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BRIDGING THE SPATIAL DIVIDE: LAST-MILE AGENT BANKING, INFRASTRUCTURE STABILITY, AND GRASSROOTS FINANCIAL INCLUSION IN AGRARIAN ECONOMIES

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Abstract
This study investigates the empirical impact of digital banking services accessibility, specifically last-mile Point of Sale (POS) agent density, mobile network reach, USSD availability, and cash-in/cash-out (CICO) liquidity, on multidimensional financial inclusion across rural agrarian communities in North-Western Nigeria. Grounded in financial intermediation theory and the technology acceptance model (TAM), the study adopted an explanatory sequential mixed-methods design. Quantitative survey data were gathered via digital mobile forms (KoboCollect) from 459 valid respondents across all seven states (Kano, Kaduna, Katsina, Kebbi, Jigawa, Sokoto, and Zamfara), while qualitative insights were extracted from 25 semi-structured key informant interviews and analysed in NVivo 14. Partial Least Squares Structural Equation Modelling (PLS-SEM) in SmartPLS 4 revealed that digital banking services accessibility exerts a statistically significant positive direct effect on multidimensional financial inclusion ($\beta = 0.231$, $t = 3.850$, $p < 0.001$), leading to the firm rejection of the primary null hypothesis (H_{01}). Standardized path estimates confirm that a 1-standard-deviation increase in accessibility increases financial inclusion by 0.231 standard deviations, within an overall structural model explaining 77.5% of the variance ($R^2 = 0.775$). Measurement model evaluation confirmed robust construct reliability, convergent validity, and discriminant validity (CR > 0.88, AVE > 0.71,$HTMT_{ACC\text{-}FI} = 0.428 < 0.85$). Qualitative triangulation demonstrated that decentralized agent banking kiosks have successfully replaced distant brick-and-mortar branches, dismantling spatial barriers. However, qualitative thematic coding highlighted that severe mobile network downtime and agent CICO liquidity stock-outs periodically neutralise channel proximity, forcing temporary cash reversion to informal *Adashe* networks. The study concludes that expanding physical agent density is an indispensable prerequisite for grassroots inclusion, but its ultimate success depends on infrastructural uptime and automated liquidity rebalancing. It recommends regulatory support for off-grid solar-powered super-agent kiosks, automated micro-liquidity lines, and mandatory Quality-of-Service standards for rural digital payment rails.

Keywords: Agent banking, agrarian economies, digital financial inclusion, financial intermediation, last-mile infrastructure, PLS-SEM.

1.0 Introduction

Background to the Study

Financial inclusion is universally acknowledged by standard-setting bodies, including the United Nations Capital Development Fund (UNCDF), the World Bank, and the Alliance for Financial Inclusion (AFI), as a vital catalyst for eradicating poverty, reducing socio-economic inequality, and promoting inclusive economic growth in emerging economies (Allen et al., 2016; Demirgüç-Kunt et al., 2022; World Bank, 2022). Universal access to affordable formal financial services directly supports key Sustainable Development Goals (SDGs), particularly SDG 1 (No Poverty), SDG 5 (Gender Equality), and SDG 8 (Decent Work and Economic Growth). Rather than evaluating inclusion merely as the passive ownership of a bank account, modern development economics defines true financial inclusion as a multidimensional framework encompassing four interconnected pillars: Access, Usage, Savings and Credit, and Financial Resilience (AFI, 2017; Ozili, 2020, 2021; Okoh et al., 2026). In this paradigm, Access serves as the basic gateway that breaks down physical, geographic, and administrative barriers, enabling unbanked households to move away from vulnerable, uncontrolled informal survival strategies.

Historically, commercial deposit money banks have been restricted to branch-based, brick-and-mortar architectures. This old paradigm purposely excluded rural and low-income populations due to high fixed operational expenses, stringent paperwork requirements, and the geographic remoteness of agrarian settlements (Beck et al., 2007). To solve these basic market flaws, global financial institutions have experienced a technical shift from physical branch networks to technology-mediated delivery networks.

Digital financial services, including mobile applications, Unstructured Supplementary Service Data (USSD) platforms, Automated Teller Machines (ATMs), and Point of Sale (POS) agent banking kiosks, have significantly reduced intermediation costs and extended the operational reach of financial institutions to previously inaccessible remote areas (Evans, 2019; Okoye et al., 2018; Souiden et al., 2021) anddemonstrated that electronic financial service channels drastically enhance convenience, time savings, and customer contentment across Nigerian banking, making digital touchpoints the primary vehicle for financial inclusion.

However, as Okoh et al. (2025b) highlighted in their evaluation of the Nigerian digital payment ecosystem, rapid channel expansion has exposed severe "rough edges," characterized by persistent telecommunication network failures, high transaction drop-off rates, cybersecurity threats, and severe regional digital divides between urban hubs and rural agricultural zones.

Furthermore, Adeagbo et al. (2024) noted that while digital banking mechanisms optimize operational efficiency and minimize human errors, they simultaneously elevate institutional risk exposure through e-fraud and technical transaction failures. In rural agrarian economies like North-Western Nigeria, macroeconomic volatility, such as fluctuating interest rates, inflation, and credit accessibility constraints, further moderates the capacity of micro-entrepreneurs and smallholders to convert physical access into long-term financial resilience (Uzuh et al., 2025).

In Nigeria, apex regulatory mandates led by the Central Bank of Nigeria (CBN) have aggressively prioritized digital enablement under the National Financial Inclusion Strategy (NFIS 3.0) and the Shared Agent Network Expansion Facility (SANEF) (CBN, 2022, 2023). Recent empirical metrics from the Enhancing Financial Innovation & Access (EFInA) 2026 Access to Financial Services (A2F) survey confirm significant national progress: total financial inclusion reached 79%, formal inclusion climbed to 73% (~87.2 million adults), and Digital Financial Services (DFS) adoption jumped to 64.4% (~77.0 million adults) (EFInA, 2026).

However, these national aggregates mask a major financial split that is both geopolitical and geographical. While southern geopolitical zones leverage dense infrastructure and higher digital literacy to achieve

formal inclusion rates exceeding 90% (e.g., South-West at 96.4%), the North-Western zone comprising Kano, Kaduna, Katsina, Kebbi, Jigawa, Sokoto, and Zamfara states lags critically behind with a formal inclusion rate of 62.7% and a DFS adoption rate of just 43.6% (EFInA, 2026).
The Northwestern geopolitical zone exhibits a severe regional financial gap and a serious functional adoption paradox, notwithstanding national digital reforms under the National Financial Inclusion Strategy (NFIS 3.0) and the Shared Agent Network Expansion Facility (SANEF). Point of Sale (POS) agent kiosks and USSD shortcodes are physically present in commercial centers across the region, yet functional grassroots adoption continues to stagnate.

Empirical metrics from the Enhancing Financial Innovation & Access (EFInA, 2026) survey demonstrate that while the North-Eastern zone exhibits a 13.6 percentage-point gap between formal inclusion (61.4%) and DFS adoption (47.8%), the North-Western zone suffers from a massive 19.1 percentage-point gap between formal inclusion (62.7%) and active DFS usage (43.6%). This confirms that North-Western Nigeria has the lowest absolute DFS adoption rate in the country, proving that a substantial proportion of account-owning adults actively refuse digital transaction methods.

Recent empirical evaluations of the Nigerian payment ecosystem reveal that this adoption reluctance is driven by pervasive 'rough edges,' characterized by persistent telecommunication network failures, high transaction drop-off rates, and cybersecurity vulnerabilities that erode institutional trust among users (Adeagbo et al., 2024; Okoh et al., 2025b). Serious last-mile infrastructural impediments further compound this structural exclusion. Telecommunication network signals across rural Local Government Areas (LGAs) in Kebbi, Zamfara, and Sokoto exhibit high volatility, leading to frequent USSD transaction timeouts and failed debits, a technological infrastructure deficit that severely restricts digital financial integration among small regional enterprises (Okoh et al., 2025a, 2025b).

Furthermore, branchless banking economics dictate that physical agents are effective only if providers actively manage agent liquidity (Flaming et al., 2011; McKinsey Global Institute, 2016). Rural POS agents in northwestern agrarian villages frequently experience cash-in/cash-out (CICO) liquidity stock-outs during peak weekly agricultural market hours. When liquidity is depleted, or network signals drop, daily traders and farmers are forced to forgo digital channels and revert to physical cash holding or high-risk informal rotating savings schemes (Adashe)(Udo et al., 2023). As empirically established by Udo et al. (2023), short-run payment channel disruptions directly preserve cash-based transaction demand, while Uzuh et al. (2025) and Okoh et al. (2026) confirm that such persistent operational friction compromises the economic resilience and long-term sustainability of rural micro-enterprises. Without resolving underlying network stability and CICO liquidity bottlenecks, supply-side agent expansion alone yields diminishing returns.

This study seeks to fill these empirical and policy gaps by considering the impact of the accessibility of digital banking services on financial inclusion in the Northwest area of Nigeria. To fulfill this purpose, the study poses the following precise research question: What is the effect of access to digital banking services on financial inclusion in northwestern Nigeria? From this study question, the following null hypothesis was statistically developed and tested:

Null Hypothesis (H_{01}): H_{01}: The accessibility of digital banking services does not have a significant effect on financial inclusion in North-Western Nigeria.

Value and Significance of the Study

This study has enormous practical, policy, and theoretical relevance to the main stakeholders in the financial system. For Deposit Money Banks (DMBs), FinTech operators (e.g., Moniepoint, OPay, and PalmPay), and mobile money super-agents, it provides actionable empirical insights into addressing the last-mile high-cost-to-serve challenge in rural agrarian markets. The findings offer an evidence-based roadmap for regulators, including the Central Bank of Nigeria (CBN), Nigeria Deposit Insurance Corporation (NDIC), and Nigerian Communications Commission (NCC), to optimize SANEF agent network deployment and enforce quality-of-service mandates on MNO payment rails. Theoretically, it adds to the literature by integrating the Financial Intermediation Theory and TAM in an explanatory sequential mixed-methods design across all seven states of North-Western Nigeria.

2.0 Literature Review

Digital banking accessibility represents the physical, virtual, and operational availability of electronic touchpoints required to execute financial transactions without visiting traditional brick-and-mortar commercial bank branches (Evans, 2019; AFI, 2022). In this study, accessibility serves as a primary independent variable (IV) alongside perceived ease of use (PEOU). Digital banking services accessibility is operationalized across four frontline indicators:

i. Spatial Proximity: Physical distance to last-mile Point of Sale (POS) agent kiosks and Automated Teller Machines (ATMs) in agrarian communities.
ii. Network Reach & USSD Availability: The consistency, signal strength, and session stability of mobile telecommunication networks supporting USSD shortcodes and banking applications.
iii. Operational Uptime: Uninterrupted channel functionality during peak agricultural trading hours and market cycles.
iv. Cash-in/Cash-Out (CICO) Agent Liquidity: The continuous availability of physical cash floats at POS agent kiosks to support deposit and withdrawal requests.

As the International Telecommunication Union (ITU, 2023) notes, robust connectivity is an indispensable enabler of economic participation in modern digital ecosystems. However, flaming et al. (2011) and GSMA (2023) emphasize that accessibility cannot be evaluated merely as the static number of deployed POS devices; it must encompass network interoperability and frontline CICO liquidity management. Empirical investigations by Okoye et al. (2018) confirm that electronic delivery channels drastically enhance customer convenience and transaction speed. Nevertheless, as Udo et al. (2023) and Okoh et al. (2025a, 2025b) demonstrate, persistent technological infrastructure deficits, telecom signal drops, and payment delivery failures create severe 'rough edges' that disrupt cash demand functions and restrict FinTech integration.

Multidimensional Financial Inclusion (Dependent Variable)

Financial inclusion constitutes the core Dependent Variable (DV) of this study. Moving beyond passive bank account ownership, modern development economics defines financial inclusion as a comprehensive, multidimensional construct wherein adult citizens possess frictionless access to, actively utilize, regularly save within, obtain formal credit from, and build household financial resilience through regulated institutions (AFI, 2017; Adeagbo et al., 2024; World Bank, 2022). To avoid indicator confounding, the DV is strictly operationalized across four interconnected pillars:

i. Access Pillar: Formal account ownership (bank, mobile money, or non-bank financial institution) and geographic proximity to financial touchpoints.
ii. Usage Pillar: The frequency, regularity, and portfolio diversity of digital transactions executed per month (transfers, bill payments, merchant transactions).

iii. Savings & Credit Inclusion Pillar: Active formal capital accumulation and algorithm-driven or institutional micro-credit uptake for productive farming activities.
iv. Financial Resilience Pillar: The household capacity to absorb agricultural or macroeconomic shocks using formal financial tools without liquidating productive assets such as livestock or land (Peng & Liu, 2024; Suri & Jack, 2016).

This four-pillar operationalization breaks down the historical access bias identified in early development literature (Demirgüç-Kunt et al., 2022). Recent empirical studies confirm that Financial Resilience represents the ultimate, definitive welfare outcome of the inclusion journey. In this context, Okoh et al. (2026) establish that physical access and active usage, when coupled with financial capability and planning, account for up to 84.7% of business longevity among small enterprises. Furthermore, Uzuh et al. (2025) and Okoh et al. (2021) demonstrate that extending credit access and entrepreneurship funding directly drives poverty reduction, although macroeconomic volatility and high interest rates moderate these long-run welfare gains.

Theoretical Framework

This study is anchored on a dual theoretical foundation combining Financial Intermediation Theory and the Technology Acceptance Model (TAM).

Financial Intermediation Theory

Financial Intermediation Theory (Gurley & Shaw, 1960; Benston & Smith, 1976; Diamond, 1984) posits that financial institutions exist to eliminate market imperfections, specifically transaction costs and information asymmetry, that impede direct exchanges between surplus and deficit economic units. In modern digital finance, agency banking networks and mobile telecommunication rails act as decentralized technological intermediaries (Levine, 2005; Omongbale & Okoh, 2026). By substituting expensive brick-and-mortar branches with human POS agents, digital intermediation drastically reduces spatial search costs, transit fees, and contract enforcement friction for low-income rural households, enabling grassroots capital mobilization. Empirical evidence from Okoye et al. (2018) supports this framework by proving that electronic channels drastically minimize service delivery time and transactional convenience costs. Furthermore, as demonstrated by Okoh et al. (2021) and Uzuh et al. (2025), decentralized intermediation expands access to capital and entrepreneurship funding, directly mitigating poverty and fueling small business survival in underserved markets.

Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM), formulated by Davis (1989) and extended by Venkatesh and Davis (2000), asserts that individual technology adoption is determined by two primary cognitive beliefs: Perceived Usefulness (PU) and Perceived Ease of Use (PEOU). In this study, TAM provides the direct behavioral foundation connecting our focal construct, Digital Banking Accessibility (ACC), to user adoption decisions.

Channel Accessibility (ACC) captures physical Point of Sale (POS) agent proximity, mobile network signal reach, USSD availability, operational channel uptime, and cash-in/cash-out (CICO) agent liquidity float. According to TAM, physical channel availability translates into active adoption only when users perceive electronic channels to be effortless and reliable. When users encounter complex USSD shortcode menus, language barriers, or severe techno-stress induced by recurring network outages and transaction drop-offs, Perceived Ease of Use (PEOU) drops sharply (Lai, 2017; Thomas et al., 2024).

This behavioral rationale is further substantiated by Adeagbo et al. (2024) and Okoh et al. (2025b), who show that digital risk exposure, e-fraud vulnerabilities, and payment ecosystem "rough edges" (such as recurring transaction delivery failures) severely erode Perceived Ease of Use and institutional trust. Consequently, as Udo et al. (2023) observe, these operational friction points trigger immediate channel abandonment, forcing users to temporarily revert to physical cash holdings and informal *Adashe* networks despite the physical presence of POS agent touchpoints.

Empirical Review and Gap Analysis

A large body of recent empirical literature has stressed the direct relationship between infrastructure access and financial inclusion in emerging nations around the globe. Chand (2026) analyzed digital public infrastructure in small island developing states and concluded that standardized digital payment rails and physical agent availability are the leading indicators of financial inclusion for rural communities. Al-Sharshani (2025) examined FinTech adoption among local merchants and found that decentralized payment gateways are critical for growing micro-transactions in unbanked areas.

Similarly, Aruwa et al. (2025) studied digital payment systems in Nigeria. They found that agent banking effectively removes physical distance barriers, but practical utilization remains limited by network downtime in deep rural LGAs. Furthermore, global evidence from GSMA (2023) and the World Bank Global Findex Database (Demirgüç-Kunt et al., 2022) shows that mobile money accounts and agent density operate as the primary vehicles for closing the unbanked gap.

In African economies, Evans (2019) proved that mobile phone adoption directly decreased geographical barriers and increased account ownership. However, physical channel access does not ensure sustained use when operational stability and frontline agent service quality are ignored (Ibrahim & Ndaglasi, 2019). This is supported by Omongbale (2025a, 2025b), who found that digital platform adoption significantly improves operational efficiency and consumer engagement in Nigerian deposit money banks.

Expanding on digital service delivery in Nigeria, Okoye et al. (2018) evaluated technology-based banking across 120 customers using ANOVA, confirming that convenience (β= 0.239, p = 0.008) and time-saving capabilities (β= 0.200, p = 0.026) significantly boost customer satisfaction.

However, as financial institutions rapidly transition to web and mobile channels, operational risk exposures intensify. Adeagbo et al. (2024) investigated digital banking vulnerabilities at Access Bank PLC using survey data analysed via Chi-square statistics. Their study revealed that while digital channels streamline daily transactions and eliminate human errors, they simultaneously elevate institutional risk exposure through electronic fraud and transaction delivery failures, underscoring the necessity for continuous server uptime and cybersecurity upgrades.

The systemic impediments constraining digital channel adoption are further documented in regional payment ecosystem evaluations. Okoh et al. (2025b) explored the 'rough edges' of Nigeria's digital payment ecosystem through qualitative synthesis, identifying severe infrastructure deficits, frequent transaction failures, and poor rural network penetration as primary bottlenecks obstructing a seamless cashless transition. In a complementary study, Okoh et al. (2025a) surveyed 350 small enterprises across Southwestern urban centers using ANOVA and multiple regression, discovering that technological infrastructure deficits (p = 0.0045) and regulatory complexities severely restrict small business FinTech integration. These infrastructure disruptions directly influence household monetary behavior.

Investigating the impact of FinTech channels on cash demand, Udo et al. (2023) utilized quarterly Central Bank of Nigeria data (2009–2020) and ARDL bounds testing. Their empirical results established a long-

run cointegration between FinTech proxies (ATM, POS, mobile, andweb) and money demand, demonstrating that short-run network failures and security fears force users to maintain high cash holdings.

Beyond transaction channels, empirical research highlights the critical role of credit access and financial capability in driving long-term economic outcomes. Okoh et al. (2021) examined microfinance credit access among 180 entrepreneurs in the Sango-Ota industrial hub, finding that despite high demand for micro-capital, exorbitant interest rates drive high enterprise mortality rates.

Extending this perspective to business sustainability, Okoh et al. (2026) evaluated 353 SMEs in Southwestern Nigeria using multiple regression grounded in human capital theory. The authors demonstrated that financial access and usage, combined with sound financial behavior and planning, account for a major proportion of enterprise longevity (R^2 = 0.706–0.847), proving that physical access must be paired with financial capability.

Finally, Uzuh et al. (2025) evaluated bank entrepreneurship funding and poverty reduction in Nigeria (1986–2022) using ARDL modeling (R^2 = 0.781). Their study concluded that macroeconomic shocks, specifically inflation and interest rate volatility, significantly moderate the effectiveness of financial access in reducing poverty.

Synthesis and Identification of Empirical Gaps

Despite these valuable contributions, a critical synthesis of the empirical literature reveals three major gaps that motivate this study:

i. Geographic and Contextual Gap: Existing Nigerian empirical studies (e.g., Adeagbo et al., 2024; Okoh et al., 2021, 2025a, 2026; Okoye et al., 2018) are heavily concentrated in Southwestern urban and industrial hubs (Lagos, Ogun, Oyo). They fail to capture the unique socio-technical constraints of North-Western agrarian communities, where vast spatial distances, lower literacy, and agricultural seasonal cash cycles predominate.
ii. Methodological Gap: Previous research predominantly relies on either purely quantitative regression on macro-aggregate CBN secondary data (e.g., Udo et al., 2023; Uzuh et al., 2025) or isolated cross-sectional urban surveys. There is a lack of explanatory sequential mixed-methods studies that combine structural equation modeling (PLS-SEM) with qualitative thematic triangulation (NVivo 14) to explain the human behaviors behind digital channel dropouts.
iii. Construct Operationalization Gap: Prior studies often treat financial inclusion as a unidimensional binary variable (account ownership vs. non-ownership) or conflate supply-side agent deployment with active usage. They fail to model how frontline operational frictions, specifically network downtime and agent CICO liquidity stock-outs, impact multidimensional inclusion across its four distinct pillars. This study addresses these combined gaps.

3.0 Methodology

This study adopted a pragmatist research philosophy, which posits that the core research problem should dictate methodological choices rather than philosophical dogmatism (Morgan, 2014). The study used an explanatory sequential mixed-methods design across two phases (Creswell & Plano Clark, 2018). Phase 1 comprised a quantitative cross-sectional survey to empirically test structural model hypotheses, while Phase 2 involved qualitative semi-structured Key Informant Interviews (KIIs) with 25 experts and community leaders to provide narrative depth and triangulate structural relationships.

The study was conducted across all seven states of North-Western Nigeria: Kano, Kaduna, Katsina, Kebbi, Jigawa, Sokoto, and Zamfara. According to the National Bureau of Statistics (NBS) and National Population Commission (NPC) projected data frames used for EFInA A2F Surveys, the total adult population (aged 18 years and above) across the zone is 32,588,111.

The target population explicitly comprised both banked adults (formal account holders) and unbanked/underbanked individuals who operate primarily within informal financial networks (Adashe and Asusu). Including both banked and unbanked populations across urban, semi-urban, and deep rural agrarian settlements was essential to capture the complete lifecycle of digital banking adoption, non-adoption drivers, and cash reversion behaviors.

A multi-stage sampling procedure was implemented for Phase 1 quantitative data collection:

i. Stage 1 (State Stratification): The study area was divided into seven distinct strata corresponding to all states in North-Western Nigeria. Sample targets were allocated proportionally using Bowley's (1926) model.
ii. Stage 2 (LGA Clustering): Within each state, two Local Government Areas (LGAs) were selected: one urban/semi-urban commercial center and one deeply agrarian/rural LGA, capturing the contrasting realities of digital infrastructure and agent density.
iii. Stage 3(Community, Market, and Kiosk Intercepts): To ensure comprehensive representation across the entire target population and eliminate selection bias, field enumerators conducted intercepts across diverse operational touchpoints, including Point-of-Sale (POS) agent kiosks, weekly agricultural markets, village square gatherings, and informal cooperative meetings (*Adashe* hubs). This multi-touchpoint technique ensured that active digital channel users, passive wallet holders, cash-reverting traders, and unbanked rural residents were all systematically captured.

As detailed in Table 1b, this multi-stage sampling technique achieved complete coverage across the entire retained sample size (N = 459), capturing active digital banking users (70.2%, n = 322), non-digital cash-reverting users (16.3%, n = 75), inactive/borderline wallet holders (8.7%, n = 40), and unbanked non-account holders (4.8%, n = 22). Synthesising these non-adopter and passive-user segments alongside active adopters across all seven North-Western states established a robust empirical baseline for evaluating digital accessibility barriers, cash retention mechanisms, and channel reversion decisions, closely aligning with EFInA's (2026) regional benchmark of 37.3% formal financial exclusion in the North-West

Sample Size Determination and Statistical Power Analysis

Sample size determination was executed through a rigorous three-step protocol:

i. Cochran Baseline Calculation: Using Cochran's (1977) formula for large or infinite populations (N > 10,000): $n_0 = \frac{Z^2pq}{e^2}$ $= n_0 = \frac{(1.96)^2(0.5)(0.5)}{(0.05)^2} = 384.16 = 384$

   Where Z = 1.96 (95% confidence level), p = 0.5 (maximum variability), and e = 0.05(5% margin of error).
ii. PLS-SEM Expansion & Buffer Justification: Methodological standards for Partial Least Squares Structural Equation Modeling (PLS-SEM) recommend expanding sample sizes beyond baseline survey formulas to optimize parameter estimation, accommodate structural model complexity, and guarantee parameter stability (Hair et al., 2019, 2021). The target sample was expanded to 500 questionnaires, providing an approximate 30% buffer (116 additional forms) against non-response, incomplete submissions, and field attrition across remote agrarian LGAs.

iii. Formal Statistical Power Assessment: A prospective G*Power 3.1 analysis for multiple regression/PLS-SEM structural evaluation with 4 main predictors (α = 0.05, medium effect size $f^2 = 0.15$, power $1 - \beta = 0.95$) indicated a minimum required sample size of N = 129. Our retained sample of N = 459 valid questionnaires yields a statistical power exceeding 0.99, confirming the study is robustly powered.

Proportional Sample Allocation and Retrieval Rates

Out of 500 administered questionnaires, 489 were retrieved (97.8% retrieval rate). Following data cleaning and missing data screening, 30 corrupted or unengaged responses were discarded, leaving 459 valid questionnaires for empirical analysis (91.8% effective response rate relative to administered sample; 119.5% relative to the Cochran baseline).

Table 1 presents the population frame, Bowley's proportional sample allocation, and the verified valid response breakdown across all seven states. Table 1b presents respondents banked and digital adoption status.

Table 1a:

Population Frame, Proportional Sample Allocation, and Verified Responses

State	NBS Projected Adult Population	Bowley Proportional Sample (N = 500)	Retrieved & Valid Responses (n = 459)	Percentage of Valid Sample (%)
Kano	10,506,148	161	153	33.3%
Kaduna	4,951,420	76	69	15.0%
Katsina	4,328,110	66	61	13.3%
Jigawa	3,496,898	54	49	10.7%
Sokoto	3,444,000	53	45	9.8%
Kebbi	3,072,925	47	43	9.4%
Zamfara	2,788,610	43	39	8.5%
Total Northwest	32,588,111	500	459	100.0%

Source: Field Survey, 2026.

Table 1b:

Distribution of Respondents by Banked & Digital Adoption Status (N = 459)

Respondent Category	Adoption Profile & Characteristics	Adoption Profile & Characteristics	Adoption Profile & Characteristics
Unbanked Non-Account Holders	Completely unbanked; rely solely on cash and informal Adashe networks	22	4.8%
Inactive / Borderline Wallet Holders	Hold a formal account/wallet but execute< 1 transaction per month	40	8.7%
Non-Digital Cash-Reverting Users	Account owners who deliberately revert to cash due to network downtime & CICO stock-outs	75	16.3%

Active Digital Banking Users	Perform regular transactions via USSD shortcodes, POS kiosks, or mobile apps	322	70.2%
Total Retained Sample	Valid survey responses across all 7 North-Western states	459	100.0%

Source: Field Survey, 2026.

Data Collection Instruments and Administration

Data collection employed a dual-instrument strategy tailored for mixed-methods execution.

i. Quantitative Instrument: Phase 1 quantitative data were collected using the standardizedQuestionnaire. To overcome severe geographical and logistical barriers in remote rural LGAs, the instrument was integrated into the KoboCollect mobile application. This enabled field enumerator to conduct both online and offline data entry with background GPS spatial tracking, automatically synchronizing responses to a secure cloud server upon establishing internet connectivity. All latent construct items were scored on a standardized 5-point Likert scale (1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree), generating the continuous variance required for matrix calculation in PLS-SEM.

ii. Qualitative Instrument (Semi-Structured Interview Guide): Phase 2 qualitative data were gathered using a targeted Semi-Structured Interview Guide administered to 25 Key Informants purposefully selected across all seven states (including financial sector regulatoryofficers, commercial bank and FinTech operations managers, POS super-agents, and rural agricultural cooperative leaders). Interviews explored ground-level socio-technical frictions, CICO liquidity bottlenecks, and cash reversion behaviors.

Analytical Techniques and Model Estimation

Quantitative and qualitative datasets were processed using specialized software applications.

i. Quantitative Analysis (PLS-SEM in SmartPLS 4): Quantitative survey data (N = 459) were analyzed using Partial Least Squares Structural Equation Modelling (PLS-SEM) in SmartPLS 4. PLS-SEM was chosen over Covariance-Based SEM (CB-SEM) due to its superior capacity to handle complex structural models with multiple latent predictors, non-normal primary survey distributions, and interaction/moderation effects without distributional inflation (Hair et al., 2019, 2022). Evaluation proceeded through a two-stage process: (i) Measurement model evaluation (assessing indicator loadings, Cronbach's Alpha, Composite Reliability, Average Variance Extracted, and Heterotrait-Monotrait [HTMT] discriminant validity); (ii) Structural inner model estimation using a non-parametric bootstrapping routine with 5,000 resamples to derive standardized path coefficients(β), t-statistics, p-values, and overall model explanatory power (R^2).

ii. Qualitative Analysis (Thematic Coding in NVivo 14): Qualitative interview transcripts were imported into NVivo 14 software and analyzed following Braun and Clarke's (2006) six-phase thematic framework. Open coding generated an 8-parent-theme and 16-child-node hierarchy comprising 287 individual coded references across 25 transcripts, capturing the qualitative nuances of network downtime, agent liquidity stock-outs, and third-party assistance reliance.

iii. Data Integration and Triangulation: In accordance with explanatory sequential design protocols (Creswell & Plano Clark, 2018), quantitative PLS-SEM path findings and qualitative NVivo 14 thematic outputs were merged at the interpretation stage via a Convergence Triangulation Matrix. Qualitative narrative themes were deployed to explain the micro-level human mechanisms driving each statistical path coefficient.

4.0 Data Analysis, Results, and Discussion

Demographic Profile of Respondents

The demographic distribution of the 459 valid respondents shows a positive geographical representation: 38.8% lived in semi-urban, 34.6% in urban, and 26.6% in rural towns. Males were 75.4% (n=346) and females 24.6% (n=113), aligning with socio-economic market survey patterns in Northern Nigeria. The sample was economically active, with 85.2% aged between 18 and 45 years (37.9% aged between 26 and 35 years). Traders and small business owners were the majority of the respondents, accounting for 50.1% (n=230), followed by public/private sector workers (20.0%), artisans (11.8%), and farmers (11.5%). Educational attainment was substantial, with 57.0% having tertiary qualifications and 37.3% having secondary/primary education, indicating excellent capacity among respondents to analyze digital banking services accessibility constructs.

Descriptive Statistics for Accessibility (ACC)

Table 2 outlines the descriptive metrics for items measuring digital banking services accessibility. All items were evaluated on a 5-point Likert scale. The standard deviations for all indicators were less than 1.0, indicating tight clustering of data around the mean. The grand composite mean for accessibility was 3.8905 (SD = 0.67623), confirming a strong positive consensus regarding the physical and operational availability of digital financial channels in the region.

Table 2:
Descriptive Statistics for Accessibility of Digital Banking Services (ACC)

Code	Measurement Item	SD	D	N	A	SA	Mean	Std.Dev
ACC1	Active performance of financial transactions via USSD, Apps, or POS	17	22	63	274	83	3.8366	0.90456
ACC4	Digital banking channels are functional whenever needed to execute transfers.	11	10	36	309	93	4.0087	0.76490
ACC5	Distance to the nearest POS agent or ATM does not hinder financial transactions.	10	22	55	309	63	3.8562	0.79093
ACC6	Platforms remain operational and accessible during peak transaction periods.	9	35	48	286	81	3.8606	0.86296
Composite	Overall Accessibility Construct Benchmark	-	-	-	-	-	3.8905	0.67623

Source: SPSS V.23 Output, 2026.

Measurement Model Assessment (PLS-SEM)

Measurement model evaluation in SmartPLS 4 assessed construct reliability, convergent validity, and discriminant validity for the focal constructs. As presented in Table 3, both Accessibility (ACC) and Financial Inclusion (FI) demonstrated high internal consistency and reliability, exceeding the established benchmarks of 0.70 for Cronbach's Alpha,ρ_A and Composite Reliability (CR), while Average Variance Extracted (AVE) values surpassed the 0.50 threshold (Hair et al., 2019, 2022).

Table 3:
Construct Reliability and Convergent Validity (PLS-SEM Measurement Model)

Construct	Cronbach's Alpha	rho_A	Composite Reliability (CR)	Average Variance Extracted (AVR)	Staus
Accessibility (ACC)	0.888	0.888	0.923	0.749	**Established (> 0.50)**
Financial Inclusion (FI)	0.892	0.895	0.925	0.732	**Established (> 0.50)**

Source: SmartPLS 4 Output (2026). All constructs exceed 0.70 CR and 0.50 AVE benchmarks.

Discriminant validity was rigorously evaluated using the Heterotrait-Monotrait Ratio (HTMT) of correlations (Henseler et al., 2015). As presented in Table 4, all HTMT values fall well below the conservative 0.85 threshold, confirming that thetwo latent constructs are conceptually and empirically distinct.

Discriminant validity was evaluated using the Heterotrait-Monotrait Ratio (HTMT) of correlations (Henseler et al., 2015). As presented in Table 4, the HTMT value between Accessibility and Financial Inclusion (0.428) falls well below the conservative 0.85 threshold, confirming that the constructs are empirically distinct.

Table 4:
Heterotrait-Monotrait Ratio (HTMT) Discriminant Validity Matrix

Construct	Accessibility (ACC)	Financial Inclusion (FI)
Accessibility (ACC)	—	
Financial Inclusion (FI)	0.428	—

Note: HTMT ratio is below the conservative 0.85 benchmark, confirming discriminant validity.

Structural Path Estimation and Hypothesis Testing

Following measurement model validation, structural path estimation was executed using bootstrapping with 5,000 resamples in SmartPLS. Table 5 presents the empirical test results for the focal hypothesis, H_{01}: Accessibility → Financial Inclusion.

Table 5:
PLS-SEM Structural Path Coefficient and Hypothesis Testing Result

Hypothesised Path	Path Coeff	Sample Mean (M)	T- Statistic	p-Value	Empirical Decision
H_{01}: Accessibility →Financial Inclusion	0.231	0.234	3.850	$p < 0.001$	**Rejected (Statistically Significant)**
Model (Financial Inclusion)	$R^2$0.775	0.778	Substantial Explanatory power	---	**---**

Note: Bootstrapping = 5,000 resamples. Standardized path coefficient β represents standard deviation change.

Detailed Empirical Evaluation of Focal Hypothesis (H_{01}):

For the primary hypothesis, H_{01}: Accessibility → Financial Inclusion, the standardized structural path coefficient was positive and statistically significant (β = 0.231, t = 3.850, p < 0.001), contributing to the

model's explanatory power of $R^2 = 0.775$. Because the p-value is well below the 0.05 alpha benchmark, the null hypothesis H_{01} is firmly rejected.

In standardized terms, a 1-standard-deviation increase in digital banking accessibility yields a 0.231-standard-deviation increase in multidimensional financial inclusion among rural agrarian households in North-Western Nigeria.

Discussion and Triangulation of Findings

To unravel the human mechanisms underlying the H_{01} structural path coefficient ($\beta = 0.231$, $p < 0.001$), quantitative PLS-SEM path results were triangulated with qualitative thematic narratives from 25 Key Informant Interviews (KIIs) analysed in NVivo 14.

Qualitative triangulation confirms that last-mile POS agent kiosks have successfully dismantled geographic barriers in rural LGAs, replacing distant commercial bank branches as the primary vehicle for deposit and withdrawal services. This physical convenience advantage mirrors the findings of Okoye et al. (2018), who established that electronic channels significantly enhance transaction speed and user satisfaction.

However, qualitative thematic coding highlighted a critical operational bottleneck: severe mobile network downtime and agent cash-in/cash-out (CICO) liquidity stock-outs routinely neutralize physical agent proximity. When network signals drop during peak agricultural market days or POS agents exhaust cash floats, the proximity advantage collapses, driving immediate reversion to cash holdings and informal *Adashe* schemes. This behavioral reversion is empirically corroborated by Udo et al. (2023), who demonstrated that short-run payment failures force users to maintain high cash balances.

Furthermore, this friction directly reflects payment ecosystem 'rough edges' (Okoh et al., 2025a, 2025b) and electronic delivery risk exposures (Adeagbo et al., 2024), while Omongbale (2025a, 2025b) stresses that digital platform stability is essential for consumer retention.

"In some of our communities, you may not find a single bank branch close by. In these communities, POS agents serve as the bank. When the USSD network signal is stable, trade flows effortlessly. But when network downtime occurs, everything collapses back to physical cash."— Participant 04 (Community Leader, Kebbi State)

These triangulated results strongly validate Financial Intermediation Theory (Diamond, 1984; Gurley & Shaw, 1960; Omongbale & Okoh, 2026), proving that agent banking networks function as effective decentralized intermediaries that eliminate geographic search costs.

The path coefficient ($\beta = 0.231$, $p < 0.001$) provides precise micro-level behavioral evidence supporting the macro-level findings of EFInA (2026), which linked the rise in formal inclusion in the Northwest (to 62.7%) with agent banking expansion. This result is consistent with the empirical work of Suri and Jack (2016) on M-Pesa in Kenya, Aruwa et al. (2025) in Nigeria, and Chand (2026) in emerging markets.

Conversely, this finding contrasts with Ibrahim and Ndaglasi (2019), who argued that static channel access alone fails to drive financial inclusion in Northern Nigeria due to low literacy levels. Our triangulated evidence demonstrates that human POS agents serve as a vital assisted bridge that neutralises initial literacy barriers, provided channel uptime and CICO liquidity are maintained

Furthermore, as emphasized by Uzuh et al. (2025), Okoh et al. (2021), and Okoh et al. (2026), ensuring uninterrupted channel uptime and liquidity support is vital to guarantee that last-mile digital access

translates into long-term enterprise sustainability, micro-capital accumulation, and poverty reduction among rural agricultural smallholders.

5.0 Conclusion and Recommendations

This study concludes that digital banking services accessibility, manifested through last-mile POS agent kiosks, mobile network reach, and USSD availability, is an indispensable, statistically significant driver of grassroots financial inclusion in the agrarian economy of North-Western Nigeria (β = 0.231, t = 3.850, p < 0.001).

By decentralising banking services directly into rural market clusters, agency networks have successfully overcome the historical spatial limitations of traditional commercial bank branches, thereby directly resolving the market failures identified in Financial Intermediation Theory.

However, the study further concludes that physical agent density alone is insufficient; that is to say, channel accessibility is highly perishable and collapses immediately when confronted by telecommunication network downtimes or agent liquidity stock-outs. True accessibility therefore constitutes a dynamic, operationally stable ecosystem in which physical touchpoints, digital network uptime, and cash-in/cash-out (CICO) liquidity continuously sustain one another, a conclusion strongly reinforced by empirical evidence on payment ecosystem 'rough edges' (Okoh et al., 2025a, 2025b), short-run payment channel disruptions (Udo et al., 2023), and enterprise economic sustainability (Okoh et al., 2026).

Practical and Managerial Implications

The results for commercial deposit money banks and FinTech super-agents (Moniepoint, OPay, PalmPay) indicate that expanding agent kiosks into rural agrarian clusters drives significant retail deposit growth. However, managers must transition from static agent onboarding to proactive liquidity management. FinTech operations teams should employ predictive data analytics to forecast high-volume transaction days during peak agricultural market cycles, ensuring rural agents receive timely cash float rebalancing to prevent the short-run cash reversions highlighted by Udo et al. (2023) and ease capital constraints identified by Okoh et al. (2021). Furthermore, enhancing USSD session stability in rural LGAs safeguards transaction processing revenues for telecom operators while simultaneously elevating user convenience (Okoye et al., 2018) and mitigating the electronic delivery risk exposures documented by Adeagbo et al. (2024).

Policy Recommendations

The following three focused recommendations are given to apex regulators and policymakers based on the empirical findings:

i. Power & Infrastructure: Shared Off-Grid Infrastructure and Super-Agent Kiosks. To directly resolve the qualitative finding on severe telecom network downtime and USSD signal dropouts during peak market cycles (NVivo Node TUA_NDS, 51 coded references), which periodically neutralises physical channel accessibility (β = 0.231), the Central Bank of Nigeria (CBN), SANEF, and the Nigerian Communications Commission (NCC) should establish a joint infrastructure intervention framework. This framework should fund and deploy off-grid solar-powered telecommunications masts and shared super-agent kiosks across deep rural agricultural LGAs in North-Western Nigeria. Co-locating agent banking hardware with reliable solar power infrastructure eliminates rural network signal outages during peak trading hours, directly resolving critical technological infrastructure deficits and payment ecosystem 'rough edges' documented in recent empirical literature (Okoh et al., 2025a, 2025b).

ii. Liquidity Management Infrastructure. Automated Rebalancing and Micro-Liquidity Lines. To address the qualitative evidence showing that rural POS agents regularly experience cash-

in/cash-out (CICO) cash float exhaustion during weekly agricultural market hours (NVivo Node TUA_PAD, 42 coded references), which forces daily traders to revert to cash holdings and informal Adashe schemes (Udo et al., 2023), the Central Bank of Nigeria (CBN) should mandate Deposit Money Banks (DMBs) and Mobile Money Operators (MMOs) to establish automated liquidity rebalancing networks. Establishing localized liquidity distribution hubs supported by automated micro-liquidity lines for rural POS agents guarantees continuous cash float availability during peak harvest and trading seasons, preventing agent stock-outs and sustaining grassroots digital engagement (Okoh et al., 2021; Udo et al., 2023; Okoh et al., 2026).

iii. Institutional and Regulatory Framework: QoS Regimes, Interoperability, and Consumer Protection. To mitigate electronic delivery risk exposures and failed-debit anxieties that erode institutional trust among rural dwellers (Adeagbo et al., 2024), the Central Bank of Nigeria (CBN) and the Nigerian Communications Commission (NCC) should enforce strict Quality-of-Service (QoS) Service Level Agreements (SLAs) across digital payment rails. Regulatory directives should institutionalize automated financial penalties for Mobile Network Operators (MNOs) in cases of unexcused USSD session dropouts and mandate automated 24-hour auto-reversal protocols for failed electronic debits. Furthermore, requiring frictionless cross-network interoperability eliminates technological lag between bank and FinTech platforms, ensuring that operational risk exposures are controlled (Adeagbo et al., 2024; Okoye et al., 2018; Omongbale & Okoh, 2026) and that last-mile digital access translates into enterprise sustainability and grassroots poverty reduction (Uzuh et al., 2025; Okoh et al., 2026).

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