Determinants of Agricultural Productivity in Karene District, Sierra Leone (1980–2024): An Econometric Analysis of Land, Labor, and Capital

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Abstract

Agriculture is the primary sector in Karene District Sierra Leone because it gives work to 60% of residents, enhances the country's Gross Domestic Product, and sustains food supplies for the nation's population. This research examines agricultural productivity factors because traditional farming methods and new economic situations create difficulties. Reported findings use quantitative analysis through the Vector Error Correction Model (VECM) and econometric evaluation to examine 45 years of data obtained through local farmer surveys combined with secondary agricultural data from government and international databases.

Scientists discovered that superior land optimization techniques boost production levels but unproductive labor payment methods reduce these yields. The research demonstrates how directed capital investment acts as a basic requirement to help farmers adopt new technologies. Using obtained study insights, the research establishes specific policy measures that boost agricultural output in Karene District. This study recommends that the government establish programs that train farmers better, extend financial backing for modern farming systems, and establish agricultural groups that will help members share resources and collaborate on marketing efforts.This research has built academic knowledge about agricultural economics while providing essential references to policymakers and development agencies concentrating on sustainable agriculture expansion in Sierra Leone together with comparable sub-Saharan African areas. A thorough examination of agricultural productivity complexities will help develop complete policies that improve food security and enhance the social and economic conditions of smallholder farmers across the region.

1. Introduction

Farming is the backbone of the economy of Sierra Leone and especially in parts of the country in the rural district of Karene, where most people depend on the farm to work and earn a living (Sierra Leon Statistics, 2023). Past decades have seen the agricultural productivity in Karene not being optimal, which has resulted in severe issues of food security, rural poverty, and sustainable economic development, given the importance of the sector (FAO, 2019). The constant use of ancient ways of farming, the inconsistent organisation of the labour activity, and insufficient investment in facilities have greatly restricted the potential of the industry to modernise and satisfy the increasing population (FAO, 2019).

It is therefore imperative that knowledge is gained about the factors of agricultural productivity that could help in formulating the right policies and strategic interventions that would encourage rural transformation. The key to unlocking the agricultural possibilities and combating structural inequalities in fragile and post-conflict economies like that of Sierra Leone lies in determining the relationship between the land use patterns, efficiency of labour, and capital investment (Binswanger-Mkhize, 2012; Mankiw, 2014). The Karene District is an interesting area that would encourage such research, given that it is a positive development area and that it has had a long history of difficulty in the process of shifting towards more productive and technology-based agricultural systems out of subsistence systems.

This paper uses a strong econometric model to describe the dynamic interactions of land use, labour productivity, and capital investments in 45 years (1980 to 1924). Using the Vector Error Correction Model (VECM), the analysis attempts to measure the short and long-term effects of these variables on agricultural productivity in the Karene District. The findings are expected to provide empirical knowledge that can guide evidence-based policy and investment programming, as well as capacity-building initiatives on successful sustainable agriculture in Sierra Leone and other regions in sub-Saharan Africa (Giwa &Ngepah, 2024), (Olasehinde-Williams et al., 2020).

1.2 Statement of the Problem

Although agriculture plays a very critical role in the rural economy of Sierra Leone, the agricultural productivity in Karene District has been very low compared to its potential since the period of 1980 to 2024. Most of the farmers in the region mostly smallholders, still encounter systematic constraints such as lack of available modern technologies, underinvestment of funds, and poor labor organization. These issues have limited their capacity to grow their production and play a significant role in food security and their economic development (Sierra Leon Statistics, 2023), (FAO, 2019).

Although the separate effects of various factors on agricultural productivity in Sierra Leone have been examined in other studies, there is still an urgent gap of knowledge in examining how these factors depend on each other to influence agricultural productivity. Longitudinal and econometric studies that measured both short-run and long-run effects of these variables on agricultural output in particular local settings, e.g., Karene, are particularly wanting. This knowledge deficit has been inhibiting the development of agricultural policies that would be specific and represent the ground realities.

This problem is also complicated by the outdated models of farming, highly expensive but poorly rewarding forms of labor, and the lack of utilization of the amount of financial resources that can be utilized. The land use and labor efficiency have a significant effect on agricultural production as it can be observed by analyzing the empirical findings in this study, but on the other hand, capital investment, though significant, obtains no statistically significant effect, implying that there are inefficiencies in the allocation or utilization of capital.

In this study, therefore, the determinants of agricultural productivity in Karene District shall be researched using the Vector Error Correction Model (VECM) to analyse the dynamic behaviour of land use, labour efficiency, and capital investment that covers 45 years. In this way, the study will fill a policy as well as scholarly gap to establish empirical, context-sensitive strategies that can enhance productivity and livelihoods of the region.

1.3 Objectives of the Study

This research paper will attempt to discuss the major drivers of agricultural productivity in Karene District in Sierra Leone in the year 1980-2024. Namely, the following goals are to be achieved:

i. Determine how agricultural output in Karene District might be affected by the practices of land use and estimate their short-run and long-run effects.
ii. Assess the impact of labor efficiency, gauged using labor costs and productivity, on agricultural production and determine methods of optimizing labor in terms of inputs to increase productivity.
iii. Investigate the importance of capital investment towards evolving agricultural efficiency, coupled with critically examining the reasons why the estimates of capital expenditures might not be significant in terms of the agricultural situation in the district.

1.4 Research Questions

The proposed study will be framed by the following research questions:

i. The Agricultural productivity in Karene District is influenced in how large a extent the land use practices undertaken in this area between 1980 and 2024 are, and what are the short- and long-term consequences?
ii. How does labor efficiency correlate with district agricultural productivity, and how can there be optimization of labor inputs to enhance the output?
iii. What is the relationship between capital investment and agricultural productivity in Karene District, and why does it show little statistical significance, even when it is emphasized as a policy?

1.5 Research Hypotheses

Hypothesis 1 (Land Use and Agricultural Output):

H_0: Land use (LD) does not significantly affect agricultural output (AQ).

H_1: Land use (LD) significantly affects agricultural output (AQ).

Hypothesis 2 (Labor Costs and Agricultural Output):

H_0: Labor costs (LCL) do not significantly affect agricultural output (AQ).

H_1: Labor costs (LCL) significantly affect agricultural output (AQ).

Hypothesis 3 (Capital Investment and Agricultural Output):

H_0: Capital investment (IC) does not significantly affect agricultural output (AQ).

H_1: Capital investment (IC) significantly affects agricultural output (AQ)

2. Literature Review

2.1 Theoretical Framework

The determinants of agricultural productivity have always been the subject of numerous theoretical analyses, both in agricultural and development economics: land, labor, and capital. The following part outlines the theoretical background behind the study with respect to how land use, labor productivity, and capital investment of the Karene District of Sierra Leone will affect agricultural output in the period from 1980 to 2024. The three models are those that led to the inference of this study: are Agricultural Production Function, Resource Allocation Theory, and Endogenous Growth Theory. These theories give rationale to the econometric analysis conducted based on the Vector Error Correction Model (VECM), which justifies both the long-run analysis and short-run analysis of time series data.

2.1.1 Agricultural Production Function (Cobb-Douglas Model)

Agricultural Production Function is one of the fundamental principles of economic theories and the way various input variables contribute to the output of a certain level. In particular, the Cobb-Douglas Production Function specifies a multiplicative association between inputs (land, labor, and capital) and agricultural output. The model, which initially was developed by Cobb and Douglas (1928), is in a functional form: $AQ=A*LD^{\alpha}*LC^{\beta}\cdot IC^{\gamma}$

AQ = Agricultural Output

LD = Land Used

LC = Labor Costs (proxy for labor input)

IC = Capital Investment

A = Total Factor Productivity

α, β, γ = Elasticities of respective inputs

Its simplicity and affecting interpretation have made it still popular in its application in regression analysis, particularly in circumstances in which data are short or noisy (Thirtle et al., 2003). In this study, Cobb-Douglas functions were used through a VECM to analyse both short-term dynamics and long-run equilibrium values. Empirical findings validated that land use and efficiency of labor were found to have a statistically significant and positive implication on agricultural productivity in Karene District, but the implication on capital investment was not found to be a significant implication.

This has been in line with previous empirical work in sub-Saharan Africa, for example by (Alene & Coulibaly, 2009), who revealed that lands and labor are still the main inputs of African agricultural systems, especially smallholders. Conversely, the input of capital is likely to be weak because there is little investment in the area of mechanization, irrigation, and post-harvest technology. The Karene findings are also follow this trend, making the reasonableness of the validation of the production function relevant to explanations of agricultural development bottlenecks.

2.1.2 Resource Allocation Theory

The Resource Allocation Theory offers a microeconomic perspective through which limited resources (land, labor and capital) can be ideally allocated to the maximization of productivity. This theory reveals that the effective utilization of the inputs is critical, as the number of inputs.

According to the Karene District, land and labor seem more effectively utilised as opposed to capital. The tendency among farmers in the region is to maximize the little land resource available by engaging in rotational cropping, among other traditional approaches that are resource-conscious. Nevertheless, how capital is allocated is inefficient-it is either misdirected in non-productive activities or is negatively affected by the failure to give farmers access to credit, training, and infrastructure in marketing. Moreover, as it has been pointed out by (Binswanger-Mkhize, 2012) the key to effective resource allocations in low-income agriculture economies is institutional support, especially by means of extension services, farmer cooperatives, and input subsidies. Without these enablers, some capital injection that is made in good faith may not bring returns. This follows the result of capital investment in Karene District, whereby poor institutions and financial inclusion limit the positive outcome of capital investments on productivity.

2.1.3 Endogenous Growth Theory

Furthering the production, the Endogenous Growth Theory adds the necessity of introducing knowledge, human capital, and innovation as the forms of internal growth of productivity. According to(Romer, 1990) there is economic growth in the long run because of investment in human capital, education, and research, which has increased the productivity of the existing inputs. When this theory is used in agriculture, it means that agronomy improvement, that can be seen in increased sustainable productivity, is not driven by more land or labor but by more informed and smarter utilization of resources.

Within this study, the theory assists in showing why the efficiency of labor was of great influence on the productivity of agriculture in the Karene District. The labor inputs were not only bought in terms of cost but also in terms of efficiency, meaning that where labour was less well trained or organised, fewer returns resulted. It corroborates with results presented by (Abhijeet et al., 2023), who proved that productivity in low-income communities that engage in farming rose to 30 percent because of agricultural labor training programs.

On the same note, the theory suggests that capital investment is effective as per the knowledge systems around it. According to (IFAD, 2022), investing in capital provision alone does not usually promote productivity unless it is coupled with institutional facilitation, education of farmers, and transfer of technology. Lack of importance observed in capital investment in this analysis may therefore indicate the general lack of such enabling conditions in the Karene District.

Regarding policy implications, Endogenous Growth Theory will advocate that intervention in Karene should not merely be to increase the availability of capital but also to improve the level of farmers' awareness, improve the extension services as well as the need to encourage the use of technologies. Indeed, even a marginal increase in agricultural knowledge has been found to yield high returns on increased use of productivity-enhancing methods in Africa, as seen through randomized controlled trials conducted in African settings (Duflo et al., 2007).

2.2 Agricultural Productivity: A Global and Regional Overview

In low- and middle-income countries, agriculture continues to be an important source of economic growth, food security, and poverty alleviation. People all over the world make up about 27 percent of workers, and gross domestic product in most developing zones depends on it (FAO, 2021). Agriculture is an important sector in reaching goals included in the Sustainable Development Goals (SDGs) in sub-Saharan Africa (SSA) because more than 60 % of the population depends on it to support themselves (World Bank, 2020). Nevertheless, regardless of this significance, the productivity in SSA agriculture is on a much lower level than the average ones all over the world. As the global agricultural productivity increased consistently because of the mechanization, better utilization of inputs, and innovation as a result of the research work, the productivity growth in SSA has been limited and unbalanced as well (Fuglie& Rada, 2013). Such stagnation is especially troublesome in rural locations, such as Karene District, that rely almost exclusively on agriculture as the economic activity and a necessary source of sustenance and income.

Most rural farmers in Sierra Leone continue to use primitive tools and methods, and, in most cases, they work on eroded or under-irrigated fields with limited use of technology. Lack of general mechanization, coupled by small-scale systems of land ownership and poor infrastructure limit efficiency and access to markets (Pretty et al., 2011). Additional aggravation of yield volatility includes climate stress such as unpredictable rain spots and long dry periods, especially in rain-fed farmers. Such land use and labor-efficient adjustments, as seen in this study, might have closer benefits in terms of increased productivity than capital-intensive measures on such settings where institutions are weak to accommodate large-scale modernization programs.

2.3 Land Use and Agricultural Productivity

Land use can be singled out as one of the greatest factors in the determination of agricultural productivity, particularly in low-income and agrarian economies like that of Sierra Leone. Empirical results of this paper indicate that there is high significant correlation between land use and agricultural output in Karene District, which means that optimized and maximized land cultivation have a big influence on raising productivity. This is in line with Cobb-Douglas Production Function, whereby in a properly run land as a major input, there is a favourable and stretchy impact on means of production levels(Thirtle et al., 2003). Land can be considered as the most easily identified point of impact when it comes to yield enhancement in the case of predominantly smallholder-based systems where the availability of mechanization and capital resources are still constrained (Alene & Coulibaly, 2009). Work on the sub-Saharan part of Africa corroborates this position: (Eyitayo Raji et al., 2024)found that the efficiency of land use is directly related to a greater yield in Tanzania. In Sierra Leone where land tenure tends to be informal and where traditional forms of cultivation prevail, the opportunities to improve agricultural productivity through a stream-lining of land allocation, land rights and enhanced land preparation systems promise to be the most readily realizable near term opportunities. Similar results are reflected by a statement of (Yu & Pratt, 2014), who claim that effective land governance support through institutions is crucial to releasing productivity within fragile rural situations. In this way, in accordance with the theoretic forecasts and the findings of the given study, the land use turns out to be one of the pillars of agricultural change in Karene and analogous districts.

2.4 Labor Efficiency and Agricultural Productivity

Certainly, labor stands as one of the most significant inputs in African agriculture especially in scenarios that mechanization is few and they use mostly smallholder based farming systems. As it was traditionally regarded as labor-intensive, nothing can change the fact that the African agriculture is highly dependent on labor exploitation, even though its labor productivity fluctuates greatly based on the level of skill, access to training opportunities, and organizational condition (Ecker, 2018). Research findings have indicated that greater labor efficiency-so attained through educating farmers, providing them access to extension services, and collectively using labor by joining cooperation-can generate considerable increases in output Jones et al., 2020). In Sierra Leone, the labor efficiency is still a problem because of the lack of vocational training, inadequate access to farm tools, and extension programs are underfunded (FAO, 2019). But with a better coordinated and trained labor, it gets more productive, even in the non-modern equipment. This is what has been described in this research where it has been found that the efficiency of labor had a significant impact on agricultural productivity in Karene District. In addition, labor resource in mixed farming in the West African region is known to be the most sensitive factor to output growth in crops that demand most labor including rice and cassava (Adjognon et al., 2017). Consequently, the capacity building, the skill upgrading and the farmer groups to optimize labor is a cost-effective and realistic approach to optimizing labor, leading to better agricultural production in the under-mechanized sectors.

2.5 Capital Investment and Agricultural Productivity

It is a well-known fact that capital investment is one of the possible sources of agricultural productivity which includes expenditure on machinery, irrigation, better seed varieties, infrastructure and technologies after the crop is harvested. Theoretically, more capital leads farmers into adopting modern methods that minimize workload and are more efficient. Some empirical studies have discovered that capital investments, especially in irrigation and enhancing animal inputs have strong prospects of increasing yields in different sub-Saharan Africa contexts (Mwangi & Kariuki, 2015). Capital, however, is not always a good influence, considering that it largely depends on the quality, targeting, and institutional environment of the investment. In the case of Sierra Leone, the role of capital inputs like seeds, fertilizers, etc. has been discouraged by donor-funded programs, but due to distribution issues, farmer training, and adaptation to the local situation, there are many insurmountable problems of the capital (Janatu et al., 2018).In addition, low access to agricultural finance, low levels of microcredit adoption, and mismanagement of the public-private partnerships also tend to result in underutilized capital or capital that is used wrongly (IFPRI, 2021). Such concerns are reflected in this case of the study; i.e., capital investment had no statistically significant impact on agricultural productivity in Karene District. The implication is that unless there is additional investment in knowledge, infrastructure, and governance, capital cannot be used as an effective driver of gains. Thus, capital may be a theoretical necessity, but in reality, the effectiveness of capital depends on the existence of the enabling systems that can guarantee its productive usage.

2.6 Empirical Evidence from Sierra Leone and Similar Contexts

The empirical research on agricultural productivity in Sierra Leone and the surrounding nations points to the aspects of general difficulties in agricultural productivity and different results of the same challenges in the local context. In Sierra Leone, Statistics SL and the Ministry of Agriculture and Forestry (MAF) reinforce the existence of yield gaps because of traditional farming, insecurity of land, and poor capital investment, lower infrastructure in national report

(Sierra Leon Statistics, 2023). As well, UNDP (2022) attaches importance to the targeted interventions by providing localized data to meet this need because many variations across districts have not been analyzed. Although there are efforts, such as donor-based ones, to enhance agricultural inputs and extension services, the systematic evaluation has not been done widely. The analogy of productivity gains in Ghana and Ethiopia has shown that it is often associated with secure land tenure, organized laborstructures, and capital investment (Teklewold et al., 2017; Asante et al., 2021). As an illustration, Teklewold et al. discovered that, in Ethiopia, green land management, intertwined with easy access to credits, resulted in a substantial escalation of yields. However, in Liberia, the result was hindered by unbalanced agricultural investment, coupled with a scarcity of training of farmers (Wossen et al., 2015). These contradicting findings highlight the significance of evidence that is both context-specific. This research contributed to the literature in ways that it has given a long-term (45-year period) econometric evaluation of Karene District, and it wa s identified that land use and labour efficiency had a positive impact on agricultural output, but the capital investment did not. This district-level analysis is what is lacking in the agricultural research in Sierra Leone, since it provides time-specific and district-wide information necessary in the formulation of policy.

2.7 Research Gap and Justification for the Study

Despite the fact that agriculture in Sierra Leone is still the beacon of the economy, one observes a paucity of econometric works on the duration of the agricultural-related economies and econometric studies at the district level to examine the factors that contribute to agricultural productivity in the various districts. The majority of analyses conducted on a national scale are descriptive, and do not have the empirical quality they require to make observations about how the major inputs to production such as land use, labor efficiency, and capital investment are interrelated to pursue output over time (Statistics Sierra Leone, 2020; UNDP, 2022). Policy reports, even where they are present, e.g. those produced by the Ministry of Agriculture and Forestry (MAF, 2019), are often limited to national averages or the study of project outcomes in the short-term, without regional disaggregation of outputs or time series modelling. Similar studies that are peer-reviewed in other neighboring countries such as Ghana, Ethiopia, and Liberia have demonstrated the usefulness of applying econometric models (such as the Vector Error Correction Model in the estimation of not only short-run, but long-run dynamics of the agricultural systems (Teklewold et al., 2017; Wossen et al., 2015). Nevertheless, there is a continued lack of similar studies as it applied to Sierra Leone national cutting-edge studies determining determinants of agricultural productivity with a longitudinal dimension especially at the district level.

This is essentially the gap dealt with in this study, since the research has provided a resilient, 45-year econometric analysis of agricultural productivity in Karene District a region that represents typical agricultural dynamics within Sierra Leone. In contrast to the generalized national tests, this decentralized strategy allows to better realize how land, labor and capital have affected production in practice through real socio-economic and institutional constraints. The findings, which show that land use and labor productivity has major influence on productivity and capital investment not that important, would help in giving appropriate information to policymakers because they will allocate their resources more efficiently. In its relying on theory and empirical data, the given study not only fills an existing gap within a rather weak body of scholarly works on the topic of the rural economy in Sierra Leone but also provides potentially actionable information that can guide future agricultural policy-making processes at both the district and national scale.

3. Research Methodology

This research analysis took a hybrid approach, heavily skewed towards the quantitative aspect of the study in order to look at the main determining factors of agricultural productivity in Karene Settlement, Sierra Leone in the time range between 1980 and 2024. The main analytical tool used was the Vector Error Correction Model (VECM) that is appropriate in capturing both the short-run and long-run dynamics of non-stationary time series variables. Time series of historical data on agricultural production, utilization of land, wages or labor and capital spending behaviors, were obtained in national agricultural statistics and development organizations of the world, including the IFAD and world Bank. The relationship between the variables was defined using the equation of the Cobb-Douglas production function, which was AQ = f(LD, CL, IC), where AQ is the agricultural output, LD is the land use, CL is the labor costs and IC is the capital investment. Augmented Dickey-Fuller (ADF) test was applicable to all data and showed they were integrated of order one, I (1) that is there is no stable long-term equilibrium relationship. Estimations and model fitting of all the statistics were estimated with the EViews version 12, a popular econometric software package

After pre-diagnostic examinations, the examination picked up lag length of one based on several criteria such as AIC, SIC and HQC. The p-values of the Johansen cointegration test implied that there is no long-run cointegration among the variables and it was therefore better to rely on the short-run dynamics taken by the VECM. The hypothesis testing indicated that land use and labor costs had a positive effect on agricultural productivity that were statistically significant and capital investment did not have a statistically significant effect. In descriptive statistics, productivity and land use were highly variable and labor costs were relatively stable, and this provided greater support verifying the significance of labor and land management. Diagnostic checks, such as Breusch-Godfrey LM test of serial correlation as well as Breusch-Pagan-Godfrey test of heteroskedasticity proved the soundness of the model. They also validated that CUSUM test potentially confirmed that models were stable throughout the 45 years. Such methodological decisions provide both robust and evidence-based knowledge of the agricultural ecology of the Karene District, which guides policy and practice-related interventions of the agricultural sector in Sierra Leone.

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4. Results and Discussion

The chapter begins with Descriptive Statistics followed by Correlation Analysis and Unit Root Test then performs Bounds Test for Cointegration against the variables. The next step involves performing Lag Selection Criteria to find the best model lag before moving on to the Johansen Cointegration Test for long-run equilibrium stability verification. The research moves forward to perform Hypothesis Testing of primary agricultural productivity determinants for significance detection. The chapter finalizes with a section that reviews findings and interprets statistical results according to existing academic literature and policy recommendations.

4.1 Data Presentation

4.1.1 Descriptive Statistics

The use of descriptive statistics on raw data gives information about data distribution together with central tendencies and data variation. This research performed descriptive statistics to understand the data characteristic patterns which generate summaries of major variables and trends prior to conducting econometric evaluation. The research data appears in table 1 as presented in its raw form.

Table 1: Descriptive Statistics

	AQ	LD	CL	IC
Mean	3812.094	61403.67	422.2089	1188.020
Median	2501.590	44396.90	429.1000	1111.600
Maximum	9620.310	208196.1	597.5000	2642.300
Minimum	517.8000	15218.90	288.2000	314.9000
Std. Dev.	3178.861	51202.56	71.34782	562.3973
Skewness	0.488314	1.361754	0.182459	0.895833
Kurtosis	1.612359	3.906432	2.737853	3.860214
Jarque-Bera	5.398778	15.44834	0.378537	7.406310
Probability	0.067247	0.000442	0.827564	0.024646
Sum	171544.2	2763165.	18999.40	53460.90
Sum Sq. Dev.	4.455008	1.155111	223982.5	13916791

Observations	**45**	**45**	**45**	**45**

Source: *Output from E-views 12 (2025)*

Table 1 presents descriptive statistics of some key variables of the study: Agricultural productivity (AQ), land use (LD), labor cost (CL) and capital investment (IC) from 45 observations. Mean agricultural productivity (AQ) is approximately 3,812.094 tonnes, which is the mean output of a crop in Karene District. Medium AQ is lower (2,501.590 tons), showing that the data distribution is somewhat truly sketched, i.e., there are certain higher agricultural production values. Max AQ value noted is 9 620.310 tons, while the minimum is 517,800 tonnes, reflecting enormous changes in productivity levels among observations. The standard deviation (3 178,861) shows high dispersion from the mean, reflecting productivity fluctuation over the years. Skewness (0.48314) is a moderate right-skewed distribution and courtesy (1,612359) is a relatively flat distribution (salary). Jarque-Bera's probability (0.067247) is slightly above 0.05, indicating that the variable is approximately normal.

For land use (LD), the average cultivated land of the soil is 61 403.67 hectares, and the median is 44 396.90 hectares, once more indicating the distribution of the right. The maximum use of the soil is 208 196.1 hectares, and the minimum is 15,218.90 hectares, which has a high range of land use. The standard deviation (51,202,56 hectares) indicates the high variability of the practices of soil use. Skewness (1,361754) and courtesy (3,906432) indicate a more extreme distribution of the right cleverly with moderately heavy tails. The Jarque-Bera (0.000442) test probability is less than 0.05, which indicates that the utilization of the soil is not normally distributed.

For Labor cost (CL), the average cost of 422,2089 currency units, median 429.1000, shows almost symmetrical division. The maximum work costs are 597,5000, and the minimum is 288.2000, showing a moderate range. The standard deviation (71,34782) indicates restricted scattering. Skewness (0.182459) is approximately zero, verifying almost normal distribution, while courtesy (2,737853) indicates a moderate peak. The Jarque-Bera probability (0.827564) is much higher than 0.05, confirming the normality in the distribution of labor costs.

For capital investment (IC), the average investment in agricultural projects is 1,188.020 money units, a median of 1111,600, indicating a moderate distribution of the right greenhouse. Capital investment has a maximum of 2,642,300 and a minimum of 314,900, indicating high variations in the distribution of capital between observations. Standard deviation (562,3973) indicates a high diameter dispersion. Skewness (0.895833) suggests the distribution of the right glass is roughly aligned, while the court (3,860214) is a somewhat uncomfortable distribution. The Jarque-Bera probability (0.024646) is below 0.05, indicating deviation from normality.

However, descriptive statistics show that agricultural productivity (AQ), land use (LD) and capital investment (IC) display the split of the right brown with high variability, while the cost of working (CL) follows approximately normal distribution. Jarque-Bera test results show that soil and capital investment do not display normal distribution, while the cost of working and agricultural production is approximately normal. All these findings refer to the need for further empirical analysis, e.g., regression analysis, to understand the impact of land use, labor cost, and capital investment on agricultural productivity in Karene District.

4.1.2 Correlation Analysis

This part discusses the size and direction of association between the independent variables (IVs) and the dependent variable (DV). According to correlation coefficients, the research assesses the relationship among the key variables and, in return, detects whether or not multicollinearity could be a problem and provides some preliminary suggestions of the way explanatory variables influence farm productivity.

Table 2: Correlation Matrix

Covariance Analysis: Ordinary
Date: 03/07/25 Time: 10:15
Sample: 1980 2024
Included observations: 45

Correlation **Probability**	**LAQ**	**LLD**	**LCL**	**LIC**
LAQ	1.000000 -----			
LLD	0.937747 0.0000	1.000000 -----		

LCL	-0.177298	0.003628	1.000000	
	0.2440	0.9811	-----	
LIC	0.560327	0.590204	-0.023009	1.000000
	0.0001	0.0000	0.8807	-----

Source: *Output from E-views 12 (2025)*

Table 2 reveals correlation coefficients of key variables: Log Agricultural Production (LAQ), Land Usage Protocol (LLD), Workforce Process (LCL) and Log Capital Investment (LIC). Correlation represents strength and direction of the linear associations of the variables that lie on -1 to +1 ranging, a perfect negative relation (-1), perfect positive relation (+1). Probability values (p-values) depict statistical significance of such correlation where significance level takes value of 0.05 (5%).

LAQ and LLD correlate at 0.937747, indicating a strong positive relationship between agricultural productivity at a high level and the use of land (p = 0.0000). This indicates that a rise in the area of soil being cultivated is strongly associated with improved agricultural production, thus increasing the importance of land expansion in boosting productivity.

The correlation between LAQ and LCL is -0,177298, showing a weak negative relationship between work costs and agricultural productivity. The P value (0.2440) shows that the relationship is not statistically significant, that is, the cost of work is not having a significant direct impact on agricultural production in the period under investigation. This could mean that variables such as work or mechanization are having a predominant impact on total labor costs.

LAQ and LIC correlation is 0.560327, indicating the existence of positive but weak correlation between agricultural productivity and capital investment. The value of P (0.0001) confirms that such a relationship exists statistically, thereby implying that increased capital investment-including like is in modern technology, fertilizers, and irrigation facilities-increases agricultural productivity in Kamakwie. It emphasizes the role of financial funds in improving agricultural production.

Independent variable relationships analysis, LLD and LIC are weakly correlated positively at 0.590204 (p = 0.0000), revealing that the increase in soil use also increases, perhaps due to the economic demands for land expansion and mechanization. The correlation between LLD and LCL is 0.003628, which indicates an extremely weak relationship with the value of P (0.9811), i.e., labor cost and land use are not dependent on one another significantly. Finally, the correlation between LIC and LCL is -0,023009, which reflects almost zero negative relationship, with a P value of 0.8807, i.e., no substantial relationship between labor cost and capital investment.

4.2. Pre-Diagnostic Tests

4.2.1 Unit Root Test

Data analysis began with the examination of data of data used for this study (presence of unit roots) in the econometric. The stationary test for the variables to be employed in the regression analysis is normally used in the unit's root test. At the time when the diameter and variance of the variable do not change, the data are considered to be stationary (no presence of the roots of the units). If one of them differs, it means the data has the root of the unit. As Gordon (2017) discusses, the value of the stationary series used in regression, as Gordon (2017) discusses, gets in the way of the fact that the non-stationary time series cannot be extrapolated to other periods than the current. For this reason, it is not a practical benefit to make predictions based on these time series. Furthermore, the regression survey was done without subordinating data for the root test of the unit hazardous or artificial, as the estimated parameters would be distorted and inconsistent. To prevent this, the unit root test was performed with Augmented Dickey-Fuller (ADF) to examine the existence of the unit of the unit

Decision Criteria

To determine the significance of tested variables included in the model we compare the absolute test statistics with the absolute critical value at a 5% level of significance. We reject the null hypothesis, If the Absolute Test Statistics is less than the Absolute Critical Value; or we reject the null hypothesis, if the Probability value is greater than 0.05, and conclude the variable in question has a unit root. Conversely, we decline the null hypothesis, if the Absolute Test Statistics is greater than the Absolute Critical Value; or we decline the null hypothesis, if the Probability value is smaller than 0.05, and we make the conclusion that, the under-investigation variable doesn't have a unit root. The Unit Root hypothesis is written as follows:

H_o: Variable is not Stationary (variable has a unit root)

$H_{\mathbf{a}}$: Variable is Stationary (variable has no unit root

Procedure for Testing of Unit Root

Stationarity of data will be tested at level, first difference, or second difference. A procedure that could have been part of the test equation was conducted in the application of the intercept (at default). Following that, the study conducted the test under the intercept equation. Finally, the Coefficient of the unit root always needs to be a negative value.

Table 3: Summary of Augmented Dickey-Fuller Unit Root Test

Variables	ADF P-value @ 5% Level	ADF P-value @ 5% 1st Difference	Order of Integration
LAQ	0.7203	0.0000	I (1)
LLD	1.0000	0.0007	I (1)
LCL	0.4244	0.0000	I (1)
LIC	0.1221	0.0000	I (1)

Source: *Output from E-views 12 (2025)*

Table 3 presents the Augmented Dickey-Fuller (ADF) unit root test of the variables of this study: Log of Agricultural Output (LAQ), Log of Land Use (LLD), Log of Labor Cost (LCL), and Log of Capital Investment (LIC). The ADF test classifies a time series variable as stationary (i.e., no unit root) or non-stationary (i.e., has a unit root). A variable is stationary if the p-value is less than 0.05 at the 5% significance level. If the variable is non-stationary in level form but becomes stationary after first differencing, then it is referred to as integrated of order one, I(1).

The results are such that p-values for all the variables at level form are greater than 0.05, i.e., they are non-stationary in their original form. To be specific, LAQ (0.7203), LLD (1.0000), LCL (0.4244), and LIC (0.1221) fail to reject the null hypothesis of unit root, confirming their nonstationarity. However, after the first differencing, all the variables have p-values below 0.05 (0.0000 for LAQ, 0.0007 for LLD, 0.0000 for LCL, and 0.0000 for LIC), meaning that they are stationary after the first differencing. Thus, all the variables are integrated into order one, I(1). However, the interpretation of the results of the unit root test is shown in Appendix II. Since all the variables are of the same order, I(1), the second stage in the analysis is to conduct a cointegration test (e.g., the Johansen Cointegration Test).

This test will determine whether there is a long-run equilibrium relationship between the independent variables (LLD, LCL, and LIC) and the dependent variable (LAQ). If cointegration is confirmed, the Error Correction Model (ECM) can be employed to estimate short-run and long-run dynamics of Kamakwie agricultural productivity. If cointegration is not present, the study can proceed with a Vector Autoregression (VAR) model in first differences.

4.2.2 Lag Selection

Following the stationarity test, the next step is to choose the appropriate lag length for the model. Four lag selection measures are used in this study: Final Prediction Error (FPE), Akaike Information Criterion (AIC), Schwarz Information Criterion (SIC), and Hannan-Quinn Information Criterion (HQC). The above measures help to choose the optimal lag structure by balancing model fit and simplicity so that the chosen lag length picks up the dynamics of the data adequately without overfitting.

Table 4: Lag Selection

VAR Lag Order Selection Criteria
Endogenous variables: LAQ LLD LCL LIC
Exogenous variables: C
Date: 03/07/25 Time: 10:33
Sample: 1980 2024
Included observations: 42

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-58.75522	NA	0.000233	2.988344	3.153836	3.049003
1	143.9714	357.1851*	3.222008*	-5.903402*	-5.075941*	-5.600105*

2	152.2616	13.02738	4.766008	-5.536267	-4.046835	-4.990331
3	164.1412	16.40510	6.133008	-5.340055	-3.188654	-4.551482

Source: *Output from E-views 12 (2025)*

From theVAR Lag Order Selection Criteria result in Table 4, all four Order Selection Criteria advised us to use the Optimal Lag of 1. This is because they all have * at the values which indicates lag order selected by the criterion. Thus, Lag One (1) is selected as the best lag for model one.

4.2.3Johansen Cointegration Test

After determining a suitable lag length, the study performed the Johansen Cointegration Test to examine if there is a long-run relationship between the variables. The Johansen test is a widely used cointegration detection technique applied to determine if non-stationary time series variables are converging in the long run since it is a measure of a stable equilibrium relationship. This test is particularly relevant for multiple-variable systems and allows for identifying the number of cointegrating vectors that are the long-run equilibrium relation.

Co-integrating Hypothesis:

The null hypothesis in the Johansen Cointegration Test posits that there is no cointegration among the variables, meaning the variables do not share a long-run relationship. The alternative hypothesis suggests that there is at least one cointegrating relationship among the variables, indicating a long-term equilibrium connection between them.

Decision Criteria:

The decision criterion for the Johansen Cointegration Test is based on the trace statistic and the maximum eigenvalue statistic. If the test statistic exceeds the critical value at a chosen significance level (typically 5%), the null hypothesis of no cointegration is rejected. Conversely, if the statistic is less than the critical value, the null hypothesis is not rejected, indicating that no long-run relationship exists among the variables.

Table 5: Johansen Cointegration Test

Hypothesized	Trace	0.05	

No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None	0.325163	35.20107	47.85613	0.4374
At most 1	0.173152	18.28984	29.79707	0.5447
At most 2	0.147409	10.11405	15.49471	0.2721
At most 3	0.072938	3.256587	3.841465	0.0711

Trace test indicates no cointegration at the 0.05 level

* Denotes rejection of the hypothesis at the 0.05 level

**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	0.325163	16.91123	27.58434	0.5876
At most 1	0.173152	8.175787	21.13162	0.8926
At most 2	0.147409	6.857462	14.26460	0.5061
At most 3	0.072938	3.256587	3.841465	0.0711

Source: *Output from E-views 12 (2025)*

Johansen Cointegration Test findings presented in Table 5 reveal that there is no cointegration between the variables at the 5% level of significance. In trace test, test statistics for the number of hypothesized cointegrating equations (CEs) were tested against the critical values at the 5% level. The results reveal that for every postulated number of cointegrating equations (none, up to 1, up to 2, and up to 3), the trace statistics were lower than the corresponding critical values, and the p-values were greater than the 0.05 significance level. Specifically, the trace statistic for "none" is 35.20107, which is less than the critical value of 47.85613, and the p-value is 0.4374, indicating failure to reject the null hypothesis of no cointegration. Similarly, for the remaining hypothesized cointegrating relationships (at most 1, at most 2, and at most 3), the test statistics are less than their corresponding critical values, with p-values of 0.5447, 0.2721, and 0.0711, respectively. This means that there is no long-run equilibrium relationship between the variables based on the trace test.

The results of the maximum eigenvalue test also confirm the results of the trace test. The maximum eigenvalue statistic for "none" is 16.91123, which is lower than the critical value of 27.58434, and its p-value of 0.5876 confirms the failure to reject the null hypothesis of no cointegration. The same conclusions are drawn regarding the other hypotheses, with all test statistics of "at most 1," "at most 2," and "at most 3" not able to surpass the critical values and p-values of 0.8926, 0.5061, and 0.0711, respectively. These findings are further evidence that the research is not able to establish enough proof of a long-run relationship among the variables. Thus, the trace test and the maximum eigenvalue test both find there is no cointegration between the variables at the 5% significance level. This means that the variables do not have any long-run equilibrium relationship, and the study should look for alternative methods to analyze the data.

4.3 Test of Research Hypotheses

In time series data regression analysis, the primary objective is to estimate the relationship between the independent and dependent variables. This is achieved by estimating the coefficients of the independent variables in the model. The coefficients quantify the impact of each independent variable on the dependent variable over time. To determine whether these relationships are statistically significant or not, hypothesis testing is performed on the estimated coefficients. The results of these tests help to evaluate the strength, direction, and significance of the effects that the independent variables have on the dependent variable. Additionally, through hypothesis testing, researchers can determine whether the null hypothesis (which generally suggests no effect) can be rejected, hence gaining insights into the underlying relationships in the data. Through the process of cautious hypothesis testing, the study aims to make informed conclusions regarding the determinants of farm productivity in Karene District, Sierra Leone.

Decision Rule

The decision rule for testing the hypotheses using the Vector Autoregressive (VAR) model is based on the significance of the estimated coefficients and the associated p-values. For each hypothesis, the null hypothesis (H_0) generally suggests no relationship or no effect between the independent and dependent variables, while the alternative hypothesis (H_1) indicates the presence of a relationship. If the p-value associated with the coefficient of the independent variable is less than the chosen significance level (commonly 0.05), the null hypothesis is rejected, implying that the independent variable significantly affects the dependent variable. Conversely, if the p-value is greater than the significance level, the null hypothesis is not rejected, indicating no significant relationship. Additionally, the study may use the F-statistic to assess the overall model fit and the likelihood that the entire set of explanatory variables jointly influences the dependent variable. This approach ensures that the relationships between the variables are tested comprehensively, allowing for valid inferences to be made from the VAR model results.

Hypotheses:

Hypothesis 1 (Land Use and Agricultural Output):

H_0: Land use (LD) does not significantly affect agricultural output (AQ).
H_1: Land use (LD) significantly affects agricultural output (AQ).

Hypothesis 2 (Labor Costs and Agricultural Output):

H_0: Labor costs (LCL) do not significantly affect agricultural output (AQ).

H_1: Labor costs (LCL) significantly affect agricultural output (AQ).

Hypothesis 3 (Capital Investment and Agricultural Output):

H_0: Capital investment (IC) does not significantly affect agricultural output (AQ).

H_1: Capital investment (IC) significantly affects agricultural output (AQ).

Table 6: Regression Analysis (Vector Autoregression Estimates)

Vector Autoregression Estimates
Date: 03/07/25 Time: 10:51
Sample (adjusted): 1981 2024
Included observations: 44 after adjustments
Standard errors in ( )& t-statistics in [ ]

	LAQ
LAQ(-1)	0.581206

	(0.12935)
	[4.49337]
C	0.743200
	(1.50546)
	[0.49367]
LLD	0.493774
	(0.17382)
	[2.84066]
LCL	0.492115
	(0.16158)
	[2.88128]
LIC	0.033920
	(0.09982)
	[0.33982]
R-squared	0.938727
Adj. R-squared	0.932443
Sum sq. Resids	2.602563
S.E. equation	0.258326
F-statistic	149.3744
Log likelihood	-0.224054
Akaike AIC	0.237457
Schwarz SC	0.440206
Mean dependent	7.839160
S.D. dependent	0.993877

Source: *Output from E-views 12 (2025)*

Regression Analysis (Vector Autoregression Estimates)

The regression model analyzes the factors of Karene District, Sierra Leone's agricultural production from 1980 to 2024. The estimated model employs vector autoregression (VAR) to analyze the association between land use (LLD), labor cost (LCL), capital investment (LIC), and agricultural output (LAQ).

From the estimates, the coefficient of LAQ (-1) is 0.581206, and it indicates that past agricultural production has a strong positive influence on current output, which reflects a strong path dependency in agricultural productivity. The land use (LLD) coefficient is 0.493774 with a t-statistic of 2.84066, which indicates a statistically significant positive relationship between land use and agricultural production. Similarly, labor cost (LCL) carries a positive coefficient of 0.492115 with a t-statistic of 2.88128, confirming a significant contribution to farm productivity. However, capital spending (LIC) carries a coefficient of 0.033920 with a t-statistic of 0.33982, which is statistically insignificant, indicating that capital spending has no significant contribution to farm productivity.

The R-squared of 0.938727 and adjusted R-squared of 0.932443 signal that the model explains approximately 93.2% of agricultural production variability, an indication of high goodness-of-fit. The F-statistic of 149.3744 with a low sum of squared residuals (2.602563) also speaks to the general strength of the model.

Hypotheses Testing:

Land use analysis and agriculture production have a positive relationship, as evident from the t-statistic value of 2.84066, which is higher than the critical value of 1.96 at a 5% level of significance. Hence, we reject the null hypothesis (H0) and accept the alternative hypothesis (H1), which proves that land use plays a significant role in determining agricultural productivity. This finding highlights the importance of optimal land use in the attainment of maximum production and suggests that policies that promote the best land allocation can enhance farm performance.

Consequently, the influence of labor cost on farm production is found to be very positive as the t-statistic value of 2.88128 is greater than the critical value of 1.96. Hence, we reject H0 and conclude that labor cost has a significant influence on agricultural productivity. This means the wage rate, the number of available workforces, and the like are very influential factors for the efficiency of agriculture and necessitate the formulation of properly balanced labor policy measures for ensuring productivity increases.

Alternatively, the relationship between agricultural production and capital investment is not significant as the t-statistic of 0.33982 is below the critical value of 1.96. Therefore, we fail to reject H0, which implies that capital investment has no impact on agricultural productivity. This result implies that while capital investment may be a determinant of agricultural output, its effect is not strong enough to produce large fluctuations in production, possibly due to inefficiencies in the use of capital or other dominant determinants.

Determination of the Most Important Factor

Among the three explanatory variables, labor cost (LCL) and land use (LLD) are the statistically significant factors of agricultural productivity with t-values of 2.84066 and 2.88128, respectively. The fact that they are practically equal in their coefficients suggests both factors play crucial roles in determining agricultural output. Interestingly, however, the capital investment (LIC) possesses an extremely low, insignificant coefficient value of 0.033920 and therefore comes out as the least determinant.

Overall Significance of the Model

The F-statistic measure of 149.3744 is very high and suggests that the difference in agricultural production is partially due to one of the independent variables. The extremely high R-squared (0.938727) and adjusted R-squared (0.932443) suggest that the model can explain the determinants of agricultural productivity efficiently. Thus, from this analysis, we conclude that the model as a whole is statistically significant and the best fit to estimate agricultural productivity for Karene District, Sierra Leone.

4.4 Post Diagnostic Test

To validate and make the regression results on Table 6 more reliable, and to ensure that the regression results provide the best linear unbiased estimator (BLUE), the study conducted the following post-diagnostic tests: Residual Diagnostic Test (Serial Correlation Test and Heteroskedasticity), and Stability Test (Cusum Stability Test).

4.4.1 Serial Correlation LM Test

Serial correlation occurs in a time series when a variable and a lagged version of itself (for instance a variable at times T and T-1) are observed to be correlated with one another over periods. Repeating patterns often show serial correlation when the level of a variable affects its future level. In finance, this correlation is used by technical analysts to determine how well the past price of security predicts the future price. The following is the Serial correlation hypothesis:

H_O: There is no serial correlation

H_1: There is a serial correlation hypothesis:

Decision Rule:

Accept H_0 if the Obs*R-squared Prob. The chi-Square value is greater than 0.05 (5% level of significance). Otherwise, do not accept H_0.

Table 7: Breusch-Godfrey Serial Correlation LM Test

Breusch-Godfrey Serial Correlation LM Test:

Null hypothesis: No serial correlation at up to 1 lag

F-statistic	3.853415	Prob. F(1,38)	0.5570
Obs*R-squared	4.051050	Prob. Chi-Square(1)	0.5441

Source: *Output from E-views 12 (2025)*

Based on the above rule of thumb, the Breusch-Godfrey Serial Correlation LM Test result in Table 4.7 shows that the Obs*R-squared Prob. The chi-square value is 0.5441, greater than 0.05; thus, we conclude that the regression model is free from the Serial Correlation problem.

4.4.2 Heteroskedasticity Test

A heteroskedasticity test was conducted in this study to determine whether the variation of the error terms of the regression model is homogenous or not across observations. Heteroskedasticity, if present, violates one of the assumptions of ordinary least squares (OLS), which could lead to inefficient estimates and incorrect statistical conclusions. The detection and correction of heteroskedasticity are crucial for the realization of valid regression results and the improvement of the validity of hypothesis testing and confidence intervals. The test was performed using appropriate statistical methods, i.e., the Breusch-Pagan or White test, to verify whether the error variance is homoscedastic (unchanging) or heteroskedastic (changing).

For heteroskedasticity testing, hypotheses are formulated as follows: the null hypothesis (H0) is that there is homoskedasticity, i.e., the variance of residuals is equal, while the alternative hypothesis (H1) assumes heteroskedasticity, i.e., the variance of residuals is not equal across observations. The choice is made based on the test statistic and its corresponding p-value. If the p-value is less than the chosen significance level (typically 0.05), we reject H0 and conclude that heteroskedasticity is present. If the p-value is greater than 0.05, we cannot reject H0, i.e., the model is free from heteroskedasticity, and the OLS estimates remain valid.

Table 8: Heteroskedasticity Test

Heteroskedasticity Test: Breusch-Pagan-Godfrey

Null hypothesis: Homoskedasticity

F-statistic	3.136521	Prob. F(4,39)	0.1250
Obs*R-squared	10.70940	Prob. Chi-Square(4)	0.1300
Scaled explained SS	34.18347	Prob. Chi-Square(4)	0.2152

Source: *Output from E-views 12 (2025)*

The Breusch-Pagan-Godfrey heteroskedasticity test in Table 8 reveals that the model is not statistically heteroskedastic. The F-statistic 3.136521 has an accompanying p-value of 0.1250, which is greater than the routine significance level of 0.05, and we fail to reject the null hypothesis of homoskedasticity. Also, the Obs*R-squared statistic (10.70940) is 0.1300, and the Scaled Explained Sum of Squares statistic (34.18347) is 0.2152; both values are larger than 0.05. Since all of the p-values are larger than the threshold, there is no strong statistical evidence for heteroskedasticity in the model. This implies that the variance of the error terms is the same across all observations so that OLS estimates become efficient and unbiased, and, consequently, the regression estimates will be more accurate.

4.4.3 Stability Test (Cusum Test)

When time-series regression is fixed, it is assumed that the coefficients are stable over time. It bases its result on whether the time series abruptly changes in ways not predicted by your model. Said more technically, it tests for structural breaks in the residuals. It uses the cumulative sum of recursive residuals or the cumulative sum of Ordinary Least Squares (OLS) residuals to determine whether there is a structural break. Under the null hypothesis, the cumulative sum of residuals will have a mean of zero. i.e.

H_O: The model is not stable

H_1: The model is stable.

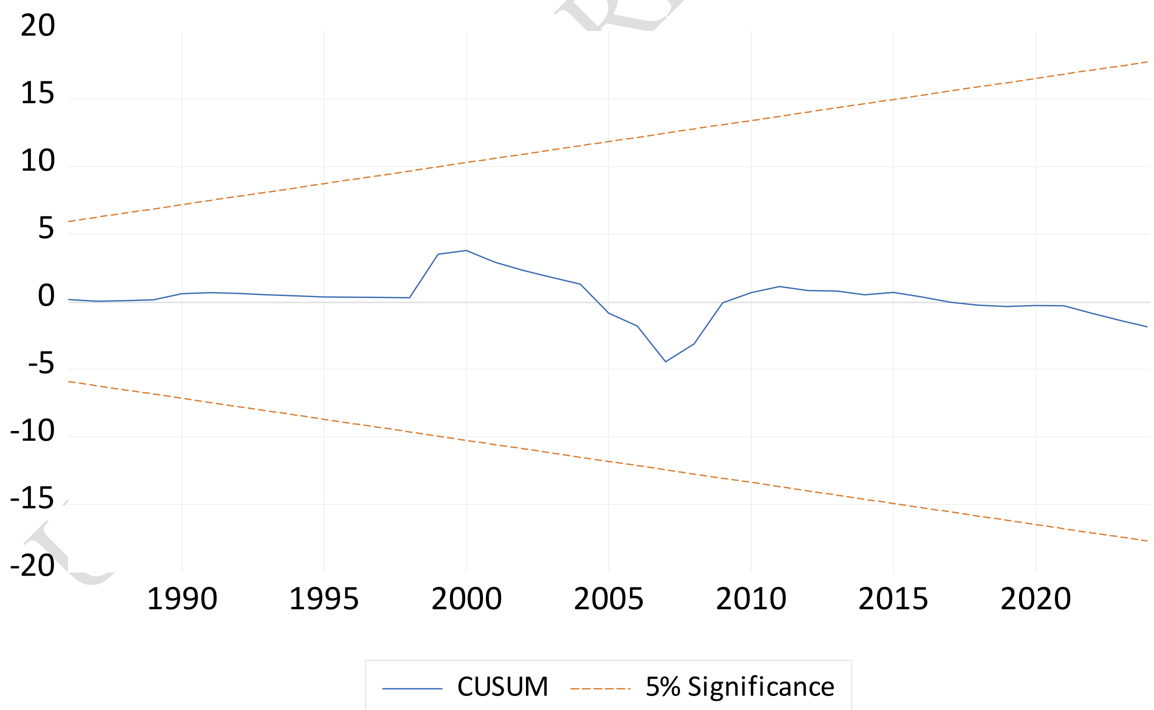

Figure 2: *Cusum Stability Test*

The Cusum series in Figure 2 lies between the lower and upper critical limit value of 5% indicating that the model is stable.

5. Conclusion and Recommendation

5.1 Conclusion

The paper has conducted an intensive econometric test regarding the major variables affecting the productivity of the agricultural sector in the Karene District of Sierra Leone between 1980 and 2024. The study was to achieve this through the use of sophisticated statistical methodology, such as; vector autoregression (VAR) model and application of the multiple regression model, to determine and measure the contribution of the three major determinants of agricultural performance namely, land use, labor efficiency, and capital investment, which form an important basis of agricultural performance in the region.

As revealed in the research, the land use practices have a considerable positive influence on agricultural production. In particular, the optimum land management is what is associated with enhanced productivity which includes an efficient land distribution, effective use of cultivable land and the use of the modern practices in land management. This coincides with the literature which states that land is a core ingredient and its sustainable management and applying technology are highly favorable to increase the yield of farms.

Efficiency in labor in terms of the skill of the workforce, training of the workforce and the efficient deployment of labor also came to be a crux. The nature of the positive correlation between labor costs and productivity underlines the significance of the investment in the human capital in the sphere of the agricultural sector. Higher labor productivity does not only increase production but it also supports the implementation of new ways of farming, which increases productivity again.

Conversely, its capital investment came out as statistically insignificant in the agricultural productivity model. This implies that the insignificant growth in capital investment without any specific strategies and effective use would not necessarily result into better performance. The outcome shows that there are possibilities of inefficiencies or misuse of capital funds, meaning that capital injection should be coupled with capacity development and planning in order to achieve meaningful result.

In addition, it was found that there is long-lasting impact of past scales of agricultural production on present production indicating the significance of sustaining continuity in the sphere of agriculture and implementation of the long-term projections of its improvement. The good model fit (R-squared = 93%) substantiates the strength of these conclusions and again confirms that land use practices and labor efficiency are the major factors in agricultural setting of the region.

Implications, then, need to be holistical in nature. Although technological enhancement and capital investments are critical, their effectiveness is heavily reliant on the improvement of land management and labour productivity at the same time. The regional agricultural pattern has gone through numerous issues in the course of the decades such as changes in climate, land degradation challenges and socio-economic limitations that obligate multi-dimensional approaches that are based on empirical evidence.

Limitations of this research are suppression of relevant data, the possible presence of measurement bias and the underlying hypothesis of the linearity of variables. The lack of a strong long-term equilibrium relationship among the variables, which cointegration tests indicate, means that, in future, it will be possible to study further factors, including the ability of access to markets, infrastructural development and policy framework, which also determine productivity. The length and depth of analysis however yield valuable results in the understanding of how specific interventions with regard to land and labor can greatly contribute to the agricultural output.

5.2 Recommendations

Enhance Policies on Land Use: Enact and implement policies on sustainable land management such as soil conservation and planting of trees and checking on land clearing. Leave new tools; USB based GPS and remote sensing to enable farmers to plan land use more correctly. Guarantee land rights to farmers so as to attract long-run investments and planning.

Increase the labour skills and productivity: Train the farmers on modern ways of farming, pest management and handling after harvesting. Motivate the union of farms as cooperatives to share and save money. Training: build training centers to educate the farmers on how to use the machines and use environmentally friendly farming. Encourage more youth and women to join the agricultural activities by offering them incentive so that they will contribute with new ideas and diversify the workforce.

Increase and Use Capital Efficiently: Invest in such technologies as quality seeds, irrigation systems, machinery and processing equipment. Enhance the local banks and microfinance organizations in the provision of low cost loans to the farmers. Promote collaboration between the government and business corporations in order to invite investments into the infrastructure of farms and new technologies**.**

Plan Supportive Policies and Goals: Develop a broad-based agricultural policy encompassing land management, labour productivity, finance, climate change adaptation and market access. Increase climate-smart agriculture to minimize the risks associated with the weather. Invest in the development of rural infrastructure like roads, storage and market linkages to enable transportation and sales.

Stimulate More Studies: Have regular data collection and analysis procedures, informing policy corrections. Learn market access, infrastructure, and socio-economic conditions to get a bigger picture. Compare various regions to know about the best practices and apply the successful models in other places.

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APPENDIXES

APPENDIX I: RAW DATA

APPENDIX II: EVIEWS 12 OUTPUTS

UNIT ROOT TEST

LAQ

Null Hypothesis: LAQ has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.067245	0.7203
Test critical values:	1% level	-3.588509	
	5% level	-2.929734	
	10% level	-2.603064	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LAQ)
Method: Least Squares
Date: 03/07/25 Time: 09:48
Sample (adjusted): 1981 2024
Included observations: 44 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.

LAQ(-1)	-0.045251	0.042400	-1.067245	0.2920
C	0.418138	0.332223	1.258606	0.2151

R-squared	0.026403	Mean dependent var	0.066410
Adjusted R-squared	0.003222	S.D. dependent var	0.278590
S.E. of regression	0.278141	Akaike info criterion	0.323011
Sum squared resid	3.249219	Schwarz criterion	0.404111
Log likelihood	-5.106245	Hannan-Quinn criter.	0.353087
F-statistic	1.139012	Durbin-Watson stat	1.898688
Prob(F-statistic)	0.291957		

Source: *Reviews 12 Output (2025)*

D(LAQ)

Null Hypothesis: D(LAQ) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.196225	0.0000
Test critical values:	1% level	-3.592462	
	5% level	-2.931404	
	10% level	-2.603944	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LAQ,2)
Method: Least Squares
Date: 03/07/25 Time: 09:50
Sample (adjusted): 1982 2024
Included observations: 43 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LAQ(-1))	-0.967248	0.156103	-6.196225	0.0000
C	0.063635	0.044728	1.422685	0.1624

R-squared	0.483583	Mean dependent var	-0.001362
Adjusted R-squared	0.470987	S.D. dependent var	0.392014
S.E. of regression	0.285124	Akaike info criterion	0.373613
Sum squared resid	3.333132	Schwarz criterion	0.455529
Log likelihood	-6.032671	Hannan-Quinn criter.	0.403821

F-statistic	38.39321	Durbin-Watson stat	1.990235
Prob(F-statistic)	0.000000		

LLD

Null Hypothesis: LLD has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		3.702725	1.0000
Test critical values:	1% level	-3.588509	
	5% level	-2.929734	
	10% level	-2.603064	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LLD)
Method: Least Squares
Date: 03/07/25 Time: 09:53
Sample (adjusted): 1981 2024
Included observations: 44 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LLD(-1)	0.023121	0.006244	3.702725	0.0006
C	-0.187875	0.066909	-2.807926	0.0075

R-squared	0.246098	Mean dependent var	0.059281

Adjusted R-squared	0.228148	S.D. dependent var	0.034804
S.E. of regression	0.030577	Akaike info criterion	-4.092718
Sum squared resid	0.039269	Schwarz criterion	-4.011618
Log likelihood	92.03979	Hannan-Quinn criter.	-4.062642
F-statistic	13.71017	Durbin-Watson stat	1.618793
Prob(F-statistic)	0.000616		

D(LLD)

Null Hypothesis: D(LLD) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.548682	0.0007
Test critical values:	1% level	-3.592462	
	5% level	-2.931404	
	10% level	-2.603944	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LLD,2)
Method: Least Squares
Date: 03/07/25 Time: 09:54
Sample (adjusted): 1982 2024
Included observations: 43 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.

D(LLD(-1))	-0.634689	0.139533	-4.548682	0.0000
C	0.039256	0.009522	4.122739	0.0002

R-squared	0.335392	Mean dependent var	0.001943
Adjusted R-squared	0.319182	S.D. dependent var	0.038425
S.E. of regression	0.031705	Akaike info criterion	-4.019298
Sum squared resid	0.041213	Schwarz criterion	-3.937382
Log likelihood	88.41490	Hannan-Quinn criter.	-3.989090
F-statistic	20.69051	Durbin-Watson stat	2.070344
Prob(F-statistic)	0.000047		

LCL

Null Hypothesis: LCL has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.699756	0.4244
Test critical values:	1% level	-3.588509	
	5% level	-2.929734	
	10% level	-2.603064	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LCL)
Method: Least Squares
Date: 03/07/25 Time: 09:57
Sample (adjusted): 1981 2024

Included observations: 44 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LCL(-1)	-0.133743	0.078684	-1.699756	0.0966
C	0.806937	0.474416	1.700906	0.0964

R-squared	0.064362	Mean dependent var	0.000862
Adjusted R-squared	0.042085	S.D. dependent var	0.090135
S.E. of regression	0.088218	Akaike info criterion	-1.973621
Sum squared resid	0.326862	Schwarz criterion	-1.892521
Log likelihood	45.41965	Hannan-Quinn criter.	-1.943545
F-statistic	2.889172	Durbin-Watson stat	2.064628
Prob(F-statistic)	0.096572		

D(LCL)

Null Hypothesis: D(LCL) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-7.112724	0.0000
Test critical values:	1% level	-3.592462	
	5% level	-2.931404	
	10% level	-2.603944	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(LCL,2)
Method: Least Squares
Date: 03/07/25 Time: 09:58
Sample (adjusted): 1982 2024
Included observations: 43 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LCL(-1))	-1.105552	0.155433	-7.112724	0.0000
C	0.000871	0.013998	0.062246	0.9507

R-squared	0.552357	Mean dependent var	0.000533
Adjusted R-squared	0.541439	S.D. dependent var	0.135553
S.E. of regression	0.091792	Akaike info criterion	-1.893178
Sum squared resid	0.345460	Schwarz criterion	-1.811261
Log likelihood	42.70332	Hannan-Quinn criter.	-1.862969
F-statistic	50.59085	Durbin-Watson stat	1.922282
Prob(F-statistic)	0.000000		

LIC

Null Hypothesis: LIC has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.501243	0.1221
Test critical values:	1% level	-3.588509	
	5% level	-2.929734	
	10% level	-2.603064	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LIC)
Method: Least Squares
Date: 03/07/25 Time: 10:03
Sample (adjusted): 1981 2024
Included observations: 44 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LIC(-1)	-0.163301	0.065288	-2.501243	0.0164
C	1.171993	0.455319	2.574006	0.0137

R-squared	0.129646	Mean dependent var	0.036120
Adjusted R-squared	0.108923	S.D. dependent var	0.231688
S.E. of regression	0.218706	Akaike info criterion	-0.157789
Sum squared resid	2.008955	Schwarz criterion	-0.076689
Log likelihood	5.471352	Hannan-Quinn criter.	-0.127713
F-statistic	6.256216	Durbin-Watson stat	1.971359
Prob(F-statistic)	0.016361		

D(LIC)

Null Hypothesis: D(LIC) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-6.534810	0.0000

Test critical values:	1% level	-3.592462
	5% level	-2.931404
	10% level	-2.603944

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LIC,2)
Method: Least Squares
Date: 03/07/25 Time: 10:05
Sample (adjusted): 1982 2024
Included observations: 43 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LIC(-1))	-1.015706	0.155430	-6.534810	0.0000
C	0.033204	0.036456	0.910784	0.3677

R-squared	0.510177	Mean dependent var	-0.004482
Adjusted R-squared	0.498230	S.D. dependent var	0.333233
S.E. of regression	0.236048	Akaike info criterion	-0.004168
Sum squared resid	2.284465	Schwarz criterion	0.077748
Log likelihood	2.089615	Hannan-Quinn criter.	0.026040
F-statistic	42.70375	Durbin-Watson stat	1.959164
Prob(F-statistic)	0.000000		

OPTIMAL LAG LENGTH

VAR Lag Order Selection Criteria
Endogenous variables: LAQ LLD LCL

LIC
Exogenous variables: C
Date: 03/07/25   Time: 10:33
Sample: 1980 2024
Included observations: 42

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-58.75522	NA	0.000233	2.988344	3.153836	3.049003
		357.1851	3.222008	-	-	-
1	143.9714	*	*	5.903402*	5.075941*	5.600105*
2	152.2616	13.02738	4.766008	-5.536267	-4.046835	-4.990331
3	164.1412	16.40510	6.133008	-5.340055	-3.188654	-4.551482

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

JOHANSEN CO-INTEGRATION TEST

Date: 03/07/25 Time: 10:38
Sample (adjusted): 1982 2024
Included observations: 43 after adjustments
Trend assumption: Linear deterministic trend
Series: LAQ LLD LCL LIC
Lags interval (in first differences): 1 to 1

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None	0.325163	35.20107	47.85613	0.4374
At most 1	0.173152	18.28984	29.79707	0.5447
At most 2	0.147409	10.11405	15.49471	0.2721
At most 3	0.072938	3.256587	3.841465	0.0711

Trace test indicates no cointegration at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	0.325163	16.91123	27.58434	0.5876
At most 1	0.173152	8.175787	21.13162	0.8926
At most 2	0.147409	6.857462	14.26460	0.5061
At most 3	0.072938	3.256587	3.841465	0.0711

Max-eigenvalue test indicates no cointegration at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegrating Coefficients (normalized by b'*S11*b=I):

LAQ	LLD	LCL	LIC
3.767356	-4.454254	4.676094	0.333516
0.110905	-1.237583	-4.241336	1.903484
0.824343	-2.076031	-0.951470	-1.014128
0.196810	0.933303	-3.969166	-1.432195

Unrestricted Adjustment Coefficients (alpha):

D(LAQ)	-0.136361	0.016144	-0.031700	-0.029196
D(LLD)	0.001122	-0.003402	-0.011007	0.001621
D(LCL)	-0.004465	0.011629	-0.009619	0.021531
D(LIC)	-0.053454	-0.065933	0.037805	0.021002

1 Cointegrating Equation(s): Log likelihood 143.2952

Normalized cointegrating coefficients (standard error in parentheses)

LAQ	LLD	LCL	LIC
1.000000	-1.182329	1.241214	0.088528
	(0.12180)	(0.39882)	(0.16400)

Adjustment coefficients (standard error in parentheses)

D(LAQ)	-0.513720
	(0.14993)
D(LLD)	0.004228
	(0.01886)
D(LCL)	-0.016820
	(0.05472)
D(LIC)	-0.201380
	(0.13396)

2 Cointegrating Equation(s): Log likelihood 147.3831

Normalized cointegrating coefficients (standard error in parentheses)

LAQ	LLD	LCL	LIC
1.000000	0.000000	5.920486	-1.934991
		(2.44460)	(0.86820)
0.000000	1.000000	3.957674	-1.711469
		(2.03416)	(0.72243)

Adjustment coefficients (standard error in parentheses)

D(LAQ)	-0.511929	0.587406
	(0.14966)	(0.18357)
D(LLD)	0.003850	-0.000788
	(0.01875)	(0.02300)
D(LCL)	-0.015530	0.005495
	(0.05427)	(0.06656)
D(LIC)	-0.208692	0.319695
	(0.12764)	(0.15656)

3 Cointegrating Equation(s): Log likelihood 150.8118

Normalized cointegrating coefficients (standard error in parentheses)

LAQ	LLD	LCL	LIC
1.000000	0.000000	0.000000	5.445142
			(2.47982)
0.000000	1.000000	0.000000	3.221937
			(1.58263)
0.000000	0.000000	1.000000	-1.246542
			(0.49748)

Adjustment coefficients (standard error in parentheses)

D(LAQ)	-0.538061	0.653216	-0.675947
	(0.15187)	(0.19949)	(0.25132)
D(LLD)	-0.005223	0.022062	0.030151
	(0.01788)	(0.02349)	(0.02959)
D(LCL)	-0.023460	0.025465	-0.061047
	(0.05521)	(0.07253)	(0.09137)
D(LIC)	-0.177528	0.241210	-0.006281
	(0.12843)	(0.16870)	(0.21253)

Post Diagnostic Test

Breusch-Godfrey Serial Correlation LM Test:
Null hypothesis: No serial correlation at up to 1 lag

F-statistic	3.853415	Prob. F(1,38)	0.5570
Obs*R-squared	4.051050	Prob. Chi-Square(1)	0.5441

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Date: 03/07/25 Time: 11:18
Sample: 1981 2024
Included observations: 44
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.309361	0.201063	-1.538627	0.1322
C(2)	0.312419	1.461925	0.213704	0.8319
C(3)	0.382392	0.257102	1.487320	0.1452
C(4)	-0.317796	0.299951	-1.059493	0.2961
C(5)	-0.014860	0.096652	-0.153748	0.8786
RESID(-1)	0.490353	0.249796	1.963012	0.0570

R-squared	0.092069	Mean dependent var	-7.39E-16
Adjusted R-squared	-0.027395	S.D. dependent var	0.246018
S.E. of regression	0.249365	Akaike info criterion	0.186324
Sum squared resid	2.362947	Schwarz criterion	0.429623
Log likelihood	1.900866	Hannan-Quinn criter.	0.276551
F-statistic	0.770683	Durbin-Watson stat	2.053076
Prob(F-statistic)	0.576805		

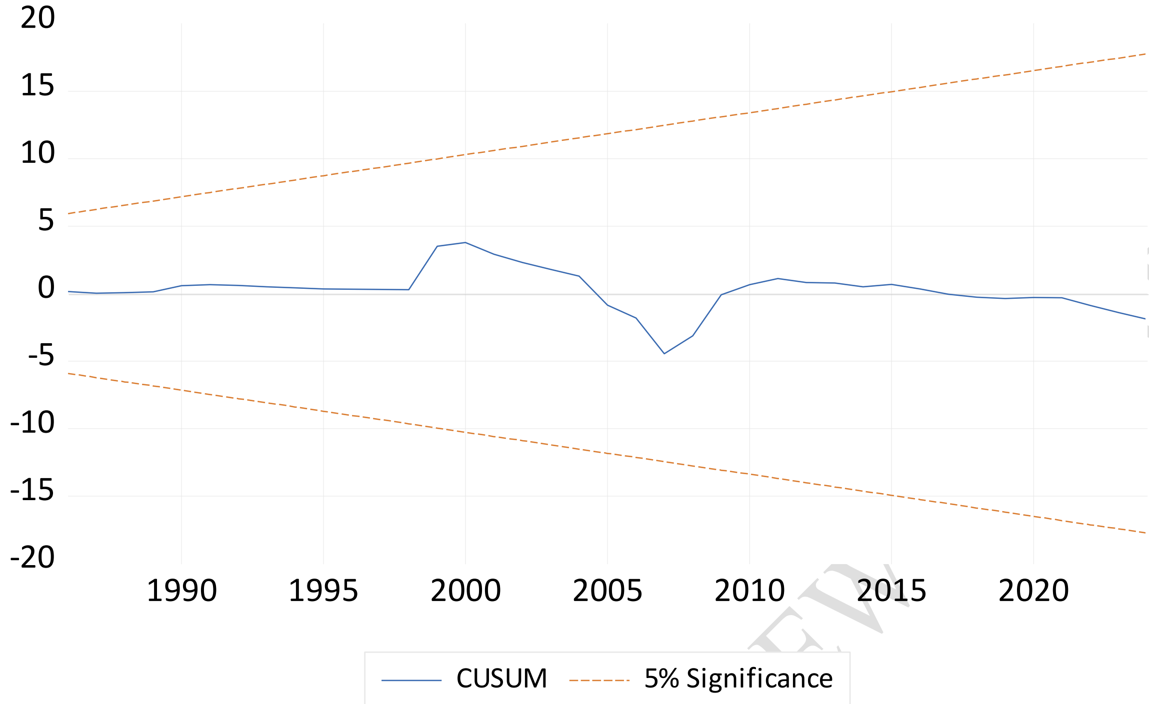
Heteroskedasticity Test: Breusch-Pagan-Godfrey
Null hypothesis: Homoskedasticity

F-statistic	3.136521	Prob. F(4,39)	0.1250
Obs*R-squared	10.70940	Prob. Chi-Square(4)	0.1300
Scaled explained SS	34.18347	Prob. Chi-Square(4)	0.2152

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 03/07/25 Time: 11:19
Sample: 1981 2024
Included observations: 44

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.707714	0.907835	1.881086	0.0674
LAQ(-1)	-0.222459	0.078000	-2.852035	0.0069
LLD	0.267192	0.104820	2.549045	0.0148
LCL	-0.493419	0.157743	-3.127997	0.0033
LIC	0.026139	0.060193	0.434245	0.6665

R-squared	0.243395	Mean dependent var	0.059149
Adjusted R-squared	0.165795	S.D. dependent var	0.170557
S.E. of regression	0.155778	Akaike info criterion	-0.774127
Sum squared resid	0.946403	Schwarz criterion	-0.571378
Log likelihood	22.03080	Hannan-Quinn criter.	-0.698938
F-statistic	3.136521	Durbin-Watson stat	2.419733
Prob(F-statistic)	0.024965		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