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Keywords: Digital exclusion; financial resilience; multilevel modelling; women; Sub-Saharan Africa.

Multilevel Modelling of Digital Exclusion for Improving Women's Financial Resilience in Sub-Saharan Africa

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ABSTRACT

Women's financial resilience in Sub-Saharan Africa is shaped by access to digital technologies, yet the association between digital exclusion and resilience is rarely examined with methods that respect the clustering of women within country contexts. This study fits two-level multilevel logistic models to 24,506 women in 48 country-waves drawn from 24 economies in the 2017 and 2021 Global Findex surveys. Financial resilience is the ability to raise emergency funds within 30 days, and digital exclusion is a composite index of phone, smartphone and internet access and use. Country-waves account for 14.9% of the variance in resilience (median odds ratio = 2.06). A one standard deviation increase in exclusion is associated with 26% lower odds of resilience (odds ratio = 0.74), equivalent to an average reduction of 6.0 percentage points in probability. The association varies across country-waves (slope variance = 0.025), and cross-level interactions show that it is weaker where mobile broadband coverage and legal gender equality are higher and stronger where the gender gap in mobile phone ownership is wider. Each moderator accounts for 59.9% to 62.3% of the slope variance. Results are stable across weighted, probit, alternative clustering and leave-one-country-out specifications. The findings are associations rather than causal effects, and they indicate where digital inclusion measures for women are most closely aligned with financial resilience.

INTRODUCTION

Financial resilience, the capacity to absorb an unexpected expense without borrowing under duress or going without essentials, has moved from the margins of financial inclusion research toward its centre since the COVID-19 period exposed how thinly many households are buffered (Adusei, 2020; Agur et al., 2022). The Global Findex Database 2021 measures it through a question on whether a person could raise emergency funds within 30 days, alongside its established indicators of account ownership and digital payments (Demirgüç-Kunt et al., 2022), and resilience has also been tied to the knowledge a person brings to money decisions (van Kippersluis & van Ourti, 2021).

For women in Sub-Saharan Africa, resilience is shaped by the same channels through which policy now seeks to extend inclusion. National strategies name women as a priority group, as the Central Bank of Nigeria's financial inclusion strategy does (Central Bank of Nigeria, 2022), and international bodies present digital financial services as a route to narrowing gender gaps in access (Global Partnership for Financial Inclusion, 2020; Sahay et al., 2020). Demand-side surveys in Nigeria track access to financial services in order to monitor progress against such strategies (Enhancing Financial Innovation & Access, 2023).

Routes of this kind assume that women can reach the devices, connectivity and skills on which digital finance depends. Where they cannot, they are digitally excluded, and the exclusion is unlikely to be evenly distributed, because the digital public infrastructure on which services run (World Bank, 2024) and the legal environment for women's economic activity (World Bank, 2023) both differ between economies and across time.

Evidence on digital finance and women's outcomes in the region has grown quickly, but much of it is analysed without regard to the structure of the data. Women interviewed in the same country and year share a policy environment, a network infrastructure and a regulatory regime, so their outcomes are correlated, whereas ordinary regression treats them as independent. Multilevel models partition outcome variation across individuals and contexts and are routinely applied to national survey data in other fields (Kisinza et al., 2024; Seyedmohammadi et al., 2023). The studies reviewed in this article, however, seldom use them to ask whether the association between digital exclusion and women's financial resilience is the same everywhere or varies with the conditions in which women live.

This article therefore models women's financial resilience in a two-level framework in which women are nested in country-waves, and it treats digital exclusion as an individual-level

exposure whose association with resilience may depend on country-level conditions. The analysis pools Global Findex waves for 2017 and 2021 and pursues three objectives. The first is to quantify the share of variation in women's financial resilience that lies between country-waves. The second is to estimate the association between digital exclusion and women's financial resilience. The third is to test whether this association varies across country-waves and whether digital infrastructure and gender-inclusion conditions explain the variation. The objectives correspond to three research questions.

RQ1. How much of the variance in women's financial resilience is attributable to country-level context?

RQ2. Is higher digital exclusion associated with lower financial resilience among women?

RQ3. Does the association vary across country-waves, and do country-level conditions moderate it?

Because the design is observational, the estimates are read as associations and conditional patterns. What the analysis offers is a way of judging where digital inclusion measures for women are most likely to coincide with higher resilience, and how much of the difference between countries is left to be explained once individual circumstances are taken into account.

Literature Review

Financial Resilience

Financial resilience is treated in the literature as the ability to withstand a shock to income or expenditure without lasting loss of wellbeing, and survey research most often proxies it by whether a person can access emergency funds within a short period (Demirgüç-Kunt et al., 2022). The proxy records perceived rather than realised capacity, but it can be asked in the same form across economies, which is why it anchors cross-country comparison. Work on middle-aged and older adults connects resilience to financial literacy (van Kippersluis & van Ourti, 2021), whereas research on poverty in developing economies approaches a related idea through vulnerability, examining how financial inclusion, measured along several dimensions, relates to poverty and to vulnerability to poverty (Koomson et al., 2020).

Measurement choices shape what resilience and exclusion are taken to mean. Ozili (2021) discusses how financial inclusion and exclusion are measured and the difficulties that arise when a single indicator stands for a condition with several parts, a concern that applies equally to a resilience item and to a digital exclusion score. Income and financial literacy have been compared as correlates of financial inclusion in Nigeria (Adetunji & David-West, 2021), a

comparison that matters here because both are plausible confounders of any link between digital exclusion and resilience, and both enter the models below as controls.

Digital Exclusion and the Gender Digital Divide

Digital exclusion refers to lack of access to, or inability to use, the devices and connections through which digital services are delivered, and research on women's digital financial capability separates access from skills. Grohmann and Menkhoff (2022) examine how skills, digital financial literacy, capability and autonomy interact in financial decision making and wellbeing, Hasan et al. (2023) ask whether digital financial literacy matters for women entrepreneurs' financial inclusion, and Yusuf and Mohd (2023) examine the moderating role of digital financial literacy in the relation between financial inclusion and women's empowerment in Nigeria. These studies treat skills as a barrier distinct from device ownership, which supports building an exclusion measure from several indicators rather than from phone ownership alone.

The gender dimension of adoption has been studied at different scales. Adeniyi et al. (2023) analyse mobile money adoption, the gender gap and household welfare in rural Nigeria, while Ibrahim and Aliero (2023) take a cross-country view of whether mobile money is closing the gender gap in access to and use of financial services in ECOWAS countries. One study works with households in a single country and the other with country-level patterns, so their results are not directly comparable, but both treat the gender gap in a digital channel as a quantity to be explained and not as a nuisance control. Studies set in Northern Nigeria, where Mohammed (2025) addresses women's digital financial inclusion and Bawa and Abdullahi (2023) relate digital microfinance and agency banking to rural women's economic agency, concentrate on a region whose conditions may differ from better-served areas, which illustrates why variation within and between countries both deserve attention.

Spatial inequality is a recurrent theme in this work. Mtei and Kimaro (2023) decompose rural-urban inequalities in financial inclusion in Tanzania, and Niyongabo (2022) examines financial inclusion choices in a post-conflict setting through the case of Burundi. The settings differ sharply, yet each shows that exclusion is patterned by place, which is the reason rural residence enters the present models as an individual-level covariate and country-level conditions enter as moderators.

Digital Finance and Women's Financial Outcomes

Studies of digital finance and women's outcomes can be grouped by the outcome they select. A first group is concerned with autonomy and empowerment: Katuromunda and Katusiime (2021) relate mobile money adoption to women's decision-making autonomy within households in East and West Africa, Loko and Yang (2022) use microdata to study fintech and women's empowerment in Sub-Saharan Africa, and Adu-Boahen et al. (2025) connect digital financial inclusion and gender equality to the empowerment of rural women in West Africa. These studies share an interest in agency but draw on different data, from multi-country household surveys to regional samples, and they differ in how directly they measure the digital channel.

A second group focuses on livelihoods. Abdallah and Bawa (2024) analyse digital financial inclusion, female micro-entrepreneurship and poverty dynamics in Sub-Saharan Africa, Ukpong and Udo (2022) study mobile financial services among women-owned agricultural micro-enterprises in Southern Nigeria, Abasilim et al. (2025) examine product usage among women nano and micro entrepreneurs in Nigeria, and Sule and Bello (2024) consider agency banking, mobile wallets and financial capability among female informal traders in Lagos State. Samples of entrepreneurs and traders are informative about those who already transact, but they are selected on economic activity and therefore say little about women who are excluded from digital channels altogether.

A third group works at the level of countries or regions. Asongu and Odhiambo (2026) and Sharaf et al. (2025) study digital financial inclusion in relation to poverty alleviation and socioeconomic sustainability in Sub-Saharan Africa, Ozili (2024b) relates women's digital financial inclusion to economic growth in Nigeria, and a longer line of work links financial inclusion to poverty and welfare in the region (Nsiah et al., 2021; Ofori-Abebrese et al., 2020; Olaoye & Zerihun, 2023; Hussaini & Chibuzo, 2022). Aggregate designs capture contextual variation but cannot show whether the individual-level association between exclusion and an outcome is stable across contexts, because the unit of analysis is the country and not the woman.

Country-Level Context

Three kinds of country-level condition recur in this literature. The first is infrastructure: the promise of fintech depends on connectivity and on an enabling environment (Sahay et al., 2020), and digital public infrastructure shapes who can use digital services at all (World Bank, 2024). The second is the gender gap in device ownership, which Ibrahim and Aliero (2023) treat as the object of study and Adeniyi et al. (2023) place alongside household welfare. The third is the legal

and institutional position of women: the World Bank (2023) profiles legal conditions affecting women's economic opportunities in the region, and Ozili (2023) analyses the effect of gender equality on financial stability and financial inclusion.

Context also appears as a source of heterogeneity in studies of women's access to finance more broadly, as in the examination of gender, enterprise size and credit access in Sub-Saharan Africa by Aterido et al. (2021), and in accounts of the state of digital financial services in Nigeria (David-West et al., 2021). Taken together these works motivate the inclusion of one indicator per condition as a candidate moderator, with the caution that conditions are correlated and the number of country-waves is limited.

Theoretical Framework

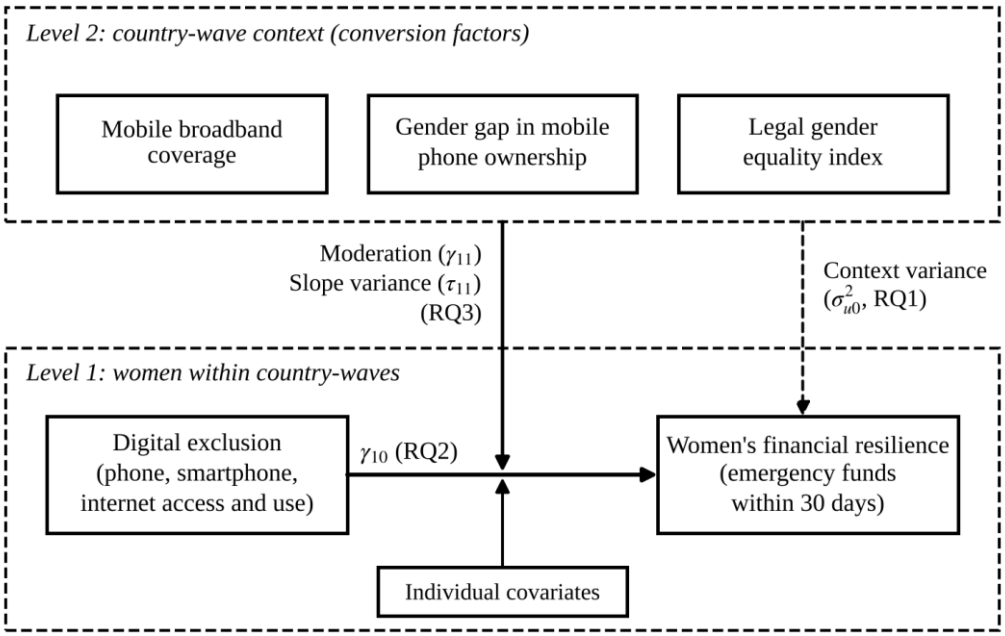
Capability Approach

The capability approach evaluates wellbeing by what people are able to do and to be, and not by resources alone (Alkire & Foster, 2021). Applied to finance, it asks whether access to a digital device and connection translates into the ability to save, borrow, transact and withstand shocks, which depends on skills and on autonomy in decision making (Grohmann & Menkhoff, 2022). Ozili (2024a) develops a related argument in a digital agency theory of financial inclusion, in which digital channels extend the capacity of individuals to act on their financial interests. Financial resilience can be read in this frame as a functioning, the realised ability to meet an emergency expense, and digital exclusion as a constraint on the capabilities from which that functioning is drawn.

Country Conditions as Conversion Factors

The same tradition holds that the translation of resources into functionings depends on conversion factors, which include social, institutional and environmental conditions as well as personal characteristics (Alkire & Foster, 2021). In the present setting, mobile broadband coverage, the gender gap in mobile phone ownership and the legal gender equality index are treated as country-level conversion factors. This reading yields a multilevel structure, because conversion factors are properties of the country-wave and not of the woman. It also yields expectations about direction: where coverage is wider and legal equality stronger, the association between exclusion and resilience should be weaker, and where the gender gap in phone ownership is wider it should be stronger. These expectations enter the third research question and are examined, not assumed.

Figure 1 Conceptual Framework of Digital Exclusion and Women's Financial Resilience in a Two-Level Structure



Note. RQ = research question. Solid arrows denote the individual-level association and the moderating role of country-wave conditions; the dashed arrow denotes variance in resilience attributable to country-wave context. Individual covariates enter all models after the null model.

Synthesis and Research Gap

Across the literature, digital channels are related to women's outcomes on dimensions such as autonomy, enterprise activity and poverty, and the studies share attention to gender gaps in access, skills and place. They diverge in unit of analysis, with household, enterprise and country designs each answering a different question, and in measurement, since exclusion is proxied in different studies by phone ownership, mobile money use or composite indices (Ozili, 2021). The outcome examined is seldom a liquidity measure such as the ability to raise emergency funds, although the measure is available in cross-country survey data (Demirgüç-Kunt et al., 2022).

What the reviewed studies do not provide is an estimate of how much of the variation in women's financial resilience lies between contexts, a test of whether the individual-level association with exclusion varies across contexts, or a test of which contextual conditions explain that variation. This article addresses those three points with a two-level model for women nested in country-waves, a composite exclusion index that excludes financial account indicators in order to avoid building part of the outcome into the exposure, and cross-level interactions that follow the conversion-factor reading of the capability approach.

Method

Data and Sample

The analysis pools responses from women aged 15 years and above in the Global Findex survey waves of 2017 and 2021 for Sub-Saharan African economies (Demirgüç-Kunt et al., 2022). An economy was retained when both waves were available and when the emergency funds item and the mobile phone and internet items were asked in both, which yielded 24 economies and 48 country-waves. The pooled file contained 25,311 women. Of these, 805 (3.2%) had a missing value on at least one analysis variable and were excluded, leaving an analytic sample of 24,506 women with between 417 and 618 women per country-wave (median 500).

Measures

Outcome Variable

Financial resilience is coded 1 when a woman reports that it would be very possible to come up with an amount equal to one twentieth of gross national income per capita in local currency within 30 days, and 0 otherwise, following the Global Findex emergency funds item (Demirgüç-Kunt et al., 2022). The item records perceived capacity and is therefore a proxy for realised resilience.

Digital Exclusion Index

Digital exclusion is measured with a Digital Exclusion Index (DEI) built from four binary indicators: not owning a mobile phone (24.8% of the pooled file), not owning a smartphone (58.7%), having no personal internet access (51.1%), and not having used the internet in the previous 12 months (63.2%). The score is the first principal component of the indicator correlation matrix, which accounts for 69.2% of total variance (Appendix A), signed so that higher values denote greater exclusion and standardised to a mean of 0 and a standard deviation of 1 in the analytic sample. Indicators of account ownership, digital payments and mobile money are excluded from the index because they are financial inclusion outcomes, and including them would build part of the outcome into the exposure (Ozili, 2021). A skills indicator is not available in both waves, so the index captures access and use more fully than capability.

Individual-Level Covariates

Covariates are age, education, within-economy income quintile, employment, rural residence and marital status. Income is retained because income and financial literacy are plausible confounders of the link between digital exclusion and financial outcomes (Adetunji & David-West, 2021), and

rural residence because rural-urban gaps are a recurrent feature of financial inclusion (Mtei & Kimaro, 2023). Financial literacy is not measured in the pooled file.

Country-Level Moderators

Three country-wave conditions are examined as moderators: mobile broadband coverage, the gender gap in mobile phone ownership, and a legal gender equality index (World Bank, 2023). GDP per capita (log) and female labour force participation enter the moderation models as controls. All country-level variables are standardised across the 48 country-waves. Table 1 lists definitions and sources.

Table 1: Variable Definitions and Sources

Variable	Definition	Level	Source
Financial resilience	1 if raising an amount equal to one twentieth of gross national income per capita within 30 days would be very possible, 0 otherwise	1	Global Findex
Digital Exclusion Index	First principal component of four binary indicators (no mobile phone, no smartphone, no personal internet access, no internet use in the past 12 months); standardised, higher values mean greater exclusion	1	Global Findex
Age	Years, centred at 30, entered per 10 years	1	Global Findex
Education	None or primary (reference), secondary, tertiary	1	Global Findex
Income quintile	Within-economy income quintile, centred at 3	1	Global Findex
Employed, rural, married	Binary indicators	1	Global Findex
Wave	1 if 2021, 0 if 2017	2	Survey design
Mobile broadband coverage	Percentage of the population covered, standardised across country-waves	2	World Bank country indicators
Gender gap in mobile ownership	Male minus female phone ownership in percentage points, standardised	2	Global Findex
Legal gender equality index	Score from 0 to 100, standardised	2	Women, Business and the Law (World Bank, 2023)

GDP per capita, female labour force participation	Natural log of GDP per capita in current US dollars; percentage of women aged 15 and above in the labour force; both standardised	2	World Bank country indicators
Mobile money account	1 if the woman holds a mobile money account (sensitivity analysis only)	1	Global Findex

Note. Level 1 variable describe women and Level 2 variables describe country-waves.

Analytic Strategy

Model Specification

Women (i) are nested in country-waves (j). The null model (M0) decomposes variance in the log-odds of financial resilience (FR) into between and within components:

$$\text{logit}\, P(FR_{ij} = 1) = \gamma_{00} + u_{0j}, \quad u_{0j} \sim N(0, \sigma^2_{u0}) \tag{1}$$

The intraclass correlation is defined on the latent logistic scale:

$$\text{ICC} = \sigma^2_{u0} / (\sigma^2_{u0} + \pi^2/3) \tag{2}$$

The second model (M1) adds the standardised Digital Exclusion Index, individual covariates X and a wave effect δ_{wave}:

$$\text{logit}\, P(FR_{ij} = 1) = \gamma_{00} + \gamma_{10}\, DEI_{ij} + \Sigma_k\, \gamma_k\, X_{kij} + \delta_{wave} + u_{0j} \tag{3}$$

The third model (M2) lets the exclusion slope vary across country-waves, with intercept and slope deviations drawn from a bivariate normal distribution whose covariance matrix T has elements τ_{00}, τ_{01} and τ_{11}:

$$\text{logit}\, P(FR_{ij} = 1) = \gamma_{00} + \gamma_{10}\, DEI_{ij} + \Sigma_k\, \gamma_k\, X_{kij} + \delta_{wave} + u_{0j} + u_{1j}\, DEI_{ij} \tag{4}$$

The fourth set of models (M3) adds one country-level moderator Z_j at a time, the controls W_{mj}, and the cross-level interaction:

$$\text{logit}\, P(FR_{ij} = 1) = \gamma_{00} + \gamma_{10}\, DEI_{ij} + \Sigma_k\, \gamma_k\, X_{kij} + \delta_{wave} + \gamma_{01}\, Z_j + \Sigma_m\, \lambda_m\, W_{mj} + \gamma_{11}\, (DEI_{ij} \times Z_j) + u_{0j} + u_{1j}\, DEI_{ij} \tag{5}$$

Moderators enter one at a time because 48 country-waves cannot support several cross-level interactions at once, and the moderators are correlated. Model M0 corresponds to RQ1, M1 to RQ2, and M2 and M3 to RQ3. The variance of the slope deviations, τ_{11}, indicates how far the exclusion association differs across country-waves, and the share of τ_{11} that falls between M2 and M3 indicates how much of that difference a moderator accounts for.

Within-Between Decomposition

To separate the individual-level association from a contextual one, the index is decomposed into a within component, the woman's deviation from her country-wave mean, and a between component, the country-wave mean:

$$DEI_{ij} = (DEI_{ij} - DEI_{j}) + DEI_{j} \quad (6)$$

Both components enter a random-intercept model, and their coefficients are compared in the sensitivity analyses.

Estimation and Model Comparison

Parameters are estimated by maximum likelihood, with the marginal likelihood evaluated by adaptive Gauss-Hermite quadrature (seven nodes per random effect), implemented in Python with NumPy and SciPy:

$$L = \Pi_j \int [\ \Pi_i f(FR_{ij} \mid u_j)\ ]\ \varphi(u_j)\ du_j \quad (7)$$

Standard errors come from the numerical Hessian. Nested models are compared with likelihood ratio tests, and the test for the random slope uses a mixture of chi-square distributions with one and two degrees of freedom because the variance lies on the boundary of its parameter space. Akaike and Bayesian information criteria are also reported. The median odds ratio and the proportional change in variance are

$$\mathrm{MOR} = \exp(\sqrt{(2\sigma^2_{u0})} \times 0.6745) \quad (8)$$

$$\mathrm{PCV} = (\sigma^2_{u0,M0} - \sigma^2_{u0,Mk}) / \sigma^2_{u0,M0} \quad (9)$$

The median odds ratio is the median factor by which the odds change when a woman moves between two randomly chosen country-waves. Average marginal effects are obtained by integrating predicted probabilities over the random-effects distribution, and their intervals come from 200 draws of the fixed-effect vector from its estimated sampling distribution. Odds ratios are conditional on the random effects and are reported together with marginal effects for that reason.

Sampling Weights and Missing Data

The primary models are estimated without sampling weights because country-wave and wave are represented in the model. A weighted pseudo-likelihood, with weights rescaled to a mean of one within each country-wave, is reported as a sensitivity analysis. Observations with missing values were deleted listwise, which assumes that missingness is unrelated to the outcome conditional on the covariates.

Sensitivity Analyses and Diagnostics

Six alternative specifications of M1 are estimated: weighted pseudo-likelihood, a probit link, the addition of mobile money account ownership as a mechanism variable, the within-between decomposition, country (24 clusters) instead of country-wave as the grouping unit, and re-estimation after the omission of each country in turn. Variance inflation factors assess multicollinearity, Shapiro-Wilk tests assess the normality of the predicted random effects from M2, and the stability of the quadrature is checked by comparing the log-likelihood with seven and fifteen nodes.

Results

Descriptive Statistics

Table 2 describes the analytic sample of 24,506 women by tertile of the Digital Exclusion Index. Overall, 41.8% of women reported that raising emergency funds within 30 days would be very possible. The share fell from 58.4% in the lowest exclusion tertile to 40.5% in the middle tertile and 26.5% in the highest, and the gradient was accompanied by a fall in the share with secondary or tertiary education from 83.2% to 23.3%, a rise in rural residence from 41.5% to 82.1%, and a decline in mean income quintile from 3.32 to 2.70. Mean age rose from 31.8 to 35.3 years across the tertiles. All differences were statistically significant at the .001 level.

Table 2 Summary Statistics by Tertile of the Digital Exclusion Index

Characteristic	All women	Low exclusion	Medium exclusion	High exclusion	Test
Women, *n*	24,506	8,169	8,168	8,169	
Digital Exclusion Index, *M* (*SD*)	0.00 (1.00)	−1.20 (0.18)	0.10 (0.50)	1.09 (0.27)	
Financial resilience, %	41.8	58.4	40.5	26.5	$\chi^2(2) = 1715.4$
Age in years, *M* (*SD*)	33.5 (12.0)	31.8 (11.6)	33.3 (11.9)	35.3 (12.3)	$F = 175.2$
Secondary or tertiary education, %	52.0	83.2	49.6	23.3	$\chi^2(2) = 5886.4$
Income quintile, *M* (*SD*)	2.99 (1.41)	3.32 (1.38)	2.97 (1.41)	2.70 (1.38)	$F = 411.9$
Employed, %	54.7	60.1	54.0	50.0	$\chi^2(2) = 172.7$
Rural residence, %	63.7	41.5	67.4	82.1	$\chi^2(2) = 2984.2$
Married, %	51.7	48.8	51.5	54.8	$\chi^2(2) = 58.5$

Note. Tertiles are defined on the Digital Exclusion Index in the analytic sample. Tests compare the three tertiles: chi-square tests for percentages and one-way analysis of variance for means.

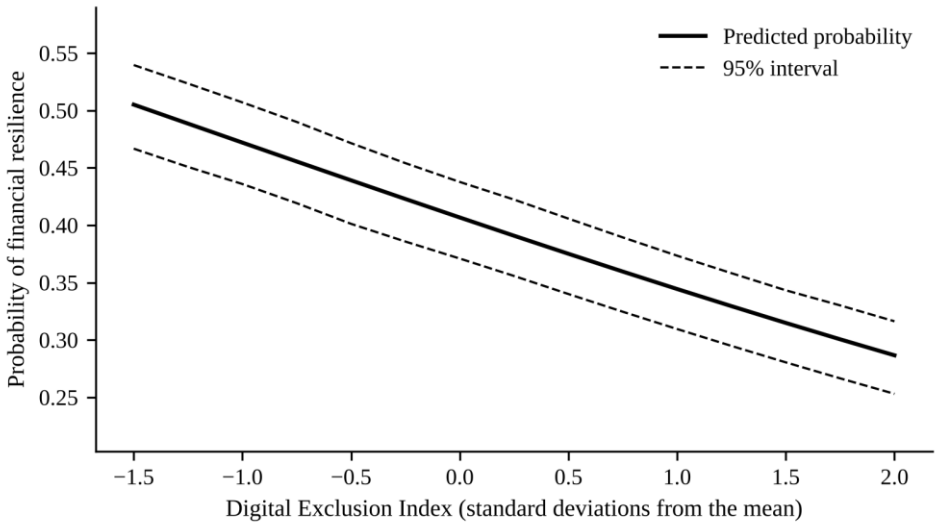
Variance Partitioning

The null model (M0 in Table 3) returned an intercept variance of 0.575 (*SE* = 0.120), which corresponds to an intraclass correlation of 0.149. Country-waves therefore accounted for 14.9% of the variance in the latent propensity for financial resilience, and the median odds ratio was 2.06. After the Digital Exclusion Index, the individual covariates and the wave effect were added (M1), the intercept variance fell to 0.350, the intraclass correlation to 0.096 and the median odds ratio to 1.76, a proportional change in variance of 39.1%.

Digital Exclusion and Financial Resilience

In M1 the odds ratio for a one standard deviation increase in the Digital Exclusion Index was 0.74 (*SE* = 0.02, 95% CI 0.71, 0.77, $p < .001$), which is 26% lower odds. The corresponding average marginal effect was −6.0 percentage points (95% CI −6.6 to −5.2). Odds of resilience were higher for women with secondary education (odds ratio = 1.38) and tertiary education (odds ratio = 1.91) relative to women with none or primary education, for each higher income quintile (1.23), for employed women (1.28) and for married women (1.12), and lower for rural residents (0.87). The wave effect was not statistically significant (odds ratio = 1.04, $p = 0.83$). Adding M1 to the null model improved fit ($\chi^2(9) = 1{,}690.1$, $p < .001$; Table 3). Figure 2 plots the predicted probability of resilience across the range of the index. The probability fell from 0.505 at 1.5 standard deviations below the mean to 0.407 at the mean and 0.287 at 2 standard deviations above it.

Figure 2 Predicted Probability of Financial Resilience Across Levels of Digital Exclusion



Note. Population-averaged predicted probabilities from M1 with 95% intervals from 200 draws of the fixed effects; covariates at their observed values.

Table 3 Multilevel Logistic Estimates for Financial Resilience, Models M0 to M2

	M0	M1	M2
Fixed effects (odds ratios, SE)			
Digital Exclusion Index (per SD)		0.74*** (0.02)	0.73*** (0.02)
Age (per 10 years)		1.06*** (0.01)	1.06*** (0.01)
Secondary education		1.38*** (0.05)	1.37*** (0.05)
Tertiary education		1.91*** (0.11)	1.93*** (0.11)
Income quintile		1.23*** (0.01)	1.23*** (0.01)
Employed		1.28*** (0.04)	1.28*** (0.04)
Rural residence		0.87*** (0.03)	0.87*** (0.03)
Married		1.12*** (0.03)	1.12*** (0.03)
Wave 2021		1.04 (0.18)	0.99 (0.16)
Intercept (odds)	0.67*** (0.07)	0.46*** (0.06)	0.50*** (0.06)
Random effects			
Intercept variance, σ_{u0}^2 (SE)	0.575 (0.120)	0.350 (0.074)	0.333 (0.072)
Slope variance, τ_{11} (SE)			0.025 (0.010)
Intercept–slope correlation (SE)			0.43 (0.17)
ICC	0.149	0.096	0.092
MOR	2.06	1.76	1.73
PCV		0.391	0.421
Average marginal effect of DEI, percentage points [95% CI]		−6.0 [−6.6, −5.2]	
Model fit			
Log–likelihood	−15357.3	−14512.3	−14499.0
AIC	30,718.7	29,046.6	29,024.0
BIC	30,734.9	29,135.7	29,129.4
Likelihood ratio test against previous model		$\chi^2(9) = 1{,}690.1$, $p < .001$	$\chi^2 = 26.6$, $p < .001$
Women, *N*; country waves, *J*	24,506; 48	24,506; 48	24,506; 48

Note. Cells show odds ratios with standard errors in parentheses. ICC = intraclass correlation; MOR = median odds ratio; PCV = proportional change in intercept variance relative to M0; AME = average marginal effect for a one standard deviation increase in the index. The ICC for M2 is evaluated at a Digital Exclusion Index of zero. The likelihood ratio test for M2 uses a chi-square mixture. *** $p < .001$.

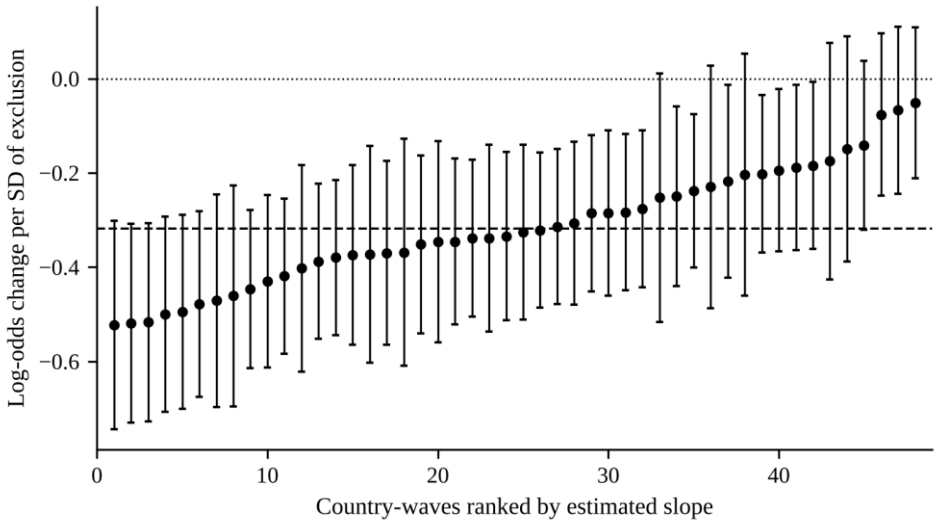
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Cross-Country Variation and Contextual Moderation

Allowing the exclusion slope to vary (M2) produced a slope variance of 0.025 (*SE* = 0.010), equivalent to a standard deviation of 0.158, and an intercept-slope correlation of 0.43 (*SE* = 0.17). The model improved on M1 ($\chi^2 = 26.6$, $p < .001$), and the pooled odds ratio for the index was 0.73. With normally distributed slope deviations, 95% of country-wave odds ratios lie between 0.53 and 0.99. Figure 3 ranks the estimated country-wave slopes, which ranged from −0.52 to −0.05 on the log-odds scale, with 39 of 48 intervals lying wholly below zero.

Table 4 reports the cross-level interactions. The interaction between the index and mobile broadband coverage had an odds ratio of 1.18 ($p < .001$), that with the gender gap in mobile phone ownership 0.87 ($p < .001$), and that with the legal gender equality index 1.15 ($p < .001$). Slope variance fell from 0.0250 in M2 to 0.0094, 0.0100 and 0.0097 in the three moderation models, reductions of 62.3%, 59.9% and 61.2%. Each model improved on M2 ($\chi^2(4)$ between 30.3 and 39.1, all $p < .001$). The main effects of the moderators were not statistically significant at the .01 level in any model. Figure 4 shows predicted probabilities from M3a. At the mean of the index, the predicted probability was 0.519 where broadband coverage was one standard deviation above the mean and 0.336 where it was one standard deviation below, and at 2 standard deviations above the mean of the index the corresponding probabilities were 0.455 and 0.176.

Figure 3 Country-Wave Specific Digital Exclusion Slopes



Note. Posterior mean slopes from M2 (pooled slope plus predicted deviation) with 95% intervals; the dashed line marks the pooled slope and the dotted line marks zero.

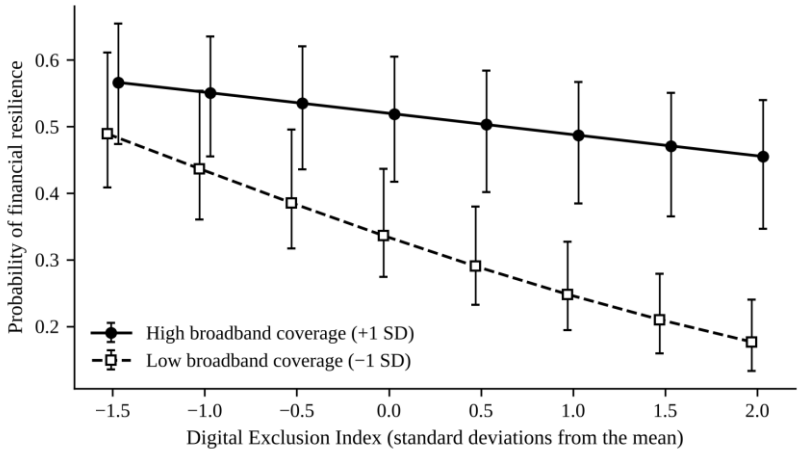
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Table 4 Cross-Level Interaction Estimates for Digital Exclusion and Country-Wave Conditions

	M3a: Broadband coverage	M3b: Gender gap in phone ownership	M3c: Legal gender equality
Fixed effects (odds ratios, SE)			
Digital Exclusion Index (per SD) at mean Z	0.74*** (0.02)	0.74*** (0.02)	0.74*** (0.02)
Moderator Z (per SD)	1.52* (0.31)	0.88 (0.11)	1.04 (0.13)
Index × Z	1.18*** (0.03)	0.87*** (0.02)	1.15*** (0.03)
GDP per capita, log (per SD)	0.91 (0.17)	1.17 (0.16)	1.25 (0.17)
Female labour force participation (per SD)	0.98 (0.07)	0.95 (0.07)	0.96 (0.08)
Individual covariates and wave	Included	Included	Included
Random effects			
Intercept variance (SE)	0.227 (0.049)	0.256 (0.055)	0.258 (0.056)
Slope variance (SE)	0.0094 (0.0049)	0.0100 (0.0055)	0.0097 (0.0053)
Intercept–slope correlation	−0.13	−0.13	−0.05
Share of M2 slope variance accounted for	62.3%	59.9%	61.2%
Model fit			
Log–likelihood	−14479.4	−14483.8	−14483.1
AIC	28,992.9	29,001.7	29,000.2
Likelihood ratio test against M2, $\chi^2(4)$	39.1, $p < .001$	30.3, $p < .001$	31.8, $p < .001$
Women, N; country–waves, J	24,506; 48	24,506; 48	24,506; 48

Note. Cells show odds ratios with standard errors in parentheses. Each model adds one moderator, the two country-level controls and the interaction to M2. The share of slope variance accounted for is the proportional reduction in τ_{11} relative to M2. * $p < .05$. *** $p < .001$.

Figure 4 Predicted Probability of Financial Resilience by Digital Exclusion at Low and High Mobile Broadband Coverage



Note. Population-averaged predictions from M3a at one standard deviation above and below mean broadband coverage, with 95% intervals from 100 draws of the fixed effects. Points are offset horizontally for legibility.

Sensitivity Analyses

Table B1 in Appendix B reports the alternative specifications. The odds ratio for the index was 0.74 under weighted pseudo-likelihood, 0.76 when mobile money account ownership was added, and 0.75 with 24 country clusters, and the probit coefficient was −0.183. Leave-one-country-out re-estimation returned odds ratios between 0.73 and 0.75. In the within-between model the odds ratio was 0.75 for the within component and 0.50 for the between component. Variance inflation factors did not exceed 1.62, Shapiro-Wilk tests did not reject normality of the predicted random intercepts ($W = 0.980$, $p = 0.58$) or slopes ($W = 0.975$, $p = 0.40$), and the log-likelihood differed by less than 0.001 between seven and fifteen quadrature nodes.

Discussion

Variance Structure Across Contexts

Country-waves accounted for 14.9% of the variance in women's financial resilience before any predictors were entered and for 9.6% after individual characteristics and digital exclusion were taken into account. A share of this size is modest next to the variation among women within the same country-wave, yet it is not negligible, since the median odds ratio of 2.06 implies that two otherwise identical women in different country-waves would typically differ in their odds of resilience by a factor of about two. Single-level models would treat the 24,506 women as independent and so overstate the precision of any individual-level coefficient, a concern that motivates multilevel analysis of national survey data in other fields (Kisinza et al., 2024; Seyedmohammadi et al., 2023). The result also qualifies studies that treat the country as the unit of analysis, such as the work on digital financial inclusion and poverty or sustainability in the region (Asongu & Odhiambo, 2026; Sharaf et al., 2025): context clearly matters for resilience, but most of the variation lies among women and not among countries, so aggregate associations cannot stand in for individual-level ones.

The 39% reduction in intercept variance after M0 shows that the composition of country-waves, in terms of education, income, employment, residence and exclusion, accounts for a large part of the between-context differences. The remainder, an intraclass correlation of 0.096, is available to be explained by country-level conditions that the individual-level model does not contain, which the task is taken up in the moderation models.

Digital Exclusion and Women's Financial Resilience

Higher digital exclusion was associated with lower odds of financial resilience in every specification, with an odds ratio of 0.74 per standard deviation and an average reduction of about 6 percentage points in the probability of being able to raise emergency funds. The direction agrees with studies that connect mobile money and digital financial services with women's autonomy and empowerment (Adu-Boahen et al., 2025; Katuromunda & Katusiime, 2021; Loko & Yang, 2022), although those studies examine outcomes other than liquidity and their magnitudes cannot be compared with the present ones. A closer comparison is with work that places the gender gap in mobile phone ownership at the centre of the analysis (Adeniyi et al., 2023; Ibrahim & Aliero, 2023), since the exclusion index used here is built from the same kinds of access indicators and the moderation results below return to the gender gap directly.

Two features of the evidence help to read the coefficient. First, adding mobile money account ownership reduced the exclusion odds ratio from 0.74 to 0.76, and the mobile money coefficient itself was positive (odds ratio = 1.22). Part of the association between exclusion and resilience therefore runs through the use of financial services delivered over digital channels, and most of it does not, which is consistent with the view that digital channels extend the capacity of individuals to act on their financial interests but do not fully determine it (Ozili, 2024a). Second, the between component of the index (odds ratio = 0.50) was farther from one than the within component (0.75), which means that country-waves with more exclusion had lower resilience over and above the individual association. This contextual contrast is estimated from 48 country-waves and should not be read as an effect of aggregate exclusion on any woman.

The covariates behave as the literature on financial inclusion would lead one to expect. Education and income were positively related to resilience, and rural residence was negatively related to it, which fits the emphasis that studies in Nigeria and Tanzania place on income, literacy and spatial inequality (Adetunji & David-West, 2021; Mtei & Kimaro, 2023). Because the index is correlated with these characteristics, as Table 2 shows, the coefficient for exclusion is conditional on them, and the variance inflation factors in Appendix C indicate that the correlation does not threaten the stability of the estimates.

Contextual Conditions as Moderators

The exclusion association was not uniform. Slope variance of 0.025 implies that the odds ratio for a standard deviation of exclusion ranges from roughly 0.53 to 0.99 across country-waves, so that in some contexts the association is close to nil and in others it is substantial. This is the

pattern that a conversion-factor reading of the capability approach anticipates, because the translation of access into resilience depends on conditions outside the individual (Alkire & Foster, 2021). The positive intercept-slope correlation indicates that country-waves with higher baseline resilience tend to have weaker, that is less negative, exclusion slopes.

Each of the three moderators shifted the association in the expected direction. Broadband coverage and legal gender equality attenuated it, with interaction odds ratios of 1.18 and 1.15, whereas a wider gender gap in mobile phone ownership strengthened it (0.87). Coverage matters in the way that studies of fintech and digital public infrastructure suggest, since services depend on connectivity and an enabling environment (Sahay et al., 2020; World Bank, 2024). The gender gap result accords with the attention that cross-country work gives to mobile ownership gaps (Ibrahim & Aliero, 2023), and the legal index result is consistent with analyses linking gender equality to financial inclusion (Ozili, 2023; World Bank, 2023). In Figure 4, the predicted probability of resilience at two standard deviations of exclusion was 0.46 where coverage was high and 0.18 where it was low, a difference that is large relative to the average marginal effect and shows how much the pooled estimate conceals.

Two cautions apply. The moderators explained similar shares of the slope variance (60% to 62%) because they are correlated across country-waves, so the data cannot say which condition matters most or whether they act through a common development factor. Their main effects were not statistically distinguishable from zero at the .01 level once the other country-level terms were present, which reflects limited information from 48 country-waves. The moderation results are best read as evidence that the exclusion association differs systematically with context, and not as separate causal contributions of coverage, the gender gap and legal equality.

Policy Implications

The estimates point to a targeting logic for digital inclusion measures. Where mobile broadband coverage is low or the gender gap in phone ownership is wide, exclusion is more closely associated with low resilience, and measures that address device access and connectivity for women are therefore most likely to coincide with improvements in the ability to withstand shocks. National strategies that name women as a priority group (Central Bank of Nigeria, 2022) and international guidance on women's digital financial inclusion (Global Partnership for Financial Inclusion, 2020) could use country-wave indicators of this kind to sequence investments, pairing connectivity with legal and institutional reform where the legal index is low. Because the design is observational, these are implications for where to look and what to

monitor, and the estimates do not show that closing the exclusion gap would raise resilience by the amounts reported.

Limitations and Future Research

Several limitations qualify the findings. The data are cross-sectional within waves, so reverse causation is possible, for instance if women with more liquid savings can afford devices and data. Resilience is self-reported and perceived. The exclusion index lacks a skills dimension, and financial literacy is not measured, although both are central to the capability approach (Grohmann & Menkhoff, 2022). Country-waves from the same country are not independent, and the analysis addresses this with a country-level sensitivity model and not with a three-level model, which the available wave structure would support only weakly. Moderators were examined one at a time with 48 clusters, and the models were estimated without sampling weights in the primary specification. Future work could add further waves, a skills indicator, subnational identifiers and instrumental or panel designs that bring the analysis closer to causal inference.

Conclusion

This study modelled women's financial resilience in Sub-Saharan Africa with two-level logistic models in which 24,506 women are nested in 48 country-waves. For the first research question, country-waves accounted for 14.9% of the variance in resilience and 9.6% after individual characteristics and exclusion were included. For the second, a one standard deviation increase in digital exclusion was associated with an odds ratio of 0.74 and an average reduction of 6.0 percentage points in the probability of resilience. For the third, the association varied across country-waves, was weaker where mobile broadband coverage and legal gender equality were higher, and was stronger where the gender gap in mobile phone ownership was wider, with each moderator accounting for roughly three fifths of the slope variance.

The contribution lies in treating the exclusion association as something that differs across contexts and in identifying conditions that account for the difference, which single-level and aggregate designs cannot do. The findings are associations, and the policy reading is one of targeting and monitoring: digital inclusion measures for women are most closely aligned with financial resilience where connectivity is limited and the gender gap in device ownership is wide, and legal conditions for women appear to matter alongside infrastructure. Extending the analysis with skills measures, further waves and designs that support causal claims would show how far these patterns reflect the effect of exclusion itself.

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The author(s) declare that it is not applicable.

Consent for publication
The author(s) declare that this is not applicable.

Competing interests
The author(s) declare that they have no competing interests.

References

1. Abasilim, C., Onyeji, C., & Nnamani, E. (2025). Financial inclusion and product usage among women nano and micro entrepreneurs in Nigeria. *Journal of Development and Agricultural Economics, 17*(1), 12–29. https://doi.org/10.5897/JDAE2024.1390
2. Abdallah, A., & Bawa, S. (2024). Digital financial inclusion, female micro-entrepreneurship, and poverty dynamics in Sub-Saharan Africa. *African Development Review, 36*(2), 210–225. https://doi.org/10.1111/1467-8268.12745
3. Adeniyi, O., Abiodun, O., & Oluwatobi, S. (2023). Mobile money adoption, gender gap, and household welfare in rural Nigeria. *Telecommunications Policy, 47*(5), Article 102521. https://doi.org/10.1016/j.telpol.2023.102521
4. Adetunji, O., & David-West, O. (2021). The relative impact of income and financial literacy on financial inclusion in Nigeria. *Journal of International Development, 33*(3), 485–504. https://doi.org/10.1002/jid.3407

5. Adu-Boahen, B., Donkor, E., Iyioku, G., & Mazancová, J. (2025). Digital financial inclusion, gender equality, and rural women's empowerment in West Africa. *World Development Perspectives, 37*, Article 100645. https://doi.org/10.1016/j.wdp.2024.100645
6. Adusei, M. (2020). COVID-19 and financial inclusion in Africa: Exploring the opportunities and challenges of digital financial services. *The Journal of Development Studies, 56*(12), 2523–2540. https://doi.org/10.1080/00220388.2020.1790532
7. Agur, I., Martinez Peria, S. M., & Soledad, M. (2022). *Digital finance and inclusion in the time of COVID-19* (IMF Working Paper No. WP/22/101). International Monetary Fund. https://doi.org/10.5089/9798400208157.001
8. Alkire, S., & Foster, J. (2021). Capabilities and human well-being: How to bridge the missing link? *Research Leap Journal of Development Economics, 9*(4), 33–45. https://doi.org/10.18775/rl.2158-0324.2021.94.3
9. Asongu, S. A., & Odhiambo, N. M. (2026). The impact of digital and financial inclusion on sustainable poverty alleviation in Sub-Saharan Africa. *Journal of Sustainability Research, 8*(1), Article e20260012. https://doi.org/10.20900/jsr20260012
10. Aterido, R., Beck, T., & Iacovone, L. (2021). Gender, enterprise size, and credit access in Sub-Saharan Africa. *Small Business Economics, 57*(3), 1423–1442. https://doi.org/10.1007/s11187-020-00356-9
11. Bawa, S., & Abdullahi, M. (2023). Digital microfinance, agency banking, and rural women's economic agency in Northern Nigeria. *Gender, Technology and Development, 27*(2), 185–207. https://doi.org/10.1080/09718524.2023.2195012
12. Central Bank of Nigeria. (2022). *National financial inclusion strategy (NFIS 3.0): Accelerating financial inclusion for women and youth*. https://www.cbn.gov.ng/out/2022/ccd/nfis%20strategy%20doc.pdf
13. David-West, O., Ijewere, E., & Muritala, O. (2021). Digital financial services in Nigeria: State of the market and pathway to financial inclusion. *Journal of Banking Regulation, 22*(3), 215–231. https://doi.org/10.1057/s41283-020-00067-1
14. Demirgüç-Kunt, A., Klapper, L., Singer, D., & Ansar, S. (2022). *The Global Findex Database 2021: Financial inclusion, digital payments, and resilience in the age of COVID-19*. World Bank. https://doi.org/10.1596/978-1-4648-1897-4
15. Enhancing Financial Innovation & Access. (2023). *Access to financial services in Nigeria 2023 survey report*. https://efina.org.ng/reports/a2f-2023/

16. Global Partnership for Financial Inclusion. (2020). *Advancing women's digital financial inclusion*. G20 Saudi Arabia Secretariat & World Bank Group. https://www.gpfi.org/publications/advancing-womens-digital-financial-inclusion
17. Grohmann, A., & Menkhoff, L. (2022). The interplay of skills, digital financial literacy, capability, and autonomy in financial decision making and well-being. *Journal of Economic Behavior & Organization, 200*, 712–731. https://doi.org/10.1016/j.jebo.2022.06.018
18. Hasan, R., Ashfaq, M., Parveen, T., & Gunardi, A. (2023). Financial inclusion: Does digital financial literacy matter for women entrepreneurs? *International Journal of Social Economics, 50*(8), 1089–1106. https://doi.org/10.1108/IJSE-08-2022-0542
19. Hussaini, U., & Chibuzo, I. (2022). Digital financial inclusion, poverty reduction, and gender equity in Nigeria: A structural equation modelling approach. *Journal of Economic Studies, 49*(5), 892–910. https://doi.org/10.1108/JES-03-2021-0134
20. Ibrahim, S. S., & Aliero, H. M. (2023). Access to and use of financial services in ECOWAS countries: Is mobile money closing the gender gap? *Economic Analysis Letters, 2*(3), 15–28. https://doi.org/10.58567/eal02030002
21. Katuromunda, S., & Katusiime, L. (2021). Mobile money adoption and female decision-making autonomy within households in East and West Africa. *Development Policy Review, 39*(6), 980–1001. https://doi.org/10.1111/dpr.12543
22. Kisinza, W. N., et al. (2024). Complementary feeding practices and associated factors among mothers of children aged 6 to 23 months in Tanzania: A multilevel analysis of the 2022 Demographic and Health Survey. *BMC Public Health, 24*, Article 1205. https://doi.org/10.1186/s12889-024-18692-x
23. Koomson, I., Villano, R. A., & Hadley, D. (2020). Effect of financial inclusion on poverty and vulnerability to poverty: Evidence using a multidimensional measure of financial inclusion. *Social Indicators Research, 149*(2), 613–639. https://doi.org/10.1007/s11205-019-02263-0
24. Loko, B., & Yang, M. (2022). *FinTech and women's empowerment in Sub-Saharan Africa: Evidence from microdata* (IMF Working Paper No. WP/22/204). International Monetary Fund. https://doi.org/10.5089/9798400222047.001
25. Mohammed, A. (2025). Women and digital financial inclusion in Northern Nigeria. *Gender, Technology and Development, 29*(2), 185–207. https://doi.org/10.1080/09718524.2024.2389101

26. Mtei, L., & Kimaro, A. (2023). Decomposing rural-urban inequalities in financial inclusion in Tanzania. *Development Southern Africa, 40*(5), 1012–1030. https://doi.org/10.1080/0376835X.2023.2189102
27. Niyongabo, E. (2022). Financial inclusion choices in post-conflict and fragile states of Africa: The case of Burundi. *African Development Review, 34*(3), 345–358. https://doi.org/10.1111/1467-8268.12651
28. Nsiah, A. Y., Yusif, H., Tweneboah, G., Agyei, K., & Baidoo, S. T. (2021). The effect of financial inclusion on poverty reduction in Sub-Saharan Africa: Does threshold matter? *Cogent Social Sciences, 7*(1), Article 1903138. https://doi.org/10.1080/23311886.2021.1903138
29. Ofori-Abebrese, G., Baidoo, S. T., & Essiam, E. (2020). Estimating the effects of financial inclusion on welfare in Sub-Saharan Africa. *Cogent Business & Management, 7*(1), Article 1839164. https://doi.org/10.1080/23311975.2020.1839164
30. Olaoye, O., & Zerihun, M. F. (2023). Financial inclusion and poverty reduction in Nigeria: The role of information and communication technology (ICT). *African Journal of Economic and Management Studies, 14*(4), 580–598. https://doi.org/10.1108/AJEMS-12-2022-0488
31. Ozili, P. K. (2021). Measuring financial inclusion and financial exclusion. In *New challenges for future sustainability and wellbeing* (pp. 411–427). Emerald Publishing. https://doi.org/10.1108/978-1-80043-968-920211024
32. Ozili, P. K. (2023). Effect of gender equality on financial stability and financial inclusion. *Social Responsibility Journal, 19*(9), 1612–1628. https://doi.org/10.1108/SRJ-12-2022-0565
33. Ozili, P. K. (2024a). Digital agency theory of financial inclusion: A theory of digital financial inclusion. In *Developing digital inclusion through globalization and digitalization* (pp. 53–69). IGI Global. https://doi.org/10.4018/979-8-3693-4111-7.ch004
34. Ozili, P. K. (2024b). Women digital financial inclusion and economic growth in Nigeria. *Journal of Internet and Digital Economics, 4*(3), 161–178. https://doi.org/10.1108/JIDE-07-2024-0027
35. Sahay, R., von Allmen, U. E., Lahreche, A., Khera, P., Ogawa, S., Bazarbash, M., & Beaton, K. (2020). *The promise of fintech: Financial inclusion in the post-COVID-19 era*. International Monetary Fund. https://doi.org/10.5089/9781513547145.087
36. Seyedmohammadi, M., et al. (2023). The role of mental health, academic stress, academic achievement, and physical activity on self-rated health among adolescents in Iran: A

multilevel analysis. *Frontiers in Public Health, 11*, Article 1098452. https://doi.org/10.3389/fpubh.2023.1098452

37. Sharaf, M. F., Shahen, A. M., & Alharaib, M. A. (2025). Digital financial inclusion and socioeconomic sustainability in Sub-Saharan Africa. *Discover Sustainability, 6*(1), Article 142. https://doi.org/10.1007/s43621-025-00185-w
38. Sule, A., & Bello, M. (2024). Agency banking, mobile wallets, and financial capability among female informal traders in Lagos State, Nigeria. *Journal of Financial Services Marketing, 29*(3), 210–226. https://doi.org/10.1057/s41264-023-00241-1
39. Ukpong, I. A., & Udo, E. J. (2022). Impact of mobile financial services on women-owned agricultural micro-enterprises in Southern Nigeria. *Journal of Agricultural and Applied Economics, 54*(3), 415–432. https://doi.org/10.1017/aae.2022.18
40. van Kippersluis, H., & van Ourti, T. (2021). The role of financial literacy for financial resilience in middle-age and older adulthood. *Journal of the Economics of Ageing, 20*, Article 100342. https://doi.org/10.1016/j.jeoa.2021.100342
41. World Bank. (2023). *Women, business and the law 2023: Sub-Saharan Africa regional profile*. World Bank Group. https://doi.org/10.1596/978-1-4648-1944-5
42. World Bank. (2024). *Digital public infrastructure, platform competition, and inclusive economic transformation* (World Bank Policy Research Report). World Bank Group. https://doi.org/10.1596/978-1-4648-2015-1
43. Yusuf, A. S., & Mohd, S. (2023). The moderating role of digital financial literacy on financial inclusion and women empowerment in Nigeria. *Journal of Sustainable Finance & Investment, 13*(4), 1450–1468. https://doi.org/10.1080/20430795.2021.1982045

Appendix:-

Appendix A

Digital Exclusion Index Construction

The index is the first principal component of the correlation matrix of four binary exclusion indicators, computed on the pooled file of 25,311 women. The component has an eigenvalue of 2.77 and accounts for 69.2% of total variance. Scores were signed so that higher values denote greater exclusion and standardised in the analytic sample.

Table A1 Loadings and Prevalence of Digital Exclusion Indicators

Indicator	Prevalence, %	Loading on first component
No mobile phone	24.8	0.427
No smartphone	58.7	0.524
No personal internet access	51.1	0.528
No internet use in the past 12 months	63.2	0.513

Note. Prevalence is the percentage of women in the pooled file with the indicator.

Appendix B

Sensitivity Analyses

Table B1 Digital Exclusion Estimates Under Alternative Specifications

Specification	Metric	Estimate	95% CI	σ_{u0}^2
Baseline random intercept (M1)	Odds ratio	0.74	[0.71, 0.77]	0.350
Weighted pseudo-likelihood	Odds ratio	0.74	[0.71, 0.77]	0.359
Mobile money account added	Odds ratio	0.76	[0.73, 0.79]	0.348
24 country clusters	Odds ratio	0.75	[0.72, 0.78]	0.208
Probit link	Coefficient	−0.183	[−0.208, −0.158]	0.125
Within-between model: within component	Odds ratio	0.75	[0.72, 0.78]	0.281
Within-between model: between component	Odds ratio	0.50	[0.40, 0.63]	0.281
Mobile money account (mechanism model)	Odds ratio	1.22	[1.14, 1.29]	0.348
Leave-one-country-out (24 re-estimations)	Odds ratio	0.73 to 0.75	Range of estimates	

Note. All specifications include the individual covariates and the wave effect. Intercept variances for the probit link are on the probit scale, and those for the 24-cluster model refer to countries.

Appendix C

Model Diagnostics

Table C1 Multicollinearity, Random-Effects Normality and Quadrature Diagnostics

Diagnostic	Statistic	Value
Variance inflation factor: Digital Exclusion Index	VIF	1.58

Variance inflation factor: Age	VIF	1.18
Variance inflation factor: Secondary education	VIF	1.48
Variance inflation factor: Tertiary education	VIF	1.62
Variance inflation factor: Income quintile	VIF	1.11
Variance inflation factor: Employed	VIF	1.01
Variance inflation factor: Rural residence	VIF	1.20
Variance inflation factor: Married	VIF	1.15
Variance inflation factor: Wave 2021	VIF	1.00
Normality of predicted random intercepts (M2)	Shapiro–Wilk *W*; *p*	0.980; 0.58
Normality of predicted random slopes (M2)	Shapiro–Wilk *W*; *p*	0.975; 0.40
Quadrature stability (M1)	Log–likelihood, 7 vs 15 nodes	−14512.29 vs −14512.29

Note. VIF = variance inflation factor from a linear regression of each Level 1 predictor on the others.

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