and public investment remain biased toward manufacturing, effectively placing a disproportionate burden on agriculture to support industrial expansion (Anderson & Ponnusamy, 2023).

Hirschman's theory of unbalanced growth, as applied in studies of Nigeria and other countries, describes how agriculture serves as a source of raw materials for industry, while the industrial sector benefits from backward linkages by supplying inputs and technologies (Osuagwu, 2020). Conventional studies on agriculture–industry linkages usually consider agricultural performance as externally determined and industrial performance as internally driven, suggesting a unidirectional transfer of resources toward industry and urban areas. The observed trend was primarily due to constrained market and trading opportunities in low-income agrarian economies, coupled with their predominant focus on subsistence-oriented food production (Barrett et al., 2022).

Aboobaker (2024) explores how income growth and changing consumption patterns influence sectoral linkages. The study suggests that as income rises, the demand for food increases at a slower rate compared to non-food goods and services, leading to a shift in intersectoral linkages. Instead of merely being a resource supplier, agriculture, through technological modernisation, can enhance productivity in land, labour, and capital. This shift allows the sector to stimulate industrial and service activities by creating demand for intermediate inputs and, in open economies, by generating foreign exchange through exports to finance critical industrial imports (Barrett et al., 2022). Consequently, agriculture should be seen as both a driver and a beneficiary of industrial growth, providing dynamic demand and supply-side linkages that can accelerate overall economic transformation (Barrett et al., 2022).

This interdependence aligns with Hirschman's theory of unbalanced growth, which emphasises the importance of sectoral linkages in stimulating economic development. According to Hirschman (1958), sectors with the strongest linkages, measured by their direct and indirect purchases and sales, are best positioned to spur production and employment growth. Agriculture and industry exemplify this mutual dependence: Agriculture supplies food and raw materials to industry, while industry provides inputs such as fertilisers, pesticides, and machinery to agriculture (Gollin, 2023). These relationships can be understood as backward linkages, in which a sector relies on other sectors for inputs, and forward linkages, in which it distributes its outputs to the broader economy (Gollin, 2023).

The importance of agriculture in Africa has been underscored by policy commitments, such as the African Union's Maputo Declaration of 2003, which established the Comprehensive Africa Agriculture Development Programme (CAADP) to target a 6% annual growth in agricultural output and enhance food security (Africa Agriculture Status Report 2023). This

agenda was reinforced by the Malabo Declaration of 2014, which committed to eliminating hunger by 2025, and by the 2030 Agenda for Sustainable Development, which emphasises ending hunger, achieving food security, improving nutrition, and promoting sustainable agriculture (Sakho-Jimbira & Hathie, 2020).

Although agriculture's contribution to GDP has declined over time, it remains a key economic activity in Sub-Saharan Africa (SSA). It is essential for poverty reduction, food security, employment, and economic growth, particularly in rural areas (WB, 2023). The decline in agriculture's GDP share reflects the development of other sectors rather than poor performance, signalling early stages of structural transformation (WB, 2023). Nevertheless, agriculture, contributing about 23% to SSA's GDP, has not yet reached its full potential, and food insecurity has been on the rise since 2014 (Rege & Sones, 2022). Notably, in 2023, Sierra Leone and Niger recorded the highest agricultural contributions to GDP in SSA at 64.4% and 47.8%, respectively (WB, 2023).

Meanwhile, the service sector has become the fastest-growing sector globally, driving economic growth and boosting the performance of other sectors such as manufacturing (Roza et al., 2023). In SSA, services now account for the largest share of GDP, supported by industries such as banking, telecommunications, tourism, and retail. The expansion of mobile technology has revolutionised financial services, providing access to banking for previously unbanked populations. At the same time, tourism - although disrupted by the COVID-19 pandemic- remains a significant revenue source for several countries (WB, 2024). By 2023, the service sector accounted for 44.4% of SSA's GDP, surpassing both agriculture and industry. São Tomé and Príncipe and Cabo Verde led with figures of 79.0% and 70.6%, respectively (WB, 2024).

The industrial sector has shown uneven growth across SSA. While countries such as Ethiopia and Kenya have made significant investments in manufacturing and infrastructure, boosting output and job creation, other countries continue to face challenges linked to infrastructure gaps and political instability (WB, 2024). The sector, which includes mining, manufacturing, and construction, contributed 27.4% to SSA's GDP in 2023, higher than agriculture's share. Gabon recorded the most significant industrial contribution at 52.9%, followed by Equatorial Guinea at 51.2% (WB, 2024).

Figure 1 illustrates the contribution of agriculture, industry, and services to SSA's GDP from 2013 to 2023 (UNECA, 2024). The trends show

fluctuations across all three sectors, with services consistently dominating GDP shares, followed by industry and then agriculture. Agriculture's contribution rose slightly from 15.1% in 2013 to 17.2% in 2023, while industry's share fell marginally from 28.2% to 27.4%. Services, in contrast, declined from 51.1% to 44.4% over the same period (WB, 2024). The contraction in services' share reflects factors such as economic diversification, structural change, global conditions, technological shifts, and external shocks. These sectoral shifts indicate that SSA is gradually transforming from agriculture to industry and, eventually, to services, reflecting development trajectories similar to those observed in Asia's emerging economies.

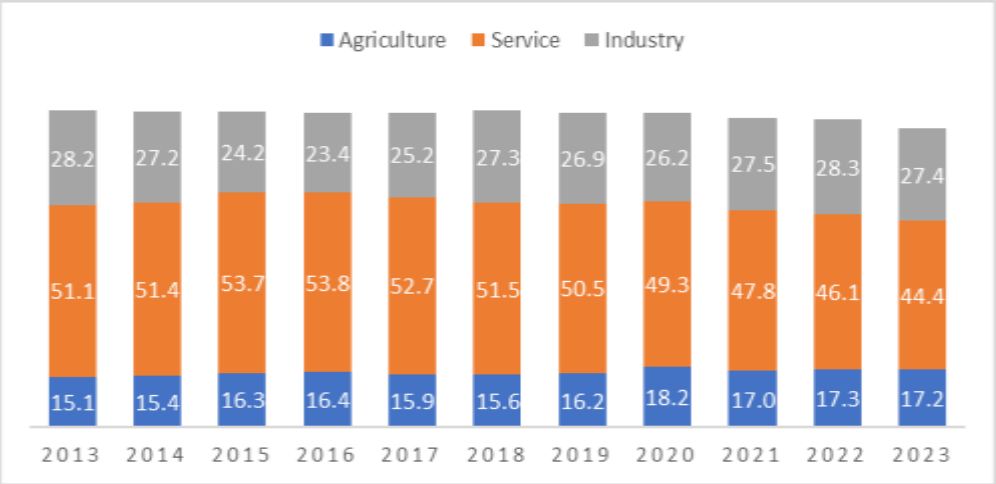

Figure 1: Percentage contribution to GDP of three major sectors in SSA countries
Source: UNECA database(2024)

The Intersectoral Linkage Theory, proposed by Hirschman (1958), posits that the strength of linkages among productive sectors propels economic development. According to the theory, a backward linkage arises when a sector stimulates upstream industries through demand for inputs, such as agricultural needs for fertilisers, machinery, and transport services. At the same time, a forward linkage occurs when the outputs of one sector serve as essential inputs for other industries, for example, agricultural raw materials used in manufacturing and agro-processing. These interactions generate multiplier effects that spread growth throughout the economy, suggesting that structural transformation depends on the degree to which sectors are integrated and mutually reinforcing.

Empirical studies have built upon Hirschman's theoretical foundation by analysing sectoral linkages across various economies. Roza et al. (2023),

employing input–output analysis in Southeast Aceh Regency, Indonesia, identified agriculture, mining, and manufacturing as sectors with strong backward linkages, while trade and services displayed robust forward linkages. In Nigeria, Osuagwu (2020) and Kelikume and Nwani (2020) applied Granger causality and vector autoregressive models, revealing bidirectional relationships between agriculture and manufacturing, highlighting mutual interdependence. Similarly, Degu (2019) found long-run equilibrium and causality among agriculture, industry, and services in Ethiopia, suggesting that intersectoral integration contributes to sustained growth.

Contrasting results emerge from other contexts. Asim and Akbar (2019) and Varkey and Panda (2018) reported mixed intersectoral effects, noting that industrial growth sometimes exerted negative pressure on agriculture, while service sector performance showed variable impacts across regions. Gollin (2023) emphasised agricultural productivity as a catalyst for structural transformation in Africa. In contrast, Anderson and Ponnusamy (2023) analysed more than 130 open economies and found that shifts away from agriculture depend on trade structures and endowments rather than policy differences. Yei (2023), examining China, demonstrated that rural industrial integration enhances agricultural total factor productivity through technological progress and efficiency improvements, further supporting the intersectoral linkage hypothesis.

Despite extensive research on structural transformation, existing studies in SSA reveal both theoretical and methodological limitations. Theoretically, Hirschman's (1958) Intersectoral Linkage Theory emphasises the interdependence between agriculture and industry but largely overlooks the growing influence of the service sector and technological innovation in shaping modern economic structures. In SSA, transformation patterns increasingly exhibit a services-led trajectory, reflecting shifts driven by digitalisation, finance, and information technology dynamics that the original framework fails to capture. Methodologically, previous empirical studies have often relied on static or time-series approaches that inadequately address key econometric issues such as cross-sectional dependence, heterogeneity, and endogeneity across countries.

To address these gaps, this study applies a panel analysis of 49 SSA countries using the Cross-Sectionally Augmented ARDL (CS-ARDL) model developed by Chudik and Pesaran (2015). This approach distinguishes between short- and long-run sectoral linkages while accommodating varying levels of variable stationarity and cointegration. Integrating the service sector

into the theoretical framework and employing a more robust econometric method, the study seeks to provide deeper insights into the causal interrelationships among agriculture, industry, and services in SSA, thereby extending both the theoretical and empirical understanding of structural transformation.

METHODOLOGY

Research Philosophy

Research philosophy refers to the underlying framework that guides how research is conceptualised and conducted, particularly in terms of assumptions about the nature of reality and the nature of knowledge (Collis & Hussey, 2014). This study adopted a post-positivist research philosophy, which is based on the assumption that truth is objective and can be understood through observable and measurable facts independent of the researcher's personal beliefs or interpretations.

The approach was considered appropriate for this study because the analysis relied on panel data obtained from the United Nations Economic Commission for Africa (UNECA) database. The use of panel data, which comprises multiple observations over time across different countries, requires objective, quantitative methods for analysing trends, relationships, and causal effects. It aligns with the post-positivist emphasis on empirical observation, statistical measurement, and hypothesis testing.

Moreover, the study employed a quantitative research design, using structured data collection methods and statistical techniques, such as panel regression analysis, to establish relationships between variables. These methods reflect the post-positivist belief in the scientific method as the basis for knowledge generation. As Žukauskas et al. (2018) note, post-positivism views the researcher as a neutral analyst who works independently of the data and whose role is to uncover facts through systematic analysis.

Research Design

This study adopted a quantitative panel research design to examine the dynamic interrelationships among the agriculture, industry, and service sectors in 49 Sub-Saharan African (SSA) countries covering the period 1980–2023. The design was suitable for capturing both cross-country variation and temporal dynamics, enabling a comprehensive understanding of structural transformation patterns across the region.

Sub-Saharan Africa is well-suited for studying intersectoral linkages among agriculture, industry, and services because it remains heavily dependent on

agriculture while undergoing a gradual structural transformation. Agriculture employs over half of the labour force, yet weak linkages with industry and services constrain value addition and balanced growth (World Bank, 2024; Sakho-Jimbira & Hathie, 2020).

The study employed a Cross-Sectionally Augmented Autoregressive Distributed Lag (CS-ARDL) model developed by Chudik and Pesaran (2015). This approach was particularly appropriate for macro-panel data, as it accounts for cross-sectional dependence, heterogeneity, and potential endogeneity among variables, common issues in multi-country analyses. The CS-ARDL framework further allows for the distinction between short-run and long-run linkages, providing insights into both immediate sectoral responses and long-term structural adjustments.

Data for the analysis were obtained from reputable secondary sources, primarily the United Nations Economic Commission for Africa (UNECA) database (https://ecastas.uneca.org/data/). The key variables included value-added contributions of agriculture, industry, and services to GDP.

The analysis followed a systematic sequence, starting with descriptive statistics and panel diagnostic tests, which included checks for stationarity, cointegration, and cross-sectional dependence, before estimating the CS-ARDL model. This design ensured methodological rigour and enhanced the robustness and validity of the study's findings, enabling meaningful policy implications on the role of intersectoral linkages in driving structural transformation across SSA.

Data Validity and Reliability

To ensure validity, the study used data from the United Nations Economic Commission for Africa (UNECA), a reputable and authoritative source that provides standardised, internationally comparable macroeconomic and sectoral indicators. The source ensured that measures of agriculture, industry, and service-sector value-added are consistent across countries and over time. The use of official statistics enhanced content validity, as the variables accurately reflected the constructs of interest in economic structural transformation.

Reliability was ensured through consistent data collection, measurement, and reporting methods across countries and time periods. The panel dataset spans 49 SSA countries, providing a sufficient sample to minimise measurement errors and improve the stability of empirical estimates. Further, the use of the Cross-Sectionally Augmented ARDL (CS-ARDL) framework allowed the

study to control for cross-sectional dependence, heterogeneity, and endogeneity, reducing potential biases and improving the reproducibility of results. Moreover, all variables were checked for stationarity using the second-generation unit root, ensuring that the data series used in the model produced robust and reliable estimates.

Furthermore, combining high-quality data sources with rigorous econometric techniques, this study ensured that both the validity and reliability of the findings are maintained, supporting sound conclusions regarding intersectoral linkages in SSA.

Variable Selection

The study focused on three key sectors, namely, agriculture, industry, and services, as the primary drivers of economic structural transformation in Sub-Saharan Africa (SSA). The selection of these variables was grounded in Intersectoral Linkage Theory (Hirschman, 1958), which emphasised the importance of forward and backward linkages among sectors in fostering economic growth. Focusing on these three sectors, the study provided a comprehensive and theory-driven framework to analyse the dynamic interactions among agriculture, industry, and services, and their collective role in SSA's economic transformation.

Table 1: Definition of the variables

Variable Name	Unit	Definition
Dependent Variable		
Independent Variables		
Agriculture Share of GDP at Current Price	%	Refers to the percentage contribution of the agriculture sector (crops, livestock, forestry, and fishing) to the total GDP measured at constant prices (real terms)
Service Share to GDP at Current Price	%	The percentage contribution of the services sector (Wholesale and retail trade, Transport, storage, and communications, Accommodation and food services, Information and communication (ICT), Financial and insurance activities, real estate, professional, scientific, and technical services, public administration and defence, education, health, and social work, arts, recreation, and other service activities) to total GDP at constant prices.
Industry Share to GDP at Current Price	%	The percentage contribution of the Industrial sector (Mining and quarrying, Manufacturing, Electricity, gas, steam, and air conditioning supply, Water supply, sewerage, waste management, and construction) to total GDP at constant prices

Source: UNECA database (2024)

Panel Data Quality Tests

To account for interdependencies among the 49 Sub-Saharan African countries, the study first tested for cross-sectional dependence using Pesaran's CD test (2021) and Frees' test (1995), both of which confirmed significant reliance. In response, a second-generation panel unit root test was employed, specifically the CIPS (Cross-sectionally Augmented Im-Pesaran-Shin) test developed by Pesaran et al. (2013), which accounts for cross-sectional correlations. Optimal lag lengths were determined using information criteria to ensure accurate dynamic modelling. These procedures provided a robust and reliable assessment of stationarity, forming a solid foundation for analysing both short- and long-run intersectoral linkages among agriculture, industry, and services.

Theoretical Model Specification

The study conceptualised the interrelationships among agriculture, industry, and services within the framework of intersectoral linkage theory (Hirschman, 1958). The model assumes that the growth of each sector is influenced by both its own dynamics and the interactions with the other two sectors, capturing forward and backward linkages.

$$AS_{it} = f(SS_{it}, IS_{it}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$SS_{it} = f(AS_{it}, IS_{it}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$IS_{it} = f(AS_{it}, SS_{it}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where:
AS_{it} = Agriculture share of GDP in country i at time t
IS_{it} = Industry share of GDP in country i at time t
SS_{it} = Service share of GDP in country i at time t

Model Specification

To examine the short- and long-run relationships among the agriculture, service, and industry sectors in Sub-Saharan Africa, the study specified a dynamic panel model in which the dependent variable is the log of one sector and the independent variables are the logs of the other sectors. Given the presence of cross-sectional dependence, heterogeneity across countries, and potential endogeneity of lagged variables of one sector, the model was estimated using the Cross-Sectionally Augmented ARDL (CS-ARDL) approach proposed by Chudik and Pesaran (2015).

The CS-ARDL model can be expressed as follows:

$$\Delta Iny_{it} = \alpha_i + \sum_{i=1}^{p} \varphi_{it} \Delta Iny_{i,t-k} + \sum_{k=0}^{q} \beta_{1,ik} \Delta Inx_{1_{i,t-k}} + \sum_{k=0}^{q} \beta_{2,ik} \Delta Inx_{2_{i,t-k}} + \emptyset_i \left(Iny_{i,t-1} - \theta_{1,i} Inx_{1_{i,t-1}} - \theta_{2,i} Inx_{2_{i,t-1}} \right) + \varepsilon_{it} \quad (4)$$

Where:
$i = 1,2,3, \ldots\ldots, N$ indexes countries and $t = 1,2,3, \ldots\ldots, T$ indexes times,
Δ denotes first differences,
α_i is the country-specific fixed effect
φ_{it} captures the short-run dynamics of the dependent variable
$\beta_{j,ik}$ are the short-run effects of independent variables at lag k
The term in parentheses is the Error Correction Term (ECT) with $\emptyset_i$ measuring the speed of adjustment toward the long-run equilibrium
$\theta_{j,i}$ represent the long-run coefficients of independent variables (sector contributions)
e_{it} is the idiosyncratic error term.
This specification allowed for capturing both short-run dynamics and long-run relationships, while controlling for cross-sectional dependence via country averages of the variables.

Ethical Consideration

Research ethics and standards were constantly observed while undertaking the study. Research ethics are necessary measures to ensure that issues of anonymity, informed consent, avoidance of deception and harm, and confidentiality are observed as much as possible. Since this study used time-series secondary data from the Economic Commission of Africa Database (https://ecastas.uneca.org/data/), the researcher adhered to ethical considerations for research involving secondary data by providing a link to the data source for reference.

RESULTS AND DISCUSSION

Summary Statistics

Table 1 presents the summary statistics of the study variables used in the regression estimations. Although agriculture has historically played a vital role in the economies of Sub-Saharan African countries, the findings in Table 1 indicate that the service sector contributes the most to economic output, followed by the industry sector, with the agricultural sector lagging. On average, the agricultural sector's value is approximately USD 24.91 million per country, ranging from a maximum of USD 80.51 million to a minimum of USD 0.89 million (Table 1). These figures highlight the relatively modest scale of agricultural output compared to services and industry, despite

agriculture being a key source of livelihoods for the majority of SSA's population (WB, 2024). Moreover, the findings reveal that the values of the service, agriculture, and industry sectors are all positively skewed, suggesting that in most SSA countries, sectoral contributions lie below the computed averages for these variables.

Table 2: The Descriptive Statistics of the Study Variables

Variable	Obs.*	Mean	Std. dev.	Min	Max	Skewness
Agriculture (AS)	2,115	24.65	15.85	0.89	80.51	0.65
Service (SS)	2,112	49.31	12.90	6.44	87.09	0.24
Industry (IS)	2,115	25.73	12.67	0.27	83.80	1.23

Source: UNECA database (2024)
[*The difference in the number of observations is due to data gaps in some panels]

Optimal Lag Selection Results

Table 2 presents the results of optimal lag selection, based on the three modified information criteria: MAIC, MBIC, and MQIC. The findings indicate that all three criteria consistently identified lag three as the optimal lag length for the estimation analysis. The result suggests that incorporating three lag periods adequately captured the dynamic relationships among the study variables, while balancing model fit and complexity. The agreement across the three criteria enhances the robustness of the lag selection, providing greater confidence in the subsequent panel data estimations. This approach aligns with standard econometric practice in dynamic panel data analysis, as recommended (Chudik & Pesaran, 2015). Empirical applications in agricultural and sectoral studies have similarly used multi-lag specifications to capture delayed effects and dynamic spillovers (Degu, 2019; Kelikume & Nwani, 2020; Asim & Akbar, 2019), reinforcing the appropriateness of the selected lag length for robust inference.

Table 3: Selection Order Criteria Results

Lag	CD	J	J p-value	MBIC	MAIC	MQIC
1	0.9996507	41.79731	0.034461	727.7138	-161.5691	-67.23799
2	0.9996401	21.20276	0.269307	747.3285	-114.3748	-51.48744
3	0.9996636	9.65458	0.379165	611.4021	-8.34542	-26.69052
4	0.9996383					

Source: UNECA database (2024)

Panel Cross-sectional Dependence Test of the Study Variables

Table 3 presents the results of panel cross-sectional dependence tests for the study variables: Agriculture, Service, and Industry sectors. The analysis estimates Cross-sectional Dependence (CD) to determine whether 49 SSA countries are interdependent, a crucial step in selecting the appropriate

estimation model for the data. Two different methods were employed to test for cross-sectional dependence: Pesaran's CD test and Frees' test.

The findings in Table 3 provide evidence of correlation among the agriculture, service, and industry sectors in SSA countries. Both methods used to test for panel cross-sectional dependence are statistically significant at the 1% level, indicating that shocks in one sector are likely to affect the others. This outcome aligns with theoretical expectations of strong intersectoral linkages in developing economies, where agriculture, industry, and services are mutually dependent for inputs, labor, and market demand (Anderson & Ponnusamy, 2023).

Empirical studies similarly report significant cross-sectoral interactions: for example, Degu (2019) finds short-run crowding-out and delayed complementarities between agriculture and non-agricultural sectors in Ethiopia, while Bashir et al. (2019) and Quddus (2021) observe interdependencies among agriculture, industry, and services in Indonesia and Bangladesh, respectively. The results underscore the importance of accounting for cross-sectional dependence in panel estimations to obtain consistent and efficient parameter estimates (Pesaran, 2021; Chudik & Pesaran, 2015).

Table 4: Panel Cross-sectional Dependence Test of the Study Variables

Test	Statistic	Probability
Pesaran CD	21.873	0.0000
Frees	6.287	0.0000
	alpha = 0.10: 0.1841	
	alpha = 0.05: 0.2431	
	alpha = 0.01: 0.3603	

Source: UNECA database (2024)

Panel Unit Root Test of the Study Variables

Table 4 presents the results of the panel unit root tests for the study variables: Agriculture, Service, and Industry sectors. (The study employed second-generation panel unit root tests, specifically the Cross-sectionally Augmented Im, Pesaran, and Shin (CIPS) test, to determine the order of integration for these variables across 49 SSA countries. These tests are crucial in the presence of cross-sectional dependence, as they enhance the reliability of stationarity assessments and guide the selection of appropriate estimation models in panel data analysis.

The results in Table 4 indicate that agriculture is non-stationary at the level, whereas the service and industry sectors are stationary. However, agriculture

becomes stationary after first differencing. The panel unit root test results suggest that all variables were integrated of order one (I (1).

The findings mirror earlier studies showing that agriculture in developing economies is more volatile due to structural and climatic factors (Degu, 2019; Kelikume & Nwani, 2020; Asim & Akbar, 2019; Gollin, 2023). In contrast, industrial and service sectors show greater stability, consistent with Anderson and Ponnusamy (2023), while Ye et al. (2023) noted that technological integration in China helped reduce agricultural volatility

Table 5: CIPS Panel Unit Root Test of the Study Variables

	Level			First Difference		
Variable	**Test Statistic**	**P-Value**	**Lag**	**Test Statistic**	**P-Value**	**Lag**
InAS	-0.3997	0.3447	3	-25.9001	0.0000	3
InSS	-3.1651	0.0008	3	-	-	-
InIS	-2.5881	0.0048	3	-	-	-

Source: UNECA database (2024)

Panel CS-ARDL Estimation of Three Models for 49 SSA countries

The Panel CS-ARDL estimation was applied to examine the dynamic relationship between the agriculture sector (AS), the service sector (SS), and the industrial sector (IS) across 49 Sub-Saharan African countries.

Table 5 shows the short- and long-run interactions among agriculture, industry, and service sectors. In agriculture, the first- and second-order lags are negative and significant. At the same time, short-run effects from services and industry are also negative, indicating immediate suppression of agricultural output, consistent with Degu (2019) and Varkey and Panda (2018). Positive and significant lagged effects of services (first and third lags) suggest delayed benefits, supporting the findings of Kelikume and Nwani (2020) and Asim and Akbar (2019). The significant ECT (1.603) indicates a strong adjustment toward the long-run equilibrium, in line with Uddin (2015).

For services, all three lags are negative and statistically significant, indicating persistent internal shocks. Agriculture and industry negatively affect services in the short run, consistent with Bashir et al. (2019) and Quddus (2021). Lagged effects are mixed, with the first and third lags of agriculture and industry being positive, highlighting delayed complementarities. The ECT (–1.815) shows rapid convergence, consistent with Roza et al. (2023).

In the industry, contemporaneous effects of agriculture and services are negative, while lagged effects reveal positive spillovers (first and third lags of

agriculture; first lag of services), suggesting delayed benefits. Insignificant service lags indicate minimal internal persistence. The ECT (–1.205) confirms stable long-run adjustment, aligning with Osuagwu (2020), Gollin (2023), and the structural transformation framework of Anderson and Ponnusamy (2023) and Aboobaker (2024).

Table 6: Panel CS-ARDL Estimation Results for Three Models

Model 1: Agriculture		**Model 2: Service**		**Model 3: Industry**	
	Coefficient		**Coefficient**		**Coefficient**
Short Run Est.		**Short Run Est.**		**Short Run Est.**	
Mean Group:		Mean Group:		Mean Group:	
LD. InAS	-0.283**	LD. InSS	-0.376**	LD. InIS	-0.056
L2D.InAS	-0.302**	L2D.InSS	-0.351**	L2D.InIS	-0.174
L3D.InAS	-0.018	L3D.InSS	-0.088*	L3D.InIS	0.025
InSS	-1.363**	InAS	-0.506**	InSS	-1.401**
InIS	-0.773**	InIS	-0.480**	InAS	-0.973**
L.InSS	1.095**	L.InAS	0.297**	L.InAS	0.696**
L2. InSS	0.319	L2. InAS	0.015	L2. InAS	-0.056
L3. InSS	0.494**	L3. InAS	0.205**	L3. InAS	0.320*
L.InIS	0.606**	L.InIS	0.275**	L.InSS	1.512**
L2. InIS	0.130	L2. InIS	-0.022	L2. InSS	-0.192
L3. InIS	0.308**	L3. InIS	0.188**	L3. InSS	0.207
Adjust. Term		**Adjust. Term**		**Adjust. Term**	
Mean Group:		Mean Group:		Mean Group:	
lr_InAS	-1.603**	lr_InSS	-1.815**	lr_InIS	-1.205**
Long Run Est.		**Long Run Est.**		**Long Run Est.**	
Mean Group:		Mean Group:		Mean Group:	
lr_InIS	0.229*	lr_InAS	0.025	lr_InAS	0.123
lr_InSS	0.611*	lr_InIS	-0.002	lr_InSS	0.108

Source: UNECA database (2024)
[* and ** indicate that coefficients are significant at 5% and 1% respectively].

In the long run, agriculture benefits significantly from both the service and industry sectors. Its effects on services are positive but insignificant, while the impact of industry on services is negative and insignificant. Similarly, agriculture and services have positive but statistically insignificant effects on

industry. These results indicate strong short-run interdependencies but weak long-run integration in Sub-Saharan Africa (SSA), with agriculture showing relatively stronger linkages than other sectors.

The negative contemporaneous effects across all sectors reflect short-run disequilibria due to shocks such as climate variability, commodity price fluctuations, and supply chain disruptions. Nevertheless, significant negative ECTs across models demonstrate robust adjustment mechanisms that restore equilibrium, highlighting SSA's sectoral resilience. Positive and significant lagged effects reveal delayed complementarities, with agricultural growth stimulating industry through agro-processing and raw materials, and service-sector expansion enhancing productivity through logistics, finance, and communication (Kelikume & Nwani, 2020; Degu, 2019; Asim & Akbar, 2019).

Evidence from other regions supports these dynamics: backward and forward linkages in Southeast Aceh (Roza et al., 2023), bidirectional agriculture–industry relationships in Nigeria (Osuagwu, 2020; Kelikume & Nwani, 2020), and rural industrial integration in China, boosting agricultural productivity (Ye et al., 2023). Contrasting findings highlight context-specific effects of industrial expansion on agriculture (Asim & Akbar, 2019; Varkey & Panda, 2018), with productivity and structural shifts shaped by factor endowments, trade patterns, and technology (Gollin, 2023; Anderson & Ponnusamy, 2023). These results underscore the central role of intersectoral linkages in driving structural transformation and sustainable growth in SSA.

CONCLUSION AND RECOMMENDATIONS

This study concludes that all sectors face significant short-run shocks, yet robust error correction terms confirm strong adjustment toward the long-run equilibrium. Agriculture benefits positively and significantly from services and industry in the long run, whereas the long-run effects on these sectors remain weak and insignificant, highlighting limited structural integration. Strengthening intersectoral linkages, promoting diversification, and improving infrastructure and technology are therefore essential to support sustainable structural transformation in the region.

Based on these findings, the study recommends that strengthening intersectoral linkages among agriculture, industry, and services, particularly through agro-processing initiatives, is essential for sustainable structural transformation in Sub-Saharan Africa. Enhancing agricultural productivity through modern technology, irrigation, and digital supply platforms can boost efficiency. Meanwhile, diversifying production toward high-value, export-

oriented crops, along with supportive service activities, can create lasting sectoral linkages.

Policymakers should provide targeted investment incentives, subsidies, and tax breaks to promote agro-industrial development. Improving infrastructure, such as roads, storage, and electricity, will facilitate the movement of goods and services and enhance market access. Regulatory frameworks should balance industrial growth with agricultural sustainability by setting quality standards and ensuring input availability.

This study extends Hirschman's Intersectoral Linkage Theory by integrating the service sector and demonstrating multidirectional sectoral interactions in Sub-Saharan Africa. Using CS-ARDL panel analysis, it captures short- and long-run dynamics while addressing cross-sectional dependence and heterogeneity. The findings provide a replicable framework for future research, emphasising technological innovation and service sector integration as drivers of structural transformation.

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