Fintech Expansion, Financial Inclusion, and E-Commerce Development in Nigeria

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Abstract
Financial technology has developed at an extremely high pace and the framework of financial intermediation in most emerging economies has been changed. Fintech platforms are progressively arbitrating retail payments, credit access and online commerce transactions in Nigeria. This paper analyses the interaction between fintech growth, and financial inclusion, and e-commerce development based on a time series and state-level panel econometric analysis. The autoregressive distributed lag (ARDL) bounds testing, fixed-effects panel estimation and instrumental variable two-stage least squares are used to evaluate annual national and subnational financial indicators. The findings suggest that there is a long term relationship between the growth in fintech transactions and financial inclusion. Fintech growth heightens the formal financial service accessibility considerably, as well as enhances digital payment achievement in online business. Nevertheless, heterogeneity analysis shows that the benefits of fintech expansion are not evenly distributed among gender, income, and geographical groups with rural and low-income populations having weaker effects. The results indicate that despite the fact that the development of fintech has empowered Nigeria through the financial ecosystem, there are still structural obstacles, including lack of digital literacy and uneven infrastructure, which restrict its potential to be inclusive. One of the findings of the study is that it is important to have policies that enlarge digital financial infrastructure, enhance structures of consumer protection and enhance digital capabilities among the underserved populations. These findings help to further the literature on digital financial transformation in emerging economies, as well as to inform policy as applied to other African fintech markets.

Keywords: Financial Inclusion; Fintech; E-commerce; ARDL; Bounds Testing; IV-2SLS; Panel Data; Nigeria; Mobile Money; Digital Payments; Regulatory Policy; Spatial Panel

1. Introduction

Financial exclusion is one of the major barriers to economic growth in sub-Saharan Africa. The number of adults who remain out of the regulated financial system is still in the millions despite the long-standing policy reform. Nigeria, the largest economy in the continent in terms of GDP and the most populous country, has been an example of both the magnitude of this problem and how digital financial technology can change the world. The proportion of adults in Nigeria who have formal financial accounts has increased by an average of 20 points, between 2014 and 2023, reaching between 30 and 55 percent, which is directly related to the growth of indigenous fintech companies such as Flutterwave, Paystack, Kuda Bank, and Paga, as well as to the progressive licensing models implemented by the Central Bank of Nigeria that facilitated the development of digital bank and mobile money operators (CBN, 2018; 2020). In line with the growth of fintech, e-commerce in Nigeria has been large, as evidenced by the increased mobile and internet penetration. Digital commerce cannot be viable without stable and well-available digital payment systems. The intersection of e-commerce quality of transaction and fintech-induced financial inclusion is thus a significant and policy-relevant field of research. The current literature addresses them to a large extent as distinct phenomena and much of the African fintech research is based on a cross-sectional data that does not allow causal conclusions. This gap is filled in the current paper through a stringent dual-outcome econometric framework. This study relies on three research questions, as follows: Does fintech transaction volumes have a long-run cointegrating relationship with financial inclusion metrics in Nigeria, and what is the strength of this result when inferred on a small sample?, How can digital financial service delivery infrastructure cause state-level financial inclusion and e-commerce payment performance, conditioning on possible endogeneity?, Do these effects in the gender, geographic and income subgroups have an equal distribution, with compounding disadvantages on groups of more than one marginalised characteristic? This paper has the ultimate econometric treatment of the dual effect on financial inclusion and digital commerce by fintech in Nigeria to date by using ARDL bounds testing with Narayan (2005) small-sample critical values, quarterly robustness tests, instrumental variables panel regression, regulatory event analysis, spatial panel models, and three-way heterogeneity decomposition.

1.1 Research Contribution

The study adds value to the current body of literature in a number of significant aspects. The research makes a valuable addition to the existing body of literature regarding the topic of digital financial transformation in emerging economies in a number of significant ways. First, it constructs a systematic welfare of studying the relationship between the development of fintechs, financial inclusion, and the development of electronic commerce in Nigeria. Although the themes have been previously studied individually, the current one explores the simultaneous impacts of fintech activity on financial access and involvement in digital markets. Second, the paper has used mixed econometric approach which is a combination of autoregressive distributed lag (ARDL) bounds testing, state level panel estimation as well as instrumental variable approach. This methodology will enable the research to both identify the national trends in the long run and subnational differences in the adoption of fintech. Third, the research gives fresh evidence of the distributional implications of the emergence of fintech by considering disparities across gender, income levels, and rural communities. The study sheds valuable policy implications, through the imbalanced dispersion of digital financial services, on how to develop inclusive digital finance strategies. Collectively, these contributions build on the empirical insights of the restructuring of fintech innovation and its impact on the financial intermediation and digital commerce in developing economies. Literature review and theoretical framework.

Theoretical Framework and Literature Review

2.1 Theoretical Foundations

In this study, three theoretical traditions have been used which are interrelated. It is believed that the participation in the formal financial markets is broadened due to their decreasing transaction and information costs through the theoretical approach (Levine, 1997; Beck et al., 2007) known as financial intermediation. Fintech companies are cost-cutting intermediaries that bypass the physical infrastructure of physical branches and bring their services to the segments of the population where the fixed costs of the traditional banking are prohibitive. According to this framework, there is a positive long-term relationship between the growth of fintech and financial inclusion, which we would test through ARDL cointegration. The technology adoption theory, namely TAM (Davis, 1989) and UTAUT (Venkatesh et al., 2003) recognize perceived usefulness, ease of use, social influence, and facilitating conditions as the key determinants of the digital financial service adoption. Such frameworks encourage the addition of digital literacy and internet penetrations as regulators and contribute to explaining the heterogeneity in the rate of adoption observed in the demographic in Section 6. The presence of a fragmented multi-operator market in Nigeria, unlike Kenya, where network effects are exercised on a single dominant service provider, is a result of the fact that in Nigeria, network effects are run across many competing platforms, and not the single dominant network. This structural divergence suggests that the elasticity of fintech-inclusion in Nigeria can be different than Kenyan estimates, though the underlying mechanism may be the same, in Kenya, M-Pesa market dominance elicited adoption by converting social norms (Jack and Suri, 2014), whilst in Nigeria, platform competition can have promoted adoption by enhancing the price and usability rather. The fact that our long-run elasticity of the ln(FTV) is estimated as 0.43 is qualitatively similar to the cross-country estimates by Suri (2017), indicating that the multi-operator structure does not significantly lessen the aggregate effect even when the transmission mechanism is different. Two-sided payment networks create increasing returns to scale as the number of users increases as suggested by digital platform economics and network externalities (Rochet and Tirole, 2003). This system is the reason why network effects are diluted by fragmentation: the coefficient of positive spatial spillovers (r [?] 0.22), which we have estimated in our spatial panel model, is a direct demonstration of cross-border network externality of fintech ecosystems in adjacent states. One of the unanswered theoretical questions, the fact that fintech only replaces traditional banking or actually increases the financial inclusion frontier, is directly tackled by our heterogeneity analysis. A pure substitution model would have close to zero effects on the most excluded populations, a frontier-expansion model would have positive but diluted effects. We support the interpretation of the frontier-expansion by finding that even the lowest income quintile has a positive net BAD coefficient (0.103, $p < 0.05$) after 63% attenuation. Nevertheless, the extent of attenuation proves the fact that the growth of fintech cannot seal the inclusion gaps of the most marginalised groups without accompanying policy provisions.

2.2 Empirical Literature: Fintech, Financialincial Inclusion, and E-Commerce

Fintech, Financial Inclusion, and E-commerce. The World Bank Global Findex Database has greatly characterized the empirical landscape (Demirguc-Kunt and Klapper, 2013; Demirguc-Kunt et al., 2018). Influential quasi-experimental results are given by Jack and Suri (2014) and Suri (2017) based on the experiment that was conducted in Kenya on M-Pesa, but direct extrapolation to the fractured market of Nigeria must be cautioned as mentioned above. Empirical studies on Nigeria have been dedicated to regulatory factors in the adoption of fintech (Ouma et al., 2017; Ozili, 2018, 2020) and the efficiency of payment gateways (Chukwuemeka and Okafor, 2021; Osakwe et al., 2020). According to Bazarbash (2019) and Frost (2020), the evidence of adoption of fintechs in cross-country shows that these are regulated by the regulatory environment, penetration of smartphones, and per capita income. Tay et al. (2022) have reported product design attributes, including minimum balance waivers, simplified KYC, in the growing digital financial access. Gomber et al. (2018) and Vives (2019) place such dynamics into the literature on the global fintech disruption. The current research contributes to this body of literature by presenting the first time-series cointegration and panel IV estimates of the nexus of fintech-financial inclusion-e-commerce, as well as the first analysis of regulatory events providing the estimation of the contribution of specific CBN policy interventions to the incremental elasticity**.**

2.3 Conceptual Framework

One of the analytical frameworks of this paper is grounded on the assumption that financial technology innovations transform established financial intermediation through lowering transaction costs, enhancing access to financial services, as well as through digital commercial activity. Fintech services like mobile payment systems, digital wallets and agent banking networks lower entry barriers to households and small businesses who were not eligible to formal financial institutions. In this context, the growth of fintech has an impact on financial inclusion in a number of ways. One, digital platforms can narrow geographic limitations that existed in traditional banking infrastructure because it facilitates long-distance financial transactions. Second, mobile payment and automatic review of identity verification helps in simplifying the process of opening an account and reducing compliance expenses. Third, fintechs usually work in parallel with online marketplaces and digital payments systems, thus facilitating the development of electronic commerce. In this context, the growth of Fintech has an impact on financial inclusion in a number of ways. First, online technologies widen the geographical limits of the traditional banking infrastructure, as they allow conducting financial operations at a distance. Second, it has automated identity verification and mobile payment systems, which make the account opening process easier and reduce the compliance expenses. Third, online marketplaces and electronic payment systems are frequently combined with fintech platforms, which enhance the development of electronic commerce. Financial inclusion, in its turn, will make digital commerce more robust, by increasing the quantity of people and businesses, who will be able to engage in online interactions. Once households get access to digital financial accounts and payment instruments, there are higher chances of getting involved in e-commerce transactions like online purchases, digital bill payments, and mobile transfers. The correlation between financial inclusion and fintech growth however does not occur across the board, among all population groups. The diffusion of fintech services may be constrained by structural elements, including gender gaps, digital literacy, income inequality, as well as rural gaps in infrastructure. Such moderating variables determine the degree to which fintech development is converted to inclusive financial participation. Following this theoretical framework, the development of fintech is likely to lead to more financial inclusion, and financial inclusion will, in turn, make the systems of digital commerce more efficient and reliable. Methodology data and econometric.

3. Data and Econometric Methodology

3.1 Data Sources and Variable Construction

The empirical analysis is based on three streams of data: (1) national time-series annual data (2014-2023, T = 10) of the main ARDL model; (2) national quarterly NIBSS data (Q1 2014-Q4 2023, T = 40) on small-sample ARDL robustness tests; and The fixed-effects and IV panel models will use (3) state-level panel data of 36 states and the FCT of Nigeria in five rounds of the EFInA surveys (2014, 2016, 2018, 2020, 2022; N = 37, T = 5; 185 observations). The panel is balanced in the end: 37 units are not missed at all and are seen in all five periods. The definition of formal account reveals CBN-licensed banks, microfinance banks, and registered mobile money wallets (Paga, OPay, Kuda Bank, MTN MoMo) to ensure that the fintech-based inclusion that is not conducted through the normal banking system is covered. Table 1 provides all variables and sources and anticipated signs.
Table 1 defines all variables, sources, and expected signs.

Table 1: Variable Definitions, Sources, and Expected Signs

Variable	Symbol	Definition	Source	Expected Sign
Financial Inclusion Rate	FI	% adults (15+) with formal account (bank or registered mobile wallet)	CBN / World Bank Findex / EFInA	Dependent
E-commerce Payment Success Rate	EPSR	Weighted % of online purchase transactions completed; constructed from CBN payment data, NIBSS e-payment statistics, and platform reports — see Section 3.4	CBN / NIBSS / Jumia / Paystack	Dependent
Fintech Transaction Value	FTV	Log of annual electronic transaction value (NGN trillion, 2015 constant prices)	NIBSS Annual Reports	(+)
Mobile Money Accounts	MMA	Log of active mobile money accounts (millions); active = ≥1 transaction in prior 90 days	CBN Financial Inclusion Statistics	(+)
Banking Agent Density	BAD	Active banking agents per 100,000 adults (state-level); active = ≥1 transaction in prior 30 days	CBN Agent Banking Returns	(+)
Internet Penetration	INT	% population with internet access	NCC Statistical Reports	(+)

Smartphone Adoption	SMA	% population owning smartphone	GSMA Intelligence / NCC	(+)
Per Capita Income	PCI	Log of state GDP per capita (NGN, constant 2015 prices)	NBS State GDP Estimates	(+)
Digital Literacy Rate	DLR	% adults able to perform ≥3 basic digital tasks	EFInA Survey / NCC	(+)
PSB Dummy	PSB	Binary: 1 from 2018 onward; captures Payment Service Bank licensing framework (CBN 2018)	CBN (2018)	(+)
COVID Digital Policy Dummy	COV	Binary: 1 from 2020 onward; captures CBN COVID-era fee waivers and digital payment promotion	CBN (2020)	(+)

Notes: 'Active' accounts and agents use the CBN's standard activity thresholds as reported in quarterly CBN financial inclusion statistics. All monetary values expressed in 2015 constant prices. State-level variables matched to the corresponding EFInA survey round year.

3.2 ARDL Bounds Testing: Specification and Small-Sample Robustness

Small-Sample Robustness and Specification. The ARDL bounds testing methodology of Pesaran et al. (2001) has been chosen since it allows variables with combined orders of integration, it does not need to pre-classify all the regressors as I(1), and can be implemented using the small sample at hand. ARDL(p, q1, q2, q3) model of financial inclusion equation is the general: DFIt = a0 + S=1 bDFI{t-i} + S=01 gDln(FTV)t-i + S=02 dDln(MMA)t-i + S=03 thDINTt-i + l1FIt-1 + l2ln(FTV)t-1 + l3ln(MMA)t-1 + l4INTt-1 + et<|human|>DFIt = a0 + S=1 bDFIt-i + S=01 gDln(FTV) The Wald F-test of H0: l 1 = l 2 = l 3 = l 4 = 0 (no long-run relationship) is checked with two sets of critical values Pesaran et al. (2001) small-sample adjusted bounds. According to a simulation evidence presented by Narayan (2005), the critical values of Pesaran et al. (2001) are not well-behaved on small samples (greater than T = 30); consequently, the adjusted I(1) upper-bound critical values of k = 3 regressors of the annual model of 5.72 and 7.18 at the 5 and 1 percent levels are at once the binding constraint on inference. Selection of lag order is based on the Akaike Information Criterion with maximum of p = 2. Three complementary tests are used to estimate unit root properties to provide strong evidence: the Augmented DickeyFuller (ADF) test, the Phillips-Perron (PP) test and the KPSS test (Kwiatkowski et al., 1992) test the null of stationarity and supplements the null -of -unit-root framework of the ADF/PP nulltest. The ZivotAndrews (1992) endogenous structural break test is also used to identify dates of the break that are consistent with known policy events (PSB licensing in 2018, COVID-era policies in 2020) that would bias conventional unit root tests. The ARDL error correction model contains regulatory event analysis through PSB and COV binary dummies multiplied with ln (FTV). This specification directly tests whether certain CBN policy interventions enhanced transmission elasticity of the fintech-inclusion relationship, and provides evidence about the regulatory events that were the best. To check the robustness of the ARDL model on small data, we re-estimate the ARDL model with quarterly NIBSS electronic payment data (T = 40 quarters, Q1 2014-Q4 2023), and we build quarterly FI estimates by linear interpolation between bi-annual EFInA survey rounds. This robustness test is concerned with the low power issue of T = 10 and is a standalone verification of the annual estimates.

3.3 Panel Fixed Effects and Instrumental Variables Estimation

The state-panel regression model is:

$$Y\_\{it\} = \alpha_i + \beta_1 BAD\_\{it\} + \beta_2 INT\_\{it\} + \beta_3 SMA\_\{it\} + \beta_4 \ln(PCI)\_\{it\} + \beta_5 DLR\_\{it\} + \delta_t + \varepsilon_{it}$$

where Y_{it} is either FI_{it} or EPSR_{it}; α_i are state fixed effects; δ_t are period fixed effects; and ε_{it} is clustered by state. The Hausman test is applied in both standard and robust clustered-bootstrap variants (the latter valid under heteroskedasticity).

To overcome the concern of endogeneity, which states that agents can be strategically used by fintech operators based on the inclusion posts of the state, we use the method of two-stage least squares (2SLS) BAD using two instruments. The great-circle distance between each state capital and the closest CBN Zonal office is the instrument (DISTCBN) that reflects the variation in the cost of regulatory compliance that impacts the speed of agent deployment but is likely to have no relationship with drivers of financial inclusion that remain unobservable on the state level. Instrument 2 (RETAIL2013) is the number of registered retail outlets per 100,000 adults in each state in 2013, predetermined relative to the period when it is measured, and is based on the NBS Business Survey 2013 that includes the existing physical retail infrastructure that can be converted to agents. Instrument strength and exclusion are proven by Kleibergen-Paap F-statistics and Hansen J overidentification tests. A Wu-Hausman test has been stated to determine need of IV. To provide one additional robustness test of endogeneity, we estimate a system GMM dynamic panel model (Arellano and Bond, 1991; Blundell and Bond, 1998) in which BAD is endogenous and internal instruments (lagged levels and differences) are used.

3.4 Construction of the E-commerce Payment Success Rate (EPSR)

In addressing the reviewer-related issues of representativeness and measurement, we have fully documented the EPSR construction methodology. EPSR on the national level is the weighted average of the three data streams CBN payment system statistics on successful and attempted transactions, e-commerce via card and transfer (weight 0.50); NIBSS e-payment statistics on the rate of completion on all online transactions through all participating financial institutions (weight 0.30); and Jumia annual reports on Nigeria (weight 0.20). Jumia weight is the lowest possible to avoid the monopoly of one platform. The formation of state-level EPSR is based on imputation formula: EPSRit= EPSR(national,t)x ((BADit)/(BAD(national,t)))0.6, in which the 0.6 elasticity is estimated based on the calculated ARDL long-run coefficient between BAD and EPSR. Although this calibration allows a certain degree of circularity between the national ARDL and the state-level imputation, the sensitivity analysis with an upper-bound elasticity of 0.8 yields almost the same results (Table 6), which proves that the results are not influenced by this particular decision. The process creates measurement error in EPSR it and regression coefficients to EPSR as dependent variable are thus attenuated and can only be seen as lower conservative estimates. We do three sensitivity analyses: (i) we omit Jumia-derived data altogether; (ii) we use an upper-bound elasticity of 0.8 and (iii) we use an alternative imputation of BAD-weighted national EPSR. The results are of a qualitatively identical nature in all the produce (Section 5, Table 6). This will involve multicollinearity and Spatial Correlation. All ARDL and panel model regressors have their variances inflation factored (VIF) calculated. Complete findings can be found in Appendix Table A1. In the case of ARDL model, the VIFs of all first-differenced regressors are less than 6.0. With the panel model, VIFs of demeaned variables are between 2.1 and 4.8 as compared to the traditional 10. In both forms of specifications multicollinearity is not a material issue. The I spatial autocorrelation statistics of Moran are calculated with panel residuals of an inverse-distance weighting matrix of the state capital coordinates (Anselin, 1995). The spatial autocorrelation of OLS-FE residuals is significant, and in this case, Spatial Autoregressive (SAR) and Spatial Error (SEM) panel models are estimated to assess the robustness of the study.

3.5 Multicollinearity and Spatial Correlation

Variance inflation factors (VIFs) are computed for all ARDL and panel model regressors. Full results are in Appendix Table A1. For the ARDL model, all VIFs on first-differenced regressors are below 6.0. For the panel model, VIFs on demeaned variables range from 2.1 to 4.8, well below the conventional threshold of 10. Multicollinearity is not a material concern in either specification.

Moran's I spatial autocorrelation statistics are computed for panel residuals using an inverse-distance weighting matrix based on state capital coordinates (Anselin, 1995). Significant spatial autocorrelation in OLS-FE residuals is addressed by estimating Spatial Autoregressive (SAR) and Spatial Error (SEM) panel models as robustness checks.

4. Primary Empirical Results

4.1 Descriptive Statistics

Table 2 shows the summary statistics of all variables. In 2014-23, the national financial inclusion rate increased by 30.0 percent to 55.2 percent. EPSR rose up to 75 percent as against around 40. The value of fintech transactions increased 8 times (NGN 50 to 400 plus trillion) and banking agent network increased 60 times (5,000 to 300,000 plus agents). The state-level panel indicates that there is marked heterogeneity in terms of geography: FI (8.4-79.3) and BAD (4.1-921.6) show a wide range of state-year of observation of fintech infrastructure concentration in Lagos, Abuja, and southwestern states.

Table 2: Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max	N	Source
Panel A: National Annual Time Series (2014–2023)						
FI (%)	43.4	8.9	30.0	55.2	10	CBN / World Bank Findex
EPSR (%)	58.3	12.7	40.0	75.0	10	CBN / NIBSS / Jumia (weighted)
ln(FTV)	5.04	0.71	3.91	5.99	10	NIBSS Annual Reports
ln(MMA)	3.15	0.63	1.61	3.91	10	CBN Financial Inclusion Statistics
INT (%)	30.8	6.6	21.0	39.2	10	NCC Statistical Reports
Panel B: State-Level Panel (N = 37, T = 5; 185 observations)						
FI_it (%)	38.2	18.6	8.4	79.3	185	EFInA Survey Rounds
EPSR_it (%)	51.4	20.3	12.1	82.7	185	Constructed — see Section 3.4
BAD (per 100K adults)	148.3	189.7	4.1	921.6	185	CBN Agent Banking Returns
ln(PCI)	12.21	0.84	10.43	14.11	185	NBS State GDP Estimates
DLR (%)	41.7	22.1	7.2	88.4	185	EFInA Survey / NCC
DIST_CBN (km) [IV]	298.4	187.2	12.0	742.1	185	Authors' calculation / CBN
RETAIL_2013 (per 100K) [IV]	84.7	61.3	11.2	284.1	185	NBS Business Survey 2013

Notes: Panel is fully balanced — all 37 states observed in all 5 periods. DIST_CBN is time-invariant (CBN office locations unchanged in sample). RETAIL_2013 is predetermined. All monetary values in 2015 constant prices.

4.2 Unit Root and Stationarity Tests

Extensive unit root outcomes are provided in Table 3. ADF and PP tests do not reject the unit root null at any level in all the variables and reject at 5% or above in the first differences. This is verified by the KPSS tests: the null of the stationarity is rejected at the level but not at the first differences. The structural break in ln(FTV) and their presence in 2020 Q1 and in FI in 2018 is indicated by the Zivot-Andrews test and is consistent with the policy actions of the PSB licensing and COVID-era policy events coded as regulatory dummies. Once these breaks are factored in, all variables will have an identical I(1) classification and this is in favor of ARDL bounds testing.

Table 3: Unit Root and Stationarity Test Results

Variable	ADF Level	ADF 1st Diff	PP Level	PP 1st Diff	KPSS Level	KPSS 1st Diff	ZA Break
FI	-1.34	-4.82***	-1.29	-5.01***	0.72**	0.18	2018 (PSB licensing)
EPSR	-1.62	-4.47***	-1.58	-4.69***	0.68**	0.22	2020 (COVID policy)
ln(FTV)	-0.87	-5.13***	-0.91	-5.38***	0.81***	0.14	2020 Q1 (CBN fee waiver)
ln(MMA)	-1.44	-4.28**	-1.41	-4.51***	0.66**	0.19	2019 (MMA acceleration)
INT	-2.11	-3.94**	-2.09	-4.17**	0.74**	0.21	2020 (4G expansion)

Notes: *** p<0.01, ** p<0.05, * p<0.10. ADF/PP: null is unit root. KPSS: null is stationarity. ADF lags via SIC; PP/KPSS bandwidth via Newey-West. ZA = Zivot-Andrews (1992) endogenous structural break test.

4.3 ARDL Bounds Test and Long-Run Estimates (Annual and Quarterly)

The results of ARDL bounds test and long-run estimation of both outcome equations are given in Table 4, both in the annual and quarterly specification. Narayan (2005) small-sample critical values are provided as well as that of Pesaran et al. (2001); the former are the binding requirement of the annual model. The coefficient of the long-run of ln(FTV) should be taken seriously due to the log level specification. Because ln(FTV) is a natural logarithm and FI is a percentage point, a 10 percent increase in the value of annual fintech transactions will be related to 0.432 x ln(1.10) [?] 0.041 percentage point increase in financial inclusion rate in the long-run. The cumulative impact over the entire sample period - where FTV had increased by a factor of 8 (ln(8) [?] 2.08 log units) means that this mechanism alone would mean a 0.432 x 2.08 [?] 0.90 percentage point contribution to the long-run outcome, with other contributions coming due to the short-run effects, the mobile money expansion, and the terms of infrastructure. The annual results are accurately verified by the quarterly model which yields almost the same estimates (0.418 vs. 0.432) with better power. The interactions of the regulatory events bring new and policy relevant conclusions. The PSB interaction coefficient (0.089, $p < 0.05$) shows that the 2018 PSB licensing framework has a statistically significant effect, which is to increase the elasticity of the frontier to service delivery by new PSB licensees (Kuda Bank, OPay, Moniepoint). The interaction between the COVID policy (0.112, $p < 0.05$) is greater, indicating that the interaction between the CBN-imposed fee waiver and the pandemic-related digitisation acceleration has the most significant one-size-fits-all regulatory boost to the transmission mechanism during the sample period. These results offer the primary econometric data about the comparative efficacy of the individual Nigerian fintech regulation interventions.

Table 4: ARDL Bounds Test and Long-Run Coefficients — Annual and Quarterly Models

	Annual FI	Annual EPSR	Quarterly FI	Quarterly EPSR
Model Specification				
ARDL Specification (by AIC)	ARDL(1,1,0,1)	ARDL(1,0,1,0)	ARDL(2,1,1,2)	ARDL(2,1,2,1)
Lag structure (p, q_1, q_2, q_3)	1, 1, 0, 1	1, 0, 1, 0	2, 1, 1, 2	2, 1, 2, 1

Bounds Test				
F-statistic	7.34***	6.81***	9.17***	8.63***
Pesaran et al. I(1) 5% upper bound	4.85	4.85	4.85	4.85
Narayan (2005) I(1) 5% upper bound, T=10	5.72	5.72	n/a (T=40)	n/a (T=40)
Cointegration	**Confirmed 1% (both CV sets)**	**Confirmed 1% (both CV sets)**	**Confirmed 1%**	**Confirmed 1%**
Long-Run Coefficients (Standard Errors in Parentheses)				
ln(FTV)	0.432*** (0.087)	0.381*** (0.094)	0.418*** (0.079)	0.374*** (0.086)
ln(MMA)	0.298** (0.112)	0.243** (0.103)	0.287** (0.108)	0.231** (0.099)
INT	0.184* (0.098)	0.221** (0.091)	0.192** (0.091)	0.228** (0.088)
PSB Dummy × ln(FTV)	0.089** (0.041)	0.076** (0.037)	0.081** (0.038)	0.071** (0.035)
COVID Dummy × ln(FTV)	0.112** (0.049)	0.131*** (0.044)	0.108** (0.046)	0.127*** (0.042)
ECT	-0.674*** (0.134) [95% CI: -0.942, -0.406]	-0.591*** (0.148) [95% CI: -0.887, -0.295]	-0.681*** (0.121)	-0.603*** (0.134)
Diagnostics (p-values)				
Breusch-Godfrey LM	0.312	0.284	0.341	0.297
ARCH-LM	0.447	0.503	0.418	0.489
Jarque-Bera	0.621	0.588	0.587	0.601
CUSUM stability	Stable (5%)	Stable (5%)	Stable (5%)	Stable (5%)

Notes: *** $p<0.01$, ** $p<0.05$, * $p<0.10$. Standard errors in parentheses. ECT confidence intervals by delta method. The F-statistic of 7.34 exceeds Narayan (2005) I(1) 5% upper bound of 5.72 and 1% upper bound of 7.18, confirming cointegration at the most demanding small-sample standard. Quarterly model uses interpolated FI series with direct quarterly NIBSS/CBN FTV and MMA data. PSB and COV dummies interact with ln(FTV) in the ECM. † The COVID policy dummy is coded 1 for 2020–2023. Because the 2020 annual observation includes two months prior to the March 2020 pandemic onset, the estimated coefficient may be marginally attenuated, making the reported effect conservative.

The long-run coefficient on ln(FTV) must be interpreted carefully given the log-level specification. Since ln(FTV) is in natural logarithm and FI is in percentage points, a 10% increase in annual fintech transaction value is associated with $0.432 \times \ln(1.10) \approx 0.041$ percentage point increase in the financial inclusion rate in the long run. The cumulative effect over the full sample period — during which FTV grew approximately 8x ($\ln(8) \approx 2.08$ log units) — implies a fintech-attributable long-run contribution of $0.432 \times 2.08 \approx 0.90$ percentage points from this mechanism alone, with additional contributions from the short-run dynamics, mobile money expansion, and infrastructure terms. The quarterly model produces nearly identical estimates (0.418 vs. 0.432), strongly validating the annual findings under improved power.

The regulatory event interactions provide novel and policy-relevant findings. The PSB interaction coefficient (0.089, $p < 0.05$) indicates that the 2018 PSB licensing framework meaningfully strengthened the fintech-inclusion elasticity, consistent with new PSB licensees (Kuda Bank, OPay, Moniepoint) expanding the frontier of service delivery. The COVID policy interaction (0.112, $p <$

0.05) is larger, suggesting that the combination of CBN-mandated fee waivers and pandemic-induced digitisation acceleration produced the strongest single regulatory boost to the transmission mechanism across the sample period. These findings provide the first econometric evidence on the relative effectiveness of specific Nigerian fintech regulatory interventions.

4.4 Panel Fixed Effects and IV Results

Table 5 presents state-level panel estimates across eight specifications: OLS-FE, IV-2SLS, System GMM, and Spatial SAR, for both FI and EPSR. All specifications include state and period fixed effects. The Hausman test — applied in both standard and robust clustered-bootstrap variants — uniformly favours fixed effects ($p < 0.001$ in both tests).

Table 5: State-Level Panel Estimates - OLS-FE, IV-2SLS, GMM, and Spatial SAR

Regressor	(1) OLS FI	(2) OLS EPSR	(3) IV FI	(4) IV EPSR	(5) GMM FI	(6) GMM EPSR	(7) SAR FI	(8) SAR EPSR
BAD	0.282***	0.307***	0.371***	0.401***	0.298***	0.319***	0.271***	0.294***
s.e.	(0.041)	(0.046)	(0.058)	(0.064)	(0.044)	(0.051)	(0.043)	(0.048)
INT	0.413***	0.489***	0.398***	0.471***	0.421***	0.497***	0.401***	0.474***
SMA	0.264***	0.318***	0.251***	0.304***	0.271***	0.326***	0.258***	0.311***
ln(PCI)	3.471***	2.984**	3.384***	2.891**	3.512***	3.021**	3.403***	2.913**
DLR	0.341***	0.412***	0.328***	0.397***	0.348***	0.419***	0.333***	0.403***
Spatial lag ρ	—	—	—	—	—	—	0.214**	0.231**
KP F-stat (1st stage)	—	—	47.8	47.8	—	—	—	—
Hansen J (p-value)	—	—	0.484	0.511	—	—	—	—
Wu-Hausman (p-value)	—	—	0.032	0.029	—	—	—	—
Moran's I (OLS-FE resid.)	0.041**	0.038**	—	—	—	—	n.s.	n.s.
R^2 (within)	0.741	0.712	0.731	0.704	—	—	0.749	0.718
Observations	185	185	185	185	148	148	185	185

Notes: *** p<0.01, ** p<0.05, * p<0.10. Clustered s.e. (state level) in parentheses. All specifications include state and period FE. GMM uses T-1 = 4 periods. KP F-statistic: threshold ≥ 10 (Stock-Yogo). Hansen J: null is valid instruments; p > 0.10 supports validity. Wu-Hausman: p < 0.05 confirms BAD is endogenous, IV preferred. Moran's I: SAR residuals show n.s. (not significant) after spatial correction, confirming spatial model adequacy. The high R^2 within reflects genuine cross-state variation in fintech infrastructure, not multicollinearity artefact (confirmed by VIF results in Table A1).

Several findings from Table 5 require discussion. First, the IV-2SLS estimates for BAD (0.371 for FI; 0.401 for EPSR) are modestly larger than OLS-FE estimates (0.282; 0.307), and the Wu-Hausman test confirms BAD is endogenous ($p \approx 0.03$). The upward direction of the IV correction IV > OLS is consistent with negative selection: agents appear to be disproportionately deployed in states with lower baseline inclusion potential (likely reflecting CBN policy targeting of underserved areas), so OLS understates the true causal effect. The Kleibergen-Paap F-statistic of 47.8 far exceeds the Stock-Yogo threshold of 10, confirming instrument strength. Hansen J p-values of 0.48–0.51 do not reject instrument validity.
Second, Moran's I tests on OLS-FE residuals are significant ($p \approx 0.04$), confirming spatial autocorrelation. The positive spatial lag coefficient ($\rho \approx 0.21$–0.23 in the SAR model) indicates positive cross-state spillovers consistent with shared mobile network coverage and cross-border commerce. After controlling for spatial dependence, the BAD coefficient declines slightly (to 0.271–0.294) but remains highly significant, confirming that the core result is not driven by spatial confounding.

5. Robustness Checks

Table 6 summarises all robustness checks. Full coefficient tables are available in the Online Appendix.

Table 6: Summary of Robustness Checks

Robustness Check	Key Change from Baseline	BAD Coeff. (FI)	Conclusion
ARDL — Quarterly data (T=40)	Replace annual with quarterly NIBSS data	n/a (ARDL level)	Long-run coefs. stable; cointegration confirmed
ARDL — Narayan (2005) CVs	Use small-sample bounds (5.72 vs 4.85 at 5%)	n/a	F=7.34 exceeds Narayan 1% bound of 7.18; robust
Panel — EPSR excl. Jumia	EPSR from CBN + NIBSS only (no Jumia)	0.271*** (0.044)	Unchanged; Jumia exclusion benign
Panel — EPSR upper-bound elasticity	Imputation elasticity = 0.8 (vs baseline 0.6)	0.291*** (0.043)	Slightly larger; direction and sig. unchanged
Panel — Mundlak CRE	Correlated random effects (Mundlak 1978)	0.276*** (0.042)	FE preferred; CRE confirms FE consistency
Panel — Conflict states excluded	Drop 6 northeastern conflict-affected states	0.301*** (0.046)	Slightly larger; security attenuation confirmed
Panel — Spatial Error Model (SEM)	Alternative spatial specification	0.268*** (0.043)	Spatial error λ significant; BAD robust
Panel — log(BAD)	ln(BAD) replaces BAD levels	3.91*** (0.68) [log-log elasticity]	Consistent direction; 3.91% elasticity
Panel — 3-way heterogeneity interaction	BAD × Female × Rural joint interaction	-0.162*** (0.059) [triple interaction]	Compounding disadvantage confirmed

Notes: All panel robustness specifications include state and period FE and cluster SE by state. ARDL robustness checks apply to the FI equation; results are qualitatively identical for EPSR. Full tables in Online Appendix.
In the nine robustness checks, the BAD coefficient of financial inclusion lies between 0.268 and 0.301 - a small range of 0.282, which is the baseline OLS-FE estimate. The ARDL F-statistic (7.34) is stronger than even the Narayan (2005) upper bound of 7.18 (not necessarily the 5) indicating the cointegration finding to be robust in small samples. The strength checks of EPSR measurement ensure that the Jumia weight and the imputation elasticity are not driving point of the results. The three-way interaction supports compounding disadvantage of rural women, and this fact is significant to the design of intervention.

Table 7: Summary of Robustness and Diagnostic Tests

Model	Estimation Technique	Diagnostic Test	Result	Interpretation
Baseline Model	ARDL Bounds Test	Bounds F-statistic	Significant at 5%	Confirms long-run relationship
Robustness Test 1	Quarterly ARDL	Serial correlation test	Not significant	Model residuals are well behaved
Robustness Test 2	Panel Fixed Effects	Hausman test	Fixed effects preferred	Controls for unobserved heterogeneity
Robustness Test 3	IV Two Stage Least Squares	First stage F-statistic	> 10	Instruments are strong
Robustness Test 4	IV Two Stage Least Squares	Hansen overidentification test	Not rejected	Instruments are valid
Robustness Test 5	Spatial Panel Model	Moran's I statistic	Significant	Spatial spillovers exist

Source: Author's computations based on data from the Central Bank of Nigeria and the Nigeria Inter-Bank Settlement System.

6. Heterogeneity Analysis

Table 8 shows the estimate of the interaction model on the different effects of BAD on the financial inclusion of various subgroups of demographic and geographical groupings. The rows correspond to different regressions that have BAD, subgroup indicator, and the interaction, as well as the complete control vector (INT, SMA, ln(PCI), DLR) and state/ period fixed effects. All regressions contain subgroup main effects; tables of complete coefficients are in the Online Appendix

ROBUSTNESS CHECKS

Table 8: Heterogeneity Analysis - Differential Effects of Banking Agent Density on Financial Inclusion

Subgroup Interaction	BAD Main	Interaction Term	Net BAD Effect	Attenuation
BAD × Female Household Head	0.282*** (0.041)	-0.109** (0.048)	0.173***	39%
BAD × Rural Location	0.282*** (0.041)	-0.134*** (0.039)	0.148***	47%
BAD × Northern Zone	0.282*** (0.041)	-0.156*** (0.052)	0.126***	55%
BAD × Lowest Income Quintile	0.282*** (0.041)	-0.179*** (0.061)	0.103**	63%
BAD × Female × Rural [3-way interaction]	0.282*** (0.041)	-0.162*** (0.059)	0.061*	78% (compounded)

Notes: *** p<0.01, ** p<0.05, * p<0.10. Clustered SE by state. Row 5 (three-way) additionally includes BAD × Female, BAD × Rural, Female × Rural, and all three subgroup main effects. Net effects computed as main BAD coefficient plus interaction. All regressions include full control vector and state/period FE.

The attenuation gradient is structured along both marginalised dimensions; gender (39%), rural location (47%), north zone (55%) and lowest income quintile (63%). All the net BAD effects are positive and statistically significant, which gives the frontier-expansion interpretation. The rural women three way interaction (78% compounded attenuation, net effect 0.061, significant level 10) is one such interesting finding: rural women have compounded restraints of reduced mobile phone access, cultural limitations to making financial choices and the geographic dispersion of agent locations. The almost zero net effect of this group (0.061 pp if an additional 10 agents are added to the health workforce per 100K) shows that it is not possible to achieve significant inclusion benefits among this particular group without special complementary measures..

7. Policy Implications

The empirical findings are followed by five evidence-based and prioritised recommendations. We measure the impacts we are expected to have where we can and trade-off where necessary.

7.1 Agent Banking Expansion in Underserved States (Highest Priority)

The Agent Banking (Top Priority) The 2SLS BAD coefficient of 0.371 suggests that the increase in the state financial inclusion caused by a 10-unit increase in the number of the agents per 100,000 adults is 0.37 percentage points. In the 12 northern states with the current average of 45 agents/100K, compared to the national average of 148, the narrowing of the gap to the national average (103 additional agents/100K) would mean a narrowing of the gap in financial inclusion in the state level by 103/10 x 0.37 [?] 3.8 percentage points. This is enhanced by the positive spatial spillover (r [?] 0.22): investment will increase the inclusion rates in neighbouring states and enhance the social payoff multiplied by the direct state-level effect. Nevertheless, there is a trade-off there that is critical to understand: in states where BAD is larger than 400, the rates of per-agent fraud incidents are approximately 2.3 times greater compared to the ones in states with BAD under 50, which implies that fast growth without corresponding compliance capacity poses a threat to consumer protection. An enhanced supervisory structure, which is tighter in the CBN of the set BAD thresholds, would permit expansion and contain fraud risk.

7.2 Digital Literacy Investment (Highest Priority)

DLR is estimated to impact on the two outcomes second-largest. One percentage point rise in state digital literacy goes with 3.4 percentage points of further financial government inclusion and 4.1 points of further e-commerce payment effectiveness. States that are less than 30% DLR: those in the northern states, some of which are under 10% have the greatest potential gains. Letting the DLR rise nationally by 10 points of 41.7% to 50%, based on the coefficient of 0.341, would produce about 0.341 8.3 [?] 2.8 percentage points of incremental financial inclusion. To overcome the generational aspect of the literacy gap, effective delivery is needed with culturally suitable programming using local languages, community based channels (cooperatives, faith-based organisations) and inclusion in the curriculum of secondary schools.

In the nine robustness checks, the BAD coefficient of financial inclusion lies between 0.268 and 0.301 - a small range of 0.282, which is the baseline OLS-FE estimate. The ARDL F-statistic (7.34) is stronger than even the Narayan (2005) upper bound of 7.18 (not necessarily the 5) indicating the cointegration finding to be robust in small samples. The strength checks of EPSR measurement ensure that the Jumia weight and the imputation elasticity are not driving point of the results. The three-way interaction supports compounding disadvantage of rural women, and this fact is significant to the design of intervention.

The econometric evidence of the presence of the specific regulatory interventions is obtained by the PSB (0.089) and COVID (0.112) interaction coefficients, which show that the fintech-inclusion transmission mechanism is significantly enhanced by the specific regulatory interventions. CBN ought to leverage on PSB model in order to eliminate the remaining disjointures between NCC mobile network operator licensing and CBN payment service licensing. More importantly, the waivers on small-value digital transfers during the COVID era the one with the greatest increase in elasticity of sample should become a permanent new policy in transfers that do not exceed a given limit (e.g., NGN 10,000). The permanent fee waiver policy increase in the elasticity would roughly increase the national financial inclusion rate by 0.112 x DlnFTV in each of the subsequent periods.

7.4 Interoperability and Network Externality Internalisation (Medium Priority)

The positive value of the spatial lag coefficient (0.22) holds true that the network expansion of agents in a particular state produces positive spillovers to the other states through shared mobile network coverage and cross-border digital trade. Those beneficial externalities are partially internalised under interoperability: open API requirements as part of the open banking framework of CBN 2023 (had they been extended to complete account-to-account interoperability) would enable users to seamlessly cross over platforms and increase network effects that are represented in the spatial model.

7.5 Gender and Geographic Equity Interventions (Sustained Priority)

The attenuation of 78 percent of rural women is a compounded policy gap that can only be bridged by market mechanisms. According to the interaction coefficients it would be possible to halve this attenuation, though, cutting it to 39% instead of 78%, and increase the effective net BAD coefficient of rural women by an estimated 2-3 percentage points, contributing 2-3 percentage points to the national financial inclusion above trend as the networks of northern agents grow. Some of the necessary interventions are: gender-disaggregated reporting obligations of licensees of fintech, matched-funding initiatives of agent models that target females, and community-based digital literacy initiatives that focus on rural women. The results strongly indicate the need to invest in the supply side of female agent training, product design, as well as the demand side, literacy, and mobile phone ownership subsidies to women in rural regions.

8. Conclusion

This paper offers the best econometric treatment ever made on fintech two-sided effect on financial inclusion and e-commerce growth in Nigeria (2014-2023). Four methodological suggestions deal with the issues raised in the preceding review: ARDL bounds testing is compared against Narayan (2005) small-sample small-scale critical values and quarterly data; panel IV-2SLS with distance-based and existing-retail-density instruments deals with BAD endogeneity; spatial panel models are used to consider cross-state spillovers; and three-way interaction terms are used to determine the disadvantages that are compounded in rural women. There are three substantive findings of importance. To begin with, the long-run cointegration between fintech transaction volumes and the two outcome variables is established under the most stringent small-sample criteria, and the quarterly model supports the results. Second, regulation event analysis tends to give new econometric data indicating that PSB licensing (2018) and COVID-era fee waiver policies (2020) both significantly enhanced the fintech-inclusion elasticity - which policy interventions worked best. Third, the three-way heterogeneity analysis shows that the BAD benefits to rural women are attenuated by 78 percent, which proves that this is one of the critical issues in policy design that needs special interventions rather than just agent network expansion. Three areas of future research are encouraged by the short annual time series, which would be extended with data over time; the EPSR state-level imputation would be better served by direct platform-level data through research collaboration with Paystack or Flutterwave, cross-country comparative panel analysis would test the generalisability of the results with other countries (Kenya, Ghana, and South Africa). The most credible causal identification in future work would be randomised controlled trials implemented within the products launches of fintech operators.

Data Availability Statement

The data that support the findings of this study are available from a combination of publicly accessible sources, including the Central Bank of Nigeria (CBN), National Bureau of Statistics (NBS), Nigerian Inter-Bank Settlement System (NIBSS), and EFInA surveys. The processed datasets and constructed variables used in the analysis are available from the corresponding author upon reasonable request.

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Appendix: Supplementary Tables

Table A1: Variance Inflation Factors

Variable	VIF — ARDL (1st Diff.)	VIF — Panel (Demeaned)	Assessment
ln(FTV)	3.41	—	Moderate; well below threshold of 10
ln(MMA)	4.87	—	Moderate; manageable
INT	5.93	4.14	Below 10; no multicollinearity concern
BAD	—	2.91	Low
SMA	—	3.74	Low to moderate
ln(PCI)	—	4.82	Moderate; manageable
DLR	—	2.13	Low

Notes: All VIFs below 6.0 (ARDL) and 5.0 (panel). The conventional problem threshold is 10. Multicollinearity is not a material concern in either model.

Table A2: IV First-Stage Results and Instrument Validity

Test / First-Stage Coefficient	Statistic	Threshold / Critical Value	Conclusion
DIST_CBN → BAD (first-stage coeff.)	-0.312*** (0.071)	—	Relevant; farther = fewer agents (negative)
RETAIL_2013 → BAD (first-stage coeff.)	1.841*** (0.312)	—	Relevant; more retail = more agents (positive)

Kleibergen-Paap weak identification F-statistic	47.8	≥ 10 (Stock-Yogo)	Strong instruments
Hansen J overidentification test (p-value)	0.484 (FI); 0.511 (EPSR)	> 0.10	Cannot reject instrument validity
Wu-Hausman endogeneity test (p-value)	0.032 (FI); 0.029 (EPSR)	< 0.05	BAD is endogenous; IV-2SLS preferred over OLS-FE

Notes: First-stage regression includes INT, SMA, ln(PCI), DLR, state FE, and period FE. DIST_CBN is time-invariant; RETAIL_2013 is predetermined (2013 values). Wu-Hausman rejects exogeneity of BAD, confirming IV is appropriate.