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Beyond Access: Digital Payment Activity, Productive Investment and Economic Growth in Nigeria

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Abstract

This study examines whether digital financial activity is linked to productive investment and economic growth in Nigeria. It uses quarterly data from 2010Q1 to 2024Q4 and applies the Autoregressive Distributed Lag (ARDL) method to assess short-run and long-run relationships. POS transaction volume is used as the main measure of digital financial activity, while gross fixed capital formation represents investment and real GDP measures economic output. The results show that POS transactions have a positive and significant long-run relationship with productive investment and real GDP. Investment is also positively associated with economic output. However, tests using other payment channels produce mixed results. Mobile payments show a positive and significant relationship with investment, while internet, ATM and cheque transactions provide weaker evidence. These findings suggest that digital payments may support investment and economic growth, but their contribution varies across payment channels. The study recommends improving digital payment services, expanding access to business finance and creating a more supportive environment for productive investment. Overall, digital finance has the potential to support Nigeria's economic development, but increased payment activity alone may not be enough to achieve this.

Keywords: *Digital financial activity; productive investment; economic growth; digital payments; ARDL*

1. INTRODUCTION

Digital financial services have changed how individuals and businesses make payments and manage financial transactions. Mobile banking, electronic transfers and point-of-sale (POS) payments can reduce transaction costs and facilitate the movement of funds (World Bank, 2025; Mohd Daud et al., 2024). However, growth in digital payment activity does not necessarily translate into higher productive investment or economic growth. The economic benefits may depend on whether businesses and other economic agents use these services to support productive activities rather than solely to facilitate routine transactions (Mare & Farazi, 2026).

In Nigeria, the expansion of electronic payment systems has transformed everyday financial transactions. The Central Bank of Nigeria has supported digital payments as part of broader efforts to modernise the financial system and reduce reliance on cash (Central Bank of Nigeria, 2023).

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Despite this progress, an important question remains whether increased digital payment activity is associated with greater productive investment and stronger economic performance. Productive investment, particularly in machinery, equipment and infrastructure, can expand an economy's productive capacity. Although financial development can support economic growth, the extent of its contribution may depend on how effectively financial resources are channelled into productive activities (Levine, 2005; Girma & Huseynov, 2025; Gizaw et al., 2024). Digital payments may facilitate business transactions and financial management, but their expansion does not necessarily mean that firms will increase investment or production.

The relationship between digital payment activity, investment and economic output may also be influenced by broader macroeconomic conditions. Inflation can affect production costs, purchasing power and investment decisions, while private-sector credit may provide businesses with funding for expansion. Trade openness can create opportunities to access larger markets and imported inputs, although its effects may vary depending on domestic economic conditions. This study therefore accounts for inflation, private-sector credit and trade openness when examining the relationships of interest.

Against this background, the study uses quarterly Nigerian data covering 2010Q1 to 2024Q4 to examine the relationships between digital payment activity, productive investment and economic output. POS transaction volume serves as the principal proxy for digital payment activity, real gross fixed capital formation (GFCF) represents productive investment, and real gross domestic product (GDP) measures economic output. Inflation, private-sector credit and trade openness are included as control variables. The autoregressive distributed lag (ARDL) approach is employed to investigate short-run and long-run relationships, subject to the relevant requirements concerning the integration orders of the variables.

The study has two objectives. First, it examines the relationship between digital payment activity and productive investment in Nigeria. Second, it investigates the relationships between digital payment activity, productive investment and economic output. By examining investment and output in separate empirical models, the study considers whether digital payment activity is

associated with productive investment and whether both variables are related to economic performance.

The study contributes to discussions on digital finance and economic development by looking beyond the expansion of electronic payments to examine their relationship with productive investment and economic output in Nigeria. While existing literature on financial inclusion and financial development provides a useful foundation for understanding the potential economic benefits of financial services, this study focuses more specifically on digital payment activity and its relationship with investment and output. Its contribution lies in examining these relationships within a quarterly time-series framework over the period 2010Q1–2024Q4. The findings may inform policy discussions on how digital payment systems can better support productive economic activity. Nevertheless, POS transaction volume captures only one aspect of digital payment activity and does not provide a comprehensive measure of digital financial services or financial inclusion. The findings are therefore interpreted in accordance with the scope and limitations of the variables and models employed.

The remainder of the paper is organised as follows. Section 2 reviews the relevant theoretical and empirical literature. Section 3 presents the methodology, model specifications and data sources. Section 4 reports and discusses the empirical findings, including the robustness tests. Section 5 concludes the paper and presents policy recommendations.

1.1 Theoretical and Empirical Literature

1.1.1 Theoretical Literature

This study draws on financial intermediation theory, the finance–growth nexus and endogenous growth theory to explain how digital payments may relate to productive investment and economic growth in Nigeria.

1.1.1.1 Financial Intermediation Theory

Financial intermediation theory explains how financial systems channel funds towards investment and other productive activities. By reducing transaction costs and improving resource allocation, effective financial systems can support investment and economic growth (Levine, 2005). Digital

payments may make transactions easier and improve business cash-flow management. However, increased payment activity does not automatically lead to higher investment, as businesses also need finance and profitable investment opportunities.

This theory supports examining the relationship between POS transactions and gross fixed capital formation (GFCF) in Nigeria.

1.1.1.2 Finance-Growth Nexus

The finance–growth literature examines how financial development relates to economic performance. Financial systems can promote growth by improving resource allocation and easing financing constraints (Levine, 2005). Digital payments may support this process by making money transfers and business transactions easier. However, increased payment activity does not necessarily translate into greater financial inclusion or higher output. Its benefits depend partly on how effectively these services support productive activities.

This perspective guides the analysis of POS transactions and real GDP, while accounting for inflation, private-sector credit and trade openness.

1.1.1.3 Investment-Led Growth and Endogenous Growth Theory

Investment-led and endogenous growth theories emphasise capital accumulation, technological progress and productivity as drivers of economic growth (Barro, 1990; Romer, 1990). Investment in buildings, machinery and equipment can expand productive capacity. This study uses GFCF to measure productive investment. Digital payments may indirectly support investment by improving transaction efficiency and business financial management. However, higher payment activity alone does not guarantee increased investment.

These theories guide the examination of digital payment activity, productive investment and real GDP. Although the results may suggest links among these variables, separate ARDL models cannot establish that investment causally transmits the effect of digital payments to economic growth. The findings are therefore interpreted as statistical relationships rather than proof of causation.

1.1.2 Empirical Literature

Previous research has examined the relationship between financial development and economic growth, with many studies highlighting the role of financial systems in supporting investment and economic activity. However, findings differ across countries and depend on the variables, periods and methods used.

Levine (2005), in a review of the finance–growth literature, identifies improved resource allocation and reduced financing constraints as important ways in which financial development can support economic growth. The review also highlights the challenges involved in measuring financial development and establishing the direction of the relationship. These issues are relevant to the present study because digital payment volumes capture activity through particular payment channels rather than the full range of financial services available to individuals and businesses.

Mohd Daud, Ahmad and Trinugroho (2024) examine the relationship between financial inclusion, digital technology and economic growth using panel data for 84 countries from 2011 to 2017. Their findings suggest that digital technology can complement the relationship between financial inclusion and economic growth. Although this provides useful evidence on the wider role of digital finance, the results may not fully reflect the economic and institutional conditions in Nigeria.

Research focusing on Nigeria has also explored the relationship between electronic payments and economic performance. Adeniji (2025) examines POS, ATM, web and mobile payments over the period 2012–2024 using an autoregressive distributed lag (ARDL) approach. According to the findings reported in that study, digital payment systems are positively related to economic growth, with mobile payments showing the strongest relationship. However, evidence of a relationship with output does not necessarily explain whether digital payment activity is also associated with increased productive investment.

Similarly, Oyadeyi (2025) investigates financial inclusion, electronic payments and economic growth using quarterly Nigerian data from 2009Q1 to 2021Q4. The study uses principal component analysis, ARDL and Granger-causality tests and reports significant relationships between several payment channels and economic growth, particularly POS transactions.

Differences in the results across payment channels suggest that individual forms of payment activity may have different relationships with economic performance and should therefore be examined carefully.

Taken together, these studies provide a useful foundation for understanding the relationship between digital payments and economic growth. However, further investigation is needed into how digital payment activity relates to productive investment and how both are associated with economic output in Nigeria. This study addresses this issue by examining the relationship between POS transaction volume and GFCF in one model, followed by an examination of the relationships between POS transaction volume, GFCF and real GDP in a second model.

Macroeconomic conditions also need to be considered when examining these relationships. Inflation can increase business costs and affect investment decisions, while private-sector credit can help businesses finance expansion. Trade openness may provide access to wider markets and imported capital goods, although its effects depend on prevailing economic conditions. Including these variables helps account for some of the wider factors that may influence investment and output. Nevertheless, the results are interpreted as statistical relationships rather than conclusive evidence that digital payment activity causes changes in investment or economic growth.

1.2 Research Gap and Contribution

Previous studies have examined electronic payments and economic growth in Nigeria. However, further research is needed to understand how digital payment activity relates to productive investment as well as economic output. This study examines these relationships using quarterly Nigerian data from 2010Q1 to 2024Q4. POS transaction volume measures digital payment activity, while real gross fixed capital formation (GFCF) represents productive investment and real GDP measures economic output. The ARDL approach is used to examine short-run and long-run relationships.

The study also considers internet, mobile and ATM transactions to see whether the findings differ across payment channels. Overall, it adds to existing research by examining payment activity, investment and economic output within the same research framework. The results show statistical

relationships, rather than proving that digital payments directly cause investment or economic growth.

2. METHODOLOGY

2.1 Research Design

This study adopted a quantitative time-series research design to examine whether digital payment activity contributes to economic growth in Nigeria through productive investment. Quarterly macroeconomic data were used to analyse the relationship between digital payment activity, productive investment, economic output and selected macroeconomic factors in both the short run and the long run.

The time-series approach was appropriate because the study focused on changes in digital payment activity and economic performance in Nigeria over time. It provided a basis for examining how developments in digital financial services were related to investment and economic growth. The study employed the Autoregressive Distributed Lag (ARDL) technique after considering the results of the preliminary unit root tests and confirming that none of the variables was integrated of order two, I (2). The suitability of the model was further assessed using relevant diagnostic tests.

Two main equations were estimated. The first examined the relationship between digital payment activity and productive investment, while the second investigated the relationship between digital payment activity, productive investment and economic output. The results from these equations provided a basis for assessing whether productive investment served as a possible channel through which digital payment activity was associated with economic growth in Nigeria.

2.2 Data Sources and Sample Period

The study used quarterly data for Nigeria covering the period from 2010Q1 to 2024Q4. This period provided a maximum of 60 quarterly observations, although the actual number used for estimation was lower where necessary due to missing data, lagged variables and other model requirements.

The data were obtained mainly from the Central Bank of Nigeria (CBN) and the National Bureau of Statistics (NBS). CBN statistical publications and payment-system reports provided data on

digital payment activities, credit to the private sector and other relevant macroeconomic indicators. The NBS national accounts provided information on real gross domestic product and gross fixed capital formation, which were used to measure economic performance and productive investment, respectively. Where necessary, data from the World Bank were also used to cross-check selected macroeconomic indicators, provided that their definitions and reporting periods were consistent with those of the Nigerian sources.

To ensure transparency and consistency, the source, measurement unit, frequency and transformation of each variable used in the analysis were documented. Where monthly data were converted to quarterly figures, the method of aggregation was also specified. These procedures helped ensure that the data were suitable for the econometric analysis and that the results could be appropriately interpreted.

2.3 Variable Definition and Measurement

The study used real GDP to measure economic output and gross fixed capital formation (GFCF) as a proxy for productive investment. POS transaction volume represented digital payment activity, while inflation, private-sector credit and trade openness served as control variables.

Table 2.1: Definition, Measurement and Expected Relationships of the Study Variables

Variable	Measurement	Expected effect
Economic output (LRGDP)	Log of real GDP at 2010 prices	Dependent variable
Digital payment activity (LPOS)	Log of quarterly POS transaction volume	Positive
Productive investment (LGFCF)	Log of real GFCF at 2010 prices	Positive
Inflation (INF)	Quarterly average of monthly year-on-year inflation (%)	Potentially negative
Private-sector credit (PSC)	Private-sector credit as a percentage of GDP	Potentially positive
Trade openness (OPEN)	Exports plus imports as a percentage of GDP	Potentially positive

Natural logarithms were applied to positive level variables to reduce scale differences and aid interpretation. Inflation, private-sector credit and trade openness remained in percentage terms.

POS transaction volume captured one aspect of digital payment activity, not its full scope. Therefore, the findings were interpreted in relation to this proxy, with alternative digital payment indicators considered for robustness testing where consistent data were available. GFCF measured investment in fixed assets but did not identify which investments directly increased productive capacity. LRGDP represented the level of real GDP rather than the GDP growth rate. Thus, the estimates described relationships with real economic output. Direct analysis of growth rates would require an additional measure, calculated as 100 multiplied by the first difference of log real GDP.

The exchange-rate variable (LEXCR) was excluded from the baseline model because the consistency of its definitions across the study period had not been established. It could be included in supplementary analysis if a comparable series was verified.

2.4 Model Specification

The study specified two equations to examine the relationship between digital payment activity, productive investment and economic output in Nigeria.

2.4.1 Digital Payment activity and Productive Investment

The first equation examined whether digital payment activity was associated with productive investment:

$$LGFCF_t = \alpha_0 + \alpha_1 LPOS_t + \alpha_2 INF_t + \alpha_3 PSC_t + \alpha_4 OPEN_t + \varepsilon_t \quad (1)$$

The coefficient of interest was α_1. A positive and statistically significant result indicated that higher POS transaction activity was associated with increased productive investment, all other factors held constant.

2.4.2 Digital Payment activity, Productive Investment and Economic Output

The second equation examined the relationship between digital payment activity and real economic output, with productive investment included as a potential transmission channel:

$$LRGDP_t = \beta_0 + \beta_1 LPOS_t + \beta_2 LGFCF_t + \beta_3 INF_t + \beta_4 PSC_t + \beta_5 OPEN_t + \mu_t \quad (2)$$

Where:

- $LGFCF_t$ = log of real gross fixed capital formation.
- $LRGDP_t$ = log of real gross domestic product.
- $LPOS_t$ = log of POS transaction volume.
- INF_t = inflation rate.
- PSC_t = private-sector credit as a percentage of GDP.
- $OPEN_t$ = trade openness.
- α_0, β_0 = constant terms.
- α_1, β_1 = coefficients to be estimated.
- ε_t, μ_t = error terms.
- t = time period.

The coefficient β_1 measured the relationship between digital payment activity and output after accounting for investment and the control variables, while β_2 captured the relationship between investment and output. A reduction in the estimated POS coefficient after including investment, alongside a positive investment coefficient, would be consistent with an investment-related transmission channel. However, these results alone would not establish causal mediation.

2.5 Preliminary Data Analysis

Before estimating the models, the study examined the data using descriptive statistics, including the mean, median, standard deviation, minimum and maximum values. Graphs were also used to identify trends, unusual observations, volatility and possible structural changes, particularly in POS transactions, inflation, private-sector credit and trade openness. The data were checked for missing values, inconsistent units and changes in national accounts or variable definitions. Quarterly GDP and investment data were also examined for seasonal patterns. Where necessary, seasonal adjustment or appropriate quarterly controls were applied.

2.6 Unit Root Tests

The study used the Augmented Dickey–Fuller (ADF) test developed by Dickey and Fuller (1979, 1981) and the Phillips–Perron (PP) test introduced by Phillips and Perron (1988) to determine whether the variables were stationary at level or first difference. The ADF test accounted for serial correlation through lagged differences, while the PP test adjusted for serial correlation and heteroskedasticity.

The tests were conducted at the 5% significance level, using an intercept and a trend where necessary. The null hypothesis was that a unit root existed. Where the results differed, alternative lag lengths, bandwidths and trend specifications were considered. The integration orders of LRGDP, LGFCF and INF were carefully checked because their preliminary results were inconsistent. Following the ARDL approach of Pesaran, Shin, and Smith (2001), the bounds test was applied only after confirming that none of the variables was integrated of order two, I (2).

2.7 ARDL Bounds Testing and Cointegration

The study used the ARDL bounds testing approach developed by Pesaran, Shin, and Smith (2001) to examine long-run relationships among the variables. The method allows a combination of I (0) and I (1) variables, provided none is I (2).

The calculated F-statistic was compared with the lower and upper critical bounds. A value below the lower bound indicated no established long-run relationship, while a value above the upper bound confirmed one. A value between the bounds was inconclusive. Where cointegration was established, long-run coefficients and the error-correction model were estimated. Otherwise, no long-run relationship was claimed.

2.8 Lag Selection and Estimation Strategy

The ARDL models were estimated using the Schwarz Information Criterion (SIC) to select the optimal lag structure. The maximum lag length was set to five for the dependent and explanatory variables. The selected lag order was determined automatically by EViews based on the specified criterion. This criterion favoured a parsimonious model suited to the 60 quarterly observations from 2010Q1 to 2024Q4. Two ARDL models were estimated. The first examined the relationship

between POS transactions (LPOS) and productive investment (LGFCF), while the second assessed their relationship with real GDP (LRGDP). Inflation (INF), private-sector credit (PSC) and trade openness (OPEN) served as control variables. ADF and PP unit root tests were conducted before estimation. The ARDL bounds test was then used to examine long-run relationships, provided no variable was integrated of order two, I (2). Where cointegration was established, long-run coefficients and short-run error-correction estimates were examined. Residual diagnostic tests were also used to assess model adequacy.

2.9 Error-Correction Model

Following evidence of cointegration, the study estimated an Error-Correction Model (ECM) to examine short-run relationships and adjustment towards long-run equilibrium, following Pesaran, Shin, and Smith (2001).

Equation for Productive Investment (ECM):

$$\Delta LGFCF_t = c_0 + \sum_{i=1}^{p} \phi_i \Delta LGFCF_{t-i} + \sum_{j=0}^{q_1} \theta_j \Delta LPOS_{t-j} + \sum_{j=0}^{q_2} \gamma_j \Delta INF_{t-j} + \sum_{j=0}^{q_3} \delta_j \Delta PSC_{t-j} + \sum_{j=0}^{q_4} \eta_j OPEN_{t-j} + \lambda_1 ECT_{1,t-1} + \varepsilon_t \quad (3)$$

Equation for Economic Output (ECM)

$$\Delta LRGDP_t = c_0 + \sum_{i=1}^{p} \rho_i \Delta LRGDP_{t-i} + \sum_{j=0}^{q_1} \beta_j \Delta LPOS_{t-j} + \sum_{i=1}^{q_2} \varphi_j \Delta LGFCF_{t-i} + \sum_{j=0}^{q_3} \vartheta_j \Delta INF_{t-j} + \sum_{j=0}^{q_4} \psi_j \Delta PSC_{t-j} + \sum_{j=0}^{q_5} \kappa_j OPEN_{t-j} + \lambda_2 ECT_{2,t-1} + \mu_t \quad (4)$$

2.10 Diagnostic and Stability Tests

The study assessed the models using the Breusch-Godfrey LM test for serial correlation, the Breusch-Pagan-Godfrey test for heteroskedasticity, the Ramsey RESET test for functional form, and the Jarque-Bera test for residual normality. Parameter stability was examined using the CUSUM and CUSUM of Squares tests, while structural break tests were considered where necessary. The results were interpreted alongside residual plots and economic reasoning, as passing these tests alone did not guarantee that all model assumptions were satisfied.

2.11 Robustness Checks

The study tested the robustness of its findings using four alternative indicators of digital financial activity: internet payments (LINTVP), mobile payments (LMPV), ATM transactions (ATMTV) and cheque transactions (CTV). Each indicator replaced LPOS separately in Model 1, while INF, PSC and OPEN remained as controls.

The model was expressed as:

$$LGFCF_t = \alpha_0 + \alpha_1 DFA_t + \alpha_2 INF_t + \alpha_3 PSC_t + \alpha_4 OPEN_t + \varepsilon_t \quad (5)$$

Where DFA_t represents one of the alternative indicators: LINTVP, LMPV, ATMTV or CTV.

Each indicator is estimated in a separate ARDL model to avoid combining potentially overlapping measures of digital financial activity. The results are compared with the baseline model in terms of the estimated long-run relationships, short-run dynamics, bounds-test results and diagnostic tests. This approach helps determine whether the main findings remain broadly consistent when alternative measures of digital financial activity are used.

2.12 Research Hypotheses

The study tested the following hypotheses:

- H1: Digital payment activity was positively associated with productive investment in Nigeria.
- H2: Digital payment activity was positively associated with real economic output in Nigeria.
- H3: Productive investment was positively associated with real economic output in Nigeria.
- H4: Productive investment served as a potential channel linking digital payment activity to economic output.

The first three hypotheses were assessed using the estimated coefficients and their statistical significance. The fourth was examined by comparing the investment and output models, without assuming a causal relationship.

2.13 Methodological Limitations

The study had some limitations. POS transaction volume captured only one aspect of digital payment activity, while gross fixed capital formation measured overall investment without showing its productivity. The results could also be affected by omitted variables, reverse causality,

data revisions and structural changes. Although ARDL examined short- and long-run relationships, it did not independently establish causality. These limitations were addressed through diagnostic tests, robustness checks and cautious interpretation of the findings.

3. RESULTS

This section examines the relationship between digital payment activity, productive investment and economic growth in Nigeria using quarterly data from 2010Q1 to 2024Q4. POS transaction volume serves as the main proxy for digital payment activity, while internet and mobile payments are used for robustness checks.

The analysis covers descriptive statistics, ADF and PP unit-root tests, ARDL bounds testing, regression estimates, diagnostic tests and robustness checks. The findings are discussed to determine whether digital payment activity is associated with economic growth and whether productive investment may be a potential channel.

3.1 Descriptive Statistics

Table 3.1: Descriptive statistics of the main variables

	LRGDP	LPOS	LGFCF	INF	PSC	LEXCR	OPEN
Mean	16.65574	17.24591	14.7379	14.87782	12.74116	5.661964	33.59972
Median	16.64985	17.39608	14.74672	12.74615	12.05026	5.722833	32.10125
Maximum	16.95616	21.98905	15.06262	33.94645	22.77123	7.391339	67.58754
Minimum	16.3642	11.68368	14.49678	7.822323	9.407157	5.013697	13.56612
Std. Dev.	0.124404	3.055526	0.116233	6.340025	2.635782	0.620976	12.52819
Skewness	-0.06474	-0.05936	0.099052	1.379749	1.636732	1.129844	0.764873
Kurtosis	2.927484	1.853514	2.698329	4.458329	6.46184	3.974334	3.089995
Jarque-Bera	0.055059	3.321314	0.325625	24.35388	56.74976	15.13879	5.870549
Probability	0.972846	0.190014	0.84975	0.000005	0.000000	0.000516	0.053116
Sum	999.3443	1034.754	884.274	892.6692	764.4695	339.7178	2015.983
Sum Sq. Dev.	0.913112	550.8382	0.7971	2371.559	409.8934	22.75106	9260.379
Observations	60	60	60	60	60	60	60

Table 3.1 summarises the seven main variables using 60 quarterly observations from 2010Q1 to 2024Q4. LRGDP and LGFCF showed little variation, while LPOS fluctuated considerably. Inflation and private-sector credit were positively skewed. The Jarque–Bera test rejected normality for inflation and private-sector credit but did not reject it for LRGDP, LPOS and LGFCF at the

5% level. These statistics describe the data but do not establish stationarity or relationships among the variables, which were examined in subsequent tests.

Table 3.2 summarises four alternative payment indicators, each with 60 observations. Internet payment volume (LINTVP) showed greater variation than mobile payment volume (LMPV). ATM transactions averaged approximately 201 million, while cheque transactions averaged 4.19 million. The Jarque–Bera test rejected normality for LINTVP and cheque transactions but not for LMPV or ATM transactions at the 5% level.

Overall, the indicators differed in their variability and distributions. Internet and mobile payments provided alternative proxies for robustness checks, while ATM and cheque transactions offered additional context. However, these measures capture different payment activities and do not independently establish relationships with investment or economic growth.

Table 3.2: Descriptive Statistics of Alternative Indicators

	LINTVP	LMPV	ATMTV	CTV
Mean	17.00979	16.97733	2.01E+08	4185663
Median	15.73334	16.39577	1.91E+08	3640407
Maximum	22.5386	21.56875	5.30E+08	10930903
Minimum	12.57531	12.04624	7762869	1468409
Std. Dev.	3.718615	2.716287	1.32E+08	2129945
Skewness	0.444418	-0.00012	0.744022	1.570191
Kurtosis	1.518796	2.015861	2.742093	4.738529
Jarque-Bera	7.459987	2.421326	5.701974	32.2112
Probability	0.023993	0.298	0.057787	0.000000
Sum	1020.587	1018.64	1.21E+10	2.51E+08
Sum Sq. Dev.	815.8578	435.3146	1.03E+18	2.68E+14
Observations	60	60	60	60

3.2 Unit Root Tests

The ADF and PP tests examined stationarity at levels and first differences. Most payment indicators, OPEN and LEXR appeared to be I (1). Results for LRGDP, LGFCF, INF, PSC and CTV were mixed and required further checks. The integration orders were therefore verified to ensure that no variable was I (2) before applying the ARDL bounds test (Pesaran et al., 2001).

Table 3.3: Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) Unit Root Test Results

Variable	ADF at Level	PP at Level	ADF at First Difference	PP at First Difference	Integration Order
LRGDP	-0.84 (0.84)	-3.70* (0.01)	-2.65 (0.09)	-14.56* (0.00)	Mixed
LPOS	-0.47 (0.89)	-0.26 (0.92)	-9.79* (0.00)	-13.20* (0.00)	I(1)
LGFCF	−1.65 (0.45)	−5.19* (0.00)	-9.88* (0.00)	-30.45* (0.00)	Mixed
INF	-2.46 (0.13)	-0.35 (0.91)	-3.98* (0.00)	-2.55 (0.11)	Mixed
PSC	-1.68 (0.44)	-2.40 (0.15)	-2.81 (0.06)	-7.41* (0.00)	Mixed
OPEN	−1.40 (0.58)	−1.53 (0.51)	-7.86* (0.00)	-7.86* (0.00)	I(1)
LEXR	2.70 (1.00)	2.60 (1.00)	-3.18* (0.03)	-6.15* (0.00)	I(1)
LMPV	-0.60 (0.86)	-0.71 (0.83)	-7.46* (0.00)	-7.51* (0.00)	I(1)
LINTVP	-0.10 (0.94)	-0.10 (0.94)	-8.03* (0.00)	-8.03* (0.00)	I(1)
ATMTV	-1.61 (0.47)	-1.81 (0.37)	-11.27* (0.00)	-11.27* (0.00)	I(1)
CTV	-2.47 (0.13)	-2.98* (0.04)	-7.07* (0.00)	-10.44* (0.00)	Mixed

4.3 ARDL Bounds Test for Cointegration

The ARDL bounds test examined long-run relationships in the two models. Model 1 focused on digital financial activity and productive investment, while Model 2 examined digital financial activity, investment and economic output.

The results reported in Table 3.4 show that the F-statistics for Model 1 (8.872931) and Model 2 (11.52064) exceeded their respective 1% upper-bound critical values of 4.947 and 4.839. Thus, the null hypothesis of no long-run relationship was rejected for both models.

Table 3.4: ARDL Bounds Test Results for Models 1 and 2

Test statistic	Model 1: Productive Investment	Model 2: Economic Output
Dependent variable	LGFCF	LRGDP
Number of regressors (k)	4	5
Actual sample size	56	55
F-statistic	8.87293	11.5206
10% lower bound, I(0)	2.345	2.226
10% upper bound, I(1)	3.28	3.241
5% lower bound, I(0)	2.763	2.617
5% upper bound, I(1)	3.813	3.743
1% lower bound, I(0)	3.738	3.543
1% upper bound, I(1)	4.947	4.839
Decision	Reject the null hypothesis	Reject the null hypothesis
Conclusion	Long-run relationship supported	Long-run relationship supported

These results supported estimating the long-run coefficients and short-run error-correction models. However, they did not independently establish causality or confirm that productive investment mediated the relationship between digital financial activity and economic output.

3.4 Long-Run and Short-Run ARDL Results

3.4.1 Model 1: Digital Financial Activity and Productive Investment

The dependent variable is LGFCF, the log of real gross fixed capital formation.

Table 3.5: Long-Run ARDL Estimates for Model 1

Variable	Coefficient	Std. Error	t-Statistic	p-value
LPOS	0.04054	0.00698	5.80934	0
INF	-0.0193	0.00495	-3.9032	0.0004
PSC	0.00917	0.00871	1.05216	0.299
OPEN	0.00368	0.00113	3.26774	0.0022
C	14.0843	0.14875	94.6859	0

POS transaction volume (LPOS) had a positive and significant coefficient (0.040535; $p<0.001$), indicating that a 1% increase in POS transactions was associated with a 0.041% increase in productive investment. Inflation (INF) had a negative and significant effect (−0.019320; $p=0.0004$). A one-percentage-point increase in inflation was associated with an estimated 1.93% decline in investment. Trade openness (OPEN) was also positive and significant (0.003684; $p=0.0022$), while private-sector credit (PSC) was positive but insignificant ($p=0.2990$).

Overall, POS activity and trade openness were positively associated with long-run productive investment, while inflation was negatively associated with it.

Table 3.6 show that the current change in POS transactions (LPOS) was negative but insignificant, while its first lag was negative and significant ($p = 0.0145$). This suggests that POS activity had a delayed negative association with investment changes. Inflation had a positive and significant effect only at the second lag ($p = 0.0215$). Private-sector credit showed alternating significant positive and negative coefficients across lags, indicating a changing short-run relationship with investment. Lagged investment was positive and significant (0.477552; $p = 0.0004$), suggesting persistence in investment changes.

Table 3.6: Short-Run ARDL Estimates for Model 1

Variable	Coefficient	Std. Error	t-Statistic	p-value
D(LGFCF(-1))	0.477552	0.122635	3.894103	0.0004
D(LPOS)	-0.01628	0.02693	-0.60435	0.549
D(LPOS(-1))	-0.06454	0.025251	-2.55602	0.0145
D(INF)	0.005651	0.009412	0.600377	0.5516
D(INF(-1))	-2.6E-05	0.011698	-0.00223	0.9982
D(INF(-2))	0.025874	0.01081	2.39365	0.0215
D(PSC)	-0.02184	0.008173	-2.67231	0.0108
D(PSC(-1))	0.020649	0.007363	2.804332	0.0077
D(PSC(-2))	-0.02415	0.008059	-2.99706	0.0047
D(PSC(-3))	0.040436	0.007868	5.139548	0.0000
CointEq(-1)	-1.18051	0.15254	-7.73901	0.0000

The error-correction coefficient was negative and significant (−1.180511; $p<0.001$), indicating adjustment towards the long-run equilibrium. Its magnitude suggests rapid adjustment, with approximately 118.05% of the previous quarter's disequilibrium corrected each quarter, implying possible overshooting. Since the model stability tests confirmed stability, the results support a stable long-run relationship despite the adjustment coefficient exceeding one.

Overall, POS transactions were positively associated with investment in the long run but had a negative association at the first short-run lag. This suggests that the relationship differed between the short and long run.

3.4.2 Model 2: Digital Financial Activity, Productive Investment and Economic Output

Table 3.7: Long-run ARDL estimates for Model 2

Variable	Coefficient	Std. Error	t-statistic	p-value
LPOS	0.019934	0.00291	6.850148	0.0000
LGFCF	0.258002	0.06735	3.830753	0.0005
INF	0.000361	0.001457	0.247795	0.8056
PSC	0.004997	0.003353	1.490404	0.1444
OPEN	-0.00122	0.000362	-3.37831	0.0017
C	12.48376	0.951635	13.11823	0.0000

POS transactions (LPOS) had a positive and significant relationship with real GDP (0.019934; $p < 0.01$). A 1% increase in POS transactions was associated with a 0.020% increase in real GDP. Productive investment (LGFCF) was also positive and significant (0.258002; $p=0.0005$). A 1% increase in gross fixed capital formation was associated with a 0.258% increase in real GDP.

Inflation and private-sector credit had positive but insignificant coefficients (p=0.8056 and p = 0.1444, respectively). Trade openness had a negative and significant relationship with real GDP (−0.001223; p = 0.0017), although this does not establish causation.

Overall, POS transactions and productive investment were positively associated with long-run economic output, while trade openness showed a negative association. Inflation and private-sector credit were not statistically significant.

Table 3.8: ARDL Error Correction Regression for Model 2

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LRGDP(-1))	0.698296	0.111811	6.245311	0.0000
D(LGFCF)	0.192332	0.062682	3.068389	0.004
D(LGFCF(-1))	-0.06707	0.058123	-1.15393	0.2557
D(LGFCF(-2))	0.017977	0.056977	0.315518	0.7541
D(LGFCF(-3))	0.107969	0.050094	2.155316	0.0375
D(PSC)	0.000801	0.004411	0.181577	0.8569
D(PSC(-1))	0.001328	0.004636	0.286477	0.7761
D(PSC(-2))	-0.00163	0.004337	-0.37649	0.7086
D(PSC(-3))	0.016752	0.004479	3.739888	0.0006
D(PSC(-4))	-0.01702	0.006153	-2.76639	0.0087
CointEq(-1)*	-1.617	0.167335	-9.66322	0.0000

Lagged real GDP had a positive and significant coefficient (0.698296; p<0.001), indicating persistence in output changes. Productive investment (LGFCF) was positive and significant in the current quarter (0.192332; p=0.0040) and at the third lag (0.107969; p=0.0375). The first and second lags were insignificant, suggesting that investment was associated with output both immediately and after a delay. Private-sector credit (PSC) was insignificant in the current quarter and first two lags. Its third lag was positive and significant (0.016752; p=0.0006), while the fourth was negative and significant (−0.017021; p=0.0087). This indicates that its short-run relationship with output varied over time.

The error-correction coefficient was negative and significant (−1.616997; p<0.001), supporting adjustment towards the long-run equilibrium. Since its magnitude exceeded one, the adjustment may involve overshooting. However, the model's confirmed stability supports the overall dynamic specification.

3.5 Diagnostic Tests and Model Stability

Table 3.9: Diagnostic Tests for Models 1 and 2

Diagnostic test	Model 1: F-statistic/statistic	p-value	Model 2: F-statistic/statistic	p-value
Breusch-Godfrey serial correlation LM test	0.83324	0.4424	2.79862	0.0742
Breusch-Pagan-Godfrey heteroskedasticity test	0.49316	0.93	1.00077	0.4763
Jarque-Bera residual normality test	2.50027	0.28647	0.26498	0.87591
Ramsey RESET specification test	0.57891	0.4513	0.09475	0.7599
CUSUM stability test	Within 5% boundaries	Stable	Within 5% boundaries	Stable
CUSUM of Squares stability test	Within 5% boundaries	Stable	Within 5% boundaries	Stable

The serial correlation tests returned p-values of 0.4424 for Model 1 and 0.0742 for Model 2. Both exceeded 0.05, indicating no significant serial correlation at the 5% level. However, Model 2 would be significant at the 10% level. Heteroskedasticity tests (0.9300 and 0.4763) showed no evidence of unequal error variance. Similarly, the Jarque–Bera results (0.286467 and 0.875911) did not reject residual normality. The Ramsey RESET results (0.4513 and 0.7599) also showed no significant evidence of model misspecification.

Furthermore, the CUSUM and CUSUM of Squares plots remained within the 5% critical boundaries, supporting parameter stability in both models.

Overall, the diagnostic results were satisfactory at the 5% level, supporting the reliability of the ARDL estimates. However, these tests do not guarantee that the models are correctly specified.

LINTVP: At the 5% significance level, the diagnostic tests revealed no evidence of serial correlation, heteroskedasticity, non-normality or model misspecification. However, the Breusch–Godfrey test produced a p-value of 0.0642, which is close to the 5% threshold and would be significant at the 10% level. The CUSUM and CUSUM of Squares tests indicated that the model remained stable throughout the study period. The bounds test also confirmed a long-run relationship among the variables. Despite this, LINTVP had a positive but statistically insignificant long-run coefficient, unlike LPOS in the baseline model. This suggests that the baseline finding is

not fully robust to the use of internet-payment transaction volume as an alternative measure of digital financial activity.

3.6 Robustness Tests Using Alternative Measures of Digital Financial Activity

Table 3.10: Summary of Robustness Tests Using Alternative Digital Financial Activity Proxies (LINTVP and LMPV)

Estimation results	LINTVP	LMPV
ARDL Estimation Results		
Selected ARDL lag order	(2, 2, 2, 4, 4)	(2, 0, 1, 4, 3)
Number of observations	56	56
Long-run proxy coefficient	0.004328	0.032123
Long-run proxy p-value	0.6881	0.0003
Long-run relationship: sign	Positive	Positive
Long-run relationship: significance	Not statistically significant	Positive and significant
Bounds Cointegration Test		
F-statistic	5.418910	7.732816
5% lower-bound critical value, I(0)	2.763	2.763
5% upper-bound critical value, I(1)	3.813	3.813
Cointegration decision	Yes, at 5%	Yes, at 1%
Short-Run and Error-Correction Results		
Significant short-run proxy effect(s)	−0.066184 (p = 0.0037), significant	No short-run effect estimated
Error-correction coefficient, ECT(−1)	−0.662745	−1.021098
ECT p-value	0.0000	0.0000
Diagnostic Tests		
Breusch–Godfrey serial correlation LM test (p-value)	0.0642	0.3093
Breusch–Pagan–Godfrey heteroskedasticity test (p-value)	0.4051	0.3335
Jarque–Bera residual normality test (p-value)	0.2336	0.3532
Ramsey RESET test (p-value)	0.7599	0.5401
Stability Tests		
CUSUM	Stable	Stable
CUSUM of Squares	Stable	Stable

LMPV: The LMPV results provide further support for a positive long-run relationship between digital financial activity and productive investment in Nigeria. The long-run coefficient was positive and statistically significant, indicating that higher mobile-payment transaction volume was associated with increased productive investment. The bounds test confirmed a long-run relationship among the model variables, while the CUSUM and CUSUM of Squares tests indicated parameter stability. However, the error-correction coefficient was greater than one in absolute

terms, suggesting possible overshooting during adjustment towards long-run equilibrium. Overall, the LMPV results support the baseline finding, although the lack of a statistically significant long-run effect for LINTVP indicates that the evidence is only partially robust across alternative measures of digital financial activity.

Table 3.11: Summary of Robustness Tests Using Alternative Digital Financial Activity Proxies (ATMTV and CTV)

Estimation results	ATMTV	CTV
ARDL Estimation Results		
Selected ARDL lag order	(2,0,2,4,4)	(2,1,2,4,5)
Number of observations	56	55
Long-run proxy coefficient	-1.03×10^{-10}	-1.78×10^{-8}
Long-run proxy p-value	0.6264	0.052
Long-run relationship: sign	Negative	Negative
Long-run relationship: significance	Insignificant	Insignificant at 5%
Bounds Cointegration Test		
F-statistic	5.539676	6.360601
5% lower-bound critical value, I(0)	2.763	2.763
5% upper-bound critical value, I(1)	3.813	3.813
Cointegration decision	Yes, at 1%	Yes, at 1%
Short-Run and Error-Correction Results		
Significant short-run proxy effect(s)	No separate short-run proxy effect estimated	Positive but insignificant
Error-correction coefficient, ECT(−1)	−0.704357	−0.870380
ECT p-value	0.0000	0.0000
Diagnostic Tests		
Breusch–Godfrey serial correlation LM test (p-value)	0.0289	0.0567
Breusch–Pagan–Godfrey heteroskedasticity test (p-value)	0.1799	0.7776
Jarque–Bera residual normality test (p-value)	0.4202	0.3385
Ramsey RESET test (p-value)	0.8222	0.8462
Stability Tests		
CUSUM	Stable	Stable
CUSUM of Squares	Stable	Stable

ATMTV: The ATMTV results show a negative but insignificant long-run relationship with productive investment (p=0.6264)). Although the bounds test confirms a long-run relationship among the variables, ATM transaction volume itself has no significant long-run effect. The error-correction term is negative and significant, indicating adjustment towards equilibrium. The CUSUM and CUSUMSQ tests confirm model stability. However, the Breusch–Godfrey test

reveals serial correlation (\(p=0.0289\)), so the results should be interpreted with caution. Overall, ATMTV does not provide strong support for the baseline findings.

CTV: The CTV results also show a negative long-run relationship with productive investment, but it narrowly misses significance at the 5% level (\(p=0.0520\)). The bounds test confirms a long-run relationship among the variables, while the significant negative error-correction term indicates adjustment towards equilibrium. The model also passes the reported diagnostic tests at the 5% level, and the CUSUM and CUSUMSQ tests confirm stability. Overall, CTV provides limited support for the baseline findings because its long-run effect is not statistically significant at the 5% level.

4. DISCUSSION

4.1 Digital Payment Activity and Productive Investment

The baseline results show a positive and significant long-run relationship between POS transaction volume and gross fixed capital formation in Nigeria. A 1% increase in POS transaction volume is associated with a 0.041% increase in productive investment. This finding is consistent with financial intermediation theory, which suggests that efficient financial services can reduce transaction costs and support investment (Levine, 2005).

However, the robustness tests produce mixed results. Mobile payment volume has a positive and significant relationship with investment, while internet payments are positive but insignificant. ATM and cheque transactions have negative relationships that are not statistically significant at the 5% level. These differences suggest that the relationship between payment activity and productive investment varies across channels. The ATM results should also be interpreted cautiously because that model shows evidence of serial correlation.

4.2 Digital Payment Activity, Investment and Economic Growth

The second model shows that POS transaction volume and gross fixed capital formation have positive and significant long-run relationships with real GDP. A 1% increase in POS transaction volume is associated with a 0.020% increase in real GDP, while a 1% increase in investment is associated with a 0.258% increase in real GDP.

These findings are consistent with financial development and investment-led growth theories, which emphasize the roles of financial services and capital accumulation in economic performance (Levine, 2005; Romer, 1990). They also broadly align with previous studies reporting positive relationships between electronic payments and economic growth, although the cited studies should be checked to confirm their specific findings. Inflation has a negative and significant relationship with investment but is insignificant in the GDP model. Private-sector credit is insignificant in both models. Trade openness is positively associated with investment but negatively associated with GDP. These results suggest that the factors related to investment may differ from those associated with economic output.

Although the findings indicate positive relationships between POS activity, investment and GDP, the models do not establish that investment is the channel through which digital payment activity affects economic growth.

4.3 Short-Run Dynamics and Model Stability

The error-correction terms are negative and statistically significant in both baseline models, supporting the presence of long-run relationships. However, their absolute values exceed one, suggesting possible overshooting during adjustment. Further checks of the model dynamics are therefore necessary. Most diagnostic tests are satisfactory, and the CUSUM and CUSUM of squares tests indicate parameter stability. However, the GDP model's serial-correlation test has a p-value of 0.0742. This is not significant at the 5% level, although it would be significant at the 10% level.

Overall, POS transaction volume shows positive long-run relationships with both productive investment and economic output, while mobile payment volume also has a positive relationship with investment. The mixed results for other payment channels suggest that increased transaction activity does not necessarily correspond to higher productive investment. These findings highlight the importance of examining how different payment channels relate to productive economic activity, while recognizing that the analysis establishes statistical relationships rather than causation.

4.4. Conclusion and Policy Recommendations

4.4.1 Conclusion

This study examined the relationship between digital payment activity, productive investment and economic growth in Nigeria using quarterly data from 2010Q1 to 2024Q4. The findings show that POS transaction volume is positively associated with productive investment and real GDP in the long run. Mobile payment activity also has a positive relationship with investment, while the results for other payment channels are mixed.

Overall, the findings suggest that digital payment activity may support investment and economic growth, but increased transactions do not automatically lead to greater productive activity.

4.4.2 Policy Recommendations

Based on these findings, three recommendations are proposed. Foremost, the government and financial institutions should improve the affordability, reliability and accessibility of POS and mobile payment services. Secondly, Financial institutions should strengthen links between digital payment services, access to credit and business support, particularly for small and medium-sized enterprises, to encourage productive investment. Thirdly, Policymakers should strengthen payment security, address inflation and improve access to private-sector credit to create a more supportive environment for investment and economic activity.

In conclusion, digital payment activity offers opportunities to support Nigeria's economic development. However, its contribution to productive investment and economic growth depends on how effectively businesses and individuals can use these services for productive purposes.

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