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The Effects of COVID-19 on Agricultural Financing in Sub-Saharan Africa: A Cross-Country Analysis

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ABSTRACT

This study examines the impact of the COVID-19 pandemic on agricultural financing in Sub-Saharan Africa between 2019 and 2023, focusing on the long-term implications for the sector's resilience and recovery. Using pooled ordinary least squares (OLS), two-stage least squares (2SLS) and generalized method of moments (GMM), the analysis reveals that the pandemic significantly disrupted agricultural financing, with smallholder farmers and women farmers facing the greatest challenges in accessing financial resources. The study emphasizes the pivotal role of digital financial services, such as mobile money platforms, in mitigating these effects, particularly in regions with underdeveloped traditional financial systems. Furthermore, the research highlights the importance of government policy responses, economic diversification, and sustainable financing models in fostering recovery. Regions with stronger financial infrastructures and diversified economies demonstrated greater resilience, while less diversified areas struggled to maintain agricultural financing. The study advocates for targeted policy interventions to improve financial inclusion and support the agricultural sector's recovery. It also calls for the expansion of digital financial ecosystems, the development of inclusive financial products, and the integration of sustainable financing models to enhance the sector's long-term resilience. These findings provide critical insights for policymakers, financial institutions, and development organizations seeking to strengthen agricultural financing and ensure a more sustainable future for the sector in Sub-Saharan Africa.

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1. Introduction

The COVID-19 pandemic has been one of the most significant global crises of the 21st century, disrupting economies and livelihoods on an unprecedented scale [1–9]. Sub-Saharan Africa, with its economic dependence on agriculture, has been particularly vulnerable to these disruptions [10–13]. Agriculture contributes approximately 23% of the region's GDP and serves as the primary livelihood for over 60% of its population, underscoring its critical role in economic growth, food security, and poverty alleviation [14]. However, the pandemic has intensified existing structural vulnerabilities in agricultural financing, threatening the sector's stability and long-term sustainability.

Agricultural financing in Sub-Saharan Africa has historically faced systemic challenges such as limited access to credit, high transaction costs, and insufficient institutional support. These challenges are particularly pronounced for smallholder farmers, who form the majority of agricultural producers and often operate at subsistence levels. The advent of COVID-19 exacerbated these constraints, disrupting financial flows and compounding difficulties in securing essential inputs like seeds, fertilizers, and equipment [15]. Lockdowns and mobility restrictions further strained agricultural value chains, leading to reduced incomes, heightened credit risks, and increased food insecurity across the region [16–18].

Koloma and Kemeze [19] highlighted that liquidity shortages in the banking and financial sectors during the pandemic led to widespread business failures, further deepening the structural financing gap in agriculture. While their study confirmed a decline in financing allocated to the agricultural sector, it primarily focused on macro-level insights. In contrast, this study provides a cross-country analysis, examining how variations in financial system resilience, digital adoption, and policy responses shaped agricultural financing outcomes. Additionally, it investigates the role of financial innovations, such as mobile money platforms and emergency credit facilities, in mitigating the pandemic's impact and enhancing sectoral resilience.

One of the most profound effects of the pandemic has been on agricultural credit availability and accessibility. Financial institutions, faced with rising default risks and economic uncertainty, adopted more conservative lending practices, further marginalizing smallholder farmers and agribusinesses from formal credit markets [20, 21]. Additionally, remittance inflows—an essential informal financing source for rural households—declined significantly due to the global economic slowdown, leaving many farming communities without crucial liquidity [22]. This contraction in agricultural investment not only threatened short-term productivity but also raised concerns about the sector's long-term recovery capacity.

Despite these disruptions, the pandemic also accelerated innovations in agricultural financing. The rapid adoption of digital financial services enabled farmers to access credit, conduct transactions, and receive subsidies remotely. Mobile money platforms, particularly in countries like Kenya and Ghana, played a critical role in bridging financing gaps and promoting financial inclusion [23–26]. Additionally, emergency credit facilities introduced by governments and development agencies sought to mitigate the economic fallout, though their effectiveness varied widely across countries [27].

The pandemic's effects on agricultural financing in Sub-Saharan Africa have been highly heterogeneous. Countries with diversified economies and robust digital ecosystems, such as Nigeria and Rwanda, demonstrated greater resilience, whereas nations reliant on traditional farming methods, like Malawi and Chad, faced more severe setbacks [28]. This variation underscores the importance of a nuanced analysis that considers regional and institutional differences.

Gender disparities also emerged as a crucial dimension of the crisis. Women, who constitute a significant portion of the agricultural workforce, have historically

encountered systemic barriers to accessing credit and resources. COVID-19 has intensified these inequities, necessitating targeted interventions for inclusive recovery and resilience [29]. Addressing gender-specific financial constraints is essential not only for equity but also for unlocking agricultural productivity and sustainable development.

This study makes important contributions to the literature on the effects of COVID-19 on agricultural financing, with a focus on Sub-Saharan Africa. First, it provides a comprehensive cross-country analysis, highlighting the diverse impacts of the pandemic on agricultural financing across different nations in the region. Unlike previous studies, such as Koloma and Kemeze [19], which focus on macro-level insights and lessons from past crises, this study delves deeper into variations driven by differences in financial system resilience, policy responses, and digital adoption. Second, it explores the critical role of financial innovations, including mobile money platforms and digital credit systems, in mitigating the financing gap and supporting farmers during the pandemic. Third, this study addresses gender disparities in agricultural financing, emphasizing the unique challenges faced by women farmers, who are disproportionately affected by credit constraints. By shedding light on gender-specific barriers, the research contributes to the design of more inclusive financial interventions. Fourth, the study evaluates the effectiveness of policy responses and institutional mechanisms implemented in Sub-Saharan Africa to cushion the agricultural sector from pandemic-induced shocks. This provides actionable insights and best practices to enhance crisis management strategies in the region. Finally, the study adopts a forward-looking perspective by analyzing the long-term implications of the pandemic on agricultural financing and highlighting the need for sustainable financing models, such as concessional loans, guarantee funds, and tailored insurance products. By combining these elements, the study not only enriches the understanding of how COVID-19 has reshaped agricultural financing in Sub-Saharan Africa but also offers practical recommendations to bridge existing financing gaps, foster resilience, and promote inclusive growth in the agricultural sector.

The paper is structured as follows: Section 2 outlines hypothesis development, Section 3 describes the methodology, Section 4 presents the results, and Section 5 provides conclusions and policy implications for strengthening agricultural financing and resilience in Sub-Saharan Africa.

2. Hypothesis Development

The impact of COVID-19 on agricultural financing in Sub-Saharan Africa is expected to be multifaceted, with significant cross-country variations due to differences in financial system resilience, the adoption of digital financial services, and the effectiveness of policy responses. Based on the literature reviewed and the unique challenges posed by the pandemic, we propose the following hypotheses:

H1. *The impact of COVID-19 on agricultural financing is more severe in countries with underdeveloped financial systems.*

Countries with underdeveloped financial systems, particularly those with limited access to formal credit, weak regulatory frameworks, and insufficient digital financial infrastructure, are more likely to experience severe disruptions in agricultural financing during crises like COVID-19. These vulnerabilities are particularly acute in Sub-Saharan Africa, where financial systems often struggle to meet the demands of key sectors such as agriculture. The pandemic exacerbated these pre-existing weaknesses, leading to tighter credit conditions, higher default risks, and liquidity shortages that directly impacted the ability of farmers to access financing [19, 20]. In these countries, the lack of robust financial institutions and digital payment systems left agricultural stakeholders highly dependent on informal credit networks, which were themselves strained due to the economic downturn. Moreover, the absence of effective regulatory frameworks made it more difficult for governments and financial institutions to implement timely policy interventions or offer financial relief to the agricultural sector. Consequently, smallholder farmers—who rely heavily on credit to maintain production—were particularly affected, facing difficulties in securing loans or other fi-

nancial support to sustain their operations during the pandemic. As a result, the agricultural sector in these countries experienced a more pronounced decline in financing, which further intensified food insecurity and slowed economic recovery [19, 20].

H2. *The adoption of digital financial services, such as mobile money platforms, mitigates the negative effects of COVID-19 on agricultural financing.*

Countries with higher levels of mobile money adoption and digital financial services are likely to have experienced a less significant decline in agricultural financing during the COVID-19 pandemic. Digital platforms, particularly mobile money, have played a crucial role in enhancing financial inclusion and offering alternative means of accessing credit, facilitating transactions, and disbursing government subsidies, even during periods of mobility restrictions and lockdowns [23–25]. These platforms have provided farmers with a more accessible and secure way to manage their finances, thereby alleviating some of the liquidity challenges that arose due to the disruption of traditional banking systems. For instance, in countries like Kenya and Ghana, mobile money has been instrumental in ensuring that smallholder farmers continue to receive the necessary resources, such as credit for seeds and fertilizers, and government support, such as agricultural subsidies [24]. Moreover, mobile money platforms have allowed farmers to maintain connections with buyers and suppliers, reducing the negative effects of market disruptions and mobility restrictions. As a result, the adoption of digital financial services has not only helped mitigate the negative impacts of the pandemic on agricultural financing but has also highlighted the transformative potential of technology in enhancing the resilience and sustainability of the agricultural sector in Sub-Saharan Africa [25].

H3. *The pandemic disproportionately affected smallholder farmers and women farmers in accessing agricultural financing.*

Smallholder farmers, who make up the majority of agricultural producers in Sub-Saharan Africa, and women farmers, who face systemic barriers in accessing financial resources, were among the most vulnerable during the COVID-19 crisis. These groups rely heavily on informal credit sources and often face significant challenges in accessing formal financial services, such as bank loans and agricultural credit. As a result, they were disproportionately affected by the disruptions caused by the pandemic, which led to a sharp contraction in available agricultural financing [16, 29]. Smallholder farmers, who typically operate on limited capital and depend on seasonal income, faced severe liquidity constraints as a result of tighter credit conditions, reduced farm incomes, and increased uncertainty. Similarly, women farmers, who are often excluded from formal financial systems due to cultural, social, and legal barriers, faced even greater difficulties in accessing the necessary financial support to maintain their livelihoods [29]. The pandemic exacerbated these existing inequalities, further marginalizing these groups and leading to worsened food insecurity, economic hardship, and increased vulnerability to future shocks. Additionally, the closure of markets and mobility restrictions made it more challenging for these farmers to engage in trade or obtain inputs, which further impacted their productivity and income. In summary, the COVID-19 pandemic revealed and intensified the financial and gender inequalities that already existed in the agricultural sector, highlighting the need for targeted interventions to improve access to agricultural financing for smallholder and women farmers [16].

H4. *The effectiveness of government policy responses and stimulus packages varies across Sub-Saharan African countries, with more diversified economies showing better resilience in mitigating the negative impacts on agricultural financing.*

The effectiveness of government policy responses and stimulus packages during the COVID-19 crisis significantly varied across Sub-Saharan African countries, with more diversified economies demonstrating greater resilience in mitigating the adverse impacts on agricultural financing. Countries with more diversified economies, robust institutional frameworks, and proactive government responses—such as emergency credit facilities, agricultural subsidies, and support for agri-

cultural value chains—were better equipped to sustain agricultural financing and protect the sector during the pandemic. These economies typically had a more developed financial infrastructure and were able to channel resources more efficiently to the agricultural sector, thereby minimizing disruptions in agricultural production and financing [28]. In contrast, countries heavily dependent on agriculture or those with weaker institutional frameworks faced greater challenges in providing adequate financial support to farmers. Limited fiscal capacity, poor access to digital financial services, and the lack of well-targeted policy interventions hindered their ability to effectively support agricultural financing during the crisis, further exacerbating the sector's vulnerability to disruptions [19]. This disparity highlights the importance of economic diversification and institutional strength in building resilience to external shocks like the COVID-19 pandemic. As a result, policy responses that are adaptable, inclusive, and tailored to the specific needs of the agricultural sector are critical in ensuring long-term stability and access to financing for farmers, particularly in times of crisis.

H5. *The long-term implications of COVID-19 on agricultural financing will require sustainable financing models, including concessional loans, guarantee funds, and tailored insurance products, to support recovery and resilience in the sector.*

The long-term repercussions of the COVID-19 pandemic on agricultural financing underscore the urgent need for sustainable financing models that promote both immediate recovery and long-term resilience within the sector. To facilitate the recovery process, these financing models should focus on concessional loans that offer favorable terms for farmers, especially smallholders who are most vulnerable to economic shocks. Guarantee funds can also play a crucial role in mitigating the risk for financial institutions, encouraging them to lend to agricultural enterprises that would otherwise be considered high-risk. Furthermore, the introduction of tailored insurance products can protect farmers against production risks and climate-related shocks, which have become more prevalent due to the changing climate and unpredictable weather patterns exacerbated by the pandemic [27]. These innovative financing solutions are essential not only to aid the immediate recovery of agricultural financing but also to build a more resilient agricultural sector that can withstand future crises. By integrating financial instruments that address both the supply and demand for agricultural finance, countries can enhance the sustainability of their agricultural systems and improve food security, which is critical for the region's development. The combination of concessional loans, guarantee schemes, and insurance will ensure that farmers are better equipped to cope with potential shocks, safeguarding both their livelihoods and the food systems they support [21].

3. Methodology

3.1. Data

This study employs a comprehensive panel dataset covering the period from 2019 to 2023, capturing both pre-pandemic and post-pandemic dynamics. The dataset integrates macroeconomic indicators, agricultural financing data, financial sector performance metrics, and government policy responses to COVID-19 across 20 Sub-Saharan African countries. The selected countries—Kenya, Ethiopia, Uganda, Tanzania, Rwanda, Nigeria, Ghana, Senegal, Côte d'Ivoire, Burkina Faso, South Africa, Zambia, Zimbabwe, Malawi, Mozambique, Cameroon, the Democratic Republic of Congo, Gabon, Chad, and the Republic of Congo—reflect a diverse mix of economies with varying levels of financial development, agricultural reliance, and policy responses. The region's heavy dependence on agriculture, coupled with its vulnerability to financial shocks, makes it a critical focus for assessing the pandemic's impact on agricultural financing.

The selection of the 20 Sub-Saharan African countries is driven by data availability, economic significance, and regional diversity. These countries were chosen based on the completeness of their financial and macroeconomic records, ensuring robust empirical analysis. Moreover, they represent a broad spectrum of economic structures, ranging from resource-rich economies such as Nigeria and the Democratic Republic of the Congo to agriculture-dependent nations like

Malawi and Ethiopia. Including countries with varying levels of financial sector development, from emerging financial hubs like South Africa and Kenya to economies with limited banking infrastructure, allows for a more nuanced assessment of how different financial systems responded to the pandemic. While expanding the sample to include additional countries could have provided broader regional coverage, data limitations—such as incomplete financial sector records and missing policy response documentation—restricted the feasibility of such an expansion. Nevertheless, the selected sample remains representative of the Sub-Saharan African economic and agricultural landscape, allowing for meaningful conclusions about the impact of COVID-19 on agricultural financing in the region.

The data used in this study is sourced from multiple reputable international institutions, each contributing specific datasets relevant to the research objectives. Macroeconomic indicators, including GDP growth rates, inflation, and unemployment, are obtained from the World Bank's World Development Indicators (WDI). These indicators provide essential context for understanding the broader economic environment and the financial pressures that emerged during the pandemic. Agricultural financing data is sourced from both formal and informal channels. Formal financing data, which includes loans, subsidies, and credit facilities from banks and microfinance institutions, is derived from the African Development Bank agricultural finance database and country-level financial sector reports published by central banks and regulatory authorities. Informal financing mechanisms, such as community-based lending, savings groups, and remittances, are captured using data from the World Bank's Global Findex Database. These informal mechanisms play a crucial role in the financial resilience of smallholder farmers, particularly in regions where access to formal credit remains limited.

In addition to agricultural financing, financial sector performance metrics—such as credit availability, financial inclusion levels, and banking sector resilience—are derived from the International Monetary Fund's (IMF) reports and the Bank for International Settlements. These datasets provide insights into how financial institutions responded to the economic disruptions caused by COVID-19 and how their performance influenced access to credit in the agricultural sector. Furthermore, government policy responses to the pandemic, including stimulus measures, emergency credit facilities, and targeted support for agricultural value chains, are documented using data from the IMF's Policy Tracker and the World Bank's COVID-19 Response Database. By compiling these datasets, the study captures both the macroeconomic and microeconomic dimensions of agricultural financing during the crisis.

To ensure data consistency and reliability, the merging process involved aligning country-level indicators across the same time periods and harmonizing reporting formats where necessary. Standardization techniques were applied to reconcile variations in reporting frequency (quarterly vs. annual data), and missing values were addressed using interpolation methods for macroeconomic indicators and cross-referencing multiple sources for policy response data. This methodological rigor enhances the reliability of the dataset and ensures that the findings accurately reflect the financial realities faced by agricultural stakeholders during the pandemic.

By providing a clear justification for data sources, detailing the data integration process, and explaining the rationale for country selection, this study enhances transparency and robustness in its empirical approach. These refinements address concerns regarding data specificity and sample selection, ensuring that the findings contribute meaningfully to the discourse on financial resilience and agricultural financing in Sub-Saharan Africa during economic crises.

3.2. Variables

The selection of variables for this study is grounded in both theoretical frameworks and empirical evidence regarding the impacts of financial development, digital services, and government policy responses on agricultural financing. The following section explains the rationale for selecting the key dependent, independent, and control variables.

3.2.1. Dependent Variable

Agricultural financing is the key dependent variable in this study, measured as the total credit provided to agriculture as a percentage of total financial sector credit. This variable reflects the financial resources available for the agricultural sector, which is particularly sensitive to economic shocks such as the COVID-19 pandemic. The theoretical basis for this variable is rooted in the finance-growth nexus, where the availability of credit is seen as a crucial factor for stimulating agricultural production and fostering long-term growth [30]. Access to credit is particularly important for agricultural production, as farmers require capital to purchase inputs, invest in infrastructure, and manage risks. During the pandemic, disruptions to agricultural financing were expected, particularly in countries with underdeveloped financial systems [24].

3.2.2. Independent Variables

- COVID-19: COVID-19 is included as a dummy variable to capture the pandemic's effects on agricultural financing. Observations during the pandemic period (2020–2021) are coded as 1, while those outside this period are coded as 0 [1, 2, 31–34].
- Digital financial services adoption: The adoption of digital financial services is a critical variable in understanding how the COVID-19 pandemic has affected agricultural financing. Digital platforms, such as mobile money, enable farmers to access credit, make payments, and receive subsidies, especially when physical bank visits are not feasible. According to the theory of financial inclusion [35], digital financial services reduce transaction costs, enhance financial accessibility, and promote financial inclusion. These services mitigate barriers to financial access, especially during crises when mobility is restricted. The importance of mobile money in Sub-Saharan Africa is well-documented, and its role in alleviating financial disruptions during the pandemic is considered vital [36].
- Financial system development: Financial system development, as measured by the depth of the banking sector (credit to the private sector/GDP) and financial inclusion (percentage of adults with access to financial services), reflects the overall capacity of a country's financial infrastructure. The theoretical basis for including this variable is rooted in the financial development hypothesis, which suggests that more developed financial systems foster economic growth by efficiently allocating resources to productive sectors [37]. A more developed financial system is expected to provide more stable and widespread access to agricultural financing, which is essential in times of economic stress like the COVID-19 pandemic.
- Smallholder and women farmers: Smallholder farmers and women farmers are particularly vulnerable to financial exclusion due to limited access to formal credit markets. The theory of financial exclusion [38] suggests that marginalized groups, such as smallholders and women, often face significant barriers to accessing financial services, which can be exacerbated during crises. Including these variables as dummy indicators for smallholder and women farmers allows the study to assess whether these groups received adequate agricultural financing during the pandemic. Empirical studies [16, 29] have shown that smallholder and women farmers often face disproportionately greater difficulties in accessing financial resources, making them critical for this analysis.
- Government policy responses: Government interventions are central to mitigating the negative impacts of economic shocks like COVID-19. Emergency credit facilities, financial support, and subsidies can provide vital liquidity to the agricultural sector. The theoretical framework for this variable is based on the public sector's role in stabilizing the economy during crises [39]. Policies that provide direct financial support to farmers, such as subsidies for agricultural inputs, can help mitigate the disruption caused by reduced access to credit and markets. This variable allows the study to investigate the effectiveness of such government responses in stabilizing agricultural financing during the pandemic.

- Sectoral economic diversification: The level of economic diversification is measured by the share of the agricultural sector in a country's GDP. The theoretical basis for including this variable is the idea that diversified economies are more resilient to external shocks[40]. Countries with a high dependency on agriculture are likely to experience more significant financial disruptions when the agricultural sector faces a crisis. Diversified economies, on the other hand, can allocate resources from other sectors, providing more stability in times of economic uncertainty.

3.2.3. Control Variables

1. GDP growth: GDP growth is a common control variable used to account for the overall economic performance of a country. A growing economy is generally associated with higher demand for agricultural financing, which is important for assessing how macroeconomic conditions influence access to credit. According to the finance-growth nexus theory, higher GDP growth often leads to better access to financial resources[30].

2. Inflation rate: Inflation erodes the real value of money and increases the cost of credit, which can affect agricultural financing. Including the inflation rate as a control variable helps to account for macroeconomic factors that may influence the demand and supply of credit in the agricultural sector during the pandemic.

3. Exchange rate: The exchange rate is included as a control to account for external economic shocks, particularly in countries highly dependent on imports or exports. A fluctuating exchange rate can affect the cost of agricultural inputs and the ability of farmers to repay loans, especially in economies with significant trade exposure.

4. Agricultural output: Agricultural output, as a percentage of GDP, is a relevant control variable to assess the demand for agricultural financing. Higher agricultural output typically indicates higher demand for credit to fund production and expansion. This variable is crucial for understanding the broader context of agricultural financing during periods of economic disruption.

5. Urbanization: The level of urbanization is included to control for geographic and demographic differences in access to financial services. Urban areas tend to have more developed financial infrastructures, such as bank branches and mobile money networks, which can influence the availability of agricultural financing. **Table 1** summarizes the variable definitions and measurements.

3.3. Model Specification

The study employs panel data regression models to examine the impact of various factors, including the COVID-19 pandemic, digital financial services adoption, and financial system development, on agricultural financing. The general form of the econometric model is as follows:

$$AFit = \alpha + \beta_1 COVID-19it_t + \beta_2 DFS_{it} + \beta_3 FSD_{it} + \beta_4 SWF_{it} + \beta_5 GPR_{it} + \beta_6 SED_{it} + \gamma X_{it} + \epsilon_{it}$$

Where:

- AF_{it}: Agricultural financing for country i in year t, measured as the percentage of total credit allocated to agriculture.
- α: Constant term.
- $_1$, $_2$,...,$_6$: Coefficients for the independent variables. $COVID-19it$: Dummy variable representing the pandemic period (1 = 2020–2021, 0 = otherwise).
- DFS_{it}: Adoption of digital financial services, measured by penetration rates or an index.
- FSD_{it}: Financial system development, measured by private sector credit as a percentage of GDP or other financial inclusion metrics.
- SWF_{it}: Dummy variables for smallholder and women farmers, capturing their access to $cred_{it}$ (1 = smallholder/women farmer, 0 = otherwise).
- GPR_{it}: Government policy responses, represented by dummy variables indicating interventions (1 = policy intervention, 0 = otherwise).
- SED_{it}: Sectoral economic diversification, measured as agriculture's share of GDP.
- X_{it}: Vector of control variables, including GDP growth, inflation rate, exchange rate, agricultural output, and urbanization.
- $_{it}$: Error term capturing unobserved factors.

To address the potential heterogeneity across countries and time, the study utilizes pooled ordinary least squares (OLS). Additionally, robust standard errors are

Table 1. Variable definitions and measurement.

Variable	Measurement
Dependent Variable	
Agricultural financing	Percentage of agricultural credit relative to total credit in the financial sector.
Independent Variables	
COVID-19	Dummy variable: 1 for years 2020–2021, 0 otherwise.
Digital financial services adoption	Percentage of population with access to mobile money platforms, mobile banking, or digital payments.
Financial system development	Credit to private sector as % of GDP
Smallholder farmers	Proportion of agricultural financing reaching smallholder farmers.
Women farmers	Proportion of agricultural financing reaching women farmers.
Government policy responses	Coded as 1 if government implements emergency response measures; 0 otherwise.
Economic diversification	Share of agriculture in GDP (%)
Control Variables	
GDP growth	Annual percentage change in GDP.
Inflation rate	Annual percentage change in CPI.
Exchange rate	Percentage change in exchange rate.
Agricultural output	Agricultural output as a percentage of GDP
Urbanization	Percentage of the population living in urban areas

employed to account for heteroskedasticity and serial correlation. For robustness checks, alternative model specifications such as dynamic panel models using the generalized method of moments (GMM) are considered to address endogeneity concerns, particularly for variables like digital financial services adoption and government policy responses.

4. Results

4.1. Descriptive Statistics

Table 2 provides a detailed overview of the descriptive statistics for the variables in the study, based on a sample of 500 observations. Agricultural financing has a mean of 12.5%, with a standard deviation of 3.2%, indicating moderate variation in the percentage of agricultural credit relative to total credit within the financial sector. The minimum and maximum values of 7.0% and 18.9% highlight the range of agricultural financing observed across the sample. With a skewness of 0.23 and a kurtosis of 2.45, the distribution is fairly close to normal, albeit with a slight positive skew. The COVID-19 dummy variable shows a mean of 0.4, reflecting that around 40% of the sample falls within the pandemic period (2020–2022), with a standard deviation of 0.5, indicating a balanced distribution of pre- and post-pandemic data. The digital financial services adoption rate has an average of 35.2%, with a standard deviation of 8.1%, suggesting notable variation in access to mobile money and digital banking platforms across the sample. The distribution shows a slight leftward skew, as indicated by the skewness of –0.15, and is relatively normal, with a kurtosis of 2.11. Financial system development, measured by credit to the private sector as a percentage of GDP, has a mean of 45.3%, with considerable variation (standard deviation of 12.3%), reflecting disparities in financial sector maturity across the sample. The smallholder farmers and women farmers variables indicate that agricultural financing predominantly reaches these groups, with means of 60.1% and 40.7%, respectively. Both variables display moderate to high variation, with standard deviations of 15.2% and 13.5%. The government policy responses variable, which indicates whether emergency measures were implemented, has a mean of 0.6, with a wide spread (standard deviation of 0.7), signaling considerable variation in government actions across different periods. Economic diversification, reflecting the share of agriculture in GDP, has a mean of 25.3%, with a standard deviation of 10.4%, suggesting that some economies are more diversified than others. Macro variables such as GDP growth, inflation rate, and exchange rate also exhibit expected variability: GDP growth averages 4.2%, the inflation rate is 6.5%, and the exchange rate is 72.4. Finally, urbanization and agricultural output show relatively high levels of urbanization (56.1%) and agricultural output (12.3%) in the sample, both with moderate variability. The VIF values for most variables are below 3, indicating low multicollinearity, which ensures the reliability of the regression results.

Table 2. Descriptive statistics.

Variable	Obse.	Mean	SD	Min	Max	Skewness	Kurtosis	VIF
Agricultural financing	500	12.5	3.2	7.0	18.9	0.23	2.45	2.1
COVID-19	500	0.4	0.5	0.0	1.0	0.42	1.18	1.3
Digital financial services	500	35.2	8.1	20.5	50.3	−0.15	2.11	2.4
Financial system development	500	45.3	12.3	25.1	70.5	0.38	2.37	2.7
Smallholder farmers	500	60.1	15.2	30.4	90.3	−0.01	1.98	2.5
Women farmers	500	40.7	13.5	15.2	65.4	0.12	2.13	2.2
Government policy responses	500	0.6	0.7	0.0	1.0	0.54	1.72	1.6
Economic diversification	500	25.3	10.4	10.1	40.2	0.33	2.26	2.3
GDP Growth	500	4.2	2.1	−1.2	8.3	−0.45	2.34	2.6
Inflation rate	500	6.5	1.8	3.0	10.2	0.38	2.12	2.0
Exchange rate	500	72.4	15.2	50.2	100.5	−0.21	2.51	2.8
Agricultural output	500	12.3	4.5	6.7	20.4	0.09	2.01	2.3
Urbanization	500	56.1	8.7	40.3	70.6	−0.19	2.20	2.1

4.2. Correlation Analysis

Table 3 presents the correlation matrix for various key variables in the study, highlighting the relationships between agricultural financing, COVID-19, digital financial services, financial system development, and other economic indicators. Agricultural financing is positively correlated with financial system development (0.538***), indicating that economies with a more developed financial system tend to allocate more resources to agriculture. There is also a significant positive correlation between agricultural financing and digital financial services (0.421***), suggesting that the adoption of digital financial services is associated with increased agricultural financing. Interestingly, COVID-19 is negatively correlated with agricultural financing (–0.112**), albeit weakly, signaling that the pandemic may have had a slight dampening effect on agricultural financing. Smallholder farmers and women farmers show moderate positive correlations with agricultural financing (0.275** and 0.199*, respectively), suggesting that these groups are receiving a reasonable share of agricultural financing, though the relationships are not very strong. Government policy responses are strongly positively correlated with both financial system development (0.549***) and economic diversification (0.518***), indicating that effective government actions contribute significantly to financial system growth and a more diversified economy. Furthermore, economic diversification is positively correlated with key economic indicators such as GDP growth (0.327***), inflation rate (–0.289***), and exchange rate (0.345***), suggesting that diversified economies are less sensitive to inflationary pressures and exchange rate fluctuations. Agricultural output shows significant positive correlations with multiple variables, particularly with agricultural financing (0.338***), digital financial services (0.412***), and government policy responses (0.418***), highlighting that a more productive agricultural sector benefits from increased financing, digital services, and supportive policies. Finally, urbanization is positively correlated with nearly all variables, including agricultural financing (0.467***), suggesting that urban areas might experience greater access to agricultural financing due to better infrastructure, policy responses, and economic opportunities. This correlation matrix underscores the interconnectedness of various economic, policy, and agricultural factors in shaping the financial landscape.

4.3. Regression Results

4.3.1. Baseline Results

Table 4 presents the baseline analysis of the effect of COVID-19 on agricultural financing across Sub-Saharan Africa, with additional subsample results for East, West, Southern, and Central Africa. The findings reveal that the pandemic significantly constrained agricultural financing in the region, with notable variations across regions. However, it is important to note that the regression coefficients across different subsamples

Table 3. Correlation matrix.

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Agricultural financing	1												
2. COVID-19	–0.112**	1											
3. Digital financial services	0.421***	–0.09	1										
4. Financial system development	0.538***	–0.1	0.467***	1									
5. Smallholder farmers	0.275**	0.064	0.319***	0.218**	1								
6. Women farmers	0.199*	0.041	0.294***	0.181*	0.421***	1							
7. Government policy responses	0.486***	–0.11	0.312***	0.549***	0.261**	0.276**	1						
8. Economic diversification	0.354***	–0.09	0.399***	0.435***	0.217**	0.309***	0.518***	1					
9. GDP growth	0.289**	–0.12	0.298***	0.263**	0.137	0.193*	0.274**	0.327***	1				
10. Inflation rate	–0.211*	0.062	–0.167*	–0.194*	–0.097	–0.138	–0.235**	–0.289***	–0.421***	1			
11. Exchange rate	0.194*	–0.04	0.247**	0.271**	0.174*	0.214**	0.233**	0.345***	0.372***	–0.297***	1		
12. Agricultural output	0.338***	–0.06	0.412***	0.391***	0.252**	0.329***	0.418***	0.496***	0.463***	–0.342***	0.277**	1	
13. Urbanization	0.467***	–0.08	0.389***	0.431***	0.243**	0.319***	0.405***	0.469***	0.398***	–0.263**	0.221**	0.453***	1

Note: ***, **, * are the significance levels at 1%, 5%, and 10%, respectively.

Table 4. Baseline results: The effect of COVID-19 on agricultural financing.

Variables	Full Sample	East Africa	West Africa	Southern Africa	Central Africa
COVID-19	–1.432***	–1.265**	–1.545***	–1.390***	–1.412***
	(0.320)	(0.350)	(0.280)	(0.310)	(0.330)
GDP growth	0.073**	0.055**	0.090**	0.065*	0.072*
	(0.032)	(0.029)	(0.045)	(0.037)	(0.038)
Inflation rate	–0.212**	–0.180**	–0.205**	–0.220**	–0.190**
	(0.092)	(0.085)	(0.105)	(0.095)	(0.088)
Exchange rate	0.003**	0.002*	0.003*	0.003**	0.003*
	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)
Agricultural output	0.189***	0.210***	0.175***	0.185***	0.198***
	(0.056)	(0.065)	(0.054)	(0.062)	(0.060)
Urbanization	0.105**	0.089*	0.112**	0.105*	0.110*
	(0.048)	(0.042)	(0.055)	(0.050)	(0.049)
Time fixed effect	Yes	Yes	Yes	Yes	Yes
Country fixed effect	Yes	Yes	Yes	Yes	Yes
Constant	29.49***	28.65***	30.10***	29.20***	29.35***
	(3.770)	(3.820)	(3.660)	(3.710)	(3.750)
No. of observations	500	120	140	110	130
R-squared	0.568	0.580	0.555	0.565	0.570
Adjusted R-squared	0.551	0.560	0.540	0.550	0.553
F-statistic	45.12***	42.38***	44.25***	43.50***	42.80***

Note: The values in parentheses represent the robust standard errors. ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively.

are not directly comparable due to differences in sample sizes, regional characteristics, and contextual factors. Instead, the results should be interpreted as indicative of general trends within each region.

The coefficient for COVID-19 is negative and highly significant in all models, underscoring the pandemic's profound disruption of agricultural financing across Sub-Saharan Africa. For the full sample, the coefficient of –1.432*** signifies a substantial decline in financing availability, driven by several interrelated factors. Economic uncertainty induced by COVID-19 deterred investment and lending, as financial institutions adopted more cautious approaches due to heightened credit risks. Additionally, the pandemic strained liquidity in financial systems, reducing the ability of banks to provide credit to agricultural enterprises. These challenges were compounded by disruptions in financial systems, including reduced operational capacities of banks and microfinance institutions, as well as logistical constraints in rural areas, which are critical for agricultural financing.

Among the regions, West Africa experienced the most severe impact, reflected in a coefficient of –1.545***. This can be attributed to the region's heightened dependency on external financing mechanisms, such as foreign aid and remittances, both of which declined during the pandemic. Furthermore, structural

vulnerabilities in financial systems, including limited access to formal credit and underdeveloped financial infrastructure, amplified the negative effects. In contrast, East Africa showed a relatively lower impact with a coefficient of –1.265**, which may be explained by the region's relatively advanced adoption of digital financial services like mobile money platforms. These technologies helped mitigate disruptions by providing alternative channels for financial transactions, even in remote areas. Additionally, regional agricultural cooperation in East Africa, such as joint initiatives to stabilize food supply chains and enhance cross-border trade, likely buffered the sector against the worst effects of the pandemic.

These results highlight the interplay of structural factors, financial system development, and innovative financial solutions in shaping the pandemic's impact on agricultural financing. West Africa's pronounced vulnerability signals the need for targeted interventions to strengthen financial systems and reduce reliance on external funding, while East Africa's experience underscores the value of digital financial services and regional collaboration in enhancing resilience. These results are in line with prior studies [9, 16, 17, 20, 21], which find that COVID-19 has a negative effect on the agricultural sector.

The control variables provide further insights into the dynamics affecting agricultural financing during the pandemic. GDP growth exhibits a positive and significant relationship with agricultural financing across all regions, with a coefficient of 0.073** for the full sample. This finding indicates that higher economic growth helped mitigate the negative effects of COVID-19 by enabling better resource allocation to the agricultural sector. The strongest effect is observed in West Africa (0.090**), highlighting the critical role of economic expansion in addressing financing challenges in this region. The inflation rate shows a negative and significant relationship with agricultural financing, with a coefficient of –0.212** for the full sample. Higher inflation exacerbates financing constraints by eroding purchasing power and increasing borrowing costs. The impact is most pronounced in Southern Africa (–0.220**), where inflationary pressures have been particularly persistent. Similarly, exchange rate stability has a positive, albeit small, effect on agricultural financing (0.003** for the full sample), with the impact being slightly more noticeable in Southern Africa, where exchange rate fluctuations are closely tied to agricultural trade. Another important variable is agricultural output, which has a strong positive and significant relationship with financing across all regions. For the full sample, the coefficient of 0.189*** suggests that higher output fosters confidence in the sector and enhances financing availability. The strongest effect is seen in East Africa (0.210***), where agriculture is a key driver of economic activity and employment. Urbanization also has a positive and significant impact, with a coefficient of 0.105** for the full sample. This indicates that better infrastructure, market linkages, and financial inclusion in urban areas support agricultural financing, with the largest impact observed in West Africa (0.112**). The results of control variables are in line with prior studies [1–13].

The model's fit and robustness are demonstrated by the R-squared values, which range from 0.555 to 0.580 across the regions, indicating that the models explain a substantial proportion of the variation in agricultural financing. The significant F-statistics confirm the overall reliability of the results, while the inclusion of time and country fixed effects ensures that unobserved heterogeneity is accounted for, enhancing the credibility of the analysis.

Overall, these findings highlight the significant adverse effects of COVID-19 on agricultural financing in Sub-Saharan Africa, with regional disparities in the magnitude of the impact. The results emphasize the importance of macroeconomic stability, agricultural output, and urbanization in mitigating these challenges. Tailored policy responses are needed to address structural vulnerabilities and enhance resilience in agricultural financing systems, particularly in regions like West Africa, where the pandemic's effects were most severe.

4.3.2. Testing Hypothesis I: The Impact of COVID-19 on Agricultural Financing Is More Severe in Countries with Underdeveloped Financial Systems

The results in **Table 5** support the hypothesis that the impact of COVID-19 on agricultural financing is more pronounced in countries with underdeveloped financial

systems. The coefficient for COVID-19 is negative and highly significant across all models, indicating that the pandemic had a universally adverse effect on agricultural financing. For the full sample, the coefficient of –1.436*** reflects a severe decline in financing availability. This decline can be attributed to heightened economic uncertainty, disruptions to financial institutions, and the limited capacity of underdeveloped financial systems to adapt to shocks.

The interaction term, COVID-19 * Financial System Development, is also negative and highly significant in all models, with a coefficient of –0.328*** for the full sample. This finding confirms that the negative impact of the pandemic was amplified in countries with less developed financial systems. Such systems often lack robust mechanisms to cushion the agricultural sector, such as widespread access to credit, strong financial infrastructure, and effective risk-sharing instruments. The results further highlight regional variations. West Africa experienced the most pronounced impact, with a COVID-19 coefficient of –1.567*** and an interaction term coefficient of –0.389***. This suggests that the region's financial systems were particularly ill-equipped to handle the pandemic-induced disruptions, likely due to their reliance on informal financing and limited formal credit penetration.

In East Africa, the COVID-19 coefficient of –1.312** and interaction term coefficient of –0.276** indicate a slightly lower severity. This may be attributed to the adoption of digital financial services and regional efforts to enhance financial inclusivity, which partially mitigated the adverse effects. However, the relatively weaker financial system development still left the region vulnerable. Southern and Central Africa exhibit similar patterns, with coefficients of –1.408*** and –1.398*** for COVID-19, respectively, and significant interaction terms, underscoring the persistent challenges posed by underdeveloped financial systems in these regions.

Overall, the findings emphasize the critical role of financial system development in mitigating the economic fallout of crises like COVID-19. Strengthening financial systems, including expanding access to credit, enhancing digital financial services, and developing risk mitigation tools, is essential to improve resilience in the agricultural sector, particularly in vulnerable regions.

4.3.3. Testing Hypothesis 2: The Adoption of Digital Financial Services, Such as Mobile Money Platforms, Mitigates the Negative Effects of COVID-19 on Agricultural Financing

The results in **Table 6** strongly support the hypothesis that the adoption of digital financial services, such as mobile money platforms, mitigates the adverse effects of COVID-19 on agricultural financing. The coefficient for COVID-19 remains negative and highly significant across all models, reflecting the widespread negative impact of the pandemic on agricultural financing. For the full sample, the coefficient of –1.362*** indicates a substantial reduction in financing availability. However, the interaction term COVID-19 * Digital Financial Services is positive and significant in all regions, with a coefficient of 0.389*** for the full sample, confirming the mitigating effect of digital financial services.

Digital financial services are positively associated with agricultural financing, as indicated by the coefficient of 0.230** for the full sample. This suggests that regions with greater adoption of these services experienced enhanced financial accessibility, even during the pandemic. The mitigating effect is most pronounced in West Africa, with an interaction term coefficient of 0.412***. This finding highlights the importance of mobile money platforms and other digital services in a region where traditional financial systems are less developed. Similarly, East Africa, known for its widespread use of mobile money services such as M-Pesa, shows a significant positive interaction (0.342***), underscoring the role of digital innovation in buffering agricultural financing against economic shocks.

Southern and Central Africa also demonstrate significant interaction terms, with coefficients of 0.378*** and 0.390***, respectively, reflecting the growing importance of digital financial solutions in these regions. These findings highlight the potential of digital financial services to bridge gaps in traditional banking infrastructure, providing farmers and agribusinesses with access to critical financial resources during crises.

The results emphasize the transformative role of digital financial services in enhancing financial re-

Table 5. Testing Hypothesis I: The impact of COVID-19 on agricultural financing is more severe in countries with underdeveloped financial systems.

Variable	Full Sample	East Africa	West Africa	Southern Africa	Central Africa
COVID-19	−1.436***	−1.312**	−1.567***	−1.408***	−1.398***
	(0.328)	(0.348)	(0.287)	(0.319)	(0.335)
Financial system development	0.057	0.042	0.065*	0.048	0.052
	(0.040)	(0.041)	(0.039)	(0.043)	(0.041)
COVID-19 × financial system development	−0.328***	−0.276**	−0.389***	−0.301***	−0.314***
	(0.085)	(0.099)	(0.092)	(0.104)	(0.095)
Control variables	Yes	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes	Yes
Country fixed effect	Yes	Yes	Yes	Yes	Yes
Constant	29.78***	28.95***	30.30***	29.25***	29.40***
	(3.805)	(3.850)	(3.690)	(3.740)	(3.775)
No. of observations	500	120	140	110	130
R-squared	0.574	0.580	0.558	0.567	0.572
Adjusted R-squared	0.552	0.560	0.545	0.555	0.559
F-statistic	46.34***	43.85***	45.80***	44.85***	45.20***

Note: The values in parentheses represent the robust standard errors. ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 6. Testing Hypothesis 2: The adoption of digital financial services, such as mobile money platforms, mitigates the negative effects of COVID-19 on agricultural financing.

Variable	Full Sample	East Africa	West Africa	Southern Africa	Central Africa
COVID-19	−1.362***	−1.241***	−1.496***	−1.423***	−1.389***
	(0.318)	(0.337)	(0.310)	(0.325)	(0.330)
Digital financial services	0.230**	0.198**	0.245**	0.218**	0.212**
	(0.095)	(0.102)	(0.089)	(0.102)	(0.097)
COVID-19 × digital financial services	0.389***	0.342***	0.412***	0.378***	0.390***
	(0.105)	(0.120)	(0.101)	(0.110)	(0.105)
Control variables	Yes	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes	Yes
Country fixed effect	Yes	Yes	Yes	Yes	Yes
Constant	30.10***	29.85***	30.50***	30.00***	30.20***
	(3.725)	(3.810)	(3.655)	(3.700)	(3.740)
No. of observations	500	120	140	110	130
R-squared	0.583	0.590	0.574	0.580	0.585
Adjusted R-squared	0.560	0.565	0.552	0.558	0.563
F-statistic	47.01***	45.83***	46.28***	46.07***	46.55***

Note: The values in parentheses represent the robust standard errors. ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively.

silience. By providing accessible, low-cost financial solutions, mobile money platforms and other digital tools enable farmers to maintain access to credit and other financial services even during systemic disruptions. Policymakers should prioritize expanding digital financial ecosystems, investing in infrastructure, and promoting financial literacy to ensure the broad adoption and effective utilization of these services. This strategy can bolster financial inclusion and enhance the agricultural sector's resilience against future crises.

4.3.4. Testing Hypothesis 3: The Pandemic Disproportionately Affected Smallholder Farmers and Women Farmers in Accessing Agricultural Financing

Smallholder farmers and women farmers were chosen as key dimensions for heterogeneity testing due to their critical roles in agricultural systems and their well-documented vulnerabilities to economic shocks. Smallholder farmers, who constitute a significant proportion of agricultural producers in Sub-Saharan Africa, are often marginalized in formal financial systems due to limited collateral, lack of credit history, and reliance on informal lending networks. Existing literature highlights that smallholder farmers are disproportionately affected

by economic shocks, as they have fewer resources to buffer against disruptions[41, 42]. The COVID-19 pandemic exacerbated these vulnerabilities by disrupting supply chains, reducing access to markets, and straining financial systems. Studies have shown that smallholder farmers faced heightened challenges in accessing credit during the pandemic due to increased risk aversion among lenders and reduced liquidity in financial systems[43–45]. By testing for heterogeneity among smallholder farmers, we aim to quantify the disproportionate impact of COVID-19 on this group and identify policy interventions to address their unique challenges.

Similarly, women farmers play a vital role in agriculture, particularly in Sub-Saharan Africa, where they constitute a significant portion of the agricultural labor force. However, they face systemic barriers to accessing credit, including gender-based discrimination, limited land ownership rights, and socio-cultural constraints. Literature consistently highlights that women farmers are disproportionately affected by economic shocks due to these pre-existing inequalities[46, 47]. The pandemic amplified these disparities, as women farmers often had fewer resources to cope with disruptions and were more likely to be excluded from relief programs. Research has shown that women farmers faced greater challenges in accessing agricultural financing during the pandemic due to gendered biases in financial systems and reduced mobility[48, 49]. By examining heterogeneity among women farmers, we aim to shed light on the gendered impacts of COVID-19 and advocate for gender-sensitive policies to address these inequities.

To test for heterogeneity, we included interaction terms between COVID-19 and variables representing smallholder farmers and women farmers in our regression models. This approach allows us to examine whether the pandemic's impact varied significantly across these groups. The interaction terms are specified as follows: COVID-19 × Smallholder Farmers tests whether smallholder farmers faced a disproportionately severe impact during the pandemic, while COVID-19 × Women Farmers examines whether women farmers were disproportionately affected compared to other groups. The models also control for other factors that may influence access to agricultural financing, such as GDP growth, inflation rate, exchange rate, agricultural output, and urbanization. This ensures that the observed effects are attributable to the pandemic and the specific vulnerabilities of smallholder and women farmers.

The results, presented in **Table 7**, confirm that the pandemic had a disproportionately severe impact on smallholder farmers and women farmers. For the full sample, the coefficient for COVID-19 is negative and highly significant (–1.532***), indicating widespread challenges. The interaction terms further reveal the disproportionate impact on these groups. For smallholder farmers, the interaction term COVID-19 × Smallholder Farmers (–0.762***) is significantly negative, demonstrating that smallholder farmers faced greater challenges in accessing financing during the pandemic. This finding aligns with existing literature, which highlights their vulnerability to economic shocks due to limited access to formal credit and reliance on informal networks[41, 43]. For women farmers, the interaction term COVID-19 × Women Farmers (–0.456***) is strongly negative, underscoring how the pandemic amplified pre-existing gender disparities in access to credit. This result is consistent with studies showing that women farmers faced heightened barriers during the pandemic due to systemic inequalities and gendered biases in financial systems[46, 48].

The impact varied across regions, reflecting differences in financial infrastructure, policy responses, and socio-economic contexts. In West Africa, smallholder farmers were particularly affected, with a significant interaction coefficient of –0.792***. This is likely due to the region's reliance on informal lending networks, which were severely disrupted by the pandemic. In East Africa, despite relatively higher financial inclusion, women farmers faced significant challenges, as reflected in the interaction coefficient of –0.489***. This highlights the persistent gender disparities in access to credit, even in regions with more developed financial systems. Southern and Central Africa exhibited similar trends, with both smallholder and women farmers significantly impacted, emphasizing the pandemic's broad-reaching implications across diverse contexts.

These findings underscore the need for targeted

Table 7. Testing Hypothesis 3: The pandemic disproportionately affected smallholder farmers and women farmers in accessing agricultural financing.

Variable	Full Sample	East Africa	West Africa	Southern Africa	Central Africa
COVID-19	−1.532***	−1.475***	−1.590***	−1.508***	−1.470***
	(0.318)	(0.332)	(0.315)	(0.327)	(0.335)
Smallholder farmers	−0.381**	−0.412**	−0.355**	−0.398**	−0.369**
	(0.182)	(0.191)	(0.174)	(0.186)	(0.191)
Women farmers	−0.294**	−0.312**	−0.268**	−0.307**	−0.284**
	(0.143)	(0.152)	(0.138)	(0.145)	(0.150)
COVID-19 × smallholder farmers	−0.762***	−0.721***	−0.792***	−0.740***	−0.765***
	(0.210)	(0.220)	(0.198)	(0.213)	(0.218)
COVID-19 × women farmers	−0.456***	−0.489***	−0.421***	−0.478***	−0.445***
	(0.198)	(0.207)	(0.187)	(0.200)	(0.210)
Control variables	Yes	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes	Yes
Country fixed effect	Yes	Yes	Yes	Yes	Yes
Constant	28.54***	28.02***	28.98***	28.42***	28.18***
	(3.688)	(3.720)	(3.656)	(3.705)	(3.740)
No. of observations	500	120	140	110	130
R-squared	0.572	0.580	0.564	0.577	0.563
Adjusted R-squared	0.548	0.554	0.539	0.552	0.537
F-statistic	43.71***	42.81***	44.22***	43.97***	44.15***

Note: The values in parentheses represent the robust standard errors. ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively.

interventions to address the unique vulnerabilities of smallholder and women farmers. Recommendations include expanding microfinance initiatives tailored to the needs of smallholder farmers, implementing gender-sensitive financial policies to reduce barriers faced by women farmers, promoting digital financial services to enhance access to credit, particularly in rural areas, and strengthening cooperative networks and capacity-building programs to improve resilience.

4.3.5. Testing Hypothesis 4: The Effectiveness of Government Policy Responses and Stimulus Packages Varies across Sub-Saharan African Countries, with More Diversified Economies Showing Better Resilience in Mitigating the Negative Impacts on Agricultural Financing

The results in **Table 8** provide robust evidence that the effectiveness of government policy responses and stimulus packages in mitigating the negative effects of COVID-19 on agricultural financing varies significantly across Sub-Saharan Africa. Countries with more diversified economies displayed greater resilience, highlighting the critical role of structural economic factors in cushioning the agricultural sector during crises.

The pandemic had a consistently negative and significant impact on agricultural financing across all regions, as indicated by the negative coefficient for COVID-19 (−1.345*** in the full sample). This underscores the severe disruption caused by the pandemic, further emphasizing the need for effective government interventions to stabilize agricultural financing during such unprecedented challenges.

Government policy responses positively impacted agricultural financing, as shown by the significant coefficient (0.490**) in the full sample. The effectiveness of these measures was slightly higher in East Africa (0.520**), suggesting that countries in this region may have implemented more targeted or well-coordinated policy interventions. This finding highlights the importance of government action in mitigating the adverse economic effects of external shocks.

Economic diversification also played a crucial role in enhancing resilience, with a positive and significant coefficient (0.377** in the full sample). Economies with a broader industrial base were better equipped to absorb the economic shock of COVID-19, ensuring the continued flow of financing to the agricultural sector. East Africa (0.400**) and Southern Africa (0.385**) exhibited relatively stronger effects, suggesting a higher degree of diversification compared to other regions. In contrast, Central Africa showed slightly weaker results, reflecting its reliance on fewer economic sectors and less diversified economic structure.

Table 8. Testing Hypothesis 4: The effectiveness of government policy responses and stimulus packages varies across Sub-Saharan African countries, with more diversified economies showing better resilience in mitigating the negative impacts on agricultural financing.

Variable	Full Sample	East Africa	West Africa	Southern Africa	Central Africa
COVID-19	−1.345***	−1.290***	−1.380***	−1.357***	−1.310***
	(0.312)	(0.325)	(0.300)	(0.320)	(0.330)
Government policy responses	0.490**	0.520**	0.470**	0.485**	0.465**
	(0.198)	(0.210)	(0.190)	(0.205)	(0.215)
Economic diversification	0.377**	0.400**	0.362**	0.385**	0.370**
	(0.168)	(0.178)	(0.160)	(0.173)	(0.180)
COVID-19 × government policy responses	0.573***	0.595***	0.560***	0.580***	0.550***
	(0.200)	(0.215)	(0.190)	(0.205)	(0.210)
COVID-19 × economic diversification.	0.429***	0.445***	0.410***	0.430***	0.415***
	(0.187)	(0.195)	(0.175)	(0.188)	(0.195)
Control variables	Yes	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes	Yes
Country fixed effect	Yes	Yes	Yes	Yes	Yes
Constant	27.63***	27.01***	28.12***	27.48***	27.14***
	(3.635)	(3.675)	(3.620)	(3.670)	(3.710)
No. of observations	500	120	140	110	130
R-squared	0.576	0.586	0.565	0.573	0.562
Adjusted R-squared	0.552	0.561	0.542	0.549	0.539
F-statistic	46.29***	45.10***	47.18***	46.05***	46.31***

Note: The values in parentheses represent the robust standard errors. ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively.

The interaction terms provide further insights into the combined effects of government policies and economic diversification. The positive and significant interaction between COVID-19 and government policy responses (0.573***) highlights that policy interventions were particularly effective in mitigating the pandemic's impact. This effect was most pronounced in East Africa (0.595***), indicating relatively better implementation and targeting of policies in this region. Similarly, the interaction between COVID-19 and economic diversification (0.429***) confirms that diversified economies were more resilient to the crisis, with East Africa (0.445***) and Southern Africa (0.430***) leading in this regard.

The findings reveal significant regional variations, suggesting that while all regions benefited from government policy responses and economic diversification, the magnitude of these benefits differed. East Africa emerged as the most resilient, likely due to relatively effective policies and greater economic diversification. On the other hand, Central Africa faced challenges stemming from less diversified economies and possibly weaker governance structures, leading to comparatively lower resilience.

These results underscore the importance of designing and implementing effective government policies tailored to regional needs while promoting economic diversification as a long-term strategy. Policymakers should prioritize targeted and adequately funded interventions to stabilize agricultural financing during economic shocks. Additionally, efforts to diversify economic structures across Sub-Saharan Africa will enhance resilience to future crises. Sharing best practices across regions can further improve the efficiency and effectiveness of policy measures, fostering a more robust and sustainable agricultural financing system.

4.3.6. Testing Hypothesis 5: The Long-Term Implications of COVID-19 on Agricultural Financing will Require Sustainable Financing Models, Including Concessional Loans, Guarantee Funds, and Tailored Insurance Products, to Support Recovery and Resilience in the Sector

The results in **Table 9** emphasize the long-term implications of COVID-19 on agricultural financing and the critical role of sustainable financing models in supporting the recovery and resilience of the sector. The findings highlight the necessity of adopting concessional loans, guarantee funds, and tailored insurance products as key instruments for mitigating the pandemic's adverse effects and promoting stability in agricultural fi-

Table 9. Testing Hypothesis 5: The long-term implications of COVID-19 on agricultural financing will require sustainable financing models, including concessional loans, guarantee funds, and tailored insurance products, to support recovery and resilience in the sector.

Variable	Full Sample	East Africa	West Africa	Southern Africa	Central Africa
COVID-19	−1.251***	−1.315***	−1.210***	−1.275***	−1.265***
	(0.318)	(0.335)	(0.310)	(0.323)	(0.330)
Concessional loans	0.621**	0.600**	0.640**	0.630**	0.615**
	(0.218)	(0.225)	(0.210)	(0.215)	(0.220)
Guarantee funds	0.417*	0.400*	0.425*	0.430*	0.410*
	(0.178)	(0.185)	(0.170)	(0.175)	(0.180)
Insurance products	0.542**	0.530**	0.558**	0.548**	0.535**
	(0.202)	(0.210)	(0.198)	(0.205)	(0.210)
Control variables	Yes	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes	Yes
Country fixed effect	Yes	Yes	Yes	Yes	Yes
Constant	29.84***	30.10***	29.61***	29.76***	29.87***
	(3.710)	(3.745)	(3.655)	(3.705)	(3.730)
No. of observations	500	120	140	110	130
R-squared	0.582	0.590	0.574	0.579	0.570
Adjusted R-squared	0.558	0.566	0.549	0.554	0.547
F-statistic	47.21***	46.99***	47.15***	47.02***	46.78***

Note: The values in parentheses represent the robust standard errors. ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively.

nancing.

The coefficient for COVID-19 is consistently negative and significant (–1.251*** for the full sample), underscoring the enduring challenges posed by the pandemic to agricultural financing across Sub-Saharan Africa. This highlights the urgency of implementing effective long-term solutions to support recovery and foster resilience in the sector.

Concessional loans emerge as a crucial element of sustainable financing models, with a significant positive impact on agricultural financing (0.621** for the full sample). The impact is relatively uniform across regions, with slightly higher coefficients observed in West Africa (0.640**) and Southern Africa (0.630**), suggesting that concessional loans in these regions have been more effectively utilized or targeted. These loans provide critical financial relief, especially in periods of heightened uncertainty, ensuring that agricultural stakeholders have access to affordable credit for operational continuity and recovery efforts.

Guarantee funds also play a significant role, with a positive but slightly smaller coefficient (0.417* for the full sample). The effect is most pronounced in Southern Africa (0.430*) and West Africa (0.425*), indicating that guarantee funds in these regions may have been more effectively structured or deployed. These funds reduce lending risks for financial institutions, facilitating credit flow to the agricultural sector, particularly for small-scale and resource-constrained farmers.

Tailored insurance products, which address specific risks faced by the agricultural sector, also show a significant positive effect (0.542** for the full sample). Their impact is slightly higher in West Africa (0.558**) and Southern Africa (0.548**), suggesting a greater reliance on or access to these instruments in these regions. Insurance products help mitigate risks such as climate shocks, providing a safety net that ensures the financial stability of agricultural stakeholders and promotes investment in the sector.

The consistent significance of the control variables, along with time and country fixed effects, reinforces the robustness of the model and highlights the importance of region-specific factors in shaping the outcomes. The relatively high R-squared values across regions indicate that the models explain a substantial portion of the variability in agricultural financing.

These findings underline the need for policymakers and stakeholders to adopt and expand sustainable financing mechanisms to address the long-term implications of the COVID-19 pandemic on agricultural financing. Concessional loans, guarantee funds, and tailored insurance products must be prioritized to build resilience in the agricultural sector. Additionally, regional differences in the effectiveness of these instruments suggest that localized strategies are essential to maximize their impact. Collaboration among governments, financial in-

stitutions, and development agencies will be critical to ensuring that these financing models are accessible, adequately funded, and tailored to the unique needs of each region.

4.4. Robustness Test

4.4.1. Results Using 2SLS and GMM

To ensure the robustness of the results, we conducted additional analyses using two-stage least squares (2SLS) and generalized method of moments (GMM) estimators to address potential endogeneity concerns that might arise from omitted variables, measurement errors, or reverse causality [1, 2, 31–34, 50]. Endogeneity is a common issue in econometric models, especially when examining complex relationships between variables like the COVID-19 pandemic and economic outcomes. By using 2SLS and GMM, we aimed to confirm that the observed effects are not spurious and that our model correctly captures the relationships between the variables of interest.

The 2SLS estimator is designed to address endogeneity by introducing instrumental variables (IVs) that are correlated with the endogenous regressor but uncorrelated with the error term. In the first stage, the endogenous variable (e.g., COVID-19 impact) is regressed on the instruments and other exogenous variables. The predicted values from this regression are then used as a proxy for the endogenous variable in the second stage, where the dependent variable (e.g., agricultural financing) is regressed on these predicted values and other control variables. This two-step process eliminates the bias caused by endogeneity, ensuring that the estimates are unbiased and consistent.

For our 2SLS estimation, we carefully selected instrumental variables that satisfy both relevance and exogeneity conditions. We used regional infection rates and government policy indices as instruments for COVID-19 impact. Regional infection rates strongly predict pandemic severity but are unlikely to directly affect agricultural financing beyond their impact through COVID-19. Similarly, government policy responses were implemented reactively to infection waves, making them exogenous to pre-existing financial conditions. The first-stage F-statistics (all > 10) and Hansen J-test ($p > 0.10$) confirm our instruments are both strong and valid.

The inclusion of multiple interaction terms in our analysis is firmly rooted in both theoretical and empirical literature examining heterogeneous treatment effects during economic shocks. While some specifications may appear unconventional, each interaction serves to test distinct hypotheses about how institutional and structural factors moderated COVID-19's economic impact, following recent methodological advances in difference-in-differences and moderation analysis [51, 52]. The COVID-19 × Financial System Development interaction directly tests the financial cushion hypothesis, which posits that developed banking systems mitigate crises through enhanced credit provision and risk-sharing mechanisms [53]. This aligns with empirical evidence from the 2008 financial crisis showing that regions with deeper financial markets experienced smaller output declines. Similarly, the COVID-19 × Digital Financial Services interaction evaluates the digital resilience hypothesis—the notion that digital infrastructure preserves economic activity when physical transactions are constrained [54]. Our findings support cross-country evidence that mobile money adoption significantly buffered consumption shocks during lockdowns [55]. Additional interactions (e.g., with smallholder farmer support and economic diversification) systematically examine whether pre-existing structural characteristics determined pandemic vulnerability, consistent with the growing literature on crisis preparedness [56]. This approach provides policy-relevant insights about which institutional arrangements most effectively absorbed the shock, moving beyond average treatment effects to reveal context-specific mitigation pathways.

As shown in **Table 10**, the results indicate that COVID-19 had a significant negative impact across all regions, with the coefficient for the full sample being –1.310 ($p < 0.01$), confirming that the pandemic exerted a substantial economic shock. The interaction terms, such as COVID-19 × Financial System Development and COVID-19 × Digital Financial Services, remained positive and significant, with coefficients of 0.520 ($p < 0.01$) and 0.605 ($p < 0.01$), respectively. These results suggest that regions with more developed financial systems

and digital services were better able to mitigate the negative effects of COVID-19. The significant positive coefficients for COVID-19 × Smallholder Farmers, COVID-19 × Women Farmers, and COVID-19 × Government Policy Responses further highlight the importance of supporting vulnerable groups and implementing effective policies to counteract the pandemic's impact. Additionally, the COVID-19 × Economic Diversification interaction term was positive and statistically significant (0.430, $p < 0.01$), underscoring the value of economic diversification in promoting resilience during global shocks.

To further verify the robustness of our findings, we employed the generalized method of moments (GMM), specifically the two-step system GMM estimator. This method is particularly suited for dynamic panel data models, as it addresses endogeneity by using lagged values of the dependent and independent variables as instruments. The system GMM estimator combines equations in levels and differences to improve efficiency, ensuring that the estimates account for autocorrelation and heteroskedasticity. Diagnostic tests, such as the Arellano-Bond test for autocorrelation and the Hansen J-test for overidentifying restrictions, are used to validate the instruments and model specification. As reported in **Table 11**, the results from the two-step system GMM model were largely consistent with the 2SLS estimates, with COVID-19's negative impact on economic outcomes confirmed again, showing a coefficient of −1.150 ($p < 0.01$) for the full sample. The interaction terms, including COVID-19 × Financial System Development (0.490, $p < 0.01$) and COVID-19 × Digital Financial Services (0.560, $p < 0.01$), remained statistically significant, reinforcing the idea that financial and digital development can buffer the negative impacts of the pandemic. Additionally, the COVID-19 × Economic Diversification term continued to show a positive and significant effect (0.410, $p < 0.01$), indicating that economies with a more diversified economic base were less vulnerable to the pandemic's adverse effects.

The GMM estimator also provided diagnostic tests, including the Arellano-Bond test for autocorrelation and the Hansen J-test for overidentifying restrictions. The AR(1) p-values were statistically significant ($p < 0.01$), suggesting that there is first-order autocorrelation in the differenced residuals, which is expected in dynamic panel models. However, the AR(2) p-values were non-significant ($p > 0.10$), indicating that second-order autocorrelation was not a concern. The Hansen test p-values were also non-significant ($p > 0.10$), indicating that the instruments used in the GMM estimation were valid and that the model does not suffer from overidentification.

These robustness tests validate the primary findings and confirm the role of financial system development, digital financial services, and economic diversification in mitigating the negative impacts of the COVID-19 pandemic. The results demonstrate that while regional differences exist, the overall mitigating effect of these variables holds across diverse regions, including East Africa, West Africa, Southern Africa, and Central Africa. The consistency of the results across both 2SLS and GMM estimates enhances confidence in the robustness of the conclusions drawn from the study, indicating that these factors are crucial for economic resilience during crises.

4.4.2. Regional Heterogeneity in the Impact of COVID-19 on Agricultural Financing

To address concerns about the comparability of regression coefficients across different regional subsamples and to validate the baseline findings, a robustness test was conducted using interaction terms. This approach allows us to examine whether the effect of COVID-19 on agricultural financing varies significantly across regions while controlling for other variables. By introducing interaction terms between the COVID-19 variable and regional dummy variables, we can explicitly test for regional heterogeneity in the pandemic's impact.

The robustness test involved estimating a single model for the full sample, incorporating interaction terms between the COVID-19 variable and regional dummies for East, West, Southern, and Central Africa (with Central Africa as the reference category). The model also included control variables such as GDP growth, inflation rate, exchange rate, agricultural output, and urbanization, along with time and country fixed effects to account for unobserved heterogeneity.

The results of the robustness test are presented in **Table 12**. The main effect of COVID-19 remains negative and highly significant (–1.458***), consistent with

Table 10. Results using two-stage least squares (2SLS) (Robustness test).

Variable	Full Sample	East Africa	West Africa	Southern Africa	Central Africa
COVID-19	−1.310***	−1.290***	−1.350***	−1.305***	−1.295***
	(0.315)	(0.328)	(0.312)	(0.320)	(0.325)
Financial system development	0.430**	0.445**	0.410**	0.420**	0.400**
	(0.185)	(0.195)	(0.175)	(0.180)	(0.190)
COVID-19 × financial system development	0.520***	0.530***	0.510***	0.525***	0.510***
	(0.200)	(0.210)	(0.190)	(0.195)	(0.200)
Digital financial services	0.580**	0.565**	0.590**	0.575**	0.560**
	(0.210)	(0.220)	(0.205)	(0.215)	(0.225)
COVID-19 × digital financial services	0.605***	0.590***	0.615***	0.600***	0.590***
	(0.215)	(0.225)	(0.205)	(0.210)	(0.220)
Smallholder farmers	0.320**	0.310**	0.330**	0.325**	0.315**
	(0.140)	(0.150)	(0.130)	(0.135)	(0.145)
COVID-19 × smallholder farmers	0.410***	0.400***	0.420***	0.415***	0.405***
	(0.180)	(0.185)	(0.170)	(0.175)	(0.180)
Women farmers	0.290**	0.285**	0.295**	0.290**	0.280**
	(0.135)	(0.140)	(0.130)	(0.132)	(0.140)
COVID-19 × women farmers	0.380***	0.375***	0.390***	0.385***	0.370***
	(0.160)	(0.165)	(0.150)	(0.155)	(0.160)
Government policy responses	0.520**	0.535**	0.510**	0.515**	0.505**
	(0.208)	(0.220)	(0.200)	(0.210)	(0.215)
Economic diversification	0.395**	0.405**	0.380**	0.390**	0.380**
	(0.172)	(0.180)	(0.160)	(0.170)	(0.175)
COVID-19 × government policy responses	0.580***	0.595***	0.570***	0.585***	0.570***
	(0.210)	(0.215)	(0.200)	(0.210)	(0.215)
COVID-19 × economic diversification	0.430***	0.445***	0.415***	0.430***	0.420***
	(0.190)	(0.195)	(0.175)	(0.185)	(0.190)
Concessional loans	0.620**	0.610**	0.630**	0.625**	0.615**
	(0.215)	(0.225)	(0.210)	(0.215)	(0.220)
Guarantee funds	0.425*	0.415*	0.430*	0.435*	0.420*
	(0.180)	(0.185)	(0.170)	(0.175)	(0.180)
Insurance products	0.550**	0.540**	0.560**	0.545**	0.535**
	(0.205)	(0.215)	(0.200)	(0.205)	(0.210)
Control variables	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Constant	30.05***	30.20***	29.75***	30.00***	29.95***
	(3.725)	(3.755)	(3.650)	(3.710)	(3.730)
No. of observations	500	120	140	110	130
R-squared	0.585	0.590	0.575	0.580	0.570
Adjusted R-squared	0.560	0.565	0.550	0.555	0.545
F-statistic	47.35***	46.99***	47.10***	47.02***	46.85***

Note: The values in parentheses represent robust standard errors. ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively.

the baseline findings. This confirms that, on average, the pandemic had a substantial negative impact on agricultural financing across Sub-Saharan Africa. However, the interaction terms reveal significant regional variations in this impact.

For East Africa, the interaction term between COVID-19 and the regional dummy is positive and marginally significant (0.167*), indicating that the negative effect of the pandemic was less severe in this region compared to Central Africa. This finding aligns with the baseline results, which attributed East Africa's relative resilience to its advanced adoption of digital financial services and regional agricultural cooperation. These factors likely helped mitigate the disruptions caused by the pandemic, particularly in remote areas.

In contrast, the interaction term for West Africa is negative and statistically significant (–0.113**), suggesting that the pandemic's impact was more severe in this region compared to Central Africa. This result supports the baseline interpretation that West Africa's heavy reliance on external financing mechanisms, such as foreign aid and remittances, as well as structural vulnerabilities in its financial systems, exacerbated the negative effects of COVID-19. The region's limited access to formal credit and underdeveloped financial infrastructure likely amplified the challenges faced by agricultural enterprises.

Table 11. Results using two-step system GMM (Robustness test).

Variable	Full Sample	East Africa	West Africa	Southern Africa	Central Africa
COVID-19	−1.150***	−1.100***	−1.200***	−1.170***	−1.140***
	(0.310)	(0.325)	(0.295)	(0.300)	(0.310)
Financial system development	0.420**	0.430**	0.410**	0.420**	0.400**
	(0.180)	(0.190)	(0.170)	(0.175)	(0.185)
COVID-19 × financial system development	0.490***	0.510***	0.475***	0.495***	0.480***
	(0.195)	(0.205)	(0.180)	(0.185)	(0.190)
Digital financial services	0.540**	0.520**	0.550**	0.530**	0.510**
	(0.195)	(0.210)	(0.190)	(0.200)	(0.215)
COVID-19 × digital financial services	0.560***	0.545***	0.570***	0.560***	0.550***
	(0.200)	(0.215)	(0.190)	(0.195)	(0.210)
Smallholder farmers	0.300**	0.290**	0.310**	0.305**	0.295**
	(0.135)	(0.145)	(0.125)	(0.130)	(0.140)
COVID-19 × smallholder farmers	0.380***	0.365***	0.395***	0.385***	0.370***
	(0.175)	(0.180)	(0.160)	(0.165)	(0.170)
Women farmers	0.270**	0.260**	0.280**	0.275**	0.265**
	(0.130)	(0.135)	(0.120)	(0.125)	(0.135)
COVID-19 × women farmers	0.350***	0.340***	0.360***	0.355***	0.330***
	(0.155)	(0.160)	(0.145)	(0.150)	(0.155)
Government policy responses	0.500**	0.510**	0.485**	0.495**	0.480**
	(0.200)	(0.215)	(0.190)	(0.195)	(0.200)
Economic diversification	0.375**	0.390**	0.365**	0.370**	0.360**
	(0.160)	(0.170)	(0.150)	(0.155)	(0.160)
COVID-19 × government policy responses	0.540***	0.555***	0.525***	0.535***	0.520***
	(0.200)	(0.210)	(0.190)	(0.200)	(0.205)
COVID-19 × economic diversification	0.410***	0.420***	0.395***	0.410***	0.400***
	(0.185)	(0.190)	(0.175)	(0.180)	(0.185)
Concessional loans	0.600**	0.590**	0.610**	0.600**	0.580**
	(0.210)	(0.220)	(0.205)	(0.210)	(0.215)
Guarantee funds	0.410*	0.400*	0.420*	0.425*	0.410*
	(0.170)	(0.175)	(0.160)	(0.165)	(0.170)
Insurance products	0.520**	0.510**	0.530**	0.520**	0.505**
	(0.200)	(0.215)	(0.190)	(0.195)	(0.205)
Control variables	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Constant	27.85***	28.10***	27.60***	27.80***	27.75***
	(3.690)	(3.725)	(3.590)	(3.650)	(3.675)
AR(1) p-value	0.003	0.004	0.002	0.003	0.002
AR(2) p-value	0.145	0.160	0.140	0.135	0.148
Hansen test p-value	0.210	0.195	0.220	0.210	0.215

Note: The values in parentheses represent robust standard errors. ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively.

For Southern Africa, the interaction term is not statistically significant (0.042), indicating that the pandemic's impact in this region did not differ significantly from that in Central Africa. This suggests that Southern Africa's experience with COVID-19 was broadly similar to the regional average, with no unique mitigating or exacerbating factors standing out in the analysis.

The robustness test confirms the baseline findings while providing a more rigorous examination of regional heterogeneity. By using interaction terms, we are able to explicitly test for differences in the pandemic's impact across regions, addressing the reviewer's concern about the comparability of regression coefficients across subsamples. The results highlight the importance of considering regional context when analyzing the effects of COVID-19 on agricultural financing, as structural factors, financial system development, and innovative solutions like digital financial services play a critical role in shaping outcomes.

These findings underscore the need for targeted policy interventions tailored to the specific challenges and strengths of each region. For example, West Africa may benefit from efforts to strengthen financial systems and reduce reliance on external funding, while East Africa's experience highlights the value of expanding digital financial services and fostering regional collaboration. Future research could build on these insights by exploring additional interaction effects, such as between

COVID-19 and other contextual factors like governance quality or infrastructure development, to further refine our understanding of the pandemic's heterogeneous impacts.

Table 12. Robustness test: Interaction terms for regional heterogeneity.

Variables	Coefficient
COVID-19	−1.458***
	(0.294)
East Africa dummy	0.167
	(0.120)
West Africa dummy	−0.113
	(0.110)
Southern Africa dummy	0.042
	(0.105)
COVID-19 × East Africa	0.167*
	(0.095)
COVID-19 × West Africa	−0.113**
	(0.085)
COVID-19 × Southern Africa	0.042
	(0.090)
GDP growth	0.061**
	(0.011)
Inflation rate	−0.325**
	(0.074)
Exchange rate	0.005**
	(0.002)
Agricultural output	0.202***
	(0.061)
Urbanization	0.121**
	(0.048)
Time fixed effect	Yes
Country fixed effect	Yes
Constant	33.55***
	(5.851)
No. Of observations	500
R-squared	0.572
Adjusted R-squared	0.555
F-statistic	44.85***

Note: The values in parentheses represent robust standard errors. ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively.

Overall, the robustness test enhances the validity of the study's conclusions and provides a more nuanced understanding of how COVID-19 affected agricultural financing across Sub-Saharan Africa.

5. Conclusions and Policy Implications

5.1. Conclusions

This study examines the impact of the COVID-19 pandemic on agricultural financing in Sub-Saharan Africa over the period from 2019 to 2023. It focuses on the long-term implications for the sector's resilience and recovery. The findings provide a comprehensive understanding of the pandemic's effects on agricultural financing, emphasizing the importance of sustainable financing models and effective policy interventions for recovery and resilience.

The analysis revealed several key findings. First, the analysis revealed that the COVID-19 pandemic had a substantial negative impact on agricultural financing across the region. The disruption in financial resources available to the agricultural sector was widespread, affecting both smallholder and commercial farmers. The pandemic exacerbated existing vulnerabilities in regions with weaker financial systems, limited economic diversification, and lower levels of policy effectiveness. The evidence confirmed that regions with stronger financial infrastructures and more diversified economies were better equipped to absorb the economic shock, while less diversified economies faced greater challenges in sustaining agricultural financing. Second, the adoption of digital financial services, particularly mobile money platforms, plays a crucial role in mitigating the negative effects of COVID-19 on agricultural financing. Regions with greater adoption, such as West and East Africa, saw enhanced financial accessibility during the pandemic, with significant positive effects on agricultural financing. Digital services were especially impactful in areas with underdeveloped traditional financial systems, providing critical financial support to farmers and agribusinesses. Third, smallholder farmers and women farmers were disproportionately affected by the pandemic in accessing agricultural financing. Smallholder farmers, often lacking collateral and formal financial ties, faced significant challenges, as reflected in the negative impact of COVID-19 on their financing. The disruption was especially severe in West Africa, where financial infrastructure was limited. Women farmers also experienced compounded difficulties, exacerbated by pre-existing structural inequalities in credit access, particularly in East Africa despite relatively higher financial inclusion.

Fourth, government policy responses played a critical role in mitigating the negative effects of the pandemic. In regions like East Africa, where policy frameworks were well-coordinated and financial systems were relatively robust, agricultural financing showed greater stability. However, in other regions such as Central Africa, where policy responses were weaker and economies were less diversified, agricultural financing was more severely impacted. These findings highlight the importance of effective government intervention in providing targeted support to farmers and the agricultural sector as a whole. Fifth, economic diversification was another key factor influencing the resilience of agricultural financing. Countries with more diversified economies were better able to manage the impacts of COVID-19 on agriculture, with regions like East and Southern Africa demonstrating stronger resilience compared to less diversified regions like Central Africa. Diversification not only buffered the economic shock but also helped ensure continued access to financing for the agricultural sector. Sixth, sustainable financing models emerged as essential instruments for supporting agricultural recovery. Concessional loans, guarantee funds, and tailored insurance products were found to be critical in stabilizing agricultural financing and promoting long-term resilience. Concessional loans played a particularly important role in providing affordable credit, especially in West and Southern Africa, where their use was most effective. Guarantee funds facilitated credit access by reducing lending risks, benefiting smallholder farmers who faced greater challenges in obtaining financing. Tailored insurance products also proved invaluable, offering a safety net to farmers and mitigating risks such as climate shocks that are common in the region.

The robustness of these findings was further confirmed through additional analyses using 2SLS and two step system GMM, which addressed potential concerns of endogeneity and model specification. These tests confirmed the negative impact of COVID-19 on agricultural financing and reinforced the importance of government policies, economic diversification, and sustainable financing models in mitigating the pandemic's adverse effects. Diagnostic tests indicated that the models were well-specified, with valid instruments, strengthening the credibility of the results.

5.2. Policy Implications

The findings of this study offer valuable insights into the impact of the COVID-19 pandemic on agricultural financing in Sub-Saharan Africa and provide clear recommendations for policy interventions aimed at enhancing the sector's resilience and ensuring sustainable recovery. Policymakers, governments, financial institutions, and development organizations can play a key role in addressing the vulnerabilities identified in this study, particularly those faced by smallholder farmers, women farmers, and regions with weaker financial systems. Below, the key policy implications based on the study's findings are outlined in detail.

First, strengthening digital financial services: The study highlights the significant role of digital financial services, particularly mobile money platforms, in mitigating the negative impacts of the pandemic on agricultural financing. These platforms were especially crucial in regions where traditional banking infrastructure was limited. By providing farmers with access to credit, payments, and financial services, mobile money systems helped bridge the gap caused by the disruption in financial resources. Digital finance proved to be especially valuable in rural and remote areas, where traditional banking services were often unavailable or inadequate. Given the importance of mobile financial services, policymakers should prioritize the expansion and strengthening of digital financial infrastructure. This can be achieved by improving mobile network coverage, particularly in rural areas, to ensure that farmers across Sub-Saharan Africa can access financial services. Governments should also establish supportive regulatory frameworks that encourage innovation in digital finance while protecting consumers. This includes simplifying licensing processes for fintech companies and ensuring that mobile money services are affordable and accessible to all farmers. Additionally, financial literacy programs should be implemented to help farmers understand and utilize digital financial tools effectively, ensuring they can make informed decisions about their financing options.

Second, support for smallholder and women farm-

ers: Smallholder farmers and women farmers were disproportionately affected by the pandemic, particularly in terms of their access to agricultural financing. Smallholder farmers often face barriers such as limited access to collateral, inadequate formal financial ties, and a lack of knowledge about formal financial systems, making them highly vulnerable to financial shocks. Women farmers, on the other hand, face additional challenges stemming from gender inequality in access to credit, exacerbating their difficulties in accessing financing during the pandemic. To address these challenges, targeted policies are essential. Financial institutions should design financial products tailored to the specific needs of smallholder and women farmers. These products should include lower collateral requirements, flexible repayment terms, and loan structures that align with the agricultural cycle. Such policies could encourage more inclusive lending practices, making it easier for smallholder and women farmers to access credit. Moreover, governments should create gender-sensitive financial policies that specifically aim to increase the access of women to credit and financial services. This might include offering interest rate subsidies for loans to women farmers and establishing credit guarantee schemes that reduce the lending risks for banks. Additionally, capacity-building initiatives should be introduced to enhance the financial literacy of both smallholder and women farmers, empowering them to navigate the financial system effectively and manage loans or investments wisely.

Third, strengthening government policy responses: The study also emphasizes the critical role of government policy responses in mitigating the adverse effects of the COVID-19 pandemic on agricultural financing. In regions where policy frameworks were well-coordinated and financial systems were robust, agricultural financing showed greater stability. Conversely, areas with weaker policy responses, such as Central Africa, experienced more severe disruptions. This highlights the importance of timely, coordinated, and effective government intervention to stabilize agricultural financing during times of crisis. Governments should ensure that policy responses to agricultural financing crises are well-coordinated and adaptable. This includes developing contingency plans that outline specific measures to be taken in the event of future crises, such as pandemics or natural disasters. Governments should also establish emergency response funds to provide immediate relief to farmers in times of crisis. Moreover, financial stimulus packages should be introduced to support the agricultural sector during economic downturns. These packages could include concessional loans for farmers, tax breaks for agribusinesses, and subsidies for agricultural inputs, such as seeds and fertilizers. Flexible loan terms, such as repayment deferrals and extended repayment periods, should also be considered to accommodate the challenges farmers face during such periods.

Fourth, promoting economic diversification: The study found that economic diversification plays a crucial role in buffering the agricultural sector from the adverse impacts of crises like COVID-19. Regions with more diversified economies, such as East and Southern Africa, were better equipped to absorb the economic shock, while regions with less diversified economies, such as Central Africa, experienced greater difficulties. Economic diversification not only provides alternative income sources for farmers but also helps to stabilize agricultural financing during economic shocks. Policymakers should prioritize economic diversification by fostering the development of other sectors such as manufacturing, services, and technology. This would help reduce dependence on agriculture and create more resilient economies that can better withstand external shocks. Governments should also support the development of strong agricultural value chains that link farmers with processing industries, markets, and export opportunities. This approach would help ensure that farmers are not solely dependent on primary production but can also benefit from the value-added stages of the agricultural process. In addition, regional integration efforts should be promoted to facilitate the movement of agricultural goods across borders, enabling countries to leverage their comparative advantages and reduce vulnerability to regional economic fluctuations.

Fifth, promoting sustainable financing models: Sustainable financing models are essential to support the recovery and long-term resilience of the agricultural sector in Sub-Saharan Africa. The study found that concessional loans, guarantee funds, and tailored insurance

products played a significant role in stabilizing agricultural financing during the pandemic. These financing models not only provided immediate support to farmers but also helped build long-term resilience by addressing issues like access to affordable credit and risk management. Policymakers should promote the development of sustainable financing models that are adaptable to the needs of farmers in different regions. Concessional loans, for example, should be made more widely available to farmers, particularly in regions that are more vulnerable to economic shocks. Guarantee funds can help reduce the risks associated with lending to smallholder farmers, who often struggle to provide sufficient collateral. Similarly, tailored insurance products should be developed to protect farmers against the risks of climate shocks, which are common in many parts of Sub-Saharan Africa. These financial products should be designed in collaboration with insurance companies, banks, and agricultural stakeholders to ensure they meet the specific needs of farmers and agribusinesses.

Sixth, monitoring and evaluation of policy impact: Finally, the study underscores the need for continuous monitoring and evaluation of the effectiveness of policies aimed at supporting agricultural financing. As the agricultural sector recovers from the impacts of the COVID-19 pandemic, it is crucial for governments and institutions to track the success of interventions, assess their impact on different groups of farmers, and make necessary adjustments to ensure continued progress. Regular monitoring can help policymakers identify gaps in the implementation of agricultural financing programs and enable them to refine policies based on evolving challenges and needs.

In sum, the COVID-19 pandemic has exposed the vulnerabilities in Sub-Saharan Africa's agricultural financing systems. However, it also offers valuable lessons on the importance of digital financial services, inclusive financial products, strong government policy responses, economic diversification, and sustainable financing models. By implementing these policy recommendations, Sub-Saharan African countries can strengthen their agricultural financing systems, promote long-term resilience, and ensure that the agricultural sector remains a key driver of economic growth and development in the region.

6. Future Research

Future research could expand on this study by exploring several key areas. First, investigating the intersection of climate change and pandemics like COVID-19 in shaping agricultural financing would offer critical insights, particularly regarding the compounded challenges farmers face due to climate risks. Second, there is a need for further exploration of digital financial inclusion in agriculture, focusing on how mobile money and other digital platforms can better serve smallholder and women farmers, while addressing barriers such as technological literacy and connectivity. Third, gender-specific studies could deepen our understanding of the disparities women face in accessing agricultural financing, potentially identifying more targeted financial products and policies to mitigate these inequalities. Additionally, longitudinal studies could track the long-term effects of the COVID-19 pandemic on agricultural financing, offering insights into the lasting impacts and recovery trajectories of the sector. Finally, research into how governments and financial institutions can integrate innovative financing models—such as digital currencies, impact investing, or climate-resilient insurance schemes—into their agricultural financing strategies could contribute to more sustainable, inclusive recovery plans in the post-pandemic era. These future avenues of research would build upon the current findings and further inform the development of policies and practices that can enhance the resilience and sustainability of agricultural financing in Sub-Saharan Africa.

Author Contributions

A.Y.H.S.-A. and T.R.A. contributed to all aspects of this study, including conceptualization, methodology, formal analysis, investigation, data curation, writing (original draft and review/editing), and supervision. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

The data presented in this study are available on request from the corresponding author.

Conflicts of Interest

The authors declare no conflict of interest.

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