Impact of Digital Financial Inclusion Index on Nigerian Agricultural Output

Kalu, Joseph Okorie[1], Ogbulu, Onyemachi Maxwell [2], Ejem, Chukwu Agwu[3], Effe-Nnamdi, Ann C.[4]
Department Banking and Finance,
Abia State University, Uturu, Nigeria
*Corresponding Author's email:
chukwu.ejem@abiastateuniversity.edu.ng

https://doi.org/10.56201/wjfir.v10.no11.2026.pg.14.49

Abstract
This study examined the impact of digital financial inclusion on agricultural output in Nigeria over the period 1999–2023. Given agriculture's importance to food security, employment and rural livelihoods, the study examined the Digital Financial Inclusion Index (DFII), agricultural credit, inflation and government capital expenditure as determinants of agricultural output. Annual time-series data were obtained from the Central Bank of Nigeria, National Bureau of Statistics, World Bank and EFInA. Agricultural output was measured by real agricultural gross domestic product, while DFII was constructed as a composite measure of digital financial access, usage and infrastructure using Principal Component Analysis. Agricultural credit and government capital expenditure were expressed in natural logarithms, while inflation and DFII were retained in their original forms. The Augmented Dickey-Fuller test and Autoregressive Distributed Lag (ARDL) bounds-testing approach examined stationarity and long-run relationships. Short-run dynamics were further examined using an error correction model and diagnostic tests. The unit root results showed that agricultural output, DFII, agricultural credit and government capital expenditure were integrated of order one, while inflation was stationary at level. The ARDL bounds test produced an F-statistic of 5.18, indicating a long-run relationship among the variables. The long-run estimates revealed that DFII, agricultural credit and government capital expenditure had positive and statistically significant relationships with agricultural output, while inflation had a negative and statistically significant relationship. In the short run, changes in DFII and agricultural credit were positively and significantly associated with agricultural output, whereas changes in inflation had a negative and significant relationship. Government capital expenditure had a positive short-run coefficient, but it was not statistically significant at the 5 per cent level. The negative and significant error correction coefficient of -0.382 indicated that approximately 38.2 per cent of short-run disequilibrium was corrected within one period. Diagnostic tests revealed no significant serial correlation, ARCH effects, non-normality or functional-form problems. The study concludes that digital financial inclusion is positively associated with agricultural output in Nigeria, alongside agricultural credit and public capital expenditure, while inflation constrains agricultural performance. It recommends expanding reliable and affordable digital financial services in rural communities, strengthening agricultural credit, improving rural telecommunications, ensuring effective implementation of agricultural

capital projects and promoting macroeconomic stability. These measures may improve the financial and infrastructural conditions supporting agricultural production. Given the 25 annual observations, findings are interpreted as estimated relationships, not definitive proof of causation; benefits also depend on affordable, reliable services suited to farmers' needs and local conditions.

Keywords: *Digital Financial Inclusion, Agricultural Output, Agricultural Credit, Inflation, Government Capital Expenditure, Nigeria.*

1. Introduction

Agriculture remains an important sector of the Nigerian economy because of its contributions to food security, employment generation, rural livelihoods, industrial raw materials and economic development. The sector supports the livelihood of a considerable proportion of the population and provides inputs for several agro-allied industries. Agricultural development is consequently important not only for increasing food availability but also for reducing poverty, improving rural welfare and strengthening the productive capacity of the economy. Despite its importance, agricultural production in Nigeria continues to face structural challenges, including inadequate access to affordable finance, high production costs, limited adoption of modern farming technologies, insufficient infrastructure and exposure to climatic and market uncertainties. Addressing these constraints requires coordinated policies that improve farmers' access to productive resources and strengthen the institutional and financial environment within which agricultural activities take place. One of the factors that may influence agricultural production is access to appropriate financial services. Farming frequently requires substantial expenditure on land preparation, improved seeds, fertilisers, agrochemicals, machinery, irrigation, labour, storage and transportation before revenue is realised from the sale of harvested produce. Farmers who cannot obtain the necessary financial resources at the appropriate time may be unable to purchase essential inputs, adopt improved production methods or expand their operations. Access to savings, credit, payment services and insurance can therefore help agricultural households and enterprises manage their financial requirements and undertake productive activities. Nevertheless, the availability of financial services alone does not guarantee higher agricultural output; the effectiveness of such services depends on their affordability, suitability and actual use in productive activities. Financial inclusion has attracted considerable attention in development policy because it concerns the ability of individuals and enterprises to access and use appropriate formal financial services. Such services include payments, savings, credit and insurance. Traditionally, financial inclusion initiatives have focused substantially on access to bank branches, conventional accounts and formal financial products. However, technological developments have changed the manner in which financial services are delivered. Mobile phones, electronic payment platforms, internet banking, automated teller machines, agent banking and other technology-enabled channels have created additional opportunities for individuals and businesses to access financial services without relying exclusively on conventional banking infrastructure.

These developments have contributed to the emergence of digital financial inclusion as an important aspect of financial sector development. Digital financial inclusion refers to the availability, accessibility and effective use of financial services delivered through digital technologies. Its significance extends beyond the mere presence of electronic payment infrastructure. Effective digital financial inclusion requires that users can access and utilise relevant services reliably, affordably and safely. Demirgüç-Kunt et al. (2022), through the Global Findex Database 2021, document developments in financial account ownership, digital payments

and the use of financial services across countries. Their work provides an important international context for understanding the expansion of digital financial access and the increasing relevance of digital transactions to economic participation.

Digital financial inclusion may be particularly relevant to agricultural development because many farming activities take place in rural areas where access to conventional financial institutions may be limited. Digital channels can potentially reduce geographical and transaction-cost barriers, facilitate the receipt and transfer of funds, improve the efficiency of payments and provide farmers with additional ways to save and manage income. Digital transaction records may also provide useful information to financial institutions when assessing customers who have limited conventional credit histories. These developments could potentially improve the financial environment within which agricultural households and enterprises operate.

The economic significance of digital financial services is illustrated by Jack and Suri (2014), whose study of mobile money in Kenya examines the relationship between mobile money, transaction costs and risk sharing. Similarly, Suri and Jack (2016) investigate the long-term poverty and gender implications of mobile money in Kenya. These studies demonstrate the relevance of digital financial services to economic and household outcomes in their respective contexts. However, the outcomes examined in those studies should not be equated directly with national agricultural output. Their relevance to the present study lies principally in the mechanisms through which digital financial services may influence economic activity, rather than in providing direct evidence of the effect of digital financial inclusion on Nigerian agricultural production.

In Nigeria, financial service delivery has undergone considerable changes since 1999. Developments in telecommunications, electronic payment systems, mobile banking, agent banking and financial technology have expanded the range of channels through which individuals and enterprises can conduct financial transactions. The Central Bank of Nigeria has also pursued financial inclusion initiatives intended to improve access to formal financial services. These developments provide an important institutional background for investigating whether the expansion of digital financial services has been associated with changes in agricultural performance. Nevertheless, the expansion of digital financial services does not necessarily translate automatically into increased agricultural output. Farmers may continue to experience inadequate access to affordable credit, unreliable electricity and telecommunications services, limited digital literacy, concerns about electronic fraud and insufficient access to suitable financial products. In addition, financial transactions may become more convenient without the resulting financial resources being directed towards productive agricultural activities. The relationship between digital financial inclusion and agricultural output must therefore be examined empirically rather than assumed to be positive. Agricultural credit constitutes another important consideration in this relationship. Agricultural activities often involve seasonal production cycles, with expenditure incurred well before the sale of produce. Credit can help farmers purchase inputs, hire labour, acquire equipment and finance other production requirements. Where appropriate credit is available, farmers may be better positioned to undertake activities that would otherwise be constrained by insufficient internal funds. However, the contribution of credit depends on its availability, cost, timing and suitability for agricultural production. High interest rates, collateral requirements, short repayment periods and uncertainty about farm income may limit the effectiveness of agricultural lending. Agricultural credit is therefore included in this study as a distinct explanatory variable rather than treated as an automatic consequence of digital financial inclusion.

Inflation is also relevant because agricultural production depends on inputs whose prices may change substantially over time. Increases in the prices of seeds, fertilisers, agrochemicals, machinery, fuel and transportation can raise the cost of production. Where farmers' incomes and available financing do not increase correspondingly, inflation may reduce their purchasing power and restrict their ability to obtain necessary inputs. Rising costs may consequently affect production decisions and the quantity of output supplied. However, the relationship between inflation and agricultural output is not necessarily uniform. Its direction and magnitude may depend on the source of inflation, changes in agricultural output prices, the availability of inputs and the responses of farmers and other market participants.

Government capital expenditure on agriculture represents a further factor that may influence agricultural production. Public investment in irrigation facilities, rural roads, storage infrastructure, agricultural research, extension facilities and other productive assets can potentially address constraints that individual farmers cannot resolve independently. Improved infrastructure may reduce transportation costs, minimise post-harvest losses, facilitate access to markets and increase the effectiveness of private agricultural investment. Nevertheless, public expenditure does not necessarily produce immediate improvements in output. Its contribution depends on the adequacy of funding, project selection, implementation, maintenance and the time required for investments to become productive. Consequently, the relationship between government capital expenditure on agriculture and agricultural output also requires empirical investigation.

Considering these factors together provides a broader basis for examining agricultural performance in Nigeria. Digital financial inclusion may improve the efficiency of financial transactions and access to services; agricultural credit may provide funds for productive inputs; inflation may influence input costs and purchasing power; and government capital expenditure may improve the infrastructure supporting agricultural production. Although these variables represent distinct mechanisms, their effects may overlap. For instance, digital financial services may facilitate financial transactions without ensuring access to agricultural credit, while public investment may improve the productive environment within which farmers use financial resources.

Sahay et al. (2015) examine the broader relationship between financial inclusion and macroeconomic objectives, including economic development and financial stability. Their work reinforces the importance of examining financial inclusion within the wider economic and institutional environment. For agricultural production, this means that the contribution of digital financial inclusion should be considered alongside other factors that may influence farmers' productive capacity and the conditions under which agriculture operates.

The period 1999–2023 provides an opportunity to investigate the relationship between digital financial inclusion and agricultural output in Nigeria over an extended period of financial and technological change. It encompasses developments in banking, telecommunications and electronic payment systems, alongside changes in agricultural production and the broader macroeconomic environment. Using annual data over this period, the study seeks to determine whether digital financial inclusion is associated with agricultural output after accounting for agricultural credit, inflation and government capital expenditure on agriculture.

Against this background, the study examines the impact of the Digital Financial Inclusion Index on Nigerian agricultural output over the period 1999–2023. By considering agricultural credit, inflation and government capital expenditure on agriculture alongside digital financial inclusion, the study aims to provide a more comprehensive assessment of the factors associated with agricultural output. Its central concern is whether the development of digital financial inclusion

has a statistically meaningful relationship with agricultural output within the Nigerian economic context.

1.2 Statement of the Problem

Agriculture remains central to Nigeria's food security, employment generation and rural economic activities. However, agricultural production is influenced by several constraints, including inadequate access to finance, high input costs, infrastructure deficiencies and difficulties in obtaining essential production inputs. These constraints may limit farmers' ability to expand production, adopt improved technologies, increase productivity and respond effectively to changing market conditions. Understanding the factors associated with agricultural output is therefore important for the development of policies aimed at strengthening the sector.

Financial inclusion has been promoted as one means of reducing financial constraints by enabling individuals and enterprises to access appropriate financial services. More recently, digital financial services have created additional opportunities to conduct financial transactions and access financial products without relying exclusively on conventional banking facilities. The expansion of digital payments, mobile banking and other technology-enabled services raises the possibility that improved digital financial inclusion could support agricultural activities by reducing transaction costs, facilitating payments and improving access to financial services.

However, the existence and expansion of digital financial services do not establish that agricultural output has increased as a result. Farmers may have access to digital payment platforms but remain unable to obtain affordable credit or finance essential production inputs. Digital financial services may improve the convenience of transactions without necessarily improving the availability of productive resources. Consequently, the extent to which digital financial inclusion contributes to agricultural output in Nigeria remains an empirical question requiring systematic investigation.

A further problem is that agricultural output is influenced by factors beyond digital financial inclusion. Agricultural credit is important because production activities require financing before revenue is received. Where farmers lack suitable credit facilities, they may be unable to purchase inputs or invest in improved production methods. Even where credit is available, its contribution may be limited by high borrowing costs, unsuitable repayment arrangements and the seasonal nature of agricultural income. It is therefore necessary to distinguish the relationship between digital financial inclusion and agricultural output from the relationship associated with agricultural credit. Inflation creates another potential constraint. Rising prices of fertilisers, seeds, machinery, fuel and transportation may increase agricultural production costs and reduce the real value of available financing. Farmers may respond by reducing input use, postponing investment or changing production decisions. Nevertheless, the precise effect of inflation on agricultural output depends on prevailing economic conditions and the extent to which changes in output prices compensate for increases in production costs. Its influence should therefore be determined empirically rather than assumed. Government capital expenditure on agriculture may help address infrastructure and productive-capacity constraints through investment in irrigation, rural roads, storage facilities, research and other agricultural assets. Yet the contribution of public investment depends on its composition, implementation and effectiveness. Expenditure that does not translate into functioning productive assets may have limited effects on agricultural output. The relationship between public capital expenditure and agricultural production consequently requires careful assessment. The research problem addressed by this study is therefore not simply whether digital financial services have expanded in Nigeria, but whether the development of digital financial inclusion is associated with agricultural output when other important economic and institutional

factors are considered. Examining digital financial inclusion alongside agricultural credit, inflation and government capital expenditure on agriculture may provide a clearer understanding of the relationships between financial access and agricultural performance.

Although the international literature provides evidence on the economic relevance of financial inclusion and digital financial services, findings concerning household welfare, consumption smoothing and general financial access do not necessarily establish their relationship with national agricultural output. Similarly, developments in Nigeria's digital payment infrastructure cannot, on their own, demonstrate that agricultural production has improved because of digital financial inclusion. A country-specific empirical investigation is therefore necessary.

Accordingly, this study investigates the relationship between the Digital Financial Inclusion Index and agricultural output in Nigeria over the period 1999–2023, while accounting for agricultural credit, inflation and government capital expenditure on agriculture. The study seeks to provide evidence on the statistical relationships between these variables and contribute to a more informed understanding of the potential role of digital financial inclusion in agricultural development.

1.3 Objectives of the Study

The general objective of the study is to examine the impact of the Digital Financial Inclusion Index on agricultural output in Nigeria, taking into account agricultural credit, inflation and government capital expenditure on agriculture over the period. While the specific objectives are to:

i. examine the impact of the Digital Financial Inclusion Index on agricultural output in Nigeria.
ii. determine the effect of agricultural credit on agricultural output in Nigeria.
iii. investigate the effect of inflation on agricultural output in Nigeria.
iv. evaluate the effect of government capital expenditure on agriculture on agricultural output in Nigeria.

1.4 Statement of Hypotheses

The following null hypotheses are formulated for the study:

H_{01}: The Digital Financial Inclusion Index has no statistically significant effect on agricultural output in Nigeria.

H_{02}: Agricultural credit has no statistically significant effect on agricultural output in Nigeria.

H_{03}: Inflation has no statistically significant effect on agricultural output in Nigeria.

H_{04}: Government capital expenditure on agriculture has no statistically significant effect on agricultural output in Nigeria.

These hypotheses will be examined using the estimation procedure adopted for the study. The direction and statistical significance of the estimated relationships will be determined from the empirical results rather than assumed in advance.

2. Review of Related Literature

2.1 Conceptual Review

The conceptual review explains the principal concepts underlying the study and examines the possible relationships among the variables. It discusses agricultural output, digital financial inclusion, agricultural credit, inflation and government capital expenditure on agriculture. Particular attention is given to the mechanisms through which each variable may be associated with agricultural production in Nigeria.

2.1.1 Concept of Agricultural Output

Agricultural output refers to the quantity or economic value of goods produced through agricultural activities during a specified period. Depending on the statistical definition adopted, agricultural production may cover crop cultivation, livestock, forestry and fishing. Agricultural output is an important indicator of the productive performance of the agricultural sector and provides information about its contribution to food supply, employment, income generation and the provision of raw materials to agro-allied industries. Agricultural output may be measured using several indicators, including agricultural gross domestic product, agricultural value added, the volume of agricultural production or an agricultural production index. Although these measures are related, they are not identical. Agricultural value-added measures the contribution of agricultural activities to economic production after accounting for intermediate consumption within the applicable national accounting framework. A physical production index, by contrast, focuses more directly on changes in the volume of agricultural production. The choice of measure is important because the concept of output must correspond to the research objective and the available data. Where the objective is to examine changes in agricultural production over time, a measure expressed at constant prices or an appropriate real agricultural production index is generally preferable to a nominal measure. Nominal agricultural output can increase because of rising prices even where the physical volume of production changes only slightly. A real measure helps reduce this problem by distinguishing changes in production value from changes attributable to prices. Agricultural output is influenced by several factors, including land availability, labour, rainfall, technology, the use of improved inputs, access to credit, market conditions and public infrastructure. Financial services may affect output by influencing farmers' ability to finance production activities, while inflation may alter the costs of obtaining inputs. Government capital expenditure may affect productive capacity through infrastructure and other public assets.

For the present study, agricultural output represents the outcome whose relationship with digital financial inclusion and the other explanatory variables is being investigated. The specific indicator selected for the empirical analysis should be clearly defined in Section Three, together with its units, source and treatment over the period 1999–2023. This is necessary to ensure that the interpretation of the findings corresponds to the actual variable used.

2.1.2 Concept of Digital Financial Inclusion

Financial inclusion generally refers to the availability, accessibility and effective use of appropriate formal financial services by individuals and enterprises. These services include payments, savings, credit and insurance. Financial inclusion is important because limited access to suitable financial services may constrain the ability of households and businesses to manage income, finance investment, make transactions and respond to economic uncertainty.

Digital financial inclusion extends this concept by emphasising the delivery and use of financial services through digital technologies. Relevant channels may include mobile banking, electronic payment platforms, internet banking, mobile money, automated teller machines, agent banking and other technology-enabled financial services. These channels can potentially reduce the need for physical visits to bank branches and make some transactions more convenient and less costly.

However, digital financial inclusion should not be understood simply as the availability of technology. Effective digital financial inclusion also concerns whether people can use digital services in practice. Factors such as mobile network coverage, electricity supply, digital literacy, affordability, user trust, consumer protection and the reliability of service providers may influence

actual use. A digital platform may be technically available without being accessible or useful to all members of a rural community.

The distinction between access and effective use is important for agricultural development. Farmers may benefit from digital services when they can receive payments promptly, transfer funds, save money and conduct transactions with input suppliers and produce buyers. Digital transaction histories may also provide useful information for financial institutions when developing products for customers with limited conventional credit records. Nevertheless, these possibilities depend on the services available and the extent to which they meet the needs of agricultural households and enterprises. Demirgüç-Kunt et al. (2022) provide an international overview of financial account ownership, digital payments and the use of financial services. Their work illustrates the relevance of digital financial access to contemporary financial inclusion debates. Sahay et al. (2015) also examine the broader macroeconomic relevance of financial inclusion. Together, these studies provide a useful foundation for considering the role of financial access in economic activity, although neither should be interpreted as direct evidence that a digital financial inclusion index increases agricultural output in Nigeria. The measurement of digital financial inclusion has become increasingly important in evaluating the extent to which technological innovations facilitate access to and usage of financial services. Khera et al. (2021) developed a digital financial inclusion index incorporating the access and usage dimensions of digital financial services. In Nigeria, Yaaba (2017) demonstrated the application of a composite financial inclusion index using the methodology developed by Sarma (2008). Furthermore, Nkechika (2022) highlighted the contribution of digital financial services, including mobile banking, point-of-sale devices and agent banking, to expanding financial inclusion in Nigeria.

For empirical research, a Digital Financial Inclusion Index may be constructed by combining selected indicators of digital financial access and usage into a composite measure. The indicators, normalization procedure, weighting method and aggregation process determine what the resulting index represents. A credible index should reflect the digital dimension of financial inclusion and should not be described as a digital index if it measures only conventional banking access or general financial depth. Consequently, the construction of the index used in this study is a significant methodological consideration. The data sources and indicators should be documented transparently, and the interpretation of the index should remain consistent with the information captured by its components. If the index is constructed by the researcher, the method should be explained in the methodology section rather than assumed in the conceptual discussion.

2.1.3 Digital Financial Inclusion and Agricultural Output

The potential relationship between digital financial inclusion and agricultural output can be explained through its influence on financial transactions, savings, access to financial services and the financing of productive activities. Agricultural production commonly requires expenditure before income is realised from the sale of produce. Farmers may therefore need access to financial services that allow them to manage seasonal cash-flow requirements and meet production expenses. First, digital payment services may reduce the time and effort required to transfer funds and receive payments. Farmers who can receive payments electronically may be able to conduct transactions with buyers and suppliers more efficiently. Reduced transaction costs may improve the management of agricultural income and expenditure, although the actual benefit depends on the cost and reliability of the services used.

Second, digital financial services may facilitate savings and the management of seasonal income. Agricultural households often experience fluctuations in cash flow because expenditure occurs at

different stages of the production cycle while revenue may be concentrated around harvesting and marketing periods. Convenient access to financial accounts and digital transactions may help users manage some of these fluctuations. The extent to which this translates into increased output, however, depends on whether the resulting financial flexibility supports productive agricultural decisions. Third, digital transaction records may potentially help financial service providers assess the activities of customers who lack extensive conventional credit histories. Where providers use such information to design suitable financial products, digital financial inclusion may support access to finance. However, the existence of digital transaction records does not guarantee that a farmer will qualify for credit or receive financing on appropriate terms.

Fourth, digital financial services may facilitate the distribution of government transfers, agricultural support payments and insurance-related payments. Where such systems operate effectively, they may reduce some of the difficulties associated with delivering funds to beneficiaries. Their contribution to agricultural output nevertheless depends on the design of the programme, the timeliness of payments and how the funds are used.

The potential benefits of digital financial inclusion are consistent with the mechanisms discussed by Jack and Suri (2014), who investigate mobile money and risk sharing in Kenya. Suri and Jack (2016) also show the importance of examining the longer-term economic and household implications of mobile money. These studies support the relevance of digital financial services to economic activity, but their findings should not be treated as direct estimates of the relationship between digital financial inclusion and Nigerian agricultural output.

There are also reasons why the relationship may be weak or uneven. Farmers may face limited network coverage, unreliable electricity, low digital literacy, service charges, fraud concerns or inadequate access to suitable agricultural credit. Moreover, agricultural output depends on factors such as land, rainfall, labour, production technology, infrastructure and access to markets. Digital financial inclusion cannot independently remove all these constraints.

The expected relationship between digital financial inclusion and agricultural output is therefore conditional. Improved digital financial access may create opportunities for more efficient financial transactions and productive investment, but these opportunities do not automatically lead to higher agricultural output. Whether a meaningful relationship exists in Nigeria over 1999–2023 is an empirical question that the present study seeks to investigate.

2.1.4 Digital Financial Inclusion in Nigeria

Nigeria provides an important context for examining the relationship between digital financial inclusion and agricultural production because the country has experienced substantial changes in financial service delivery and electronic payments. Developments in telecommunications, banking technology, electronic transfers, mobile banking, agent banking and financial technology have altered how individuals and enterprises access and use financial services.

Financial inclusion initiatives and payment-system developments have sought to widen access to formal financial services. The Central Bank of Nigeria provides an important institutional source for information on financial inclusion policies, banking statistics and payment-system developments. The World Bank's Global Findex Database also provides internationally comparable information on selected indicators of account ownership and financial service usage.

These developments create opportunities to examine whether changes in digital financial inclusion have been associated with agricultural output. Agriculture is particularly relevant because many production activities occur in rural areas, where access to conventional financial infrastructure may

be limited. Digital services may provide additional channels for receiving payments, transferring funds and conducting transactions with suppliers and buyers.

Nevertheless, the expansion of national digital payment activity should not automatically be interpreted as evidence of effective digital financial inclusion among farmers. Digital transactions may increase in urban and commercial settings without a corresponding improvement in the financial access of agricultural households. Likewise, greater access to payment services does not necessarily imply greater access to credit or insurance. An empirical study must therefore distinguish the general development of digital financial infrastructure from the specific measure of digital financial inclusion used in the analysis. The interpretation of the index should be based on its actual components and should avoid claims about agricultural users unless the data directly support such claims. The period 1999–2023 provides a basis for examining changes in digital financial inclusion alongside agricultural output over an extended period. However, because several financial, technological and macroeconomic developments occurred during these years, the observed relationship cannot be attributed to digital financial inclusion alone without considering other relevant variables. This reinforces the importance of examining agricultural credit, inflation and government capital expenditure on agriculture within the same empirical study.

2.1.5 Concept of Agricultural Credit

Agricultural credit refers to funds made available to farmers, agricultural enterprises and other participants in the agricultural value chain for financing production and related activities. Such financing may be used to purchase seeds, fertilisers, agrochemicals, machinery, livestock, irrigation equipment and other inputs. It may also support labour costs, processing, storage, transportation and marketing, depending on the purpose and terms of the loan.

Agriculture has particular financing requirements because production is often seasonal. Farmers may incur substantial costs during land preparation, planting and cultivation but receive income only after harvesting and selling their produce. This timing difference can create a financing gap, especially for farmers with limited savings. Appropriate credit may help bridge this gap and allow production activities to proceed when required.

Agricultural credit may influence output through several channels. It may enable farmers to purchase improved inputs, expand cultivated areas, adopt better production methods and invest in equipment. It may also provide working capital that helps farmers manage seasonal expenses. Where credit is used effectively and complementary resources are available, it may support increased production or productivity.

However, access to credit does not guarantee an increase in agricultural output. The effect depends on the cost of borrowing, loan availability, repayment schedules, collateral requirements, the timing of disbursement and the suitability of the financing arrangement for agricultural production. Credit received after the relevant planting period, for example, may not provide the intended support for that production cycle. Similarly, funds used for non-productive purposes may have limited direct effects on output.

Agricultural lending also involves risks arising from weather conditions, crop diseases, price fluctuations and uncertainty about harvests. Financial institutions may respond to these risks by restricting lending or imposing conditions that are difficult for some farmers to satisfy. These constraints can limit the contribution of credit to agricultural development.

Digital financial inclusion and agricultural credit should therefore be treated as related but distinct concepts. Digital financial inclusion concerns access to and use of financial services through

digital channels, while agricultural credit represents financing provided for agricultural activities. Digital services may facilitate credit transactions or support the development of financial products, but digital access alone does not establish that agricultural credit has increased.

Including agricultural credit in the present study allows its relationship with agricultural output to be examined separately from that of digital financial inclusion. The precise measure of agricultural credit must be defined in the methodology section, including whether it represents total bank credit to agriculture or a narrower category of lending. The measure should be interpreted in accordance with its actual coverage.

2.1.6 Concept of Inflation and Agricultural Output

Inflation refers to a sustained increase in the general price level of goods and services in an economy over time. It reduces the purchasing power of money and can influence production, consumption, investment and financial decisions. In agriculture, inflation is particularly relevant because farmers purchase inputs and services whose prices may change significantly during the production cycle. An increase in the prices of seeds, fertilisers, agrochemicals, fuel, machinery and transportation can raise the cost of agricultural production. If farmers cannot obtain additional financing or adjust their production arrangements, they may reduce the quantity or quality of inputs used. This may affect planting decisions, farm maintenance, mechanisation and other activities that influence output. Inflation can also reduce the real value of funds available to farmers. Where agricultural credit or household savings do not keep pace with rising input prices, the same nominal amount of money may purchase fewer productive resources. Farmers may therefore find it more difficult to finance production, particularly where access to additional credit is limited.

The effect of inflation on agricultural output is not necessarily negative in every circumstance. Changes in agricultural selling prices may influence the incentives facing producers, and the relationship between input prices and output prices may differ across commodities and periods. Some producers may benefit from increases in the prices received for their products, while others may face higher costs without equivalent increases in revenue. The overall relationship depends on the nature of the price changes, production conditions and farmers' ability to respond.

Inflation may also interact with agricultural credit and public expenditure. Rising input costs may reduce the purchasing power of available credit, while increases in construction and equipment costs may affect the real value of government capital expenditure. Consequently, the influence of inflation may extend beyond its immediate effect on production costs.

For this study, inflation is included as an explanatory variable because changes in the general price level may influence the economic environment within which agricultural production takes place. Its effect on agricultural output in Nigeria over 1999–2023 must be established empirically rather than inferred solely from the theoretical expectation that higher input costs can constrain production.

2.1.7 Government Capital Expenditure on Agriculture and Agricultural Output

Government capital expenditure on agriculture refers to public spending intended to acquire, develop or improve productive assets and infrastructure that support agricultural activities. Depending on the classification used in government accounts, such expenditure may include investment in irrigation facilities, rural access roads, storage infrastructure, agricultural research facilities, extension infrastructure and other long-term assets that support production.

Public investment can contribute to agricultural development because some infrastructure has benefits that extend beyond individual farms. Irrigation facilities may improve water availability;

rural roads may reduce transportation difficulties and improve access to markets; storage facilities may help reduce post-harvest losses; and research and extension infrastructure may support the development and dissemination of improved agricultural practices. Such investments may complement private resources and improve the conditions under which farmers operate.

Government capital expenditure may also support agricultural output indirectly by reducing the costs and risks associated with production and marketing. For example, improved rural roads may make it easier to transport inputs to farms and produce to markets. Better storage facilities may reduce losses between harvesting and sale. Publicly supported research and extension services may improve access to information about production techniques and crop management.

However, the relationship between government capital expenditure and agricultural output depends on more than the amount allocated in a budget. The effectiveness of public expenditure may be affected by project selection, implementation delays, cost overruns, maintenance arrangements, the location of infrastructure and whether completed projects meet farmers' actual needs. Capital spending may also take time to influence output because infrastructure and other productive assets are not always completed or fully utilised within the year in which expenditure occurs. It is therefore important to distinguish budgetary allocations from actual expenditure and to distinguish capital expenditure from recurrent expenditure. These categories do not measure the same thing. The empirical measure used in this study should accurately reflect the concept of government capital expenditure on agriculture and should be applied consistently throughout the study period. Government capital expenditure may also interact with digital financial inclusion and agricultural credit. For example, access to digital financial services and credit may be more useful to farmers where roads, irrigation, storage and other complementary infrastructure are available. Conversely, improvements in public infrastructure may increase the opportunities for farmers to use financial resources productively. The inclusion of government capital expenditure on agriculture in this study recognises that agricultural output may be associated with public investment as well as financial access and macroeconomic conditions. Its contribution will be assessed empirically, taking into account the definition and limitations of the available expenditure data.

2.1.8 Interrelationships among the Study Variables

The four explanatory variables considered in this study represent different but potentially related influences on agricultural output. Digital financial inclusion concerns access to and use of financial services through digital channels; agricultural credit concerns financing directed towards agricultural activities; inflation reflects changes in the general price level; and government capital expenditure on agriculture represents public investment in productive assets and infrastructure.

Digital financial inclusion may support agricultural activity by improving transaction efficiency and making some financial services more accessible. Agricultural credit may provide funds for purchasing inputs and meeting production expenses. Inflation may influence the cost of these inputs and the real purchasing power of available funds. Government capital expenditure may improve the infrastructure and public services needed to support agricultural production.

These relationships may operate simultaneously. For example, a farmer who can receive payments digitally may still be unable to expand production if affordable credit is unavailable. Similarly, access to credit may not produce the expected increase in output if inflation substantially raises input costs or if inadequate infrastructure prevents the efficient movement of agricultural produce to markets. Public investment may improve productive capacity, but its benefits may be limited if farmers lack the finance needed to acquire inputs and use the available infrastructure effectively.

The variables may also be interrelated in ways that require careful empirical interpretation. Digital financial inclusion and agricultural credit, for example, may be associated because digital services can facilitate financial transactions. Including both variables allows their conditional relationships with agricultural output to be examined, but it does not by itself establish the direction of causation between them. Likewise, the relationship between government expenditure and output may reflect both the influence of public investment on production and policy responses to changing agricultural conditions.

The conceptual implication is that agricultural output should not be understood as a function of digital financial inclusion alone. Rather, digital financial inclusion is the principal variable of interest within a broader economic environment that includes agricultural credit, inflation and government capital expenditure on agriculture. Examining these variables together may provide a more informative assessment of their individual relationships with agricultural output than considering digital financial inclusion in isolation.

2.2 Theoretical Review

This study draws on financial intermediation theory and the financial inclusion perspective as its principal theoretical foundations. The technology acceptance perspective provides a complementary explanation of why access to digital services may not necessarily translate into effective use. In addition, the Keynesian perspective on public expenditure and the cost-push explanation of inflation help explain the possible relationships between government capital expenditure, inflation and agricultural output.

2.2.1 Financial Intermediation Theory

Financial Intermediation Theory, as developed by Gurley and Shaw (1955, 1960), explains that financial institutions perform an important function in mobilising savings and transferring funds from surplus units to deficit units in the economy. Through this process, financial intermediaries facilitate investment, improve resource allocation and promote economic growth. Goldsmith (1969), McKinnon (1973) and Shaw (1973) further emphasised the importance of financial development in enhancing investment and economic performance.

The theory is relevant to agricultural production because farming often requires expenditure before revenue is realised. Farmers with insufficient internal funds may be unable to purchase inputs or invest in equipment, even where the proposed activity could be productive. Access to suitable financial services may help relax these constraints by enabling farmers to obtain financing and manage the timing of their income and expenditure.

Digital financial inclusion may strengthen aspects of financial intermediation by facilitating payments, reducing some transaction costs and improving the delivery of financial services. Digital records may also provide information that financial institutions can use when assessing customers. Where such developments improve access to appropriate finance, they may support investment in agricultural activities. Nevertheless, financial intermediation theory does not imply that every improvement in financial technology will lead automatically to increased lending to agriculture or higher agricultural output. Financial institutions must be willing and able to provide suitable products, and farmers must be able to use the services for productive purposes. Lending decisions may also be influenced by credit risk, collateral requirements, expected returns and uncertainty surrounding agricultural production.

The theory is therefore relevant to the present study because it provides an economic explanation for the potential relationship between financial access and productive activity. It also supports the

distinction between digital financial inclusion and agricultural credit: the former concerns access to and use of digital financial services, while the latter concerns financing directed towards agricultural activities.

2.2.2 Financial Inclusion Perspective

The Financial Inclusion Perspective emphasises the importance of providing affordable and accessible financial services to all segments of society, particularly individuals and businesses traditionally excluded from the formal financial system. Sarma (2008) conceptualised financial inclusion through dimensions of banking penetration, availability and usage of financial services. Similarly, Beck et al. (2007) emphasised the importance of access to financial services in promoting economic opportunities, while Demirgüç-Kunt and Klapper (2013) highlighted the role of financial inclusion in improving household welfare and economic participation.

Digital financial inclusion extends this perspective by recognising that technology can reduce some of the geographical and transaction-cost barriers associated with conventional financial service delivery. Mobile banking, electronic payments, digital accounts and other technology-enabled services can provide alternative channels for accessing financial services, particularly where conventional bank branches are less accessible.

For agricultural households and enterprises, these channels may improve the convenience of financial transactions and provide additional ways to receive payments and manage funds. Where digital services are linked to suitable savings, credit or insurance products, they may also help address some financial constraints associated with agricultural production.

However, effective financial inclusion requires more than the availability of an account or digital platform. Users must be able to access services that are affordable, reliable, understandable and appropriate to their needs. Digital literacy, telecommunications infrastructure, consumer protection and trust in financial institutions may all influence whether potential users benefit from the services available to them. The financial inclusion perspective consequently provides a useful foundation for examining the relationship between digital financial inclusion and agricultural output. It suggests that wider access to suitable financial services may support productive activity, while recognising that the economic effect depends on effective use and the broader conditions within which financial services operate.

2.2.3 Technology Acceptance Perspective

The Technology Acceptance Model developed by Davis (1989) provides an explanation for the adoption of digital financial services. The model identifies perceived usefulness and perceived ease of use as major determinants of technology acceptance. Applied to financial inclusion, individuals and businesses are more likely to adopt digital financial services when such platforms are perceived as convenient, accessible, reliable and capable of reducing the cost and time associated with conventional banking transactions.

This perspective is relevant to agriculture because the availability of digital financial services does not guarantee that farmers will adopt them or use them for productive purposes. Farmers may face difficulties arising from limited digital literacy, unreliable network coverage, electricity constraints, access to mobile devices or concerns about fraud. Such factors may affect the extent to which digital financial services become part of their financial activities.

The technology acceptance perspective therefore provides a useful explanation of the difference between the expansion of digital financial infrastructure and effective digital financial inclusion.

It suggests that the potential economic benefits of digital financial services depend partly on adoption and sustained use.

Nevertheless, this perspective primarily explains technology adoption and use. It does not independently establish the effect of digital financial inclusion on national agricultural output. For that reason, it is used as a complementary perspective rather than the principal theory underpinning the study.

2.2.4 Keynesian Perspective on Public Expenditure

The Keynesian Perspective on Public Expenditure, associated with Keynes (1936), explains that government expenditure is an important instrument for stimulating aggregate demand, output and employment. According to the theory, increased government spending can generate a multiplier effect through which initial public expenditure stimulates additional income, consumption and investment. Applied to agriculture, government capital expenditure can promote agricultural output through the provision of infrastructure, irrigation facilities, research and development, and other productive support services.

In agriculture, public capital investment in irrigation, rural roads, storage facilities, research infrastructure and related productive assets may help address constraints that limit production. Such investment may improve access to markets, reduce transportation difficulties, support better resource use and create conditions that enable private agricultural investment to become more productive. The potential contribution of government capital expenditure depends on the quality and effectiveness of spending. Allocations that do not result in completed, functioning or well-maintained assets may have limited productive benefits. Furthermore, the relationship between expenditure and agricultural output may involve delays because infrastructure projects often require time before their effects become apparent.

The Keynesian perspective is relevant to this study because it provides a theoretical basis for considering government capital expenditure on agriculture as a factor associated with agricultural output. However, the theory does not imply that every increase in public expenditure will increase agricultural output. The empirical relationship depends on the nature of the expenditure, implementation and the wider economic environment.

2.2.5 Cost-Push Explanation of Inflation

The Cost-Push Explanation of Inflation attributes increases in the general price level to rising production costs. Increases in the prices of labour, energy, transportation, fertilisers and other intermediate inputs raise the cost of production, thereby exerting upward pressure on the prices of goods and services. In the agricultural sector, inflation can increase the cost of farm inputs, machinery, transportation and other production requirements, potentially discouraging investment and constraining agricultural output (Rowthorn, 1977).

This perspective is relevant to agricultural production because farmers depend on purchased inputs such as fertilisers, seeds, agrochemicals, fuel and machinery. Increases in these prices may raise production costs and reduce the quantity of inputs that farmers can afford. Where additional financing is unavailable, farmers may reduce production activities or postpone investment.

Inflation may also affect the real value of agricultural credit and government expenditure. A fixed nominal amount of credit may finance fewer inputs when prices rise, while the cost of implementing agricultural infrastructure may increase. These mechanisms suggest that inflation may influence agricultural output directly through production costs and indirectly through the real purchasing power of available financial resources.

However, the cost-push explanation should not be interpreted as implying that inflation must always reduce agricultural output. Changes in agricultural selling prices, production responses and differences among commodities may produce varied outcomes. The direction and strength of the relationship are therefore mattering for empirical investigation.

2.2.6 Theoretical Framework for the Study

The study adopts financial intermediation theory as its principal theoretical foundation, supported by the financial inclusion perspective. The technology acceptance perspective provides additional insight into the adoption and effective use of digital financial services. The Keynesian perspective on public expenditure and the cost-push explanation of inflation provide the theoretical basis for considering the other explanatory variables included in the study.

Financial intermediation theory explains how financial services may facilitate the allocation of funds to productive activities, while the financial inclusion perspective explains why extending access to appropriate financial services may improve economic participation. Applied to agriculture, these perspectives suggest that digital financial inclusion may contribute to agricultural output by facilitating transactions and potentially improving access to financial services that support production.

The technology acceptance perspective qualifies this expectation by recognising that the availability of digital services does not guarantee their effective use. Farmers must be able to access and use services that are suitable for their circumstances. The potential relationship between digital financial inclusion and agricultural output therefore depends partly on the extent to which digital services are adopted and linked to productive activities.

The Keynesian perspective provides a rationale for examining government capital expenditure on agriculture because public investment may improve the infrastructure and productive capacity supporting agricultural activities. The cost-push explanation of inflation provides a basis for considering how rising production costs may influence the resources available to farmers and their production decisions. Taken together, these perspectives suggest that agricultural output may be associated with financial access, the availability of agricultural credit, inflation and public investment. They do not establish in advance that any of these relationships must be positive or statistically significant. Instead, they provide the theoretical justification for investigating the relationships using Nigerian data covering 1999–2023.

2.3 Empirical Review

The empirical literature relevant to this study covers research on financial inclusion, digital financial services, economic activity and the broader conditions affecting productive investment. These areas provide insights into possible mechanisms through which digital financial inclusion may be associated with agricultural output. However, the outcomes examined in international financial inclusion studies must be distinguished from agricultural output, and findings from other countries should not automatically be assumed to apply to Nigeria.

2.3.1 Financial Inclusion and Economic Performance

Demirgüç-Kunt et al. (2022), in *The Global Findex Database 2021: Financial Inclusion, Digital Payments, and Resilience in the Age of COVID-19*, document international patterns in account ownership, digital payments and the use of financial services. The publication provides a broad evidence base for understanding changes in financial access and the role of digital payments in financial inclusion. Its principal relevance to the present study is contextual: it demonstrates the

importance of measuring financial access and digital service usage. It does not, however, directly estimate the impact of a Digital Financial Inclusion Index on agricultural output in Nigeria.

Sahay et al. (2015), in their International Monetary Fund discussion note *Financial Inclusion: Can It Meet Multiple Macroeconomic Goals?* examine the broader macroeconomic significance of financial inclusion. Their work considers financial inclusion in relation to development objectives and financial stability, highlighting the importance of understanding financial access within the wider economic environment. The study is relevant to the present article because agricultural production is one of the productive activities that may be influenced by access to finance. Nevertheless, its broader macroeconomic focus does not constitute a direct empirical test of the relationship between digital financial inclusion and Nigerian agricultural output.

These publications provide a foundation for understanding the broader importance of financial inclusion, but they also highlight the need to identify the particular outcome being investigated. Evidence that financial inclusion is relevant to economic development does not, by itself, establish that a digital financial inclusion index has a statistically significant relationship with agricultural output. The present study addresses this more specific question within the Nigerian context.

2.3.2 Digital Financial Services and Economic Activities

Jack and Suri (2014), in their article, "Risk Sharing and Transactions Costs: Evidence from Kenya's Mobile Money Revolution," published in the *American Economic Review*, investigate the relationship between mobile money and risk sharing in Kenya. Their study examines how mobile money can affect the ability of individuals to manage financial shocks and share resources. The research provides evidence relevant to the economic mechanisms associated with digital financial services, particularly the potential role of reduced transaction costs and improved financial transfers. The relevance of Jack and Suri (2014) to the present study lies in their examination of the economic implications of mobile money. More efficient transactions and improved financial transfers may be important to households and enterprises that face geographical or financial constraints. In agricultural settings, such mechanisms could potentially facilitate payments between farmers, suppliers and produce buyers. However, the outcome examined by Jack and Suri is not national agricultural output, and their findings should not be presented as a direct estimate of the effect of digital financial inclusion on agricultural production in Nigeria.

Suri and Jack (2016), in "The Long-Run Poverty and Gender Impacts of Mobile Money," published in *Science*, examine the longer-term implications of mobile money for poverty and gender-related economic outcomes in Kenya. Their research adds to the evidence that digital financial services can have consequences extending beyond the immediate convenience of electronic payments. The study is relevant to the present article because it demonstrates why the potential effects of digital financial services should be examined in relation to meaningful economic outcomes. Nevertheless, poverty reduction and gender-related welfare outcomes are not equivalent to agricultural output. Differences in institutional arrangements, financial infrastructure, agricultural systems and economic conditions also mean that findings from Kenya cannot automatically be transferred to Nigeria. These studies therefore provide evidence supporting the plausibility of economic mechanisms associated with digital financial services, while leaving the specific relationship between digital financial inclusion and Nigerian agricultural output to be investigated.

2.3.3 Financial Inclusion and Agricultural Development

Financial inclusion may be relevant to agricultural development because farmers often need external financial resources to meet production expenses. Access to appropriate financial services may allow farmers to purchase inputs when required, manage seasonal cash-flow constraints and make investments that would otherwise be difficult to finance from current income.

Agricultural credit is particularly important because the timing of financing can influence the ability to undertake production activities. Farmers who obtain funds before the relevant production period may be better positioned to purchase inputs and carry out planned operations. Conversely, inadequate or delayed credit may constrain production even where farmers have access to markets and potentially productive opportunities.

Digital financial inclusion may complement agricultural financing by facilitating payments, improving access to financial accounts and potentially supporting the delivery of financial products. However, its contribution depends on whether digital services are connected to appropriate financial products and whether farmers can use those products effectively. Digital payment access should not be treated as equivalent to access to agricultural credit.

The conceptual relationship is therefore plausible, but it requires direct empirical investigation. The four foundational publications discussed above—Demirgüç-Kunt et al. (2022), Jack and Suri (2014), Sahay et al. (2015), and Suri and Jack (2016)—provide useful background on financial inclusion and digital financial services, but they do not collectively constitute a comprehensive empirical review of agricultural credit and agricultural output in Nigeria. A publication-ready empirical review should be supplemented with verified studies that directly investigate agricultural financing and agricultural production, including their data, estimation methods and reported findings.

2.3.4 Inflation and Agricultural Output

The relationship between inflation and agricultural output can be considered through the effect of changing prices on production costs, purchasing power and investment decisions. Where the prices of fertilisers, seeds, machinery, energy and transportation increase, farmers may face higher costs of maintaining or expanding production. If their available income and credit do not increase correspondingly, their ability to purchase inputs may decline.

However, the relationship between inflation and agricultural output can vary according to the source of inflation, the response of agricultural output prices and the capacity of producers to adjust. A rise in general prices does not necessarily have the same effect on all agricultural commodities or all producers. Some producers may experience higher output prices, while others may face increased input costs without equivalent increases in revenue.

The cost-push explanation provides a theoretical basis for expecting inflationary pressures to constrain production where input costs rise faster than farmers' financial resources. Nevertheless, a theoretical expectation is not a substitute for empirical evidence. The direction and significance of the relationship between inflation and agricultural output in Nigeria over the study period must be established using the selected data and estimation procedure.

The materials supplied for this article do not contain a sufficiently documented set of Nigerian empirical studies on inflation and agricultural output, including their methods and findings. Specific claims about such studies should therefore be added only after the original publications have been identified and verified.

2.3.5 Government Capital Expenditure and Agricultural Output

Government capital expenditure may influence agricultural output by supporting infrastructure and public assets that improve the conditions under which agricultural production takes place. Investment in irrigation, rural roads, storage facilities, research infrastructure and related productive assets may reduce some of the constraints faced by farmers and other agricultural enterprises. The effectiveness of such expenditure depends on whether public investment is implemented successfully and produces assets that meet agricultural needs. Budgetary allocations alone do not demonstrate that expenditure has resulted in functioning infrastructure or higher output. In addition, the effects of capital investment may emerge over several years rather than immediately within the year of expenditure.

These considerations suggest that the relationship between government capital expenditure on agriculture and agricultural output should be examined with attention to the measurement of public spending and the possible timing of its effects. Actual expenditure, budgeted expenditure and capital expenditure recorded under different government classifications should not be treated as interchangeable measures. The original proposals provide a theoretical rationale for including government capital expenditure on agriculture, but they do not provide a sufficiently documented collection of direct empirical studies from which specific Nigerian findings can be reported. Accordingly, this subsection establishes the relevant empirical question without inventing coefficients, study outcomes or publication details. Verified studies examining agricultural public expenditure and output should be incorporated before the article is submitted for publication.

2.3.6 Synthesis of the Empirical Literature

The literature reviewed provides several insights relevant to the present study. First, research on financial inclusion establishes the importance of examining access to and use of financial services within the wider economic environment. Demirgüç-Kunt et al. (2022) provide an international overview of financial inclusion and digital payments, while Sahay et al. (2015) examine the broader macroeconomic significance of financial inclusion.

Second, studies of mobile money demonstrate that digital financial services can influence economic and household outcomes through mechanisms such as improved financial transfers and risk sharing. Jack and Suri (2014) investigate mobile money and risk sharing, while Suri and Jack (2016) examine longer-term poverty and gender-related outcomes. These studies provide relevant evidence concerning the potential economic importance of digital financial services, although their outcomes differ from national agricultural output.

Third, the conceptual relationships examined in this article suggest that agricultural output may also be associated with access to agricultural credit, inflation and government capital expenditure on agriculture. Credit may support the acquisition of production inputs, inflation may influence production costs and purchasing power, and public capital expenditure may improve infrastructure and productive capacity. The direction and magnitude of these relationships, however, cannot be established solely from theoretical arguments.

A central distinction emerging from the review is that evidence on general financial inclusion or digital payment use does not necessarily establish the effect of digital financial inclusion on agricultural output. Similarly, evidence concerning household welfare or risk sharing cannot automatically be interpreted as evidence of higher national agricultural production. The Nigerian context also requires attention because the relationship between financial access and agricultural output may depend on local financial institutions, infrastructure, production conditions and public investment.

The present study addresses this specific question by examining the relationship between the Digital Financial Inclusion Index and agricultural output in Nigeria over 1999–2023, while accounting for agricultural credit, inflation and government capital expenditure on agriculture. The contribution of the study will depend on the quality and consistency of the data, the precise construction of the index, the measurement of agricultural output and the suitability of the empirical method.

2.4 Research Gap

The literature on financial inclusion and digital financial services provides useful insights into how financial access and digital payment systems may influence economic activity. Existing international studies examine such outcomes as risk sharing, poverty, financial resilience and broader macroeconomic development. These contributions provide a foundation for considering the possible economic relevance of digital financial inclusion, but they do not by themselves resolve whether digital financial inclusion is associated with agricultural output in Nigeria.

The first gap concerns the outcome being investigated. Much of the general financial inclusion literature focuses on account ownership, payment use, household welfare, poverty or broader economic performance. These outcomes are important but differ from agricultural output, which is the specific dependent variable in the present study. Evidence concerning financial access or household welfare cannot automatically be treated as evidence of higher agricultural production.

The second gap concerns the digital dimension of financial inclusion. General financial inclusion measures may capture conventional bank access or the use of formal financial services without adequately distinguishing digital financial access and usage. A study focused on a Digital Financial Inclusion Index therefore needs to define its index carefully and establish what its indicators measure. This distinction is particularly important when interpreting the relationship between the index and agricultural output.

The third gap concerns the Nigerian context. Findings from other countries may provide useful theoretical and empirical insights, but the effects of digital financial services may differ according to financial infrastructure, telecommunications access, agricultural structure and institutional arrangements. Country-specific evidence is consequently important for assessing the relationship within Nigeria.

The fourth gap concerns the consideration of other determinants of agricultural output. Digital financial inclusion is not the only factor that may influence agricultural production. Agricultural credit, inflation and government capital expenditure on agriculture may also be associated with farmers' ability to finance production, the cost of obtaining inputs and the availability of productive infrastructure. Examining these variables within a common empirical framework may help distinguish their conditional relationships with agricultural output.

The fifth gap concerns the period of investigation. The period 1999–2023 provides an opportunity to examine the relationship between digital financial inclusion and agricultural output over an extended period of financial and technological development in Nigeria. The usefulness of this period depends on the availability of consistent annual data and the suitability of the estimation procedure for the number of observations.

In response to these issues, the present study examines the impact of the Digital Financial Inclusion Index on agricultural output in Nigeria over the period 1999–2023, while accounting for agricultural credit, inflation and government capital expenditure on agriculture. It seeks to contribute evidence on whether digital financial inclusion is statistically associated with agricultural output when these additional factors are considered.

This research gap is provisional rather than an assertion that no previous study has examined the subject. A systematic search of recent Nigerian and international empirical literature is necessary to establish the precise extent to which comparable studies already exist. The final statement of contribution should be adjusted to reflect the results of that search and the exact variables, data and estimation methods used in the article.

2.5 Conceptual Framework

The conceptual framework presents the expected relationships between the explanatory variables and agricultural output. It is based on the premise that agricultural production may be associated with access to digital financial services, the availability of agricultural credit, changes in the general price level and public investment in agricultural infrastructure.

The principal explanatory variable is the Digital Financial Inclusion Index. It represents the main focus of the study because the article seeks to examine whether changes in digital financial inclusion are associated with changes in agricultural output in Nigeria.

Agricultural credit is included because financing may support the purchase of inputs and other production activities. Inflation is included because changes in the general price level may affect production costs and the purchasing power of available funds. Government capital expenditure on agriculture is included because public investment may influence the infrastructure and productive conditions supporting agricultural activities.

The conceptual relationships are summarised below.

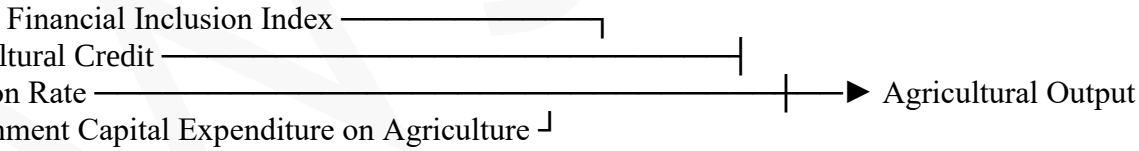
Explanatory variables:

1. Digital Financial Inclusion Index (DFII).
2. Agricultural Credit (AC).
3. Inflation Rate (INF).
4. Government Capital Expenditure on Agriculture (GCEA).

Dependent variable:

Agricultural Output (AGO).

Conceptual representation:



The expected transmission mechanisms are as follows:

- **Digital Financial Inclusion Index:** Potentially improves the accessibility and efficiency of financial transactions and may facilitate the use of appropriate financial services.
- **Agricultural Credit:** May provide funds for acquiring agricultural inputs, meeting working-capital requirements and financing productive investment.
- **Inflation Rate:** May influence input prices, production costs and the real purchasing power of farmers and other agricultural producers.
- **Government Capital Expenditure on Agriculture:** May improve infrastructure and productive capacity through investment in irrigation, rural roads, storage facilities, research infrastructure and other agricultural assets.

The framework allows the relationship associated with each explanatory variable to be examined while considering the other variables included in the study. It does not assume that all relationships

must be positive or statistically significant. Nor does it imply that every proposed transmission mechanism is directly measured in the empirical analysis.

In particular, the framework recognises that digital financial inclusion may be associated with agricultural output through several possible channels, but the study will not establish each intermediate channel unless the relevant variables are separately measured. Similarly, the conceptual framework does not establish causation merely because two variables move together over time.

3. Methodology

3.1 Data Sources and Description

This study examines the relationship between digital financial inclusion and agricultural output in Nigeria over the period 1999–2023, using annual time-series data. The study draws on data from institutional sources, including the Central Bank of Nigeria (CBN), the National Bureau of Statistics (NBS), the World Bank's World Development Indicators (WDI) and Global Findex Database, and Enhancing Financial Innovation & Access (EFInA).

Data on agricultural output, agricultural credit and relevant macroeconomic indicators are obtained from the CBN Statistical Bulletin and NBS publications. Digital financial inclusion indicators, including mobile phone subscriptions, internet access and automated teller machine (ATM) availability, are sourced from the World Bank databases. Information on digital payment infrastructure, including Point-of-Sale (POS) terminals and mobile money access channels, is supplemented with EFInA reports.

The study uses five variables: agricultural output, the Digital Financial Inclusion Index (DFII), agricultural credit, inflation rate and government capital expenditure on agriculture. Agricultural output is the dependent variable, while DFII is the principal explanatory variable. Agricultural credit, inflation and government capital expenditure on agriculture serve as control variables.

The agricultural output, agricultural credit and government expenditure variables are expressed in natural logarithms, as indicated in the model specification. DFII and inflation remain in their original forms. This distinction is important when interpreting the estimated coefficients because coefficients on logarithmic variables have a different interpretation from coefficients on variables measured in levels.

3.2 Variable Specification and Measurement

The variables are defined and operationalised as follows.

Agricultural Output (AGROUT): Agricultural output is measured using real agricultural gross domestic product, expressed in billions of naira. It serves as a proxy for the performance of Nigeria's agricultural sector. The natural logarithm of this variable, lnAGROUT, is used in the empirical model.

Digital Financial Inclusion Index (DFII): DFII is a composite indicator intended to capture the development and use of digital financial services. The proposed index is constructed using Principal Component Analysis (PCA), drawing on indicators representing digital financial access, usage and infrastructure. These include ATM availability, POS and mobile money transaction activity, mobile cellular subscriptions and internet access. The index is the study's principal explanatory variable.

Agricultural Credit (AGRCR): This variable measures the volume of commercial bank credit allocated to the agricultural sector. It represents the availability of formal credit for agricultural production and investment. The variable is expressed in natural logarithms and is included to account for the contribution of conventional bank financing.

Inflation Rate (INF): Inflation is measured by the annual percentage change in the consumer price index. It captures changes in the general price level that may affect agricultural production costs, input affordability and investment decisions.

Government Capital Expenditure on Agriculture (GEXP): This variable measure annual public capital expenditure allocated to agriculture. It represents government investment in agricultural development and is expressed in natural logarithms.

3.3 Model Specification

The functional relationship between agricultural output and the explanatory variables is expressed as:

$AGROUT_t=f(DFII_t,AGRCR_t,INF_t,GEXP_t)$

The corresponding log-linear stochastic model is specified as:

$\ln AGROUT_t=\beta_0+\beta_1 DFII_t+\beta_2 \ln AGRCR_t+\beta_3 INF_t+\beta 4 \ln GEXP_t+\varepsilon_t$

Where:

- $\ln AGROUT_t$ represents the natural logarithm of agricultural output in period tt.
- $DFII_t$ represents the Digital Financial Inclusion Index.
- $\ln AGRCR_t$ represents the natural logarithm of agricultural credit.
- INF_t represents the inflation rate.
- $\ln GEXP_t$ represents the natural logarithm of government capital expenditure on agriculture.
- β_0 is the intercept.
- β_1,β_2,β_3, and β_4 are the coefficients to be estimated.
- ε_t is the stochastic error term.
- t denotes the annual observation from 1999 to 2023.

The a priori expectations are $\beta_1>0$, $\beta_2>0$, $\beta_3<0$ and $\beta_4>0$. These expectations reflect the proposition that digital financial inclusion, agricultural credit and public capital expenditure may support agricultural output, while inflation may constrain production through higher input costs and macroeconomic uncertainty. The actual signs and statistical significance of the estimated coefficients are determined empirically.

3.4 Estimation Technique and Analytical Framework

The empirical analysis employs a sequence of procedures to examine the time-series properties of the variables, test for a long-run relationship and estimate the short-run and long-run relationships between agricultural output and its explanatory variables.

3.4.1 Construction of the Digital Financial Inclusion Index

Principal Component Analysis is proposed for constructing DFII from the selected digital financial indicators. PCA transforms a set of potentially correlated variables into principal components that summarise their shared variation. This approach provides a systematic means of combining several indicators into a composite measure.

The resulting index should be constructed from appropriately prepared indicators, with the scaling, component-retention rule, component loadings and final index calculation documented. The supplied methodology specifies retaining components with eigenvalues greater than one. However, the actual eigenvalues, loadings and PCA output should be reported in the article to demonstrate how the final index was obtained.

3.4.2 Unit Root Testing

The Augmented Dickey-Fuller (ADF) test is used to investigate the stationarity of the variables. The test is important because regressions involving non-stationary series may produce misleading statistical relationships if the series are not appropriately modelled.

The null hypothesis of the ADF test is that a series contains a unit root. The results are evaluated at levels and, where necessary, at first differences. A variable that is non-stationary at level but becomes stationary after first differencing is classified as integrated of order one, I(1). A variable that is stationary at level is classified as I(0).

The Phillips-Perron (PP) test is also identified in the original methodological framework as a possible complementary test. However, the results supplied for Section Four contain ADF statistics only. Accordingly, the empirical discussion below is based on the reported ADF results; PP results should be added if the test was actually conducted.

3.4.3 ARDL Bounds Test for Cointegration

Following the unit root analysis, the study employs the Autoregressive Distributed Lag (ARDL) bounds-testing approach associated with Pesaran, Shin and Smith (2001). The method permits the estimation of a dynamic relationship when the variables are a mixture of I(0) and I(1), provided that none is integrated of order two, I(2).

The general ARDL representation is:

$$Y_t = \alpha_0 + \sum_{i-1}^{p} \alpha 1 Yt - i + \sum_{j-0}^{q1} \beta j X1t - j + \sum_{k=0}^{q2} \gamma_k X2t - k + \sum_{l=0}^{q3} \delta l X3t - l + €t$$

$Where$:

- $(Y_{t)} = Dependent\ variable.$
- $(X_{\{1,t\}}, X_{\{2,t\}}, X_{\{3,t\})} = Explanatory\ variables.$
- $(\alpha_{0)} = Intercept.$
- $(\alpha_{i)} = Coefficients\ of\ lagged\ dependent\ variables.$
- $(\beta_j, \gamma_k, \delta_{l)} = Coefficients\ of\ explanatory\ variables\ and\ their\ lags.$
- $(p) = Lag\ order\ of\ the\ dependent\ variable.$
- $(q_1, q_2, q_{3)} = Lag\ orders\ of\ explanatory\ variables.$
- $(\varepsilon_{t)} = Error\ term.$

$$lnAGROUTt = \alpha_0 + \sum_{i-1}^{p} \alpha 1 lnAGROUTt - i + \sum_{j-0}^{q1} \beta j\ \text{iDFII}\ t - j + \sum_{k=0}^{q2} \gamma_k \ln AGRCRt - kt - k + \sum_{l=0}^{q3} \delta llINFt - l + \sum_{s=0}^{q4} \delta 2InGEXPt - s + €t$$

Here, p and q_1 to q_4 denote the selected lag lengths for the dependent and explanatory variables, respectively.

For the bounds test, the ARDL model is reparameterised as an unrestricted error-correction model containing both first differences and lagged level terms. The null hypothesis is that the coefficients on the lagged level terms are jointly equal to zero, implying no long-run relationship among the variables.

The calculated F-statistic is compared with the relevant lower-bound I(0) and upper-bound I(1) critical values. A statistic above the upper bound provides evidence of cointegration; a statistic below the lower bound does not support cointegration; and a statistic between the bounds yields an inconclusive result. Because this study uses only 25 annual observations, the choice of critical values and the sensitivity of the result to the small sample should be considered carefully.

3.4.4 Error Correction Model

Where a long-run relationship is established, the short-run dynamics can be represented through an error correction model. The general specification is:

$$\Delta Y_t = \alpha_0 + \sum_{t-1\alpha 1}^{p-1} \Delta Yt - 1 + \sum_{t-j}^{q-1} \beta j \Delta X_{1t\text{-}j} + \sum_{t-k}^{q2-1} \lambda_k \Delta X_{2t\text{-}k} + \sum_{t-l}^{q3-1} \delta 1 \Delta X_{3t\text{-}l} + \sum_{t-m}^{q4-1} \mu m \Delta X_{4t\text{-}m} + \lambda ECT_{t-1} + €_t$$

$$\Delta \ln AGROUT_t = \alpha_0 + \sum_{t-1\alpha 1}^{p-1} \Delta \ln AGROUTt - 1 + \sum_{t-j}^{q-1} \beta j \Delta DFII_{1t\text{-}j} + \sum_{t-k}^{q2-1} \lambda_k \Delta \ln AGRCR_{t\text{-}k} + \sum_{t-l}^{q3-1} \delta 1 \Delta INF_{t\text{-}l} + \sum_{t-m}^{q4-1} \mu m \Delta GEXP_{t\text{-}m} + \lambda ECT_{t-1} + €_t$$

Where Δ denotes the first-difference operator, ECT_{t-1} is the lagged error correction term, and λ is the adjustment coefficient.

A negative and statistically significant adjustment coefficient supports convergence towards the estimated long-run equilibrium. Its magnitude indicates the proportion of the previous period's disequilibrium corrected within one period, subject to the model's specification and stability.

3.4.5 Diagnostic and Stability Tests

The study reports diagnostic tests for serial correlation, heteroscedasticity, residual normality and functional form. These include the Breusch-Godfrey serial-correlation LM test, ARCH test, Jarque-Bera normality test and Ramsey RESET test.

The null hypotheses for these tests generally correspond to no serial correlation, no ARCH effects, normally distributed residuals and no evidence of the functional-form misspecification assessed by RESET, respectively. A probability value above the selected significance level indicates that the corresponding null hypothesis is not rejected.

The methodology also identifies CUSUM and CUSUM of Squares (CUSUMSQ) as procedures for assessing parameter stability. Their interpretation should be supported by the actual plots or test output.

4. Empirical Results and Discussion

4.1 Unit Root Test Results

The ADF test was conducted to establish the stationarity properties of the variables before estimating the ARDL model. The results supplied for the study are presented in Table 2.

Table 2: Augmented Dickey-Fuller Unit Root Test Results

Variable	ADF statistic at level	Probability level	ADF statistic at first difference	Probability at first difference	Order of integration
lnAGROUT	-1.142	0.682	-4.891	0.001	I(1)
DFII	-0.854	0.791	-5.114	0.000	I(1)
lnAGRCR	-1.520	0.504	-4.362	0.002	I(1)
INF	-3.741	0.012	Not required	—	I(0)
lnGEXP	-1.229	0.645	-4.015	0.005	I(1)

Source: Study's reported ADF test results.

The results indicate that lnAGROUT, DFII, lnAGRCR and lnGEXP are non-stationary at level but become stationary after first differencing. These variables are therefore classified as I(1). In contrast, INF is stationary at level, with an ADF statistic of -3.741 and a reported probability of 0.012, indicating rejection of the unit-root null at the 5% significance level.

The results consequently show a mixture of I(0) and I(1) variables. This pattern is compatible with the use of the ARDL bounds-testing approach, provided that none of the variables is I(2). The reported ADF results do not indicate an I(2) variable.

The mixed integration orders alone, however, do not establish the existence of a long-run relationship. That question is addressed by the bounds test presented in the next subsection.

4.2 ARDL Bounds Test for Cointegration

The study reports that the lag-selection procedure produced an ARDL(1, 1, 0, 0, 1) specification using the Akaike Information Criterion (AIC). The calculated bounds-test F-statistic is 5.18.

Table 3: ARDL Bounds-Test Results

Significance level	Lower bound I(0)	Upper bound I(1)	Reported decision
10%	2.45	3.52	Reject the null
5%	2.86	4.01	Reject the null
1%	3.74	5.06	Reject the null

Source: Critical values and test statistic reported in the supplied study document.

The F-statistic of 5.18 exceeds the upper-bound critical value of 4.01 at the 5% significance level. It also exceeds the reported 1% upper-bound value of 5.06. On the basis of these critical values, the null hypothesis of no long-run relationship is rejected.

The result provides evidence of a long-run relationship among agricultural output, digital financial inclusion, agricultural credit, inflation and government capital expenditure on agriculture over the study period. It therefore provides a basis for examining the reported long-run coefficients and short-run error-correction results. .

4.3 Long-Run ARDL Estimation Results

Following the bounds-test result, the study estimates the long-run relationship with lnAGROUT as the dependent variable. The coefficient estimates are presented in Table 4.

Table 4: Long-Run ARDL Estimation Results

Variable	Coefficient	Standard error	t-statistic	Probability
DFII	0.245	0.058	4.224	0.000
lnAGRCR	0.112	0.041	2.731	0.014
INF	-0.008	0.003	-2.666	0.016
lnGEXP	0.074	0.032	2.312	0.033
Constant	7.841	0.512	15.314	0.000

Source: Study's reported ARDL estimation results.

4.3.1 Digital Financial Inclusion

The reported coefficient of DFII is positive at 0.245 and statistically significant, with a reported probability of 0.000. This result indicates a positive association between the Digital Financial Inclusion Index and real agricultural output in the estimated long-run relationship, holding the other included variables constant.

The economic interpretation requires care because DFII enters the model in levels, whereas agricultural output is expressed in logarithms. The coefficient is therefore not an elasticity. Subject to the exact index scaling and model specification, a one-unit increase in DFII is associated with an approximate 24.5% increase in agricultural output under the usual semi-logarithmic approximation. This is an approximation, not a direct percentage elasticity; the exact percentage change for a one-unit increase would be 100(e0.245−1)100(e^{0.245}-1), approximately 27.8%.

The substantive result is that the estimated association is positive and statistically significant. A plausible explanation is that digital financial services can reduce the time and cost involved in making payments, receiving funds and accessing certain financial services. These mechanisms may be relevant to farmers who face long distances to formal financial institutions. However, the regression results by themselves do not establish which mechanism accounts for the observed relationship.

4.3.2 Agricultural Credit

Agricultural credit has a positive coefficient of 0.112 and is statistically significant at the 5% level, with a reported probability of 0.014. Since both agricultural output and agricultural credit are expressed in logarithms, the coefficient can be interpreted as a long-run elasticity within the specified model.

The estimate indicates that a 1% increase in agricultural credit is associated with an estimated 0.112% increase in agricultural output, other things being equal. This finding is consistent with the possibility that credit supports farmers' acquisition of inputs, working capital and productive equipment. It also suggests that conventional bank lending remains relevant alongside the expansion of digital financial services.

Although the DFII coefficient is numerically larger than the agricultural-credit coefficient, the two coefficients are measured differently: DFII is in levels, while agricultural credit is in logarithms. Their magnitudes should therefore not be compared directly as evidence that one variable has a greater economic impact than the other.

4.3.3 Inflation Rate

The estimated coefficient of INF is negative at -0.008 and statistically significant at the 5% level, with a reported probability of 0.016. The negative sign is consistent with the possibility that inflation increases the cost of agricultural inputs, transportation and other production requirements, thereby constraining output.

Because inflation enters the model in levels and agricultural output is logged, this coefficient is a semi-elasticity rather than an elasticity. If INF is measured in percentage points, a one-percentage-point increase in the inflation rate is associated with an approximate 0.8% decrease in agricultural output, under the usual semi-logarithmic approximation. The exact interpretation depends on the unit in which INF was entered into the estimation.

This result highlights the importance of macroeconomic conditions in assessing agricultural performance. Even where access to finance improves, high and unstable input prices may limit the productive benefits that farmers can obtain from additional funds.

4.3.4 Government Capital Expenditure on Agriculture

Government capital expenditure has a positive coefficient of 0.074 and is statistically significant at the 5% level, with a reported probability of 0.033. As both lnGEXP and lnAGROUT are in logarithms, the coefficient represents an estimated long-run elasticity.

The result indicates that a 1% increase in government capital expenditure on agriculture is associated with an estimated 0.074% increase in agricultural output, holding the other variables constant. Public investment may support agricultural activity through infrastructure, irrigation, storage facilities, extension services and other capital projects. The extent to which these channels explain the result depends on the composition and implementation of expenditure, which the estimated coefficient does not separately identify.

Overall, the long-run results show positive and statistically significant coefficients for DFII, agricultural credit and government capital expenditure, while inflation has a negative and statistically significant coefficient. These findings are consistent with the study's principal argument that digital financial inclusion is associated with agricultural performance, while credit conditions, public investment and macroeconomic stability also matter.

4.4 Short-Run Dynamics and Error Correction Results

The short-run ARDL results are reported in Table 5. The dependent variable is the first difference of lnAGROUT, representing the change in the logarithm of agricultural output.

Table 5: Short-Run Dynamic and Error Correction Coefficients

Variable	Coefficient	Standard error	t-statistic	Probability
ΔDFII	0.095	0.028	3.392	0.003
ΔDFIIt−1_{t-1}	0.061	0.024	2.541	0.021
ΔlnAGRCR	0.042	0.018	2.333	0.031
ΔINF	-0.003	0.001	-3.000	0.007
ΔlnGEXP	0.029	0.014	2.071	0.052
ECTt−1_{t-1}	-0.382	0.072	-5.305	0.000

Source: Study's reported short-run ARDL and error-correction results.

4.4.1 Short-Run Effect of Digital Financial Inclusion

The coefficient on the current change in DFII is positive at 0.095 and statistically significant, with a probability of 0.003. The coefficient on lagged ΔDFII is also positive at 0.061 and statistically significant, with a probability of 0.021.

These estimates indicate that changes in the digital financial inclusion index are positively associated with changes in agricultural output in both the current and preceding-period terms included in the model. The positive lagged coefficient suggests that the association is not limited to the contemporaneous period. Since DFII is not logged, these coefficients should not automatically be described as 9.5% and 6.1% output increases. Their interpretation depends on the units and scaling of the index. The estimates instead show that the reported coefficients on current and lagged changes in DFII are positive and statistically significant.

4.4.2 Short-Run Effect of Agricultural Credit

The coefficient on ΔlnAGRCR is 0.042 and statistically significant at the 5% level, with a probability of 0.031. This indicates a positive short-run relationship between changes in agricultural credit and changes in agricultural output.

Because both variables are expressed in logarithmic form, the coefficient is interpretable as a short-run elasticity under the estimated specification. The result suggests that increases in agricultural credit are associated with increases in agricultural output in the short run, although the magnitude is smaller than the reported long-run coefficient.

4.4.3 Short-Run Effect of Inflation

The coefficient on ΔINF is -0.003 and statistically significant, with a reported probability of 0.007. This indicates a negative short-run relationship between changes in inflation and changes in agricultural output.

The finding is consistent with the possibility that increases in the inflation rate put pressure on production costs and reduce the purchasing power of farmers' available funds. As with the long-run estimate, the precise percentage interpretation depends on the units used to measure inflation.

4.4.4 Short-Run Effect of Government Capital Expenditure

The coefficient on ΔlnGEXP is positive at 0.029, with a reported probability of 0.052. The positive sign is consistent with a potentially supportive relationship between changes in government capital expenditure and agricultural output.

However, the probability of 0.052 is marginally above the conventional 5% significance threshold. It is therefore not statistically significant at 5%, although it is significant at the 10% level if that level is adopted. The result should not be described as significant at 5%.

4.4.5 Error Correction Term and Speed of Adjustment

The estimated error correction coefficient is -0.382, with a reported probability of 0.000. The coefficient is negative and statistically significant, meeting the usual sign and significance conditions for an error-correction mechanism. Its magnitude indicates that approximately 38.2% of the previous period's deviation from the estimated long-run equilibrium is corrected within one period, under the model's specification. This suggests that deviations are partly corrected over time rather than persisting unchanged. The adjustment coefficient provides evidence of convergence towards the estimated equilibrium. It does not mean that the system returns completely to equilibrium within 2.6 years in every circumstance; the adjustment path depends on the dynamic specification and the nature of subsequent shocks. Taken together, the short-run results show positive and statistically significant coefficients for current and lagged changes in DFII and for changes in agricultural credit. Changes in inflation have a negative and statistically significant coefficient. The government expenditure coefficient is positive but only marginally significant at the 10% level. The significant, negative error correction coefficient is consistent with adjustment towards the estimated long-run relationship.

4.5 Post-Estimation Diagnostic and Stability Tests

Diagnostic tests were reported to assess whether the estimated model satisfies selected statistical conditions. The results are summarised in Table 6.

Table 6: Econometric Diagnostic Test Results

Diagnostic objective	Test	Reported statistic	Probability	Interpretation at 5%
Serial correlation	Breusch-Godfrey LM test	1.124	0.341	Fail to reject the null of no serial correlation
Heteroscedasticity	ARCH test	0.781	0.472	Fail to reject the null of no ARCH effects
Residual normality	Jarque-Bera test	1.450	0.484	Fail to reject the null of normality
Functional form	Ramsey RESET test	1.892	0.185	Fail to reject the null of no detected functional-form problem

Source: Study's reported diagnostic test results.

The Breusch-Godfrey test has a probability of 0.341, which exceeds 0.05. The null hypothesis of no serial correlation is therefore not rejected. This result provides no statistical evidence of serial correlation under the reported test specification.

The ARCH test has a probability of 0.472. The null hypothesis of no ARCH effects is not rejected at the 5% level. Thus, the test does not provide evidence of the conditional heteroscedasticity it is designed to detect. This should not be interpreted as proof that every form of heteroscedasticity is absent. The Jarque-Bera test has a probability of 0.484. The null hypothesis of normally distributed residuals is not rejected at the 5% level. The result is consistent with residual normality under the test, although failure to reject the null is not definitive proof of a normal distribution.

The Ramsey RESET test has a probability of 0.185. The null hypothesis is not rejected at the 5% level, indicating that the test does not detect a statistically significant functional-form problem.

Overall, the reported diagnostic results do not identify statistically significant problems in the four areas assessed. This supports the adequacy of the estimated model in these respects, subject to the accuracy of the reported statistics and the limitations of a relatively small annual sample.

4.5.1 Parameter Stability

The study reports that CUSUM and CUSUMSQ plots were examined and that the plotted lines remained within the 5% critical boundaries over the study period. If confirmed by the original plots, this would indicate that the tests did not detect parameter instability at the stated significance level. For publication, the CUSUM and CUSUMSQ figures should be included or otherwise made available to support this statement. The supplied text describes the outcome but does not include the plots themselves. It is therefore preferable to report this as the study's stated result rather than treat it as independently verified.

4.6 Discussion of Findings

The empirical results point to a positive and statistically significant association between digital financial inclusion and agricultural output in Nigeria over the period examined. The reported long-run DFII coefficient is positive, and the coefficients on both current and lagged changes in DFII are positive and statistically significant in the short-run model.

One possible explanation is that digital financial services can make financial transactions more accessible and convenient. For agricultural households and businesses, access to digital payment

channels may reduce the time and cost associated with receiving funds, paying suppliers and conducting transactions. Where digital services are reliable and accessible, they may complement conventional banking and support agricultural commercial activity. These are plausible channels through which digital financial inclusion may relate to agricultural output; they are not separately tested by the present model. The positive coefficient on agricultural credit also indicates that conventional financial intermediation remains relevant to agricultural performance. Digital financial inclusion should therefore not be viewed as a substitute for agricultural lending. Rather, digital channels and conventional credit may serve complementary roles: digital services can facilitate access and transactions, while credit can provide funds for production and investment.

Inflation has a negative and statistically significant coefficient in both the reported long-run and short-run results. This suggests that the benefits associated with improved financial access may be constrained when rising prices increase the cost of seeds, fertiliser, equipment, transport and other production requirements. Macroeconomic stability is consequently relevant to policies intended to improve agricultural productivity. Government capital expenditure has a positive and statistically significant long-run coefficient. Its short-run coefficient is also positive, although its reported probability of 0.052 places it just above the conventional 5% threshold. The distinction between the long-run and short-run results matters: the evidence for a positive long-run association is stronger under the reported estimates than the evidence for an immediate short-run effect.

Finally, the negative and statistically significant error correction coefficient is consistent with a process through which short-run deviations from the estimated long-run relationship are corrected over time. The diagnostic results reported in the study do not reveal significant problems in the areas tested. Nevertheless, the sample size, index construction, model specification and need to verify the critical values should be considered when interpreting the results.

The findings support the view that digital financial inclusion is a potentially important element of agricultural development policy. However, the time-series estimates establish statistical relationships within the specified model; they do not, by themselves, prove that changes in digital financial inclusion cause changes in agricultural output.

5. Conclusion and Policy Recommendations

5.1 Conclusion

This study examined the relationship between digital financial inclusion and agricultural output in Nigeria over the period 1999–2023. Agricultural output was modelled as a function of the Digital Financial Inclusion Index, agricultural credit, inflation and government capital expenditure on agriculture. The empirical analysis employed ADF unit root testing and the ARDL bounds-testing framework, followed by estimation of long-run coefficients, short-run dynamics and diagnostic tests. The reported ADF results classified agricultural output, DFII, agricultural credit and government capital expenditure as I(1), while inflation was classified as I(0). This mixture of integration orders was compatible with the use of the ARDL framework, subject to the requirement that no variable be I(2). The reported bounds-test statistic of 5.18 exceeded the stated upper-bound critical value at the 5% level, providing evidence of a long-run relationship among the variables under the reported test specification.

The long-run estimates showed a positive and statistically significant coefficient for DFII. Agricultural credit and government capital expenditure also had positive and statistically significant coefficients, while inflation had a negative and statistically significant coefficient. These findings suggest that digital financial inclusion, conventional agricultural lending, public

capital expenditure and macroeconomic conditions are relevant to the statistical explanation of agricultural output over the study period.

The short-run results similarly showed positive and statistically significant coefficients for current and lagged changes in DFII and for changes in agricultural credit. Changes in inflation had a negative and statistically significant coefficient. Government capital expenditure had a positive short-run coefficient, although the reported probability of 0.052 was marginally above the 5% threshold. The error correction coefficient was negative and statistically significant, indicating adjustment towards the estimated long-run relationship.

The diagnostic results reported in the study did not identify significant serial correlation, ARCH effects, non-normality or functional-form problems at the 5% level. The study also reports that the CUSUM and CUSUMSQ tests indicated parameter stability, a claim that should be supported in the final article by the corresponding plots.

On balance, the findings suggest that digital financial inclusion is positively associated with agricultural output in Nigeria, alongside the contributions associated with agricultural credit and government capital expenditure. Inflation, by contrast, is negatively associated with agricultural output in the reported estimates. These results support policy attention to the accessibility and reliability of digital financial services, the availability of agricultural finance, effective public investment and a stable macroeconomic environment.

The findings should be interpreted in light of the study's limitations. The analysis covers 25 annual observations, DFII is a constructed index whose scaling and component weights should be documented, and the reported regression relationships do not independently establish causation. The results are therefore best understood as evidence of estimated relationships within the specified model rather than definitive proof that any single factor causes changes in agricultural output.

5.2 Policy Recommendations

Based on the reported empirical findings, the following policy recommendations are proposed.

1. Expand Digital Financial Services in Rural and Agricultural Communities

The Central Bank of Nigeria, in collaboration with relevant financial-service providers, should encourage the expansion of accessible and reliable digital financial services in rural communities and major agricultural production areas. Policy attention should be given to the availability of agent banking, mobile payment services and other appropriate digital channels in locations where physical banking facilities are limited. Expansion programmes should be guided by evidence of local demand, service reliability, transaction costs and the needs of smallholder farmers. Appropriate consumer protection, transparent charges and effective complaint-resolution mechanisms should accompany expansion so that greater digital access translates into usable financial services.

2. Improve Rural Telecommunications and Digital Infrastructure

The federal government, the Nigerian Communications Commission and telecommunications providers should work towards improving the availability, reliability and affordability of telecommunications services in agricultural communities. Reliable connectivity can help farmers and agricultural businesses use digital payment and financial services more effectively.

Infrastructure initiatives should take account of differences in rural coverage, network quality, electricity availability and affordability. Implementation should be monitored using measurable

indicators, such as coverage, service reliability, usage and transaction costs, rather than relying only on the number of infrastructure installations.

3. Integrate Digital Financial Services into Agricultural Support Programmes

The Federal Ministry of Agriculture and Food Security and relevant state agencies should consider using suitable digital payment channels in the administration of agricultural support programmes. Where appropriate, digital systems could facilitate the delivery of agricultural assistance, payments and input-support benefits to verified beneficiaries.

Such arrangements should be supported by transparent beneficiary selection, accessible enrolment procedures, data protection, effective grievance mechanisms and alternatives for farmers who cannot readily use digital services. Digital delivery should improve the transparency and accessibility of support rather than create new barriers for underserved farmers.

4. Strengthen Access to Agricultural Credit

The positive and statistically significant agricultural-credit coefficients suggest that conventional financing remains relevant to agricultural output. Commercial banks, development finance institutions and relevant government agencies should therefore continue efforts to improve the availability and suitability of credit for agricultural producers.

Possible measures include credit facilities tailored to agricultural production cycles, improved access to risk-sharing arrangements, appropriate loan maturities and better financial information for assessing borrowers. Digital transaction records may be considered as one supplementary source of information in credit assessment, subject to borrowers' consent, data protection and appropriate safeguards. Credit programmes should be monitored not only by the amount disbursed but also by access among different categories of farmers, repayment performance, the cost of borrowing and the productive use of funds.

5. Improve the Effectiveness of Government Capital Expenditure on Agriculture

The positive long-run coefficient on government capital expenditure supports attention to public investment in agriculture. The federal and state governments should prioritise well-designed projects that address demonstrable constraints on agricultural production and market access.

Relevant areas may include rural roads, irrigation, storage, processing facilities, extension services and other productive infrastructure. Project selection should be guided by needs assessments, feasibility studies and clear implementation plans. Transparent procurement, monitoring and evaluation are also necessary to ensure that approved expenditure results in functioning assets and services. Given that the short-run coefficient is only marginally significant at the 10% level, policymakers should avoid assuming that increases in expenditure automatically produce immediate output gains. The quality, timing and implementation of public investment remain important considerations.

6. Strengthen Macroeconomic Stability and Agricultural Input Affordability

7. Monitor Digital Financial Inclusion Outcomes in Agriculture

The relevant government agencies, financial regulators and research institutions should strengthen the collection and publication of data on digital financial access and use among agricultural households and businesses. Monitoring should distinguish between the availability of digital infrastructure and actual use of financial services.

Useful indicators could include rural access to digital payment channels, transaction frequency, service reliability, cost of transactions and the extent to which farmers use digital financial services to receive payments or conduct agricultural business. Better data would support more targeted policies and allow future research to examine the pathways linking digital financial inclusion with agricultural performance.

5.3 Contribution of the Study and Suggestions for Further Research

The study contributes to the discussion of financial inclusion and agricultural development by examining digital financial inclusion alongside agricultural credit, inflation and government capital expenditure within a single time-series framework. Its use of a composite digital index is intended to capture more than one dimension of digital financial access and infrastructure.

Future research could extend the analysis by testing alternative constructions of DFII, examining the robustness of the estimates to different lag structures and appropriate finite-sample critical values, and considering additional measures of agricultural performance where reliable data are available. Research using disaggregated data could also investigate whether the relationship differs across regions, categories of farmers or agricultural subsectors.

Further work may examine the specific channels through which digital financial inclusion is associated with agricultural performance, including payment efficiency, access to credit, market participation and the delivery of agricultural support. Such analysis would help distinguish the association documented in the present study from the causal mechanisms that may underlie it.

In conclusion, the results indicate that digital financial inclusion is positively associated with agricultural output in Nigeria over the period examined. Together with the estimated relationships involving agricultural credit, inflation and government capital expenditure, the findings provide a basis for policies that improve the accessibility of digital financial services while strengthening agricultural finance, public investment and the broader conditions necessary for productive agricultural activity.

References

Aminu, U & Eshiozemhe, M.I (2022) – "Financial Inclusion and Agricultural Output Nexus in Nigeria: An Asymmetric Approach" Applied *Journal of Economics, Management and Social Sciences*, 3(4):1-12

Banerjee, A., Dolado, J., & Mestre, R. (1998). Error-correction mechanism tests for cointegration in a single-equation framework. *Journal of Time Series Analysis, 19*(3), 267–283.

Beck, T., Demirgüç-Kunt, A., & Peria, M. S. M. (2007). Reaching out: Access to and use of banking services across countries. *Journal of Financial Economics, 85*(1), 234–266.

Central Bank of Nigeria. (2012). *National financial inclusion strategy*.

Central Bank of Nigeria. (2019). *National financial inclusion strategy: Revised*.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly, 13*(3), 319–340.

Demirgüç-Kunt, A., & Klapper, L. (2013). Measuring financial inclusion: Explaining variation in use of financial services across and within countries. *Brookings Papers on Economic Activity, 2013*(1), 279–340.

Diamond, D. W. (1984). Financial intermediation and delegated monitoring. *The Review of Economic Studies*, 51(3), 393-414.

EFInA – *Access to Financial Services in Nigeria* survey reports (2018, 2020, 2023), providing benchmark statistics on financial exclusion rates among farmers.

Fawowe, B (2020) – "The effects of financial inclusion on agricultural productivity in Nigeria" Journal of Economics and Development, 22(1):61-79

Goldsmith, R. W. (1969). *Financial structure and development*. Yale University Press.

Gordon, R. J. (1981). Output fluctuations and gradual price adjustment. *Journal of Economic Literature, 19*(2), 493–530.

Gurley, J. G., & Shaw, E. S. (1955). Financial aspects of economic development. *The American Economic Review*, *45*(4), 515–538.

Gurley, J. G., & Shaw, E. S. (1960). *Money in a theory of finance*. Brookings Institution.

Hayami, Y., & Ruttan, V. W. (1971)**.** *Agricultural Development: An International Perspective.* Baltimore: Johns Hopkins Press.

Jahan, S., Mahmud, A. S., & Papageorgiou, C. (2014). What is Keynesian economics? *Finance & Development, 51*(3).

Keynes, J. M. (1936). *The general theory of employment, interest and money*. Macmillan.

Khera, P., Ng, S. Y., Ogawa, S., & Sahay, R. (2021). *Measuring digital financial inclusion in emerging market and developing economies: A new index*. International Monetary Fund.

Levine, R. (1997). Financial development and economic growth: Views and agenda. *Journal of Economic Literature, 35*(2), 688–726.

McKinnon, R. I. (1973). *Money and capital in economic development*. Brookings Institution.

Nkechika, C. G. (2022). Digital financial services and financial inclusion in Nigeria: Milestones and new directions. *CBN Economic and Financial Review*, *60*(4), 151–170.

Olaniyi, E (2017) – Back to the Land: The impact of financial inclusion on Agriculture in Nigeria””Iranian Economic Review (IER) Faculty of Economics, University of Trehran, Tehran, Iran, Vol. 21(4), pages 885-903, Autumn

Omeje, A.N, Nwodo, I.P & Rena, R (2025) – "Financial Inclusion and Agriculture: How Has Digital Finance Influenced Payments for Agricultural Goods in Nigeria?" Springer Books , in: Firdous Ahmad Malik & Samriti Mhajan & Devendra Kumar Yaday & Naveed Ahmad

Lone & Shahid Amin (ed.) *Financial Resilience and Environmental Sustainability*,page 499-519 Springer

Otitoju, M. A., Adelere, O. E., Akinbola, A. O., & Abah, E. G. (2023). Implications of Digital Financial Inclusion for Smallholder Farmers in Nigeria: A Review. *International Journal of Social Science and Humanities Research*, 11(3), 152-157.

Pesaran, M. H., & Shin, Y. (1999). An autoregressive distributed lag modelling approach to cointegration analysis. In S. Strom (Ed.), *Econometrics and economic theory in the 20th century: The Ragnar Frisch Centennial Symposium* (pp. 371–413). Cambridge University Press.

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics, 16*(3), 289–326.

Rowthorn, R. E. (1977). Conflict, inflation and money. *Cambridge Journal of Economics, 1*(3), 215–239.

Sarma, M. (2008). *Index of financial inclusion* (Working Paper No. 215). Indian Council for Research on International Economic Relations.

Shaw, E. S. (1973). *Financial deepening in economic development*. Oxford University Press.

Taylor, L. (1983). *Structuralist macroeconomics: Applicable models for the third world*. Basic Books.

Venkatesh, V., & Davis, F. D. (2000). A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management Science, 46*(2), 186–204.

World Bank. (2014). *Global financial development report 2014: Financial inclusion*. World Bank.