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Analysis of the Correlation Between Rwanda's Agricultural Growth and Economic Development

Leonard Ndayishimiye[a*], Zhang Xinling[b]

a. Department of Agricultural Economics and Management, PhD candidate, Inner Mongolia Agricultural University, China
b. Department of Agricultural Economics and Management, Inner Mongolia Agricultural University, China

Abstract: Rwanda's economy has historically been based chiefly on agriculture, although it remains crucial to the country's economic growth. For most people in this largely rural nation, the agricultural sector remains an essential means of livelihood, income, and food security. This research analyzed the relationship between economic development and agricultural growth. Based on data from the Rwanda National Institute of Statistics and the World Bank, the study employed regression analysis to test for correlation using the ARIMA model, the error correction model, unit root tests, and cointegration analysis. The findings show that agricultural growth, defined as the annual increase in the general average output level, positively impacts Rwandan economic development as measured by GDP, the GINI index, the CPI, and Poverty reduction. Considering the incredibly high R-squared value of 0.848 for the estimated parameters, where the intercept is equal to 4.338883, and the related slope coefficients are negative, this shows the strong relationship between Rwanda's economic development and agricultural growth. The correlation matrix shows the existence of perfect collinearity with the minimum and maximum values of 0.531 and 0.994, respectively. The ADF test provides unit root tests for specific variables and associated critical values at 1%, 5%, and 10% significance levels, with negative values indicating stationarity; the variables are found to be stationary. Thus, consistent efforts are required to modernize, mechanize, and transform agriculture as the main drivers of agricultural growth, boosting the economy's output and providing long-term, steady growth and development.
Keywords: Agricultural Growth, Correlation Analysis, and Economic Development.

1. Introduction

Rwanda has significantly transformed its agricultural landscape in recent years through a range of legislative changes, technological advancements, and sustainable practices. The goals of these initiatives have been to raise household incomes, boost productivity, and promote economic stability. In Rwanda, there is a complex relationship between the expansion of agriculture and economic development that immediately boosts the GDP, creates many jobs, and is a significant factor in the decline of poverty. Understanding the relationship between agricultural expansion and economic development is crucial, particularly given the nation's emphasis on sustainable development and on enhancing the lives of its rural populations. Argued that agriculture is the primary driver of economic growth and development, serving as the foundation for economic success and poverty alleviation.

In addition, (Newfarmer et al., 2019) provided clear evidence that rising agricultural output and economic expansion were positively correlated. The agricultural sector is frequently promoted as a critical tool for economic growth and poverty reduction in several recognized development reports (Byerlee et al., 2009). Despite limited trade opportunities, modernizing and developing the agricultural industry may be more significant for growth in closed, landlocked countries (Wambugu et al., 2018).

Moreover, (Jaganyi et al., 2018) illustrated that the industry's growth is frequently cited as the key engine of economic progress, while agriculture is often disregarded. However, the paradigm changed in the 1970s to emphasize economic development from an increasingly agricultural perspective (Alam et al., 2009). found that

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Corresponding email: ndayishimieleonard1@gmail.com (Leonard Ndayishimiye)
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more investments in the agricultural sector, a growing world economy, and higher prices for natural resources are the main drivers of this growth process. Therefore, Pingali (Malunda & Musana, 2012) stated that Brazil and India have demonstrated that agricultural development can produce an enormously beneficial effect. India's Green Revolution significantly increased agricultural output, accelerating the country's industrialization and GDP growth. Determined that a significant portion of the growth in GDP per capita can be attributed to gains in agricultural production. A nation's capacity to boost agricultural production enabled it to move labor from the traditional agricultural sector to other industries or services. observed that development strategies started to suggest a greater emphasis on agriculture, whereas in the past, the domestic policies of developing countries showed a strong bias against the agricultural sector through price, tax and exchange-rate policies that harmed agricultural productivity, the reports and development strategies in the early 1980s suggested more favorable agricultural policies and a greater emphasis on the agricultural sector in the process of economic development (Van Keulen et al., 2022).

According to (Ornert, 2018)The role of agriculture in development is distinguished by open and closed economies, where nations have abundant resources, such as metals and oil, that they can supply international commodity markets. In addition, the agricultural sector continues to be the dominant industry in most developing nations, providing inputs, food, employment opportunities, raw materials for various industries, and foreign profits through the export of agricultural products (Fukase & Martin, 2018). Low productivity and the agricultural industry's slow development are believed to be the primary reasons for emerging countries' low incomes and slow economic growth (Los & Gardebroek, 2015).

Reported that Rwanda Government-sponsored initiatives, including the Crop Intensification Program (CIP), have boosted earnings for smallholder farmers and significantly increased yields, which have contributed to a decrease in poverty (Cramer et al., 2020). Rwanda's GDP is heavily influenced by agriculture, and the National Institute of Statistics of Rwanda estimated that, over recent years, agriculture accounted for approximately 24 per cent of Rwanda's GDP.

Moreover, (Pingali, 2012) Rwanda stated that the employment Generation for those living in the countryside, where poverty is greatest, depends on this sector for their livelihoods. Therefore, improving agricultural output can be highly significant in mitigating poverty. However, there are other viewpoints regarding the robust and beneficial correlation between agricultural and economic growth. Agricultural development is emphasized in specific literature as a necessary condition for economic growth.

The causal relationship between economic development and agricultural expansion noted earlier may account for the recent economic growth observed across most developing African nations. Growth in the agricultural sector requires robust institutional structures with effective government initiatives. Rwanda's development frameworks and Vision 2020 are examples of strategic plans that have considerable value for environmentally friendly farming practices and farmer support systems (Raza et al., 2023). The main objective of this research is to understand and analyze Rwanda's agricultural growth and its effect on the determinants of economic development. The study independently analyzes the determinants of economic development in depth, focusing on their impact on agricultural growth. The main question this research aims to address is how economic development and agricultural growth interact. Beyond this, other empirical research in the field has failed to make use of panel time-series analysis, which enables the application of time-series techniques and combines them with additional data and power gained from panel analysis. Applying these techniques contributes to the existing empirical literature on the relationship between agricultural growth and economic development.

In contrast, the experiences of other developing nations demonstrate the variety of ways in which agricultural prosperity can contribute to economic advancement. Harnessing the full potential of agriculture to drive comprehensive, sustainable economic development requires sustained investment in technology, policies that support it, and sustainable practices. The experiences of other African nations demonstrate the importance of implementing supportive policies and technologies to accelerate agricultural growth and economic development.

2. Methodology

The analysis method starts by collecting and sorting the existing literature on agricultural growth and economic development determinants at home and abroad, and by identifying relevant documents needed to analyze the

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current situation of the Rwandan economy. The process of gathering, compiling, evaluating, and interpreting statistical data to draw specific conclusions about the problems it reflects is referred to as a statistical approach. Statistical methods are suitable only for high-probability events; the more events studied, the more accurate the results. The paper primarily draws on data from the Rwanda Bureau of Statistics, the Ministry of Economic Planning and Finance (MINECOFIN), the World Bank, and the International Monetary Fund.

This paper comprehensively uses two analysis methods: qualitative analysis and quantitative analysis. Under the guidance of the framework and direction of qualitative analysis, the quantitative analysis means are used to support and verify the conclusions of qualitative analysis, and the two complement each other, to correctly reflect the dynamic relationship between Rwandan economic growth and agricultural development, and to provide practical policy recommendations (Pingali, 2012). Comparative analysis consists of quantitative, identical content, comparisons of various factors, indicators, and socio-economic phenomena of the exact nature, and the analysis of the magnitude of changes in each research indicator defines empirical analysis as a research method that obtains objective data through repeated observations, experiments, and investigations of research subjects, and summarizes the essential properties and developmental laws of things from the individual to the general (Fukase & Martin, 2018).

Empirical analysis includes many methods, such as static analysis and dynamic analysis, static equilibrium analysis, comparative static equilibrium analysis, dynamic equilibrium analysis, average street analysis, non-equilibrium analysis, qualitative analysis, and quantitative analysis. It concerns foreign theoretical research and successful experience. Corresponding value judgments and feasible policy measures are put forward to optimize and improve the Rwandan work system for economic development through agricultural growth. They argue that combining time-series and cross-sectional data enables relatively accurate data analysis. Panel time-series, or non-stationary panels, aim to use techniques from time-series and econometric analysis to address issues such as non-stationarity and to combine these with the increased data and power across the different cross-sections. Empirical research in the field of agricultural and economic development that uses these techniques, however, is still very scarce. The study of the causal relation between economic development and agricultural growth estimates a separate time-series equation. This study, therefore, aims to combine time-series techniques with the additional data and power provided by the different panels.

3. Variable description and Model specification

Several empirical studies employing various macroeconomic variables (as suggested by theory) in cross-country regression analyses have examined the relationship between agricultural growth (independent variables) and economic development determinants (dependent variable).

In this research, we use regression analysis to assess the correlation among the study's variables. Using the above-mentioned techniques and methods, quantitative data are expected to be assessed with minimal error terms and residuals, thereby enabling proper identification of the problem. In this research, the dependent and independent variables are clearly identified. Based on the conceptual framework and research hypotheses to figure out the links between agricultural growth and economic development, two equations were developed:

$$\Delta \text{Log ECODEVi} = \beta 0 + \beta 1 \Delta \text{LogAGRi} + \text{Ui} \ldots\ldots\ldots\ldots\ldots (1)$$

$$\Delta \text{LogECODE} = \beta 0 + \beta 1 \Delta \text{LogGDPi} + \beta 2 \Delta \text{LogGINIi} + \beta 3 \Delta \text{LogCPIi} + \beta 4 \Delta \text{LogPOVi} + \text{Ui} \ldots\ldots (2)$$

Equation 1 implies that Rwandan economic development is an increasing function of Agricultural growth.
Equation 2 implies that Rwandan economic development is determined by GDP, GINI index, CPI, and Poverty reduction.

The Time Series and Trends Projection played an important role in various circumstances. The research is mainly based on the systematic study of available records. In this study, we used annual time-series data from the World Bank and the Rwanda National Institute of Statistics for the period from 2005 to 2024 (Huang & Rozelle, 2018). Both descriptive and econometric techniques were used. Unit Root test, Co-integration test, Error

Correction Mechanism, ANOVA, and ARIMA model were used to examine the relationship between agricultural growth and the determinants of Rwanda's economic development. SPSS and STATA are important software used for data analysis.

3. Results and discussion

3.1. Rwanda Agricultural Sector

Rwanda's economy, with limited natural resources, depends mainly on subsistence agriculture, carried out by local farmers with basic implements. In 2010, farming and agriculture accounted for an estimated 90% of the working population and 42.0% of GDP. The entire country grows potatoes, sorghum, coffee, tea, pyrethrum, bananas, beans, and coffee tea are crucial cash crops for export, with the higher altitudes, steep slopes, and volcanic soils providing favorable conditions. Rwanda's reliance on agricultural exports makes it vulnerable to price fluctuations (Ogundari, 2021).

Coffee is one of Rwanda's major cash crops. In 2012, agriculture accounted for 33% of Rwanda's economy. Rwanda's economy suffered heavily during the 1994 Genocide, with widespread loss of life, failure to maintain the infrastructure, looting, and neglect of important cash crops. This led to a significant decline in GDP and destroyed the country's ability to attract private and foreign investment. The economy has since strengthened, with per-capita GDP (PPP) estimated at $2,225 in 2018, compared with $416 in 1994. Major export markets include China, Germany, and the United States.

The economy is managed by the Central Bank of Rwanda, and the currency is the Rwandan franc; in June 2010, the exchange rate was 588 francs per United States dollar. Rwanda joined the East African Community in 2007, and there are plans for a common East African shilling, which is hoped to be in place by 2015. According to (Professionalisation, 2010) Rwanda's mining sector contributed US$93 million in 2008. The minerals mined comprised coltan, sapphires, wolframite, cassiterite, and gold. These minerals are used to make electronic and communication devices, notably smartphones.

3.2. Rwanda's agricultural production

Historically, agriculture has been an essential part of economic growth, especially in developing nations. This analysis examines whether agriculture contributes to Rwanda's economic growth and compares it with other nations where the sector plays a significant role. The sector provides livelihoods for most of the rural population, where poverty levels are highest (Roemer, 1979).

The evaluation examines the relationship between agricultural growth and GDP, employment, poverty reduction, and overall economic stability. Figure 1 below shows the agricultural production situation in the Rwandan economy, based on the annual agricultural output considered in this study. Agricultural development makes a critical contribution to overall economic growth in many developing countries. The Rwandan economy is based on the largely rain-fed agricultural production of small, semi-subsistence, and increasingly fragmented farms. While coffee and tea production are well-suited to Rwanda's small farms, steep slopes, and cool climates, the average family farm size is 0.5 hectares, unsuitable for most agribusiness purposes. In 2018, agribusiness accounted for approximately 33.6% of Rwanda's GDP and 45% of exports. Rwanda is a country with few natural resources, and the economy is based mainly on subsistence agriculture by local farmers using simple tools. An estimated 90% of the working population farms, and agriculture accounted for 42.1% of GDP (Professionalisation, 2010).

Despite Rwanda's fertile ecosystem, food production often fails to keep pace with population growth, requiring food imports. Crops grown in the country include three types: Firstly, food crops such as cereals (maize, rice, sorghum, wheat, millet), tubers (Irish potatoes, sweet potatoes, cassava); leguminous (beans, peas, soja, banana) and they occupy 92.7 % of the arable land and account for 89% of food supply of rural and urban population. Secondly, traditional cash crops, such as coffee, tea, and pyrethrum, are the major export crops, with high altitudes, steep slopes, and volcanic soils providing favorable conditions.

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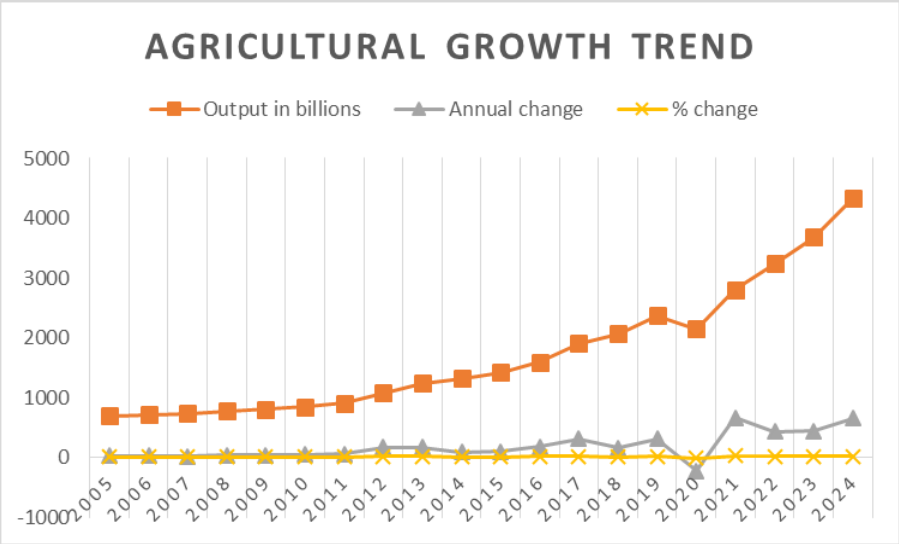

Figure 1: Rwanda agricultural production trend 2005-2024

They are cultivated on 7.2% of the arable land and account for 45% of Rwanda's total exports. Lastly, new cash crops include vegetables and fruits, flowers, and some spices, which are cultivated on 0.1% of the land (Ssozi et al., 2019). Figure 1 above shows the agricultural production of different periods, indicating a consistent increase and a sustainable output trend. The general observation indicates that agriculture has maintained its contribution to the country's economic growth as the primary sector of the Rwandan economy.

3.4. Rwanda agricultural development and its implications for Rwanda's economic development indicators

3.4.1. Rwanda economic growth (GDP)

The gross domestic product at current prices is defined based on the GDP in national currency converted to U.S. dollars using market exchange rates (yearly average). The GDP represents the total value of final goods and services produced during a year. Figure 2 illustrates the Rwandan economy's situation, focusing on Gross Domestic Product. It provides a trend image of the Rwandan economy, focusing on annual economic growth.

Rwanda has experienced sustained variability in economic growth rates over the past few years, as shown in the figure above. The crucial decline occurred in 2020 due to the global pandemic, which negatively affected the world economy (Alston, 2014).

The Government of Rwanda is actively working to develop the economy and reform the financial and business sectors, improving the business climate dramatically, increasing its rank from 139 to 62 on the annual World Bank Doing Business Report. Rwanda's primary foreign exchange earners include mining, tourism, coffee, and tea, and continued growth in these sectors is crucial for economic development.

USAID investments focus on enhancing private-sector competitiveness, with particular emphasis on expanding market access. In the staple crops, dairy, and horticulture sectors, USAID helps farmers expand their markets to increase the competitiveness of their products in the region and supports private businesses in growing their supply chain networks.

USAID also supports the growing role of the private sector along the fertilizer supply chain by facilitating policy reforms that enable the private sector to take the lead in the fertilizer imports and distribution industry. USAID helped Rwanda benefit from regional trade within the East African Community by improving trade facilitation policies, increasing the competitiveness of Rwandan products, and upgrading infrastructure at border posts.

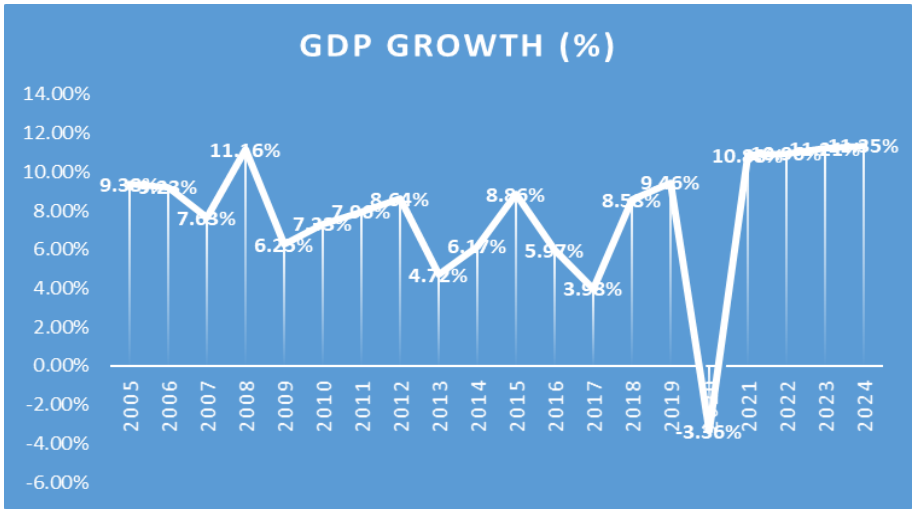

Figure 2: Rwanda economic growth (GDP), 2005-2024

As a landlocked country, Rwanda will need to maintain efficient and effective trade with its neighbors, including Uganda, Tanzania, and the Democratic Republic of Congo, to achieve its goal of becoming a middle-income country. USAID support resulted in a 46% reduction in the time it takes for goods to clear customs: a 64% reduction in export release time and a $225 reduction in import costs per truck. As shown in the figure above, Rwanda experienced both increases and decreases in economic growth rates as measured by a country's GDP, especially in 2020 due to the general pandemic crisis, where the rate went even below zero, but the general average ranges between 8% and 8.5% of annual economic growth. Economic growth has been sustained at a rising rate over the last four years, following the pandemic.

3.4.2. Rwanda Income distribution (GINI coefficient)

The GINI coefficient measures the extent to which the distribution of income (or, in some cases, consumption expenditure) among individuals or households within an economy deviates from a perfectly equal distribution. A Lorenz curve plots the cumulative percentages of total income received against the cumulative number of recipients, starting with the poorest individual or household. The Gini index measures the area between the Lorenz curve and a hypothetical line of absolute equality, expressed as a percentage of the maximum area under the line. Thus, a Gini index of 0 represents perfect equality, while an index of 100 implies perfect inequality. The data on income distribution, as indicated by the GINI coefficient, are illustrated in Figure 3.

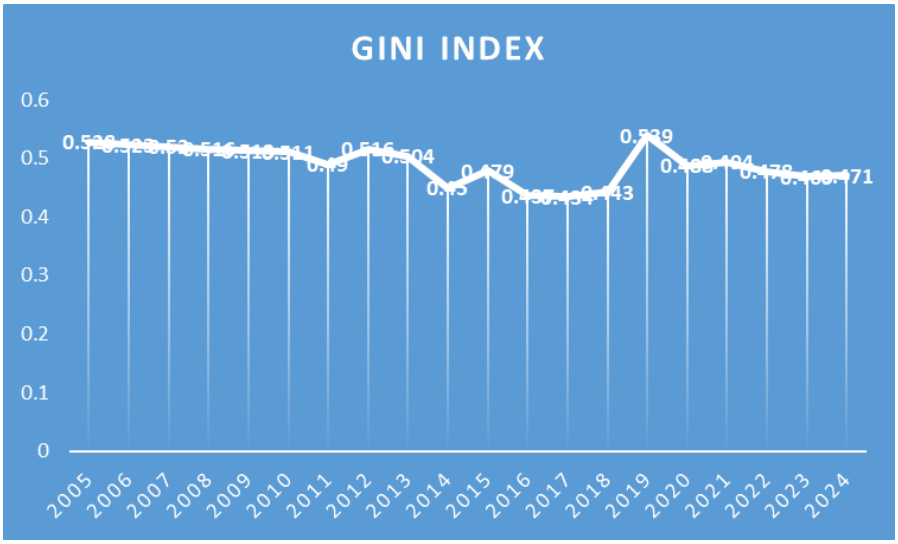

Figure 3: Rwanda GINI coefficient, 2005-2024

For that indicator, we provide data for Rwanda from 2005 to 2024. The average value for Rwanda during that period was 49% index points, with a minimum of 43.4% index points in 2017 and a maximum of 53.9% index

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points in 2019. Oxfam (2016) uses the share of Gross Domestic Product (GDP) claimed by the wealthiest 10% of the population divided by that of the poorest 40% to assess income distribution in East Africa. This illustrates that income inequality in Rwanda was the highest in the region in 2011, but has since declined, as shown in the figure above, where it decreased by 43% in 2017 and 2018.

3.4.3. Rwanda inflation rate as defined by the consumer price index (CPI)

Inflation, as measured by the Consumer Price Index, reflects the annual percentage change in the cost to the average consumer of acquiring a basket of goods and services, which may be fixed or revised at specified intervals, such as yearly. Figure 4 shows the inflation rate situation.

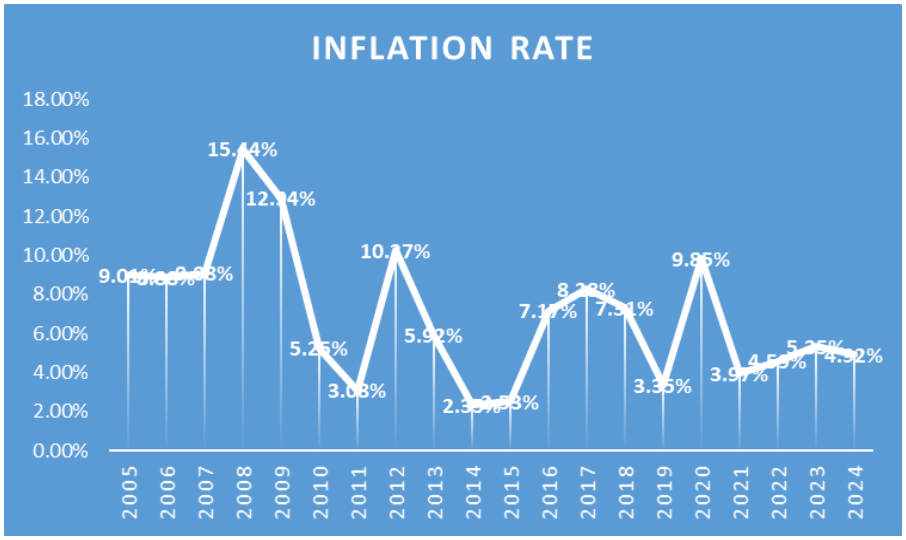

Figure 4: Rwanda inflation rate, 2005-2024

In only a few countries have negative inflation rates been achieved. This means that the general price level is declining, and consumer prices are getting cheaper. This is called deflation. Compared with most other countries, the drastic price increases are no longer the norm (Byiringiro & Reardon, 1996).

Usually, this is a sign of political and economic turmoil. Rwanda is one of the African countries experiencing price instability, but, due to the government's economic development strategies, inflation decreased in 2011, 2014, 2015, 2019, and 2024, as indicated by the Rwanda Institute of National Statistics (Figure 4). The general average is 6.98% over 20 years under the study period.

It indicates that Rwanda maintained an economic growth rate through an increased agricultural growth sector where is high potential for the development of the sector with the introduction of modern methods of farming increased both productivity and quality of products, the development of value added production and initiatives to increase exports so that the agricultural sector makes its full potential contribution to the economy and reducing the consumer prices.

3.4.4. Poverty and Its Dimension in Rwanda

Since independence, the Government of Rwanda has endeavored to improve the quality of life of the people through planned development efforts. It has implemented various Economic Development and Poverty Reduction Plans. The goals of these plans were to accelerate economic growth and poverty reduction through employment creation (Dorosh & Thurlow, 2018). However, the trends in poverty incidence and inequality are based on the lower and upper poverty lines estimated with the cost of basic needs method and the direct calorie intake method. The level of poverty decreased significantly within the period under study, 2005-2024. The drop in poverty in recent years was larger in urban areas than in rural areas. Thus, rural poverty remained much higher than urban poverty in both the lower and upper poverty lines.

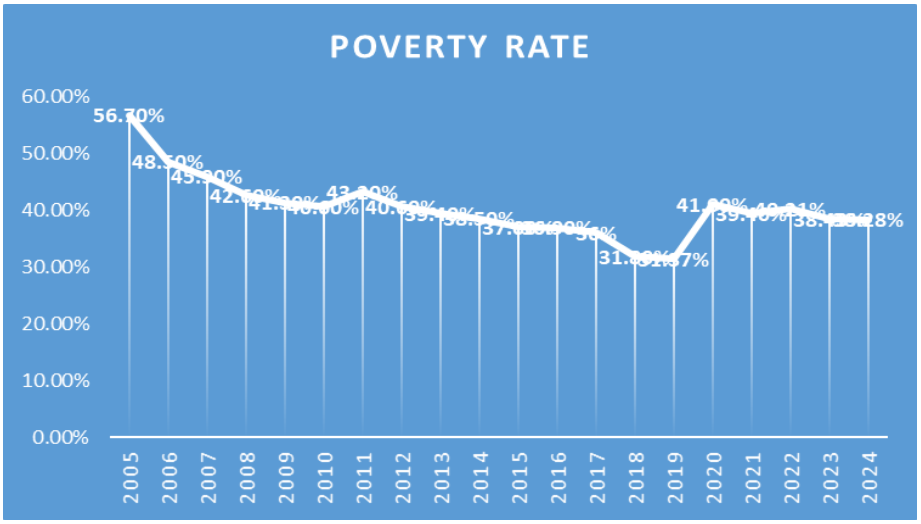

Figure 5: Poverty situation between 2005 and 2024

Rwanda is now increasingly regarded as a model for economic growth and stability in Africa. Real GDP has multiplied by more than 7 in the last 20 years; this growth is coupled with high stability, which makes the country part of Africa's Stable growers (Jaganyi et al., 2018).

This growth is mainly explained by the service sector, especially in the last decade. This growth and the positive trends in poverty reduction have prompted several policies and research questions, both nationally and worldwide. One important question is to demonstrate the extent to which ongoing economic growth policies, programmers, and home-grown initiatives have translated into poverty reduction in Rwanda. The contribution of this research is to establish knowledge of how and whether the observed economic growth in the past has been pro-poor, and to identify the enablers and constraints of poverty reduction in Rwanda.

Poverty has reduced linearly from 2005 to 2024 (Figure 5). This implies that, although achieving zero poverty is ambitious, reducing poverty and ensuring sustainable growth are possible in the mid- to long-term. We also learn from the findings that poverty reduction interventions will need to concentrate further efforts in rural areas. The results show a higher poverty prevalence in rural areas than in urban areas. The ongoing urbanization and secondary cities policy in Rwanda are expected to further contribute to poverty reduction, especially by creating the infrastructure needed for efficient economic transactions. These results show stable, high, and pro-poor economic growth.

There is substantial poverty reduction, mainly due to an inclusive model of economic growth, as the 20-year average indicates 40.38%. Even though the agricultural sector is the primary determinant of poverty reduction in Rwanda, as revealed by several studies, further investigation is needed to better understand the sustaining factors in future growth, focusing on the roles of economic productivity, public investment, and their interaction in Rwanda.

3.5. Econometric analysis

Regression analysis, a collection of statistical methods, is used to estimate the relationship between a dependent variable and one or more independent variables. In this section, the researcher took time to analyze the correlations between variables, estimate parameters from the coefficients, and analyze variances.

3.5.1. Cointegration Regression Results

The cointegration regression of time-series data considers only a long-run equilibrium relationship among the series. However, a good time series model should jointly describe the long-run equilibrium and the short-run dynamics. For this, the short- and long-term behavior of an economic variable can be reconciled using the Engle-Granger error-correcting mechanism (ECM). In the study, both the long-run dynamics analysis and unrestricted error-correction mechanisms are used.

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Table 1: Summary of regression analysis results

Variable entered	Coefficient	Std. error	t-statistics	P value
Constant	4.338883	0.5060189	8.57 0.000	3.194189
Gross Domestic Product	-.1833253	0.1852814	-0.99	0.348
GINI Index	-.2086578	0.0318492	-3.202	0.007
Consumer Price Index	-.1107763	0.0929046	-1.19	0.264
Poverty reduction	-2.113251	0.4162019	-5.08	0.001
R-squared	0.848		Adjusted R-squared	0.7988
S. E	1.9552			

Source: Authors' calculation based on NISR& World Bank data, 2024

The results of the error correction analysis suggest that, in the long run, agricultural growth and economic development have a strong positive correlation, as indicated by the multiple correlation coefficient of 0.848, adjusted to 0.7988 (Table 1). However, the result from ECM is similar to that from OLS regression because the time series data are stationary and non-co-integrated. This concurrently delivers long-run equilibrium and short-run dynamics.

3.5.2. Correlation between Variables

The general objective of this research is to examine the influence of agricultural growth and economic development on the Rwandan economy, and one of the specific objectives is to test the interconnectivity among the model's study variables. The table below illustrates well the correlation between regression variables.

Table 2: Correlation matrix

Variables entered	Agriculture	GDP	GINI	CPI	Poverty reduction
Agriculture	1.000	0.531	0.864	0.931	0.898
GDP	0.761	1.000	0.974	0.871	0.795
GINI	0.682	0.719	1.000	0.675	0.722
CPI	0.943	0.605	0.836	1.000	0.994
Poverty reduction	0.898	0.924	0.882	0.790	1.000

Source: Authors' calculation based on NISR& World Bank data, 2024

The correlation coefficient, which illustrates the relationship between the study variables, is shown in the table above. As the results presented above show, each variable demonstrated a beneficial relationship (Fujita, 2010).

The findings facilitate the detection of a partial regression analysis in which agricultural growth reacts to GDP, with a coefficient of 0.761, which implies a positive relationship between the two variables. Agricultural growth responds positively to income distribution, as indicated by a correlation coefficient of 0.682 with the GINI coefficient. Furthermore, agricultural growth shows a strong correlation with inflation rates, as indicated by a coefficient of 0.943 with the CPI, which measures the consumer price index (Cramer et al., 2020).

Lastly, it was found that agricultural growth positively correlates with poverty reduction in Rwanda, with a correlation coefficient of 0.898 (Boliko, 2019). The analysis found serial correlation among economic development determinants, which implies multicollinearity in the regression model and its implications for this research (Umutoni, 2016).

3.5.3 Augmented Dickey-Fuller (ADF) Unit Root Test

The underlying time series is assumed to be stationary in regression analysis based on time series data. We applied the Augmented Dickey-Fuller (ADF) test to determine whether the data were stationary (Table 3).

Table 3: Unit root test results

Variable	Significance level	Critical values	ADF Statistics
Agricultural production	1%	-2.718	-2.485
	5%	-1.796	
	10%	-1.363	
Gross Domestic Product	1%	-2.660	-5.602
	5%	-1950	
	10%	-1.600	
GINI Coefficient	1%	-2.660	-3.229
	5%	-1.950	
	10%	-1.600	
Consumer Price Index	1%	-2.660	-5.170
	5%	-1.950	
	10%	-1.600	
Poverty reduction	1%	-2.660	-2.940
	5%	-1.950	
	10%	-1.600	

Source: Authors' calculation based on NISR& World Bank data, 2024

An augmented Dickey-Fuller test (ADF) in statistics and econometrics tests the hypothesis that a time series sample contains a unit root. Depending on the test version used, the alternative hypothesis varies, although it typically involves stationarity or trend-stationarity. It is an improved Dickey-Fuller model for a more comprehensive and intricate collection of time series models. The test's enhanced Dickey-Fuller (ADF) statistic is negative (Professionalisation, 2010).

At a given level of confidence, the hypothesis that there is a unit root is firmly rejected the more negative it is. In general, you can rule out the null hypothesis that there is a unit root when the p-value is less than 5%. Computed DFT statistics, along with a tabular value of significance, can also be compared. A time series is stationary if its statistical characteristics or, more accurately, the process that produces it, do not vary with time (Van Keulen et al., 2022). Although many helpful analytical methods, including statistical tests and models, depend on significant stationarity (Kovač et al., 2012). Tests for stationarity in a time series are commonly called unit root tests. If an adjustment in time is not reflected in the distribution, the time series is said to be stationary; non-stationarity may have several causes. One example is unit roots (Malunda & Musana, 2012). Low statistical power is a recognized characteristic of these tests. From the analysis, the ADF test provides unit root tests for specific variables, with associated critical values at 1%, 5%, and 10% significance levels. Here, all the variables are found stationary because the ADF statistic exceeds the critical values at the 1%, 5%, and 10% significance levels, and thus there is no unit root, as indicated by the consistency of negative values observed in the analysis.

3.5.4. Analysis of Variance Results

The collection of statistical models and the associated estimation method is referred to as analysis of variance, which is used to examine differences in means.

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Table 4: Analysis of Variance Results

Model		Sum of Squares	df	Mean Square	F	Sig.
	Regression	44.019	1	44.019	40.883	0.000[a]
	Residual	7.537	7	1.077		
	Total	51.556	8			

Source: Authors' calculation based on NISR& World Bank data, 2024

The ANOVA test enables a concurrent comparison of more than one group to determine whether a relationship exists among them (Hebebrand, 2011). The F-statistic, referred to as the F-ratio, which is the outcome of the ANOVA formula, enables the study of several data sets to determine the variability both within and across samples. The null hypothesis states that there is no significant difference between the tested groups, as indicated by an ANOVA F-ratio statistic close to 1.

Testing three or more variables is made simpler by ANOVA. ANOVA involves distributing the variation among several sources and group differences by comparing the means of each group. It is used with test groups, subjects, groups within categories, and groupings among groups. The results revealed that ANOVA enabled us to test for the significance of the model (Hildyard, 2023).

From Table 4, we find F 0.01 = 40.883, where the mean square is equal to 44.19, and the total sum of squares equals 51.556, and Fv> Ft, so it is evident that the explanatory variable (agricultural growth) has a significant correlation with economic development determinants, and the regression model indicates the goodness of fit.

3.5.5. Autoregressive Integrated Moving Average (ARIMA)

The fundamental AR model for forecasting is extended to ARIMA (autoregressive integrated moving-average) models, which employ three methods to model the serial correlation in the disturbance term. The study analysis considers the ARIMA process (1, 0, 1), which means a purely AR (1) and M (1) stationary process.

Table 5. ARIMA analysis results

Var	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
GDP	0.076161	0 .097632	0.78	0.435	-0.115195	.2675181
GINI	0.017081	0 .030572	0.56	0.576	-0.042840	.0770024
CPI	-0.399135	0 .359445	-1.11	0.267	-1.103635	.3053643
POV	-0.033667	0.032796	-1.03	0.305	-0.097946	.0306118
ARI 1	0.913716	0 .226321	4.04	0.000	0.470133	1.357299
MA1	0.999907	6152.732	0.00	1.000	-12058.13	12060.13
Sigma	0.0220344	67.78667	0.00	0.500	0	132.8815

Source: Author's calculation based on NISR& World Bank data, 2024

Autoregressive integrated moving-average (ARIMA) models are employed in time-series analysis to determine which time-series model best fits historical data (Table 5). An autoregressive integrated moving average (ARIMA) model is an extension of an autoregressive moving average (ARMA) model in statistics and econometrics, specifically in longitudinal analysis (Ornert, 2018). Each of these models is applied to time series data to forecast future values or to improve understanding of the data. The developing variable of interest is regressed on its own delayed (i.e., prior) values, as shown by the AR component of ARIMA (Baltagi & Kao,

2001). The MA component indicates that the regression error is a linear combination of error terms with contemporaneous or lagged past values.

The "integrated" indicator (I) denotes that the data values have been replaced by the difference between their current and historical values. This method of differentiating could have been carried out once or more (Baltagi, 2008). Each of these features aims to get the model as close to the data as feasible. Here, the results of the analysis suggest that GINI and GDP are more positively correlated, and Poverty and CPI are more negatively correlated, at different lag periods. This implies that economic development increases after a lag and indicates a long-run positive relationship with agricultural growth.

4. Conclusion

Rwanda is an impoverished country where the primary means of economic growth and overall development is agriculture (Newfarmer et al., 2019). Considerable interdependence between the agricultural and economic sectors is evident in the correlation between Rwanda's agricultural progress and its economic development. Rwanda's overall economic expansion has been primarily fueled by agricultural growth, which has boosted GDP, GINI index, CPI, employment, and rural development.

Food security has increased due to higher agricultural productivity driven by government initiatives, technological advances, and infrastructure improvements. This increase has also had a knock-on effect on other economic sectors. This expansion has made it easier to reduce poverty and raise living standards, underscoring agriculture's significance in Rwanda's economic transition.

Nevertheless, sustaining this development requires ongoing investments in innovative farming methods, robust supply networks, and supportive legislation that addresses issues such as market access and climate change. All things considered, Rwanda's experience shows how important the agricultural sector is to promoting comprehensive, sustainable economic development.

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Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent

Not applicable. This study uses publicly available, de-identified secondary data and does not involve human subject participants or personal information.

Competing interests

The authors declare no competing interests.

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