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Gender differences in agricultural credit demand, receipt and rationing among smallholder cassava farmers in Southwestern Nigeria

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Abstract

Gender disparities in agricultural finance may arise from differences in credit demand, credit receipt, or the extent to which lenders fulfil borrowers' requests. This study examines gender differences in these three dimensions among smallholder cassava farmers in Ogun and Oyo States, Nigeria. Survey data from 355 farming households were analyzed, with the main credit-outcome analysis restricted to 262 farmers who requested and received credit. Ordinary least squares models were used to estimate gender differences in the amounts of credit requested and received, including credit receipt conditional on the amount requested. Fractional logit models were used to analyze proportional credit rationing, defined as the share of requested credit that remained unfulfilled, while alternative specifications and inverse-probability weighting assessed the robustness of the findings. Female farmers requested approximately 26.5% less credit and received approximately 22.2% less credit than male farmers after adjustment for observed characteristics. However, the gender difference in credit receipt was no longer statistically significant after accounting for the amount requested. Female gender was also not significantly associated with proportional credit rationing or the probability of experiencing any rationing. These findings remained consistent across formal, informal and combined credit-market categories and in the sensitivity analyses. The results distinguish gender differences in the scale of credit demand from differences in the fulfilment of credit requests. The observed disparity in absolute credit amounts was associated with lower credit demand among women, rather than a statistically detectable gender difference in proportional rationing among farmers who received credit. Policies seeking to improve gender inclusion in agricultural finance should therefore investigate the factors shaping women's borrowing decisions alongside potential barriers to credit supply.

Keywords Agricultural credit, Credit demand, Credit receipt, Credit rationing, Gender; Smallholder farmers, cassava, Nigeria

1 Introduction

Agricultural credit plays an important role in smallholder agriculture because farm households commonly face a temporal mismatch between production expenditures and the realization of farm income. Limited liquidity can constrain the purchase of productive inputs, timely farm operations and investment in improved technologies. Access to appropriate financial services can therefore contribute to agricultural investment, productivity and household welfare, particularly where farmers have limited savings and substantial seasonal financing requirements [7, 22, 24, 27, 34]. Credit constraints can also limit investment, technology adoption and production-risk management, with implications for agricultural productivity and rural welfare [7, 11, 23, 27].

Agricultural credit markets are, however, characterized by imperfections on both the demand and supply sides. Lenders may restrict credit because of information asymmetry, uncertainty about repayment capacity, inadequate collateral and default risk [35, 38, 42, 45]. On the demand side, farmers may not apply for credit, request smaller amounts than they would ideally prefer, or avoid particular lenders because of interest rates, transaction costs, information constraints or repayment concerns [7, 9, 13]. Thus, observed borrowing cannot automatically be interpreted as the amount of credit farmers would demand in an unconstrained market. This distinction is important for understanding credit constraints among smallholders. Evidence from Ethiopia and Tanzania shows that demand-side

constraints can be as important as supply-side constraints, while the mechanisms generating credit constraints vary across farmers [7]. In Nigeria, both demand- and supply-side factors contribute to agricultural credit constraints, including collateral, risk, information and transaction costs [7, 26]. Earlier Nigerian evidence also shows that agricultural credit demand and supply are influenced by socioeconomic and institutional characteristics [29, 36, 44]. Consequently, observing that one group borrows less than another provides insufficient information about the underlying source of the financing difference.

Gender adds an important dimension to agricultural-credit markets. Women farmers may have more limited access to productive assets, financial information, formal financial institutions and institutional networks, while social norms and intrahousehold resource allocation can shape their economic decisions [10, 20, 32, 35]. Limited control over productive resources and collateral can affect both participation in formal credit markets and the amount borrowed [12, 13, 33–35]. Women may also face a "glass ceiling" in loan size, whereby participation in credit markets does not necessarily translate into loans of the same magnitude as those obtained by men [3]. Evidence from Nigeria likewise documents gender differences in agricultural and microfinance borrowing, although their magnitude and direction vary across locations and financial institutions [1, 6, 36, 40].

Recent evidence confirms that gender disparities in agricultural finance remain substantial. A cross-country study using more than 18,000 households across Côte d'Ivoire, Mozambique, Nigeria, Tanzania and Uganda found substantial gender differences in agricultural-credit access, with the gap particularly pronounced in Nigeria [5]. Socioeconomic, institutional and geographic characteristics also contribute to these differences. Evidence from Eastern India similarly shows that gender and spatial characteristics are associated with access to institutional agricultural credit and the amount of credit available to farming households [14]. However, evidence of a gender gap in credit access does not establish whether women request less credit, receive less conditional on their requests, or experience a greater shortfall between requested and received credit.

An important conceptual distinction is therefore required between credit demand, credit receipt and credit rationing. Credit demand concerns the amount requested, whereas credit receipt concerns the amount actually obtained. Credit rationing concerns the shortfall between the requested and supplied amounts. These outcomes can generate very different interpretations of gender differences. This distinction matters because lower credit receipt among women does not necessarily indicate greater supply-side rationing. Women may request smaller amounts because of lower financing requirements, risk aversion, limited information, transaction costs, repayment concerns or gender-related constraints affecting borrowing decisions. [18], for example, show that gender norms can contribute to women requesting smaller agricultural loans. Such demand-side differences can generate gender gaps in observed loan amounts even when lenders fulfil a similar proportion of women's and men's requests. The credit-constraint literature increasingly emphasizes these distinctions. [9] highlight the conceptual difficulty of identifying credit constraints from observed borrowing behaviour, while [7] emphasize the importance of distinguishing demand- from supply-side constraints. [39], using evidence from smallholder farmers in Kenya, similarly examine gendered credit constraints and distinguish different mechanisms through which farmers become constrained. These studies caution against interpreting gender differences in borrowing automatically as evidence of discriminatory credit allocation.

The extent of the credit shortfall is also important, binary measures of credit constraint can conceal differences in severity. [19] distinguishes different levels of credit constraint and show that their severity has implications for agricultural productivity and household welfare. In Nigeria, [28], using 1,200 small-scale farmers across the six geopolitical zones, distinguish loan demand from quantity, risk and price rationing. Their findings reinforce the need to treat credit demand and rationing as related but distinct outcomes. Similarly, observed loan size may combine differences in borrower demand with differences in lender allocation. [27], using agricultural lending data from Mali, find that interest rates, the agricultural cycle, the macroeconomic environment and gender are associated with granted loan

amounts, with female farmers receiving smaller amounts. However, granted loan size alone cannot determine whether women received less because they requested less or because a smaller proportion of their requests was fulfilled. Distinguishing these mechanisms is therefore essential when assessing gender differences in credit allocation.

Institutional characteristics can further shape credit outcomes. Interest rates affect borrowing costs, while distance to credit providers and travel costs increase the non-price costs of borrowing. Credit-market type can also determine documentation, collateral, screening and repayment requirements. Institutional and transaction-cost factors have been identified as important determinants of agricultural credit access and borrowing outcomes [4, 29, 36]. Differences between formal and informal credit arrangements may consequently contribute to gender differences in observed credit outcomes. Selection into credit markets provides an additional empirical consideration, farmers who enter the observed credit market may differ systematically from those who do not apply or do not obtain credit. [4] distinguish determinants of agricultural microcredit access from those determining loan size, while [8] further show that selection into agricultural credit markets is itself economically important. Consequently, gender comparisons among observed borrowers may not necessarily represent gender differences in the wider population of agricultural producers. These issues are particularly relevant in Nigeria, where farmers obtain credit through heterogeneous formal and informal arrangements. [28] document different forms of rationing, while [7] demonstrate the importance of both demand- and supply-side mechanisms nationally. More recent Nigerian studies also report gender differences in credit outcomes, [17] identify gender differences in credit constraints among smallholder farmer co-operators in Oyo State.

Cassava production requires substantial expenditure on labour and other inputs, while the timing of farm revenues can create seasonal liquidity requirements. The availability and adequacy of agricultural finance can therefore influence farmers' ability to undertake production activities. Recent evidence from cassava-based farmers in South-East Nigeria further demonstrates that gender differences can occur in credit-rationing outcomes. [41], using 360 cassava-based farmers, report gender differences in the extent to which applicants' loan demands were met. Their findings underscore the importance of how credit constraints and rationing are measured. Despite this literature, an important empirical gap remains. Existing studies have examined credit access, credit constraints, loan demand, loan size and different forms of rationing, but relatively few examine the amount requested, the amount received, the amount received conditional on the amount requested, and proportional credit rationing within the same smallholder sample. This distinction is important because lower absolute credit receipt among women does not necessarily imply greater supply-side rationing. If women request smaller amounts but receive a similar proportion of their requested credit, the observed gender difference in absolute receipt may arise primarily from differences in observed credit demand rather than differential fulfilment of requests.

This study addresses this gap using data from smallholder cassava farmers in Nigeria. It examines gender differences in four related dimensions of agricultural credit: credit requested, credit received, credit received conditional on credit requested, and proportional credit rationing. Credit demand is defined as the amount of agricultural credit requested by farmers in the analytical credit sample and therefore represents observed requested credit rather than unrestricted latent demand among all farmers. Credit receipt captures the amount actually obtained, while the conditional receipt analysis assesses whether gender differences in received credit persist after accounting for the amount requested. Proportional credit rationing captures the extent to which received credit falls short of requested credit. The study makes three contributions. First, it moves beyond a simple borrower/non-borrower classification by examining multiple stages of the agricultural-credit allocation process within a common empirical framework. Second, it distinguishes absolute credit receipt from conditional credit allocation and proportional credit rationing, avoiding the assumption that women who receive smaller loans necessarily experience greater supply-side restrictions. Third, it incorporates institutional characteristics of the credit environment, including interest rates, distance to credit sources, travel costs

and credit-market type, while examining the potential implications of selection into the analytical credit sample.

The central question is therefore not simply whether female cassava farmers receive less credit than male farmers, but where within the credit-allocation process the gender difference emerges. If women request smaller amounts but do not experience a larger proportional shortfall, lower female credit receipt would be consistent with differences in the scale of observed credit demand rather than greater supply-side rationing. Conversely, if women receive systematically less relative to what they request, the evidence would be more consistent with a gender difference in conditional credit allocation. Distinguishing these possibilities is important for agricultural-finance policy because interventions designed solely to expand credit supply may not address disparities arising primarily from observed demand, whereas evidence of greater conditional rationing would point to constraints in credit allocation requiring greater attention from financial institutions and agricultural-finance programmes.

2 Literature review

2.1 Conceptual review

Agricultural credit enables smallholder farmers to finance production expenditures that precede farm income realization and can therefore contribute to farm productivity. Recent Nigerian evidence confirms this relevance, [34] found a positive association between agricultural-credit accessibility and soybean output among rural women farmers in Kaduna State. However, credit-market participation comprises distinct dimensions that should not be treated interchangeably; the amount requested, the amount received, and the proportion of the request left unfulfilled.

Credit demand in the context of this study refers to the amount of credit requested by a farmer. Observed demand may differ from latent financing needs because information constraints, transaction costs, collateral requirements, risk and perceived barriers can influence whether and how much farmers request [7, 9]. Credit receipt refers to the amount actually granted, which may be smaller than the amount requested. Credit rationing, in contrast, concerns the unfulfilled portion of expressed demand. Proportional rationing therefore provides a measure of credit shortfall relative to the farmer's own request rather than the absolute amount received. This distinction is particularly important in gender analysis. Women may receive less credit than men simply because they request smaller amounts; alternatively, they may receive less conditional on the amount requested or have a larger proportion of their requests unfulfilled. Gender differences in assets, collateral, information, institutional relationships and transaction costs can influence these stages differently [5, 13]. [34] identify information asymmetry and collateral requirements as important constraints affecting agricultural-credit access among rural women in Nigeria, reinforcing the relevance of these mechanisms. Accordingly, lower absolute credit receipt should not automatically be interpreted as greater credit rationing. The present study therefore distinguishes three related outcomes: credit demand, conditional credit receipt, and proportional credit rationing. This distinction allows the analysis to determine whether the gender gap arises primarily from differences in the amount requested or from differential fulfilment of women's credit requests.

2.2 Theoretical review

The study is underpinned by the credit rationing theory of [37], complemented by the demand–supply perspective on agricultural credit constraints. The theory explains how information asymmetry can prevent credit markets from clearing even when borrowers are willing to obtain additional credit at prevailing lending terms. Because lenders cannot perfectly observe borrowers' risk characteristics, increasing the interest rate may increase default risk and adverse selection. Lenders may therefore respond by limiting the quantity of credit supplied rather than fully meeting borrowers' requests. These mechanisms are particularly relevant in smallholder agriculture, where production and income are uncertain, collateral is often limited, information is imperfect, and the costs of screening and monitoring

borrowers can be relatively high. Consequently, credit constraints may arise from both borrower-side and lender-side factors [7].

The theory is particularly pertinent to understanding gender differences in agricultural finance because men and women may enter credit markets with different access to productive assets, collateral, information and financial institutions. Such differences can influence both the amount of credit farmers seek and the amount lenders are willing to provide. Evidence shows how gender-related asset constraints and market imperfections can limit women's access to rural credit [13], while recent findings indicate that gender disparities in agricultural finance remain important across sub-Saharan Africa [5]. In the Nigerian context, a study applying Credit Rationing Theory to rural women soybean farmers identified information asymmetry and collateral requirements as important constraints to agricultural-credit access [34]. Their findings reinforce the argument that institutional and information-related barriers can shape women's position in agricultural credit markets.

Nevertheless, the credit rationing theory also implies an important distinction between the amount a borrower demands and the extent to which that demand is fulfilled. A lower amount of credit received by women does not necessarily indicate greater rationing if women initially request smaller amounts. Conversely, women may request similar amounts to men but receive a smaller proportion of their requests if lenders impose greater restrictions on their borrowing. Thus, a gender difference in absolute credit receipt cannot, by itself, establish a gender difference in credit rationing. This distinction is consistent with evidence that agricultural credit constraints may reflect both demand-side factors, such as risk, information and transaction costs, and supply-side factors, such as collateral and lender screening [7].

The theoretical framework therefore motivates a sequential examination of credit-market outcomes. The study first considers whether gender is associated with the amount of credit requested, then assesses whether gender remains associated with the amount received after accounting for the requested amount, and finally examines whether the proportion of requested credit that remains unfulfilled differs by gender. This approach distinguishes a gender difference in the scale of credit demand from a conditional difference in credit allocation and from differential proportional rationing. It consequently provides a more precise test of whether lower credit received by female smallholder farmers reflects lower expressed demand or greater restriction of their credit requests.

3 Methodology

3.1 Study area and sampling

The study was conducted in Southwest Nigeria, one of the six geopolitical zones of the country. The zone comprises six states, namely Ogun, Oyo, Osun, Ondo, Ekiti, and Lagos States. Geographically, Southwest Nigeria lies approximately between latitudes 6°00′N and 9°00′N and longitudes 3°00′E and 6°00′E. The region is one of the most densely populated areas in Nigeria, with an estimated population of about 50 million people [25]. Southwest Nigeria is characterized by a tropical climate with two distinct seasons: a rainy season, which typically extends from March/April to October/November, and a dry season, which occupies the remaining months of the year. The region experiences a bimodal rainfall pattern with annual rainfall ranging between 1,200 mm and 1,500 mm, while the mean annual temperature averages about 27°C [25]. The favourable climatic conditions, fertile soils, and extensive arable land make the region a major hub for food crop production, particularly cassava, maize, yam, and other staple crops.

A multistage sampling procedure was employed for this study. In the first stage, Ogun and Oyo States were purposively selected because they were among the leading cassava-producing states in Southwest Nigeria. In the second stage, two Agricultural Development Programme (ADP) zones were randomly selected from the four ADP zones in each state, resulting in four sampled zones. The selected zones were Abeokuta and Ikenne in Ogun State, and Ibadan/Ibarapa and Oyo in Oyo State. The third stage involved random selection of three blocks from each sampled ADP zone, giving a total of twelve

blocks. In the fourth stage, three circles were randomly selected from each block, resulting in thirty-six circles across the study areas.

The selected blocks in Ogun State included Olorunda, Ilugun and Wasimi in Abeokuta zone, as well as Isara, Someke and Obafemi in Ikenne zone. The selected circles under these blocks included Olorunda, Ijale Papa, Idi-Emi, Odeda, Olodo, Osi-Ele, Wasimi, Itori, Ajegunle, Isara, Ilara, Iperu, Owode, Kobape, Ibafo, Obafemi, Kajola and Adigbe. Similarly, in Oyo State, the selected blocks comprised Iddo, Ona Ara and Oluyole in Ibadan/Ibarapa zone, and Oyo West, Afijio and Iseyin in Oyo zone. The corresponding circles included Akufo, Akinware, Omi-Adio, Adigun, Gbedun, Olorunda, Idi-Ayunre, Olojuoro, Olode, Mogaji, Olorunda, Lakonu, Awe, Fiditi, Iware, Serafu, Akinwumi and Idi-Iya. In the final stage, cassava-based farmers were selected from each sampled circle. Ten farmers were selected from each of the eighteen circles in Ogun State, yielding 180 respondents, while eleven farmers were selected from each of the eighteen circles in Oyo State, resulting in 198 respondents. Consequently, a total of 378 cassava-based farmers were initially surveyed across the two states. Following data screening, validation, and cleaning, only 355 questionnaires were retained for analysis, comprising 171 respondents from Ogun State and 184 respondents from Oyo State.

3.2 Analytical sample

The original survey comprised 355 smallholder cassava farmers. The analytical sample comprised 262 farmers who reported requesting and receiving agricultural credit, with the amount received not exceeding the amount requested. Because all farmers in this sample reported positive amounts of credit received, the natural logarithm of received credit could be used without adding a constant. The full sample and analytical credit sample were compared using descriptive statistics and tests of differences in observed characteristics. Because inclusion in the analytical credit sample was not necessarily random, a separate selection model was estimated as a diagnostic exercise. This allowed the analysis to determine whether observable characteristics systematically predicted inclusion in the sample used for the credit-outcome models.

The selection analysis was not interpreted as proof that selection bias was present or absent. Rather, it was used to identify observable differences between the full and analytical samples and to motivate inverse-probability-weighted sensitivity analyses. Recent methodological literature emphasizes that weighting approaches for incomplete data depend critically on the specification of the response/selection model and should not automatically be interpreted as eliminating selection bias [16, 21].

3.3 Study design and analytical framework

This study used a cross-sectional econometric design to examine gender differences in three related dimensions of agricultural credit access: credit demand, credit receipt, and credit rationing among smallholder cassava farmers. The empirical strategy was structured to distinguish the amount of credit farmers requested from the amount they actually received and, subsequently, from the proportion of requested credit that remained unmet. This distinction is important because a lower amount of credit received by female farmers does not necessarily imply greater credit rationing. A difference in receipt may arise because women request smaller amounts, because they receive a smaller fraction of the amount requested, or because both processes operate simultaneously. Accordingly, the analysis proceeded through four complementary components: (i) unconditional and adjusted models of requested credit; (ii) unconditional and adjusted models of received credit; (iii) fractional-response models of proportional credit rationing; and (iv) sensitivity analyses addressing selection into the analytical credit sample.

The analysis was framed as an estimation of conditional gender differences rather than causal effects of gender. This distinction is important because gender is not a randomly assigned treatment and the cross-sectional design does not provide a credible experimental counterfactual. The econometric

framework therefore focuses on conditional associations while explicitly avoiding causal interpretations that cannot be supported by the design [43].

3.4 Measurement of credit outcomes

To measure credit outcomes, three principal credit outcomes were analyzed. First, credit demand was measured as the amount of agricultural credit requested for by farmer *i*. Because credit amounts were positively skewed, the natural logarithm was used:

$$D_i = \ln(CR_i) \quad (1)$$

Where D_i denotes log requested credit and CR_i represents the amount of credit requested. Second, credit receipt was measured as the amount of credit actually received:

$$R_i = \ln(CA_i) \quad (2)$$

Where R_i denotes log received credit and CA_i represents the amount of credit received. Third, proportional credit rationing was calculated as the fraction of requested credit that was not received:

$$PR_i = \frac{CR_i - CA_i}{CR_i} \quad (3)$$

Thus, $PR_i = 0$ indicates that the farmer received the full amount requested, whereas larger values indicate a larger proportional shortfall between the amount requested and the amount received. The measure is bounded between zero and one. The proportional measure captures the intensive margin of credit rationing, namely the magnitude of the credit shortfall relative to the amount requested. A separate binary indicator of any rationing was used to capture the extensive margin, defined as whether the farmer received less than the amount requested ($PR_i > 0$).

3.5 Explanatory variables

The principal explanatory variable was farmer gender, specified as a binary indicator taking the value of one for female farmers and zero for male farmers, with male farmers serving as the reference category. The control variables included age, educational attainment, marital status, household size, farming experience, farm size, cooperative membership, interest rate, distance to the loan source, transportation cost to the loan source, and state. Educational attainment was represented by indicator variables for primary, secondary, and tertiary education, with no formal education as the reference category, while state was represented by an indicator for Oyo State, with Ogun State as the reference category. These covariates were selected because they capture observable farmer and institutional characteristics that may be associated with credit demand, credit receipt, and the extent to which requested credit is fulfilled. Their inclusion helps account for observable compositional differences between male and female farmers and improves the comparability of the estimated gender associations, without implying that all relevant determinants of credit outcomes are observed or adequately controlled for.

3.6 Model of credit demand

The first empirical model examined whether the amount of credit requested differed by gender. The unconditional specification was:

$$D_i = \beta_0 + \beta_1 Female_i + \varepsilon_i \quad (4)$$

Where β_1 captures the unconditional gender difference in log requested credit. The adjusted model was specified as:

$$D_i = \beta_0 + \beta_1 \text{Female}_i + \beta_2 \text{Age}_i + \beta_3 \text{Primary}_i + \beta_4 \text{Secondary}_i + \beta_5 \text{Tertiary}_i + \beta_6 \text{Married}_i + \beta_7 \text{HHS}_i + \beta_8 \text{Experience}_i + \beta_9 \text{FarmSize}_i + \beta_{10} \text{Cooperative}_i + \beta_{11} \text{Interest}_i + \beta_{12} \text{Distance}_i + \beta_{13} \text{TravelCost}_i + \beta_{14} \text{Oyo}_i + \varepsilon_i \quad (5)$$

where HHS denotes household size. The coefficients were estimated using ordinary least squares (OLS). The coefficient on the female indicator was interpreted as the conditional difference in log requested credit between female and male farmers, holding the included covariates constant. Because the

dependent variable is logarithmic and gender is binary, the exact percentage difference associated with the female coefficient was calculated as:

$$Percentage\ difference = [\exp(\beta_1) - 1] \times 100 \quad (6)$$

This transformation avoids interpreting a log-point difference as an exact percentage difference when the coefficient is not close to zero [43].

3.7 Model of credit receipt

A parallel set of models was estimated for the amount of credit actually received. The unconditional model was:

$$R_i = \alpha_0 + \alpha_1 \text{Female}_i + u_i \quad (7)$$

The adjusted model was:

$$R_i = \alpha^0 + \alpha^1 \text{Female}_i + \alpha^2 \text{Age}_i + \alpha^3 \text{Primary}_i + \alpha^4 \text{Secondary}_i + \alpha^5 \text{Tertiary}_i + \alpha^6 \text{Married}_i + \alpha^7 \text{HHS}_i + \alpha^8 \text{Experience}_i + \alpha^9 \text{FarmSize}_i + \alpha^{10} \text{Cooperative}_i + +\alpha^{11} \text{Interest}_i + \alpha_{12} \text{Distance}_i + \alpha_{13} \text{TravelCost}_i + \alpha_{14} \text{Oyo}_i + u_i \quad (8)$$

The coefficient on Female_i therefore represents the conditional difference in log credit received between female and male farmers. The analysis deliberately distinguishes this model from the rationing model. A lower amount received by female farmers may simply reflect lower credit demand; it does not by itself demonstrate that women are more heavily rationed.

3.8 Credit receipt conditional on credit requested

To investigate whether the gender difference in credit receipt persists after accounting for the amount requested, a conditional receipt model was estimated:

$$R_i = \gamma_0 + \gamma_1 \text{Female}_i + \gamma_2 D_i + \gamma_3 \text{Age}_i + \gamma_4 \text{Primary}_i + \gamma_5 \text{Secondary}_i + \gamma_6 \text{Tertiary}_i + \gamma_7 \text{Married}_i + \gamma_8 \text{HHS}_i + \gamma_9 \text{Experience}_i + \gamma_{10} \text{FarmSize}_i + \gamma_{11} \text{Cooperative}_i + \gamma_{12} \text{Oyo}_i + \nu_i \quad (9)$$

Where D_i is log requested credit. This specification addresses a substantively important question: whether female farmers receive different amounts of credit conditional on the amount they requested. However, this model was interpreted as a conditional association rather than a causal allocation equation. Requested credit is closely related mechanically to received credit, and controlling for it changes the estimate from the overall gender difference in receipt to the gender difference conditional on demand. Consequently, the coefficient on Female_i should not be interpreted as evidence of discriminatory lending or as a causal effect of gender.

3.9 Fractional-response model of proportional credit rationing

The principal analysis of credit rationing used a fractional-response logit model. This choice follows the econometric framework of [30], which is specifically designed for dependent variables bounded between zero and one and permits observations at both boundary values without ad-hoc transformations. This is particularly appropriate for the present study because proportional credit rationing is defined on the unit interval and includes a substantial number of observations with zero rationing. Current Stata documentation likewise describes fractional regression as appropriate for outcomes between zero and one and notes that fractional-logit estimation can be implemented using a logit conditional-mean specification with robust inference. The conditional mean was specified as:

$$E(PR_i \mid X_i) = G(X_i\beta) \quad (10)$$

Where:

$$G(X_i\beta) = \exp(X_i\beta) / [1 + \exp(X_i\beta)] \quad (11)$$

and X_i contains Female_i and the vector of control variables. The full specification was therefore:

$$E(PR_i \mid X_i) = G[\beta_0 + \beta_1 \text{Female}_i + \beta_2 \text{Age}_i + \beta_3 \text{Primary}_i + \beta_4 \text{Secondary}_i + \beta_5 \text{Tertiary}_i + \beta_6 \text{Married}_i + \beta_7 \text{HHS}_i + \beta_8 \text{Experience}_i + \beta_9 \text{FarmSize}_i + \beta_{10} \text{Cooperative}_i + \beta_{11} \text{Oyo}_i] \quad (12)$$

The model was estimated by quasi-maximum likelihood. A key advantage of the fractional-response framework is that consistency depends on correct specification of the conditional mean rather than requiring the complete conditional distribution of the dependent variable to follow a particular beta-type distribution [30]. Current Stata documentation retains this quasi-likelihood interpretation for fractional regression. Robust standard errors were used because the conditional variance need not follow the variance function implied by a fully specified binomial likelihood. This follows the fractional-response literature and current implementation of fractional regression in Stata, where robust inference is the default approach.

3.10 Average marginal effects of gender on proportional rationing

Because coefficients from nonlinear fractional-response models do not directly represent changes in the observed fraction, the principal measure of gender difference was the average marginal effect (AME). [31] explicitly demonstrate the usefulness of average partial effects in nonlinear fractional-response models. For the binary female indicator, the AME was calculated as:

$$\text{AMEFemale} = \left(\frac{1}{N}\right) \sum_i [\hat{P}R_i(\text{Female} = 1, X_i) - \hat{P}R_i(\text{Female} = 0, X_i)] \quad (13)$$

where $\hat{P}R_i$ denotes the predicted proportion of requested credit that remains unmet.

This approach calculates the predicted rationing for every farmer under the two counterfactual gender values while retaining that farmer's observed values for the remaining covariates. The average difference therefore provides an interpretable estimate of the adjusted gender difference in proportional credit rationing. The AME, rather than the raw fractional-logit coefficient, was therefore used as the principal basis for substantive interpretation.

3.11 Binary incidence of credit rationing

As a complementary analysis, a binary indicator was constructed to identify whether a farmer experienced any positive credit rationing:

$$AR_i = 1 \text{ if } PR_i > 0 \quad (14)$$

$$AR_i = 0 \text{ if } PR_i = 0 \quad (15)$$

The probability of any rationing was then estimated using a logistic specification:

$$\Pr(AR_i = 1 \mid X_i) = \exp(X_i\delta) / [1 + \exp(X_i\delta)] \quad (16)$$

This specification examines the extensive margin of credit rationing, whereas the fractional-response model examines its intensity. The binary model was therefore treated as a complementary specification rather than a replacement for the fractional-response model. Average marginal effects were reported because the coefficient from a nonlinear logit model is not itself a direct probability difference [43].

3.12 Heterogeneity by credit-market type

To determine whether gender differences in proportional credit rationing varied according to the type of credit market accessed, gender was interacted with credit-market indicators. The model was specified as:

$$E(PR_i \mid X_i) = G[\beta_0 + \beta_1 \text{Female}_i + \beta_2 \text{Formal}_i + \beta_3 \text{Informal}_i + \beta_4(\text{Female}_i \times \text{Formal}_i) + \beta_5(\text{Female}_i \times \text{Informal}_i) + \beta_6 X_i] \quad (17)$$

Where Formal_i and Informal_i identify the relevant credit-market categories, with the omitted category serving as the reference group. Because interaction effects in nonlinear models cannot generally be interpreted from the interaction coefficient alone, predicted outcomes and gender-specific AMEs were calculated for each credit-market category. A joint Wald test of the interaction terms was used to assess whether the gender difference varied statistically across credit-market types. This approach is consistent with the broader nonlinear-model framework in [43].

3.13 Diagnostic model for selection into the analytical credit sample

Because only 262 of the 355 surveyed farmers entered the analytical credit sample, observable predictors of sample inclusion were examined using a binary selection model. Let:

$S_i = 1$ if farmer i is included in the analytical credit sample

$S_i = 0$ otherwise

The probability of inclusion was estimated as:

$$\Pr(S_i = 1 \mid Z_i) = \exp(Z_i\delta) / [1 + \exp(Z_i\delta)] \quad (18)$$

Where Z_i contains the observed characteristics available for both the full and analytical samples.

The purpose of this model was diagnostic. A statistically significant predictor of inclusion indicates systematic differences in observable characteristics between farmers included and excluded from the analytical credit sample; it does not, by itself, establish that the substantive credit-rationing estimates are biased. This distinction is important because selection adjustment based only on observed characteristics cannot account for selection arising from unobserved determinants. [43] provides a broad treatment of missing-data and sample-selection problems, while recent methodological work emphasizes that the performance of inverse-probability weighting depends strongly on the response model and the plausibility of the assumed missingness/selection mechanism.

3.14 Inverse-probability weighting

Inverse-probability weighting (IPW) was used as a sensitivity analysis to assess whether the gender-rationing results were sensitive to observable differences in the probability of inclusion in the analytical credit sample. Using the predicted inclusion probability:

$$\hat{P}_i = \hat{P}(S_i = 1 \mid Z_i) \quad (19)$$

The inverse-probability weight was defined as:

$$w_i = \frac{1}{\hat{P}_i} \quad (20)$$

Thus, observations with a lower predicted probability of appearing in the analytical sample receive greater weight. IPW is a recognized approach for adjusting analyses involving incomplete samples or differential selection based on observed characteristics. Recent methodological reviews describe IPW as a widely used approach in incomplete-data settings but emphasize that its validity depends on appropriate specification of the selection model and the assumptions underlying the missingness mechanism [16, 21]. Accordingly, the IPW estimates in this study were not interpreted as definitive corrections for selection bias. Rather, they provide evidence on whether the main gender-rationing conclusion is robust to reweighting observations according to their predicted probability of analytical-sample inclusion.

3.15 Assessment and trimming of extreme weights

The distribution of the estimated IPW weights was examined before conducting the weighted sensitivity analyses. Extreme weights can increase estimator variance and make results disproportionately dependent on observations with very small estimated selection probabilities. Recent methodological work has emphasized both the potential instability of IPW and the importance of carefully specifying the weighting model [16, 21]. As a sensitivity analysis, weights were trimmed at the 1st and 99th percentiles:

$$w_i = \min[\max(w_i, P_1(w)), P_{99}(w)] * \quad (21)$$

Where $P_1(w)$ and $P_{99}(w)$ denote the first and 99th percentiles of the estimated weight distribution.

The untrimmed and trimmed IPW results were compared with the principal fractional-logit estimates. Similar conclusions across these specifications would indicate that the substantive inference is not driven by a small number of observations receiving unusually large weights. Importantly, trimming changes the weighting scheme and therefore defines a sensitivity estimate rather than providing an automatic statistical correction. It was consequently treated as a robustness exercise rather than as the preferred estimator.

3.16 Estimation and inference

The demand and receipt equations were estimated by OLS using the logarithm of credit amounts. Heteroskedasticity-robust standard errors were used for inference. The fractional-response and binary-response models were estimated using robust variance estimators. For the fractional-response model, robust quasi-maximum-likelihood inference is appropriate because the conditional mean is the central modelling object and the full conditional distribution of the fractional outcome need not be correctly specified [30]. For the nonlinear models, statistical inference was based primarily on AMEs, predicted values, confidence intervals, and joint Wald tests. Statistical significance was assessed at the 1%, 5%, and 10% levels. All analyses were conducted in Stata. The fractional-response estimation is consistent with Stata's implementation of fractional regression models, which permits logit, probit, and related conditional-mean specifications for outcomes bounded between zero and one.

3.17 Identification and interpretation

The empirical strategy does not identify a causal effect of gender on credit outcomes. Instead, it estimates adjusted differences between male and female farmers conditional on observed characteristics. Three distinctions are particularly important; First, the demand model estimates whether women and men request different amounts of credit. Second, the receipt model estimates whether the amount actually received differs by gender. Third, the proportional-rationing model asks whether the fraction of requested credit that remains unmet differs by gender. These are conceptually distinct outcomes and should not be conflated.

The conditional receipt model provides an additional diagnostic by asking whether the gender difference in received credit persists after controlling for requested credit. Because requested credit is closely connected to received credit, this model should be interpreted as a conditional association rather than a structural causal allocation model. Finally, the IPW and trimmed-IPW specifications address potential differences in analytical-sample inclusion attributable to observed characteristics. They do not establish that unobserved selection has been eliminated. Recent methodological evidence cautions that IPW can be sensitive to response-model specification and may not necessarily remove selection bias under more complicated missing-data mechanisms [21]. Accordingly, the strongest interpretation of the study is whether there is evidence of gender differences in credit demand, credit receipt, and proportional credit rationing conditional on observed characteristics, rather than whether female farmers are causally discriminated against by lenders.

4 Results

4.1 Characteristics of full sample and analytical credit sample

Table 1 compares the analytical credit sample (N = 262) with the excluded sample (N = 93) and reports institutional characteristics for the analytical sample. Gender, age, education, farm size and farming experience did not differ significantly between the groups. Cooperative membership and state of residence differed significantly: cooperative membership was 79.01% in the analytical sample and 27.96% among excluded farmers ($p < 0.001$), while Oyo State residents accounted for 61.07% and 25.81%, respectively ($p < 0.001$). In the analytical sample, the mean interest rate was 12.42%, mean travel time to the credit source was 1.55 hours, and mean travel cost was ₦1,157.41.

Panel B presents the institutional characteristics of the 262 farmers in the analytical credit sample. The mean interest rate was 12.42% (SD = 6.71), while farmers travelled an average of 1.55 hours to their credit source and incurred an average travel cost of ₦1,157.41. Credit-market composition also indicates substantial reliance on different source; 54.58% of farmers used formal credit only, 36.64% used informal credit only and 8.78% used both formal and informal sources.

Table 1. Characteristics of the full sample and analytical credit sample

Panel A. Socioeconomic, demographic and farm characteristics

Variable	Analytical credit sample (N = 262)	Excluded sample (N = 93)	p-value
Gender			0.103
Male, n (%)	182 (69.47)	56 (60.22)	
Female, n (%)	80 (30.53)	37 (39.78)	
Age (years), mean (SD)	51.263 (10.897)	49.452 (12.170)	0.207
Household size, mean (SD)	7.494 (5.105)	6.688 (2.908)	0.066
Education, n (%)			0.117
No formal education	58 (22.14)	14 (15.05)	
Primary education	93 (35.50)	28 (30.11)	
Secondary education	81 (30.92)	33 (35.48)	
Tertiary education	30 (11.45)	18 (19.35)	
Marital status, n (%)			0.017
Single	9 (3.44)	6 (6.45)	
Married	234 (89.31)	73 (78.49)	
Divorced	4 (1.53)	7 (7.53)	
Widowed	15 (5.73)	7 (7.53)	
Farm size (ha), mean (SD)	2.176 (1.772)	1.946 (1.346)	0.198
Farming experience (years), mean (SD)	18.515 (11.923)	19.387 (12.656)	0.563
Cooperative membership, n (%)			0.001
Non-member	55 (20.99)	67 (72.04)	
Member	207 (79.01)	26 (27.96)	
State, n (%)			0.001
Ogun	102 (38.93)	69 (74.19)	
Oyo	160 (61.07)	24 (25.81)	

Source: Data analysis, 2026

Panel B. Institutional characteristics of the analytical credit sample

Variable	Analytical credit sample (N = 262)
Interest rate (%), mean (SD)	12.422 (6.709)
Distance to credit source (hours), mean (SD)	1.546 (1.570)
Travel cost to credit source (₦), mean (SD)	1,157.41 (1,512.92)
Credit-market source, n (%)	
Formal only	143 (54.58)
Informal only	96 (36.64)
Both formal and informal	23 (8.78)

Source: Data analysis, 2026

4.2 Credit demand and receipt by gender

Table 2 reports credit requested and received by gender for 182 male and 80 female farmers. Mean credit requested was ₦613,516.5 for male farmers and ₦337,062.5 for female farmers, a statistically significant difference of ₦276,454.0 ($t = 3.62$, $p < 0.001$). Mean credit received was ₦500,274.7 for

male farmers and ₦275,312.5 for female farmers, a statistically significant difference of ₦224,962.2 (t = 3.71, p < 0.001). Median requested amounts were ₦400,000 and ₦200,000, while median received amounts were ₦300,000 and ₦200,000, respectively.

Table 2 Credit demand and receipt among smallholder cassava farmers by gender

Variable	Male	Female	Difference	t-statistic	p-value
Credit requested (₦)	613,516.5	337,062.5	276,454.0	3.62	<0.001
Standard deviation	(642,963.4)	(347,752.9)			
Median	400,000	200,000			
Credit received (₦)	500,274.7	275,312.5	224,962.2	3.71	<0.001
Standard deviation	(513,560.5)	(263,817.3)			
Median	300,000	200,000			
Observations	182	80	262		

Source: Data analysis, 2026

4.3 Distribution of proportional credit rationing by gender

Table 3 shows that mean proportional credit rationing was 0.1356 among male farmers and 0.1130 among female farmers; the difference was not statistically significant (difference = 0.0226, t = 0.85, p = 0.394). The pooled mean was 0.1287. The median and 25th percentile were zero for both groups. The 75th percentile was 0.25 among male farmers and 0.20 among female farmers. The rank-sum test also found no statistically significant difference (z = 0.55, p = 0.585).

Table 3 Distribution of proportional credit rationing by gender

Statistic	Male	Female	Overall
Observations	182	80	262
Mean	0.1356	0.1130	0.1287
Standard deviation	0.2088	0.1666	0.1968
Median	0.0000	0.0000	0.0000
25th percentile	0.0000	0.0000	0.0000
75th percentile	0.2500	0.2000	0.2500
Minimum	0.0000	0.0000	0.0000
Maximum	1.0000	0.6000	1.0000
Mean difference			0.0226
t-statistic			0.85
p-value			0.394
Rank-sum z			0.55
Rank-sum p-value			0.585

Source: Data analysis, 2026

4.4 Gender differences in credit demand

Table 4 presents OLS estimates for log credit requested. The female coefficient was negative and statistically significant in both the unadjusted model ($\beta = -0.571$, SE = 0.114, $p < 0.001$) and adjusted model ($\beta = -0.308$, SE = 0.106, $p < 0.01$). The adjusted coefficient corresponds to approximately 26.5% lower requested credit among female farmers. Model R^2 increased from 0.086 to 0.380 after adjustment. In the adjusted model, farm size, age, primary, secondary and tertiary education, and interest rate were positively associated with requested credit at the reported significance levels; the remaining covariates were not statistically significant.

Table 4 Gender Differences in Credit Demand

Variable	Unadjusted Coefficient	SE	t-value	Adjusted Coefficient	SE	t-value
Female	−0.571***	0.114	−5.01	−0.308***	0.106	−2.90
Age				0.014**	0.006	2.34
Primary education				0.388***	0.135	2.87
Secondary education				0.691***	0.149	4.64
Tertiary education				0.420**	0.199	2.11
Married				−0.001	0.161	−0.01
Household size				−0.004	0.009	−0.44
Farming experience				−0.007	0.006	−1.17
Farm size (ha)				0.187***	0.028	6.68
Cooperative membership				0.190	0.129	1.47
Interest rate				0.032**	0.016	2.00
Distance to loan source				0.023	0.038	0.60
Travel cost to loan source				0.111	0.230	0.48
Oyo state				−0.167	0.111	−1.50
Constant	12.931***	0.064	201.95	11.446***	0.356	32.15
Observations	262			262		
R^2	0.086			0.380		
F-statistic	25.17***			31.76***		

***, ** and * means $p < 0.01$, $p < 0.05$ and $p < 0.10$ respectively.
Source: Data analysis, 2026

4.5 Gender differences in credit receipt

Table 5 reports OLS estimates for log credit received. The female coefficient was negative and statistically significant in the unadjusted model ($\beta = -0.457$, $p < 0.001$) and remained negative and significant in the adjusted model ($\beta = -0.251$, $p < 0.05$), corresponding to approximately 22.2% lower received credit. Model R^2 increased from 0.032 to 0.302 after adjustment. Education, farm size, age and interest rate were statistically significant covariates in the adjusted specification, as shown in Table 5.

Table 5 Gender differences in credit receipt

Variable	Unadjusted Coefficient	SE	t-value	Adjusted Coefficient	SE	t-value
Female	−0.457***	0.129	−3.54	−0.251**	0.113	−2.22
Age				0.013*	0.007	1.86
Primary education				0.353***	0.140	2.52
Secondary education				0.779***	0.153	5.09
Tertiary education				0.521**	0.226	2.31
Married				−0.078	0.157	−0.50
Household size				−0.005	0.011	−0.45
Farming experience				−0.006	0.006	−1.00
Farm size (ha)				0.160***	0.028	5.71
Cooperative membership				0.398	0.271	1.47
Interest rate				0.030**	0.014	2.19
Distance to loan source				0.016	0.035	0.46
Travel cost to loan source				0.088	0.203	0.43

Variable	Unadjusted Coefficient	SE	t-value	Adjusted Coefficient	SE	t-value
Oyo state				0.044	0.187	0.24
Constant	12.676***	0.097	130.68	11.018***	0.407	27.07
Observations	262			262		
R^2	0.032			0.355		
F-statistic	12.51***			21.43***		

***, ** and * means $p < 0.01$, $p < 0.05$ and $p < 0.10$ respectively.
Source: Data analysis, 2026

4.6 Credit receipt conditional on credit requested

Table 6 reports OLS estimates of log credit received conditional on log credit requested. The model was jointly significant ($F = 116.88$, $p < 0.001$) and had $R^2 = 0.571$. Log requested credit was positively associated with log received credit ($\beta = 1.016$, $p < 0.001$). The female coefficient was positive but statistically insignificant ($\beta = 0.062$, $t = 0.71$). The remaining covariates were not statistically significant in this specification.

Table 6 Credit receipt conditional on credit requested

Variable	Coefficient	SE	t-value
Female	0.062	0.087	0.71
ln(requested credit)	1.016***	0.107	9.50
Age	−0.001	0.004	−0.25
Primary education	−0.041	0.116	−0.35
Secondary education	0.077	0.108	0.71
Tertiary education	0.094	0.120	0.78
Married	−0.077	0.076	−1.01
Household size	−0.001	0.006	−0.17
Farming experience	0.002	0.004	0.50
Farm size (ha)	−0.029	0.033	−0.88
Cooperative membership	0.204	0.201	1.02
Oyo state	0.214	0.164	1.30
Constant	−0.613	1.488	−0.41
Observations	262		
R^2	0.571		
F-statistic	116.88***		
Root MSE	0.797		

***, ** and * means $p < 0.01$, $p < 0.05$ and $p < 0.10$ respectively.
Source: Data analysis, 2026

4.7 Proportion of credit rationing

Table 7 presents fractional-logit estimates for the proportion of requested credit not received. The female coefficient was small and statistically insignificant ($\beta = 0.017$, $t = 0.067$). Farm size was positively associated with proportional rationing at the 10% significance level ($\beta = 0.084$, $p < 0.10$). The other socioeconomic, educational, household, cooperative and location covariates were not statistically significant.

Table 7 Fractional-Logit estimates of proportional credit rationing

Variable	Coefficient	SE	t-value
Female	0.017	0.253	0.067

Variable	Coefficient	SE	t-value
Age	0.0003	0.013	0.023
Primary education	0.437	0.493	0.886
Secondary education	0.694	0.525	1.322
Tertiary education	0.591	0.538	1.099
Married	0.235	0.454	0.518
Household size	0.009	0.017	0.529
Farming experience	−0.001	0.014	−0.071
Farm size (ha)	0.084*	0.043	1.953
Cooperative membership	−0.020	0.316	−0.063
Oyo state	−0.200	0.266	−0.752
Constant	−2.726***	0.835	−3.264

***, ** and * means $p < 0.01$, $p < 0.05$ and $p < 0.10$ respectively.
Source: Data analysis, 2026

4.8 Average marginal effects of gender on credit rationing

Table 8 reports average marginal effects of gender across the alternative rationing models. The female AME was 0.0041 in the OLS model ($p = 0.884$), 0.0019 in the fractional-logit model ($p = 0.947$), and 0.0361 for the probability of any rationing in the binary-logit model ($p = 0.610$). None of these estimates was statistically significant, and the reported confidence intervals included zero.

Table 8 Average marginal effects of gender on credit rationing

Model	Female AME	SE	z/t	p-value	95% CI
OLS: proportional rationing	0.0041	0.0278	0.15	0.884	[−0.0505, 0.0586]
Fractional logit: proportional rationing	0.0019	0.0280	0.07	0.947	[−0.0531, 0.0568]
Binary logit: any rationing	0.0361	0.0708	0.51	0.610	[−0.1027, 0.1750]

Source: Data analysis, 2026

4.9 Gender–credit-market interactions in credit rationing

Table 9 reports estimates by credit-market type. The estimated marginal effects of female gender were not statistically significant for formal-only, informal-only or combined credit markets. The joint test of the gender-by-credit-market interaction was also not statistically significant (χ^2 (2) = 0.53, $p = 0.769$).

Table 9 Gender differences in credit rationing by credit-market type

Credit-market type	Male predicted rationing	Female predicted rationing	Female − Male AME	SE	p-value
Formal only	0.1093	0.1318	0.0216	0.0331	0.514
Informal only	0.1521	0.1343	−0.0181	0.0514	0.725
Both formal and informal	0.2003	0.2044	0.0041	0.0906	0.963
Joint test of gender × credit-market type	$\chi^2(2) = 0.53$	$p = 0.769$.			

Source: Data analysis, 2026

4.10 Supplementary and sensitivity analyses

Table 10 and Supplementary Tables S1–S9 report the selection and sensitivity analyses. In the selection model, female gender was negatively associated with inclusion in the analytical credit sample (β = −0.857, p = 0.014), while cooperative membership and Oyo State residence were positively associated with inclusion. Predicted inclusion probabilities averaged 0.737 in the full sample and 0.827 in the analytical sample. Inverse-probability weights averaged 1.373 and had a maximum of 16.11. The inverse-probability-weighted fractional-logit female coefficient was not statistically significant (β = −0.334, p = 0.289); the selection-adjusted binary model and trimmed-weight specifications also showed no statistically significant gender differences in rationing outcomes.

Table 10 Robustness and sensitivity analysis for gender differences in credit rationing

Specification	Female coefficient	SE	Female AME	AME SE	p-value
Main fractional logit	0.0168	0.2531	0.0019	0.0280	0.947
HHS < 20: fractional logit	−0.0006	0.2603	−0.0001	0.0290	0.998
IPW fractional logit	−0.3339	0.3150	−0.0373	0.0358	0.298
Trimmed IPW fractional logit	−0.2457	0.2935	−0.0283	0.0343	0.410
Main binary logit	0.1639	0.3203	0.0361	0.0708	0.610
IPW binary logit	−0.2266	0.3533	−0.0500	0.0772	0.518

Source: Data analysis, 2026

5 Discussion

This study examined gender differences in agricultural credit demand, credit receipt and proportional credit rationing among smallholder cassava farmers in Nigeria. The findings reveal an important distinction between the amount of credit farmers seek and the extent to which their requests are fulfilled. Female farmers requested and received significantly lower absolute amounts of credit than male farmers. However, the gender difference in credit receipt was no longer statistically significant after controlling for the amount requested, and the analysis provided no statistically significant evidence of greater proportional credit rationing among women. These findings highlight the importance of distinguishing borrowers' demand for credit from lenders' fulfilment of that demand when assessing gender disparities in agricultural finance [7, 9, 28, 39].

5.1 Gender differences in credit demand and receipt

The descriptive and multivariate results consistently indicate that female farmers requested smaller amounts of agricultural credit than their male counterparts. The unadjusted difference in mean requested credit was ₦276,454, while the adjusted log-linear model indicated that female farmers requested approximately 26.5% less credit, conditional on observed socioeconomic, farm, institutional and location characteristics. Although adjustment reduced the magnitude of the gender coefficient, its continued statistical significance indicates that the measured characteristics did not fully account for the difference in requested credit.

This finding is consistent with evidence that gender disparities in agricultural finance may emerge at the demand stage rather than exclusively through lenders' decisions. Previous studies have documented gender differences in loan sizes and access to agricultural and microfinance credit [3, 5, 13]. Evidence also suggests that women may request smaller agricultural loans in contexts where gender norms shape borrowing decisions and intra-household dynamics influence access to and control over financial resources [13, 18, 32]. These considerations are important because observed borrowing outcomes reflect not only the financing needs of farmers but also their expectations about borrowing conditions, repayment obligations, information availability and access to financial institutions [7, 9].

The present findings nevertheless do not establish why female farmers requested smaller amounts. Differences in expected financing needs, farm investment plans, perceived borrowing risks, access to credit information and household decision-making are possible explanations, but these mechanisms were not directly identified in the analysis. The results should therefore be interpreted as

evidence of a persistent gender difference in requested credit rather than proof of a particular behavioural or institutional explanation.

The positive associations of farm size, age and education with requested credit provide additional insight into the characteristics associated with borrowing amounts. Farmers operating larger farms requested more credit, consistent with the possibility that larger production operations require greater expenditure on land preparation, planting materials, labour and other inputs. Education was also positively associated with requested credit across the reported educational categories relative to farmers without formal education. Education may be associated with the ability to obtain financial information, evaluate loan conditions and engage with credit providers. Previous research has identified information constraints, transaction costs and institutional conditions as important features of agricultural credit markets [4, 7, 17]. However, these associations do not establish that education or farm size causes higher credit demand.

The unadjusted and adjusted models also showed that female farmers received lower absolute amounts of credit than male farmers. The adjusted gender coefficient declined in magnitude, from −0.457 to −0.251, corresponding to approximately 22.2% lower credit receipt among women, conditional on the observed covariates. This attenuation indicates that differences in observed characteristics account for part of the unconditional gap, although they do not fully explain it. Similar gender differences in agricultural credit access and loan size have been documented in developing-country settings and in sub-Saharan Africa [3, 5, 13]. Nigerian evidence also highlights the relevance of institutional barriers and information asymmetry in women's access to agricultural finance [34].

Importantly, the results for credit receipt must be interpreted alongside those for credit demand. A lower amount received does not necessarily indicate that a borrower has been treated less favourably by a lender when that borrower also requested a smaller amount. Agricultural credit constraints can arise through borrowers' decisions to seek credit and lenders' decisions about the amount supplied [7, 9, 28, 39]. Consequently, comparisons of absolute loan amounts alone cannot adequately distinguish differences in borrowing demand from differences in the fulfilment of credit requests.

5.2 Credit receipt conditional on requested amounts and proportional rationing

The conditional credit-receipt model provides a more direct assessment of whether the gender difference in absolute credit receipt persists after accounting for the amount requested. Requested credit was strongly and positively associated with received credit, with an estimated coefficient of 1.016. By contrast, the female coefficient was positive but statistically insignificant after the amount requested and other observed characteristics were controlled for. Thus, the analysis found no statistically significant conditional gender difference in the amount of credit received.

This result is central to interpreting the unconditional gender gap. Although women received smaller amounts of credit on average, the conditional model does not indicate that they systematically received less credit than men requesting comparable amounts, after accounting for the included covariates. The disappearance of the statistically significant gender coefficient is consistent with the interpretation that differences in the scale of credit demanded account for an important part of the observed difference in absolute credit receipt. It does not, however, establish that lenders behave identically towards male and female applicants. The conditional model is based on observed characteristics and does not fully account for potentially unobserved differences in loan purpose, creditworthiness, collateral, credit history or lender assessment.

The findings for proportional credit rationing provide complementary evidence. The descriptive comparison showed no statistically significant gender difference in the proportion of requested credit that remained unfulfilled. The mean rationing measure was 0.1356 for men and 0.1130 for women, while the overall mean of 0.1287 indicates that approximately 12.9% of requested credit was not received, on average. The fractional-logit estimates likewise showed no statistically significant association between female gender and proportional rationing. The supplementary marginal-effects

estimates and the binary model of experiencing any rationing also failed to identify a statistically significant gender difference.

These findings reinforce the distinction between the amount borrowed and the extent to which credit demand is satisfied. Previous studies have documented gender differences in agricultural credit access and loan sizes [3, 5, 13], but differences in absolute loan amounts do not necessarily imply differences in the proportion of credit requests fulfilled. The demand–supply perspective on credit constraints emphasises that borrowers may differ in the amounts they seek, while lenders determine the amounts they are willing or able to provide [7, 9, 28, 39]. The present findings therefore qualify interpretations of lower female credit receipts as evidence of greater lender-side rationing.

The absence of a statistically significant gender difference should not be interpreted as evidence that rationing is absent or that gender-related barriers do not exist in agricultural finance. The distribution of the rationing measure indicates that some farmers received less credit than they requested, and the results do not rule out gender differences in particular institutions, loan products or borrower subgroups. Rather, within this analytical sample and conditional on the observed covariates, the study did not detect a systematic difference between male and female farmers in proportional rationing or in the probability of experiencing any rationing. Statistical insignificance also does not establish that the gender effects are exactly zero.

Farm size was positively associated with proportional rationing in the fractional-logit model, although the association was statistically significant only at the 10% level. This result suggests that farmers operating larger farms may experience a greater shortfall relative to their requested credit, even though farm size was positively associated with the absolute amounts requested and received in the corresponding models. One possible explanation is that financing requirements may increase with farm scale without a corresponding increase in the amount of credit supplied. However, this explanation remains tentative because the analysis does not directly identify lenders' reasons for limiting particular loan amounts. The result nevertheless illustrates why absolute credit receipt and proportional fulfilment should be examined as distinct outcomes when studying agricultural credit constraints [7, 9, 39].

5.3 Credit-market type and institutional conditions

The analysis by credit-market type did not identify a statistically significant gender difference in proportional rationing among farmers relying exclusively on formal credit, those relying exclusively on informal credit, or those using both sources. The joint test of the gender-by-credit-market interaction was also statistically insignificant (χ^2 (2) = 0.53, p = 0.769). Thus, the study found no detectable evidence that the association between gender and proportional rationing differed across the three credit-market categories.

This result is relevant given the coexistence of formal and informal borrowing in smallholder agriculture. In the analytical sample, farmers obtained credit through formal sources only, informal sources only, or a combination of both. Such a pattern is consistent with research showing that smallholders may operate across different credit-market segments rather than relying exclusively on formal financial institutions [2, 15, 28, 36]. The conditions, information requirements and transaction costs associated with borrowing may differ across these segments, potentially influencing farmers' financing choices and the amounts they seek [7, 9]. However, the insignificant interaction does not demonstrate that formal and informal credit markets operate identically or that their lending practices are gender-neutral. It indicates only that the analysis did not detect statistically significant differences in the gender–rationing association across the specified market categories.

The institutional characteristics of the analytical sample also help contextualise these findings. Variation in interest rates, travel time and the costs of reaching credit sources indicates that borrowers face different financial and non-financial conditions when accessing credit. Transaction costs can affect credit-market participation even where lending sources are available [7]. Cooperative participation may also influence access to information and institutional networks, while geographical location may reflect

differences in the availability of financial services and lending arrangements [4, 5, 17]. These factors support the inclusion of institutional and location controls in the empirical models, although the present results do not establish their causal effects on credit outcomes.

5.4 Sample selection and robustness of the findings

The supplementary selection model indicated that female farmers were less likely to enter the analytical credit sample, while cooperative membership and residence in Oyo State were positively associated with inclusion. The analytical sample was therefore not randomly drawn from the full sample with respect to these observed characteristics. This matters because comparisons based exclusively on farmers included in the credit analysis may not represent the experiences of all surveyed cassava farmers. Selection into agricultural credit markets is itself an important process and may reflect a combination of borrower characteristics, institutional conditions and credit-market constraints [7, 8, 9].

The differences between included and excluded farmers were especially pronounced for cooperative membership and state of residence. These findings suggest that institutional participation and geographical location are relevant to the composition of the analytical sample, consistent with research highlighting the role of institutional characteristics and regional differences in agricultural credit access [4, 5, 17]. The lower probability of inclusion among female farmers also reinforces the importance of distinguishing gender differences in participation from gender differences in the outcomes observed among those who obtain credit.

Inverse-probability-weighted estimates and analyses using trimmed weights did not materially change the principal rationing findings. Across the weighted and trimmed specifications, the female coefficients for proportional rationing remained statistically insignificant. The corresponding analyses of the probability of experiencing any rationing also found no statistically significant gender difference. These results provide reassurance that the main finding is not driven solely by the observed differences in sample inclusion or by a small number of influential inverse-probability weights.

Nevertheless, these sensitivity analyses do not eliminate every possible source of selection bias. Inverse-probability weighting relies on the specification of the selection model and the adequacy of the observed variables used to estimate inclusion probabilities. It cannot fully account for unobserved differences that affect both selection into the analytical sample and credit outcomes. The results should therefore be interpreted as evidence of robustness to the observed selection process examined in this study, rather than proof that selection bias has been eliminated.

This qualification is particularly important because the analysis focuses on farmers who both demanded and received positive credit. The findings do not establish whether gender differences exist in the likelihood of demanding credit across the full survey sample or among farmers who demanded credit but received nothing. Earlier research on gender differences in agricultural credit access and loan size provides an important context for these distinctions [3, 5, 13, 34, 41]. The present study adds to this literature by separately examining the amounts requested and received and the proportion of requested credit left unfulfilled.

5.5 Implications for agricultural finance and gender inclusion

The findings have implications for how gender disparities in agricultural credit are measured and addressed. First, assessments based solely on the absolute amounts requested or received may obscure the distinction between differences in credit demand and differences in lenders' fulfilment of that demand. The lower amounts requested and received by female farmers indicate a gender disparity in the scale of borrowing, but the conditional receipt and rationing analyses do not show that women experienced significantly greater proportional shortfalls within the analytical sample. Evaluations of gender inclusion in agricultural finance should therefore examine credit demand, loan approval, amounts disbursed and the proportion of requested financing fulfilled as separate outcomes [7, 9, 28, 39].

Second, the persistence of a gender difference in requested credit after adjustment suggests a need to investigate why female farmers seek smaller amounts. Possible areas for further assessment include whether women have different financing requirements, face constraints in accessing information about loan products, anticipate difficulties meeting collateral requirements, or perceive borrowing and repayment risks differently. Previous evidence has highlighted information asymmetry and collateral requirements as potential barriers to women's agricultural credit access in Nigeria [34], while other studies have documented gender differences in agricultural credit access, loan size and credit rationing [3, 5, 13, 41]. These findings provide a useful basis for further investigation, but the mechanisms they identify should not be treated as confirmed explanations for the present results.

Financial institutions and agricultural development programmes could consequently examine whether loan information is accessible to women and men on comparable terms, whether application procedures and transaction costs impose avoidable burdens, and whether available loan products align with the financing needs of different categories of farmers. Financial advisory services and transparent information on eligibility, loan costs and repayment conditions may also help farmers make better-informed borrowing decisions. These measures are relevant policy considerations, although their effectiveness cannot be established from the cross-sectional associations reported here. Any programme intended to address gender disparities should evaluate both participation in credit markets and the adequacy of financing relative to borrowers' production requirements.

6 Limitations and directions for future research

Several limitations should be considered when interpreting these findings. First, the study uses cross-sectional data, which limit the ability to establish causal relationships between gender, observed farmer characteristics and credit outcomes. The estimated coefficients represent conditional associations and do not identify the causal mechanisms underlying differences in requested or received credit.

Second, the principal credit-outcome analysis is restricted to 262 farmers who demanded and received positive credit. It therefore does not provide a complete assessment of gender differences in the decision to demand credit across the entire survey sample or of the experiences of applicants who received no credit. Although the selection-adjusted and inverse-probability-weighted analyses address differences associated with observed sample inclusion, residual selection bias remains possible. The findings should consequently not be generalized without qualification to all smallholder cassava farmers, particularly those who did not seek credit or whose applications resulted in no disbursement.

Third, the analysis cannot fully distinguish the influence of unobserved financing needs, loan purposes, collateral availability, credit history, lender assessments and institutional lending rules. The absence of a statistically significant conditional gender coefficient does not rule out discrimination or other gender-related barriers at earlier stages of the credit process. Future research using longitudinal data or linked borrower–lender records could distinguish more directly between farmers' desired financing, loan applications, approval decisions and actual disbursements. Such data would also help establish whether gender differences vary by loan purpose, lender type, collateral requirements and borrower characteristics.

Overall, the findings indicate that the gender disparity in agricultural credit among the sampled cassava farmers is more clearly reflected in the amounts requested and received than in the proportion of requested credit left unfulfilled. Female farmers sought and received smaller absolute amounts, but the study found no statistically significant gender difference in conditional credit receipt, proportional rationing or the probability of experiencing rationing. The selection-adjusted sensitivity analyses and credit-market-specific estimates support this central conclusion, subject to the limitations of the analytical sample and the observational research design. The results highlight the importance of distinguishing the scale of borrowing from the fulfilment of credit demand when assessing gender inclusion in agricultural finance.

7 Conclusion

This study examined gender differences in agricultural credit demand, receipt and rationing among smallholder cassava farmers in Ogun and Oyo States, Nigeria. The findings revealed that female farmers requested and received significantly less credit than male farmers, and these differences remained significant after controlling for demographic, socioeconomic, farm and institutional characteristics. However, the gender difference in credit receipt became statistically insignificant after conditioning on requested credit, while neither proportional credit rationing nor the probability of experiencing any positive rationing differed significantly by gender. The absence of a gender difference in rationing was also consistent across formal, informal and combined credit markets. Selection-adjusted and trimmed inverse-probability-weighted models further confirmed the robustness of these findings. Thus, the evidence suggests that the principal gender disparity in agricultural credit lies in the scale of credit demanded and consequently received, rather than in differential fulfilment of credit requests.

These findings have important implications for agricultural finance policy in Ogun State. Interventions should focus on the factors underlying women's lower credit demand rather than assuming that female farmers are systematically more rationed by lenders. Financial institutions and agricultural development programmes should strengthen access to credit information, financial literacy and credit-planning services to enable women farmers to better assess their financing requirements and make informed borrowing decisions. Strengthening farmer cooperatives and their linkages with formal financial institutions could further reduce information and transaction costs and improve women's engagement with agricultural credit markets. Credit programmes should also consider the productive scale and financing needs of female cassava farmers when designing loan products, while maintaining transparent and sustainable lending criteria. Finally, monitoring frameworks should distinguish between credit demand, credit receipt and credit rationing when assessing gender equity. This distinction is essential because lower female loan amounts do not necessarily indicate greater credit rationing and may instead reflect differences in the amount of credit women seek.

Author contributions

Kazeem Oriyomi Aboaba: Conceptualization, formal analysis, writing—original draft, project administration. Oluwatoyin Morenike Sodipe: Investigation, writing—review and editing, Validation.

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Data availability

The data will be made available upon reasonable request.

Declarations

Ethics approval

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki and the research ethics guidelines of the Federal University of Agriculture, Abeokuta (FUNAAB), Nigeria. The research protocol, survey instrument and data collection procedures were reviewed and approved by the Postgraduate Committee of the Department of Agricultural Economics and Farm Management, FUNAAB, prior to field implementation. The committee does not issue formal ethics approval reference or permit numbers for postgraduate survey-based research; therefore, no approval number is available for this study.

Consent to participate

Participation was entirely voluntary. All respondents were informed of the research objectives, the nature of their participation, and their right to decline participation or withdraw at any time without penalty. Informed consent was obtained from all participants before data collection. All information collected was treated confidentially and used solely for academic and research purposes.

Consent for publication

All authors have read and approved the final version of the manuscript and consented to its publication.

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Supplementary tables

Table S1. Multivariable diagnostic model for inclusion in the analytical credit sample

Variable	Coefficient	SE	z	p-value
Female	−0.8568**	0.3494	−2.45	0.014
Age	−0.0070	0.0186	−0.37	0.709
Primary education	0.5003	0.4650	1.08	0.282
Secondary education	0.0900	0.4968	0.18	0.856
Tertiary education	−0.7890	0.5969	−1.32	0.186
Married	0.1198	0.4688	0.26	0.799
Household size	0.0212	0.0328	0.65	0.519
Farming experience	−0.0104	0.0151	−0.69	0.490
Farm size (ha)	−0.1257	0.0876	−1.43	0.152
Cooperative membership	2.4746***	0.3545	6.98	<0.001
Oyo state	1.7281***	0.3513	4.92	<0.001
Constant	−0.2305	1.055	−0.22	0.827
Observations	355			
Wald $\chi^2(11)$	66.74			
Prob. > χ^2	<0.001			
Pseudo R^2	0.294			

***, ** and * means $p < 0.01$, $p < 0.05$ and $p < 0.10$ respectively.

Source: Data analysis, 2026

Table S2. Distribution of predicted selection probabilities

Statistic	All observations in selection model	Valid-credit observations
Observations	355	262
Mean	0.7373	0.8265
Standard deviation	0.2528	0.1863
Minimum	0.0621	0.0621
25th percentile	—	—
Median	—	0.9091
75th percentile	—	—
Maximum	0.9877	0.9877
p(selection) < 0.10	1	1
p(selection) > 0.90	—	139

Source: Data analysis, 2026

Table S3. Distribution of inverse-probability-of-selection weights

Statistic	IPW weight
Observations	262
Mean	1.3732
Standard deviation	1.0723
Minimum	1.0125

Statistic	IPW weight
1st percentile	1.0157
5th percentile	1.0218
25th percentile	1.0378
Median	1.1000
75th percentile	1.3039
95th percentile	2.4758
99th percentile	4.5292
Maximum	16.1116

Source: Data analysis, 2026

Table S4. Selection-adjusted fractional-logit model

Variable	IPW coefficient	SE	p-value
Female	−0.3339	0.3150	0.289
Age	−0.0015	0.0154	0.921
Primary education	0.3520	0.5194	0.496
Secondary education	0.4355	0.5695	0.442
Tertiary education	0.3305	0.5797	0.569
Married	0.1579	0.5700	0.781
Household size	0.0146	0.0195	0.453
Farming experience	−0.0099	0.0158	0.531
Farm size (ha)	0.1091**	0.0461	0.018
Cooperative membership	−0.0385	0.3119	0.901
Oyo state	−0.2685	0.2817	0.340
Constant	−2.1935**	1.080	0.042
Observations	262		
Wald $\chi^2(11)$	17.24		
Prob. > χ^2	0.101		
Pseudo R^2	0.024		

Source: Data analysis, 2026

Table S5. Selection-adjusted predicted proportional credit rationing

Gender	Predicted rationing	SE	95% CI
Male	0.1414	0.0200	[0.1022, 0.1806]
Female	0.1059	0.0230	[0.0608, 0.1510]
Female − Male AME	−0.0373	0.0358	[−0.1075, 0.0330]

Source: Data analysis, 2026

Table S6. Selection-adjusted binary logit of any credit rationing

Variable	Coefficient	SE	p-value
Female	−0.2266	0.3533	0.521
Age	0.0017	0.0199	0.933
Primary education	1.1536	0.5216	0.027
Secondary education	1.1750	0.5588	0.036
Tertiary education	0.6516	0.6664	0.327
Married	0.1071	0.6182	0.861
Household size	0.0401	0.0288	0.166
Farming experience	−0.0035	0.0169	0.834
Farm size (ha)	0.1905**	0.0899	0.034
Cooperative membership	0.2445	0.3523	0.487
Oyo state	−0.0134	0.3005	0.964

Variable	Coefficient	SE	p-value
Constant	−2.1201*	1.268	0.095
Observations	262		
Wald $\chi^2(11)$	15.92		
Prob. > χ^2	0.144		
Pseudo R^2	0.070		

***, ** and * means p < 0.01, p < 0.05 and p < 0.10 respectively.
Source: Data analysis, 2026

Table S7. Selection-adjusted probability of any credit rationing

Gender	Predicted probability	SE	95% CI
Male	0.4290	0.0408	[0.3490, 0.5091]
Female	0.3791	0.0629	[0.2558, 0.5023]
Female − Male AME	−0.0500	0.0772	[−0.2013, 0.1014]

Source: Data analysis, 2026

Table S8. Trimmed selection-adjusted fractional-logit model

Variable	Coefficient	SE	p-value
Female	−0.2457	0.2935	0.403
Age	0.0060	0.0143	0.677
Primary education	0.4163	0.5088	0.413
Secondary education	0.5445	0.5597	0.330
Tertiary education	0.5347	0.5650	0.345
Married	−0.0473	0.5189	0.928
Household size	0.0171	0.0190	0.374
Farming experience	−0.0095	0.0150	0.528
Farm size (ha)	0.1039**	0.0451	0.022
Cooperative membership	−0.1018	0.3008	0.735
Oyo state	−0.3051	0.2777	0.269
Constant	−2.4319**	0.978	0.013
Observations	262		
Wald $\chi^2(11)$	17.19		
Prob. > χ^2	0.102		
Pseudo R^2	0.022		

Source: Data analysis, 2026

Table S9. Predicted proportional rationing after ipw trimming

Gender	Predicted rationing	SE	95% CI
Male	0.1430	0.0192	[0.1053, 0.1807]
Female	0.1157	0.0232	[0.0703, 0.1612]
Female − Male AME	−0.0283	0.0343	[−0.0954, 0.0389]

Source: Data analysis, 2026

Table S10. Consolidated sensitivity results

Specification	Female coefficient	SE	Female AME	AME SE	p-value
Main fractional logit	0.0168	0.2531	0.0019	0.0280	0.947
HHS <20 fractional logit	−0.0006	0.2603	−0.0001	0.0290	0.998
IPW fractional logit	−0.3339	0.3150	−0.0373	0.0358	0.298
Trimmed IPW fractional logit	−0.2457	0.2935	−0.0283	0.0343	0.410
Main binary logit	0.1639	0.3203	0.0361	0.0708	0.610

Specification	Female coefficient	SE	Female AME	AME SE	p-value
IPW binary logit	−0.2266	0.3533	−0.0500	0.0772	0.518

Source: Data analysis, 2026