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Agricultural credit constraints in smallholder farming in developing countries: Evidence from Nigeria

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ABSTRACT

The agricultural sector in developing countries like Nigeria is characterized by low productivity, driven partly by low use of modern agricultural technologies. Poor access to credit is seen as a key barrier to adoption of these technologies. Policy discourses and literature often associate credit constraints by smallholders with supply-side factors such as inadequate access to sources of rural finance or high costs of borrowing. However, demand-side factors, such as smallholders' risk-averse behavior, high transaction costs and information asymmetry predominate in rural areas of developing countries equally play important roles in the functioning of rural credit market. Using a nationally representative LSMS-ISA data from 5000 smallholders in Nigeria and seemingly unrelated econometric models, we examine the nature of rural credit, the factors affecting rural credit, and the effects of credit constraints on adoption of four agricultural technologies – inorganic fertilizer, improved seed, agrochemicals, and mechanization. Contrary to policy discourses focusing on supply-side factors of rural credit, we found that demand-side factors are equally important for improving access and utilization of rural credit. On the supply side, inadequate collateral is the key constraint; hence supply-side policies should focus on enhancing smallholders' capacity to possess bankable collateral, such as land title or assets. On the demand-side, interventions such as crop insurance, information access and extension services are needed to increase credit access, technology adoption, and smallholder's agricultural productivity.

1. Introduction

With a population of around 207 million people, Nigeria is the most populous country in Africa and the seventh populous in the world. About half of the population live in rural areas and poverty disproportionately affected rural households. Among those living below the US$1.9 international poverty line, 84.6% live in rural areas (World Bank, 2018). Food insecurity and a shortage of energy and nutrient-rich foods remain the major challenges in rural Nigeria [34]; NPC and IFC, 2019. Like most other developing countries, agriculture is a key economic sector and major source of employment in Nigeria, contributing about 23% to GDP and a 70% share of the labor force. However, the sector suffers from two major challenges: (i) the sector's inability to meet domestic food requirements and (ii) its inability to export at quality levels required for market success [34]. Agricultural productivity remains low due to inadequate use of yield-enhancing agricultural inputs and technologies (e.g., fertilizer and improved seeds), limited access to extension services, credit constraints, and inadequate market linkages. Yields of staple cereals and root crops in Nigeria are lower than half the world's average, e.g., average yield gaps for the three major staple crops in Nigeria – rice, maize and cassava are more than 75%; 84%; and 25%, respectively (WDI, 2014; World Bank, 2018).

The two recent agricultural policy documents for Nigeria – the Agricultural Transformation Agenda (ATA) (2010/11–2016) and the agricultural promotion policy (APP) (2016–2020) argue that low agricultural productivity driven by low use of modern agricultural inputs or technologies, such as improved seed and inorganic fertilizer, is the major constraint hindering the performance of the agriculture sector in the country. Poor rural financial service was identified as a basic constraint limiting adoption of these agricultural technologies. The policy documents also claim that, beyond smallholder farmers, limited access to financial services also has adversely impacted input suppliers, crop processors and traders, and other private sector firms engaged in agribusiness value chains and in rural economic activities more broadly. According to the APP, insufficient access to rural credit and insurance products, high interest rates, and non-recognition of cooperatives and farmer-based organizations by financial institutions are among the major constraints to agricultural financing in Nigeria. Several policy interventions, such as the Nigerian 'incentive-based risk sharing system for agricultural lending' (2011); the 'growth enhancement support scheme'

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(2012), and the 'anchor borrowers' programme' (2015), were instituted by the government to mitigate the problem. Though government claims some positive results, e.g., agricultural lending increased from 1% in 2011 to 6% in 2015, access to agricultural credit remains a major challenge for farmers and others involved in the agricultural sector in Nigeria.

In line with these policy documents, much of the published research literature elsewhere highlights that lack of access to agricultural credit forms a major impediment to technology adoption among smallholder farmers in developing countries [31]; Feder and Umali, 1993; Fernandez-Cornejo and Mc [1,18,23,41,47]. The credit constraints faced by smallholders are being asscociated largely with supply-side factors, such as limited availability of alternative credit sources in local areas, unavailability of financial products that suit the needs of smallholders, or high costs of borrowing. Consequently, improving rural credit through policies that mitigate such supply-side constraints is often recommended as an effective strategy to boost technology adoption and agricultural productivity. However, improving credit access via the easing of supply-side constraints may not necessarily increase credit uptake and the use of modern inputs without equally addressing demand-side factors and behaviors that constrain smallholders' access to and use of credit [7,26,82]. Even if the supply-side constraints were removed, e.g., by lowering interest rates, smallholders might still not take loans for several reasons including: (i) smallholders' risk-aversion behavior, specifically fear of an inability to pay back the loan and subsequent loss of collateral; (ii) collateral requirements and repayment schedule that many smallholders cannot afford; (iii) smallholders may find the option of financing input purchases from their own resources through crop sales or other sources of income, e.g., through non-farm employment rather than through taking a loan; and (iv) high transaction costs, including cumbersome loan application procedures.

In addition to the supply-side constraints, these demand-side factors can play an important role in the functioning of rural credit markets and credit-rationing to smallholder borrowers. Empirical knowledge gaps exist in understanding the nature of rural credit among smallholders (i.e., supply-side vs. demand-side credit constraints) and whether credit constraints are a major limiting factor for modern technology adoption by smallholders. Using the 2018/19 Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA) survey data[1] for Nigeria and multinomial probit (MNP) and seemingly unrelated regression (SUR) models, the main objectives of this paper were to: (i) identify the credit-constraint status of smallholders – unconstrained, supply-side constrained, or demand-side constrained; (ii) examine the factors affecting access to agricultural credit among smallholders; and (iii) investigate the effects of credit constraints on adoption of four agricultural technologies – inorganic fertilizer, improved seed, agrochemicals, and mechanization.

A better understanding of the functioning of rural credit constraints; the factors affecting access to rural credit; and whether credit access could enhance technology adoption would provide empirical evidence to support policy decisions to alleviate these constraints and enable smallholders to improve their productivity and livelihoods. In terms of rural credit policy options, for instance, if farmers are credit-constrained from the demand-side, such as due to risk aversion, a financial product that integrates credit with an insurance mechanism may be considered. On the other hand, if the reason for not seeking credit is due to lack of business aspirations or lack of knowledge among smallholders, then improving their financial literacy, access to information, and enhancing their entrepreneurial skills could be important. Finally, supply-side problems such as high interest rates may require interventions that reform the structure and conduct of rural financial intermediaries.

The remainder of this paper is organized as follows. Sections 2 presents a concise review of literature on the linkages between rural credit and agricultural technology adoption and a summary of recent agricultural credit policies in Nigeria. Section 3 describes the methodologies (data and econometric models) used in the study. Sections 4 and 5 respectively present descriptive and econometric results. The final section concludes the paper with key policy recommendations.

2. Literature review

2.1. Rural credit and agricultural technology

A growing body of empirical literature suggests that in rural areas of developing countries credit constraints have adverse effects on farm output [72], profits [36], and investment [23]. These constraints have often been linked to credit market imperfections hindering adequate access to credit for smallholders [4,44]; Meyers 2015; [2]. Studies found that access to interlinked credit and insurance contracts increases the likelihood of agricultural technology adoption [53]. Information asymmetries [13,81]; weak government policies [54,81], and attitude towards risk aversion [50,78] were emphasized as key factors constraining credit access and adoption of agricultural technologies among smallholder farmers in sub-Saharan Africa [15,35,50,64]. The studies of Ali and Deininger [10] in Ethiopia, Jia et al. [46] in China and Kenya, and Shoji et al. [77] in Sri Lanka highlight that access to credit is a key factor in the adoption of agricultural technologies and innovations. Similar findings were reported in the contexts of sub-Saharan African [17,27,33,49,56,59]. Moreover, access to credit may be connected to the use of specific inputs, thus limiting choices across technologies [24,54,73].

However, drawing on an extensive review of the literature on the adoption of agricultural technologies, Doss [28] pointed out the limitations of the conclusions drawn from micro-studies both in terms of lacking to accommodate spatial variations and temporal dynamics of agriculture technology adoption processes. Moreover, many of these micro-studies used a simple dichotomous variable approach for the definition of technology adoption, neglecting to recognize that adoption can be only partially implemented, so could be measured on a continuum. Lastly, most of these studies did not examine a household's joint decision around technology adoption or how the household's behavior affects whether the household is credit constrained or not. For instance, Feder et al. [31] and Boucher et al. [19,21] argue that access to credit is likely to yield the expected positive and significant impacts on technology adoption only if credit is a binding constraint to the farmer. If credit is not a binding constraint to a farmer's agricultural production, credit may be diverted to non-productive activities, such as consumption or non-agricultural activities.

The extent to which credit contributes to agricultural investment and rural livelihood outcomes are likely to be higher for smallholders whose production decisions are effectively constrained by credit than for those that are less credit constrained [46,77,78]. Nonparticipation of some smallholders in credit market does not necessarily imply an unmet credit need [10,26,78]. Thus, for designing and implementing rural financial interventions and policies, understanding the credit constraint status of smallholders empirically and, for those that face credit constraints, whether the constraint is from the supply-side or demand-side is important. In addition, a better understanding of the factors that affect credit access of farm households and whether access to credit could enhance technology adoption is important for designing effective rural development policies and programs. This paper aims to fill some of these knowledge gaps and provide evidence for better policy decisions in rural finance in Nigeria and other similar developing countries.

[1] The survey data is publicly available at the World Bank microdata libraray and can be accessed using this web link: Nigeria - Living Standards Survey 2018-2019 (worldbank.org).

2.2. Agricultural credit in Nigeria

In the context of developing countries, sources of rural credit consist broadly of formal, semi-formal, and informal credit markets [16,20]. Under formal credit markets, financial institutions registered by a central monetary authority, such as commercial banks, supply the market with a wide range of financial products and services, including, inter alia, loans, savings, money transfers, and insurance [37]. Examples of such formal financial bodies instituted to provide loans tailored to agriculture sector in Nigeria include the Nigeria Agricultural Cooperative and Rural Development Bank, the Nigerian Agricultural Cooperative Bank, and the Bank of Agriculture. Sources of credit in the semi-formal sector include microfinance institutions, cooperatives, associations, agricultural input dealers and some non-government organizations. The informal credit market consists of money lenders, neighbors or friends, relatives, and informal credit associations to which participants gain access through informal and less stringent screening mechanisms, such as social capital, established networks, and membership in local associations. However, a trade-off for the relatively greater access and faster processing that informal financial institutions in Nigeria offer is that they generally require a higher interest rate on their loans compared to formal lenders [63]; World Bank 2008.

Given the potentially vital role of agricultural credits in spurring rural development, the government of Nigeria has established rural finance policies through which numerous formal agricultural finance institutions, schemes, and programmes were developed. The policies were put in place with a view to guaranteeing sustainable availability and accessibility of credit funds to the agricultural sector to constructively revitalize rural economic sectors, to enhance national food and nutrition security, to reduce liquidity constraints within agricultural production, to increase agricultural productivity, to enhance employment creation, and to improve livelihood diversification, thereby leading to a vibrant rural economy [6,15,55,62]. Table 1 summarizes the key policy interventions and schemes around rural credit in Nigeria over the past two decades.

In addition to the array of agricultural financial schemes described in Table 1 at the Federal Government level, various smaller-scale schemes have been launched to address agricultural financing challenges in specific states. These include the Special Emergency Agricultural Loans Scheme, the Supervised Agricultural Credit Scheme, the Small and Medium Enterprises Equity Investment Scheme, and the Large-Scale Agricultural Credit Scheme. Though some successes through these schemes have been documented (Okafor, 2006; Mohammed and Hassan, 2008; Agba et al., 2009; Nosiru, 2010; [13,81], most of the challenges facing agricultural credit markets in Nigeria remain unresolved Udry 1990, 2007; Okafor 2006; Mohammed and Hassan 2008; Agba et al. 2009; Nosiru 2010; [15,62,64]; Obasi 2015; [13,67,68,81]. Most of these studies highlighting ongoing challenges with agricultural credit in Nigeria show that the mechanisms for administering the credit have been porous, vague, and inconsistent; monitoring, evaluation and learning systems to track implementation of the credit schemes were poor or absent; and most faced enormous bureaucratic bottlenecks.

Agricultural credit made up only 3.4 and 4.0% of the total credit released to the private sector in Nigeria in 2017 and 2018, respectively [58]. Agriculture is considered a risky business associated with exogenous risk factors, such as weather, crop disease, and price instability. These uncontrollable risks together with a higher loan default rate among farmers underpin the reluctance of commercial banks to lend to small-scale farmers [31,70]. While there exist multiple institutional factors hindering credit supply, as discussed above, credit constraints also emanate from the demand-side [20,29,79,83]. High transaction costs, such as loan processing, and the risk aversion behaviors of borrowers are the major demand-side constraints in agricultural credit market participation [14,19,21,22,41]. Other factors identified in the rural credit literature in developing countries include demographic factors, distance to loan sources, loan processing duration, interest rates, loan size, and income [39,42,48,57,65]; Mohamed 2013). Studies in Nigeria show that key factors influencing access to agriculture credit include farming experience, size of landholdings, value of assets, household expenditures, income level, collateral security, and level of agricultural commercialization [9,66,67,71,74]. For instance, Ugoani et al. [80] explain that low financial literacy makes it difficult for rural farmers to interpret the financial products on offer and negotiate for credit on favorable terms. Some agricultural schemes and banks limit their credit facilities to cooperatives. Women were also found to be excluded from credit access in some parts of the northern and western parts of Nigeria partly due to cultural beliefs [63].

3. Materials and methods

3.1. Data

We used the 2018/19 round of the Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA) data, which is the fourth wave of the LSMS-ISA panel dataset for Nigeria. As the earlier waves do not have adequate information on credit, we limited our study to the cross-sectional data of the fourth wave. This wave consisted of a nationally representative sample of over 5000 households sampled across 519 enumeration areas (EAs). Households were visited twice , post-planting and post-harvest visits, between July and September 2018 and January or February 2019, respectively. Using the unique household identifier, we merged data files from the post-planting and post-harvest surveys and extracted relevant information on household demographics, farm and off-farm incomes, remittances, other household incomes, land holdings, physical assets, access to information and communication technologies (ICT), access to extension services, household savings and insurance access, labor use, crop types grown, livestock production, use of agricultural technologies, and sources and access to credit. Information on credit[2] consisted of answers to a range of questions regarding loan applications in the past 12 months prior to the survey, the purpose for which the loan was sought, and general access to credit. The survey also obtained information on household savings and insurance coverage. We used these responses to classify farm households by credit constraint status – supply-side-constrained, demand-side-constrained, or unconstrained – as described in Table 2.

3.2. Conceptual framework

Economic theory suggests that agricultural credit constraints impede individuals from investing in agricultural technologies. Thus, poor farmers that are constrained in their ability to obtain credit are prevented from undertaking high-return agricultural activities [21]. Empirical studies identify lack of access to credit as one of the major barriers to agricultural technology adoption by smallholders [3,25]. It is argued that credit access allows farmers to increase their purchases of agricultural inputs and, thus, increase their productivity [31]. In a competitive market with symmetric information, borrowers can access credit under any interest rate and collateral combination conditional on the borrowers' behavior [21]. The existence of asymmetric information, however, makes such credit contracting infeasible, limits the set of credit contract options, and induces non-price rationing of credit [19,31]. Information asymmetry creates adverse selection and moral hazards, which in turn may negatively affect the performance of credit markets [79]. The presence of adverse selection and moral hazard, together with high monitoring and enforcement costs, gives rise to the theoretical explanation for non-price credit rationing. Lenders face problems of informa-

[2] Details of credit related questions in the post-planting household questionnaire in the 2018/19 LSMS-ISA Nigeria (pp.22-24) can be accessed from the World Bank Microdata library (accessible in this permanent World Bank web link: https://microdata.worldbank.org/index.php/catalog/3557/download/47668).

Table 1
Selected government policy interventions and schemes undertaken to facilitate credit access for agricultural sector in Nigeria.

Key interventions or schemes	Years	Key objectives and modalities	Target beneficiaries or value chains	Challenges	References (Sources)
Nigerian agricultural credit guarantee scheme fund (ACGSF).	1977 to present	To encourage banks to extend their loans to agricultural enterprises by reducing risk involved in lending. Funded by Federal Government of Nigeria (FGN) and Central Bank of Nigeria (CBN) in the ratio 60:40 (75% guarantee). Original share capital and paid-up capital were ₦100 million and ₦85.6 million, respectively.	Agricultural sector	Low rate of loan repayment. Low participation rate among lending institutions. Delays in disbursement of funds to farmers. Fishery sector received low amounts.	Akinleye et al. [8]; Adetiloye [6]; Oparinde et al. [69]
Commercial agriculture credit scheme (CACS)	2009 to present	To provide finance for the country's commercial agricultural value chains. Established jointly by CBN and the Federal Ministries of Agriculture and Ministry of Water Resources. Operated under two tranches of ₦100 billion each – first phase from May to December 2009; second commenced in February 2010. Loans disbursed at a maximum interest rate of 9% shared between CBN at 7 percent and the issuing bank at 2%.	• Input supply • Production • Processing • Storage • Marketing	Criticized for being discriminatory against certain beneficiaries and types of enterprises. Rigid credit screening requirements before funds are released.	Olomola and Yaro [68].
Nigerian Incentive-based Risk Sharing System for Agricultural Lending (NIRSAL)	2011 to present	NIRSAL is a USD 500 million non-bank financial institution owned by CBN established to: • Share any risks of losses on agricultural loans. • Expand insurance products for agricultural lending, such as weather index insurance. • Provide technical assistance to banks. Holistic bank rating used that is based on effectiveness of a potential participant bank's agricultural lending and social impact record. Targets to reach 3.8 million agricultural producers by 2020 and annual growth in agricultural production from 1.4 to 7.0%.	Agricultural industry	Banks are reluctant to give loans due to poorly packaged proposals from applicants. Bureaucracy and slow processing of loan applications. Applicants unwilling to pay additional 3% guarantee fee. NIRSAL having difficulty in validating information provided by counterparties. Lack of information technology infrastructure.	Olomola and Yaro, [68].
Growth Enhancement Support Scheme (GESS)	2012 to 2015	Delivers government subsidized farm inputs directly to farmers via an electronic wallet system based on mobile phones. Electronic wallet system is at the center of technology applications under GESS. Implemented by the Federal Ministry of Agriculture and Rural Development with the collaboration of participating states and the private sector. Stages in GESS implementation – farmers' enumeration, input redemption, reconciliation of records, and subsidy payment. Once farmers receive their subsidy support on their mobile phones, they pay 50% of the cost of seed or fertilizers to agro-dealers. Targets 5 million farmers each year– totalling 20 million at the end of four years.	Farmers	Administrative and operational challenges, such as poor mapping of farmers, mishandling identification, and redemption bottlenecks. Problems with technology platform leading to farmers not receiving text messages. Manpower constraints, – inadequacy of personnel, insufficient training of required staff, and deficiencies in equipping the staff. Political interests interfere, politicians seek to divert inputs to their states.	Olomola (2016)
Anchor Borrowers' Programme	2015 to present	To create economic linkages between smallholder farmers and large-scale processors to increase agricultural output. Funds from the ₦220 billion Micro, Small and Medium Enterprises Development Fund. Loans disbursed through any of the following participating financial institutions: • Deposit money banks • Development finance institutions • Microfinance banks. Interest rate is 9%. Participating financial institutions receive from CBN a 2% subsidy on loans made.	Smallholder farmers engaged in: • Cereals, • Cotton, • Roots and Tubers, • Sugarcane, • Tree crops, • Legumes, • Tomato, and • Livestock (fish, poultry, ruminants)	Late disbursement of funds and inputs, with negative implications for production. Program supplied expired seedlings. Misunderstandings around the modalities of the program: • Farmers expected disbursement in cash and not as in-kind inputs. • Low loan repayments. • Loans paid directly to smallholder farmer instead of through the participating financial institution.	Odutola Odukoya [60]
Federal Government's Farmer Moni Scheme and Trader/Market Moni Scheme	2016 to present	Aimed at improving financial inclusion and increasing access to affordable credit. Initiative of Government Enterprise and Empowerment Programme (GEEP) implemented by the Bank of Industry. Three key products: MarketMoni; FarmerMoni; and TraderMoni. GEEP grants interest-free loans but applies a 5% administrative fee. Loans range from ₦10,000 to ₦300,000 in a graduating scale	Micro enterprises, including petty traders, farmers, youth, women, and artisans	Low loan amounts. Scheme focused on urban markets rather than rural markets where target beneficiaries resides. Verification process is porous leading to non-target beneficiaries accessing loans. Loan repayment is low.	Abubakar [5]; Ogbette et al. [61]

Note: Naira (₦) is the currency of Nigeria. The market exchange of Naira during writing of this paper (August 2020) is: 1US dollar is equal to around ₦ 384. But currently (May 2022) the market exchange rate is 1US dollar= ₦ 570.
Sources: Authors' compilation from documents listed in the 'References (Sources)' column.

Table 2
Classification of the credit constraint status of households.

Unconstrained		Constrained: Supply-side		Constrained: Demand-side		
					Due to risk-aversion	Due to transaction costs
Borrowers:	Obtained amount of loan requested	Applied or attempted:	But rejected: Applied or otherwise attempted to obtain a loan. Ready to pay the existing interest rate, but loan application rejected.	Non-borrowers:	Afraid of taking risks, for example, afraid of losing collateral	Do not have any lender, for example, lenders not located nearby
Non-borrowers:	Do not need a loan; have enough money	Borrowers:	But unsatisfied: Obtained less than the amount of loan requested; wanted a larger loan at same interest rate	Non-borrowers:	Afraid that cannot pay the money back	Procedure too cumbersome, too much paperwork, too expensive
Non-borrowers:	Prefer working with their own liquidity, that is, reason for not borrowing is “do not like to be in debt”	Non-borrowers:	Non-applicants who perceive themselves to "certainly be rejected": Were certain that their loan application would be rejected due to inadequate collateral; past credit history; existing outstanding loans; or irregular income	Non-borrowers:	Do not want to be worried; afraid.	Need to pay bribes, too much politics involved

Source: Authors’ representation.

tional asymmetries when trying to identify the riskiness of lending to specific subsets of borrowers. This may lead lenders to increase collateral requirements to cushion themselves from the risks of default that arise from problems of adverse selection and moral hazards [43]. In the context of smallholder farmers in sub-Saharan Africa, empirical knowledge gaps exist in understanding the nature of credit constraints and the extent to which credit affects agricultural technology adoption by smallholders.

To guide the empirical analyses of credit constraints and their potential effects on technology adoption, we adapted the Boucher et al. [21] framework for a household credit constraint identification strategy summarized in Table 2. Using this conceptual framework and based on the respondents’ answers to the series of credit questions in the wave-4 LSMS-ISA post-planting household questionnaire (https://microdata.worldbank.org/index.php/catalog/3557/download/47668), survey households were classified into three: (a) *unconstrained* –households consisted of either satisfied borrowers, that is, borrowers who obtained the amount requested; or non-borrowers who did not need loans or who preferred to work with their own liquidity; (b) *supply-side constrained* – households consisted of rejected loan applicants; unsatisfied borrowers, that is, those who received less than the loan amount requested; or non-borrowers who perceived that their application, if made, would be rejected; and (c) *demand-side constrained* –risk-averse households or other non-borrowers that consider the transaction costs of acquiring a loan to be too high and hence not worth it.

Such a classification strategy, termed as a direct elicitation method (DEM), has been applied in similar studies [11,21].This will allow us to answer our key research objective i.e., the effects of credit constraints on agricultural technology adoption through comparing constrained and non-constrained smallholders. Households who tried to get credit, whether they were successful (unconstrained) or not (constrained), reveal their demand for credit and their credit behavior can be compared in the analysis. Similarly, households that would have liked to borrow, but did not apply or attempt to borrow due to various factors, such as fear of risk, lack of collateral, or high transaction costs, also possess a positive but unrevealed demand for credit. Such households can also be classified as credit constrained due to demand-side constraints. Using the identification strategy portrayed in Table 2, we can classify households either as ‘supply-side constrained’ ‘demand-side constrained’ or ‘unconstrained’ and compare and analyze the factors affecting this status and whether credit constraints affect adoption of agricultural technology.

3.3. Econometric approach

Two econometric models were used in this study – a multinomial probit (MNP) and seemingly unrelated regression (SUR) models. The MNP was used to model the likelihood of the credit constraint status of the household (i.e., whether the household is likley to be credit unconstrained; supply-side constrained; or demand-side constrained) given the characteristics of the household and other covariates. The SUR was used to model the joint adoption decision of the four agricultural technologies considered in this study and the role of credit on adoption decision of these technologies.

3.3.1. Multinomial probit (MNP) model

Multinomial probit (MNP) model is commonly used when the outcome (dependent) variable is categorical and takes more than two categories. In such a situation, the dependent variable y is an unordered categorical variable and an individual may select one of the alternatives or fall under one of the categories. The choices or categories can be coded as $j = 0,\ 1,\ \ldots,\ m$, where m is the number of available choices or categories. In our analysis, we let y_i be the categorical variable that takes values $j = 0,\ 1,\ 2$ that represents the i^{th} household’s credit constraint status, i.e., unconstrained, supply-side constrained, and demand-side constrained, respectively. Define y_i^* as the unobserved propensity of the i^{th} household to be in credit constraint status j (Eq. (1)):

$$y_{ij}^* = x_i' \beta + \varepsilon_{ij} \tag{1}$$

The observed category is the one with the highest propensity. The MNP probability model that the i^{th} household falls in the j^{th} credit constraint status can thus be modelled as in Eq. (2):

$$P_{ij} = P(y_i = j) = P\left(y_{ij}^* > y_{ik}^*\right) = \phi(x_j'\beta) + \varepsilon_i,\ \forall j \neq k \tag{2}$$

Where P_{ij} represent the probability that the i^{th} individual falls into the j^{th} category, x_j' is a vector of regressors, β= the parameters to be estimated, and ϕ is a probit functional evaluator. The variables included in the empirical model are presented in Table 3.

3.3.2. Seemingly unrelated regression (SUR) model

Four agricultural technologies are considered in this study – use of inorganic fertilizer, improved seed, agrochemicals, and agricultural machinery. A farmer’s decision to adopt these technologies can be affected by several factors, such as socio-demographic factors, endowments, access factors, e.g., to ICT and extension services, financial literacy, and

Table 3
Descriptive results of the variables used in the econometric analysis, by credit constraint status.

Variables/household attributes	Applied/ Attempted	Non-applicants	Difference(t-stat.)	Credit Constrained	Uncon-strained	Difference(t-stat.)	Constrained(demand-side)	Constrained(supply-side)	Difference (t-stat.)
Household demographics and labor:									
Age (years)	49.1	49.9	−1.21	50.1	48.9	−2.50**	48.8	49.0	−0.25
Male headed (0/1)	17.96	20.51	−1.62	20.93	18.49	−1.90*	19.37	17.48	0.91
Married (0/1)	77.46	72.94	2.61**	72.72	75.54	2.02**	74.35	76.90	−1.10
Literate household head (0/1)	80.60	71.38	5.27***	71.01	76.26	3.71***	76.67	75.84	0.36
Used hired labor (0/1)	94.55	94.26	0.23	93.99	94.88	0.85	94.05	95.69	−0.97
Active members (aged between 15 and 65 years) (number)	3.0	2.7	3.38***	2.7	2.9	3.04***	2.8	2.9	−1.58
Household asset ownership:									
Land size (hectare)	1.40	1.41	−0.07	1.39	1.47	0.98	1.41	1.53	−0.91
Land title (0/10)	26.67	19.52	3.71***	17.24	21.42	−2.36**	17.94	17.28	0.25
Livestock values (Naira)	200,131	319,058	−2.52***	319,537	241,378	−1.92**	246,793	236,286	0.16
Household durable assets (Naira)	178,834	146,125	1.96**	148,127	152,506	0.33	156,304	148,092	0.42
Household income (by source):									
Crop Income (Naira)	149,031	177,065	−1.49	157,305	216,983	3.84***	226,329	207,632	0.46
Livestock Income (Naira)	170,678	35,177	2.35**	65,683	34,812	−0.62	25,285	43,970	−1.07
Non-farm income (Naira)	223,222	168,247	2.27**	185,348	202,362	0.83	204,336	200,190	0.14
Remittance (Naira)	9041	7578	0.42	7076	8540	0.54	10,085	6805	0.77
Household access to:									
ICT (mobile, internet) (0/1)	97.15	94.07	4.14***	93.75	96.29	4.61***	96.75	95.79	2.65***
Distance to input market (km)	5.44	5.86	−0.79	6.07	5.19	−2.10**	5.15	5.24	−0.15
Used extension advice (0/1)	18.44	14.59	2.26**	15.39	14.46	0.15	13.00	15.85	0.34
Social and financial capital:									
Membership in association (0/1)	12.50	9.33	1.90*	8.26	14.07	3.90***	14.56	13.43	0.39
Member of cooperative (0/1)	20.59	8.03	7.41***	10.61	9.61	−0.66	7.91	11.57	−1.50
Household has insurance coverage (0/1)	6.36	3.43	3.88***	3.92	3.34	−0.96	3.11	3.60	−0.52
Member of informal savings groups (0/1)	57.98	42.57	7.97***	41.24	53.46	7.84***	50.74	56.54	−2.18**
Household use of agricultural technologies:									
Used improved seed (0/1)	15.63	15.98	−0.20	13.74	21.51	5.53***	21.92	21.06	0.32
Used inorganic fertilizer (0/1)	39.40	41.98	−1.11	37.28	43.10	−3.10***	36.18	38.27	−0.66
Used agro-chemicals (0/1)	43.90	50.92	−2.98***	48.59	53.23	2.63***	53.51	52.85	0.30
Used mechanization (0/1)	12.38	11.32	0.71	11.43	11.21	−0.18	8.99	13.32	−2.09**
Used manure (organic fertilizer) (0/1)	27.95	24.22	1.84**	25.59	22.84	−1.70*	23.03	22.62	0.15

Source: Authors' computations from LSMS-ISA (Nigeria) panel wave 4 (2018/19) data. *** $p<0.01$. ** $p<0.05$. * $p<0.10$.

household non-farm income. Though such variables are observable and can be controlled in the econometric model, there could be unobservable heterogeneities such as the farmer's entrepreneurial capacity, risk behavior, preferences, and business aspirations that could affect adoption decisions. Moreover, the factors affecting the farmer's choice of one agricultural technology could also affect the adoption of other types of agricultural technology. For instance, adoption of improved seed may also entail increased use of inorganic fertilizer or agrochemicals. Thus, cross-equation error terms of different agricultural technologies may be correlated for the same farm household. Thus, though the decision to adopt any of these technologies may seemingly be independent and their parameters thought to be estimated independently (equation by equation) using a linear model, the error terms of these models are likely to be correlated [12,30]. Consequently, to examine the effects of credit constraints on the farmer's decisions to adopt the various agricultural technologies considered, a system of simultaneous equations – the seemingly unrelated regression (SUR) model – was adopted to permit the joint estimation of several regression models, where the error terms associated with the dependent variables are assumed to be correlated across the equations [75]. Equations in a SUR system seems unrelated in the sense that no endogenous (left-hand side) variables appear on the right-hand side of other equations. Their errors, however, can be correlated, sharing a multidimensional distribution. Simultaneous estimation that considers the full covariance structure of error terms is, in general, more efficient [40,52].

In a generic and compact form, the SUR model can be represented as:

$$y' = x'\theta + \varepsilon' \tag{3}$$

where: y' is a vector of order $(1 \times m)$, representing the m SUR equations, $x' = (x_{1,} \ldots, x_{k,})'$ is a vector of explanatory variables, ε' is a vector of error terms of order $(1 \times m)$, and θ is a matrix coefficients of order $(m \times k)$, i.e., k is the number of parameters for each of the m seemingly unrelated simultaneous regression equations. The error terms are assumed to be identically and independently distributed (i.i.d) with zero means and a convariance matrix of Σ, i.e., $\varepsilon'|x \sim i.i.d., N(0, \Sigma)$. Following the generic equation format (Eq. (3)), the empirical model of the four agricultural technologies is specified as a set of four simultaneous equations (Eqs. (4.1 to 4.4)):

$$AgTec_{i1} = \beta_1 CR_{ssi} + \psi_1 CR_{ddi} + \gamma_1 X_{i1} + \varepsilon_{i1} \tag{4.1}$$

$$AgTec_{i2} = \beta_2 CR_{ssi} + \psi_2 CR_{ddi} + \gamma_2 X_{i2} + \varepsilon_{i2} \tag{4.2}$$

$$AgTec_{i3} = \beta_3 CR_{ssi} + \psi_3 CR_{ddi} + \gamma_3 X_{i3} + \varepsilon_{i3} \tag{4.3}$$

$$AgTec_{i4} = \beta_4 CR_{ssi} + \psi_{41} CR_{ddi} + \gamma_4 X_{i4} + \varepsilon_{i4} \tag{4.4}$$

where $AgTec_i$, $AgTec_{i2}$, $AgTec_{i3}$, and $AgTec_{i4}$ are the four agricultural technologies considered in this study, CR_{ssi} and CR_{ddi} respectively represent supply-side and demand-side constrained households and take values of 0 or 1 for unconstrained and constrained households, X_{i1} *to* X_{i4}, as described in Table 3, are control explanatory variables for the four equations, which may or may not be the same set of variables in each equation; and β_m, ψ_m, and Y_m are parameters of the m^{th} equation to be estimated. The SUR equations were estimated using the conditional mixed process(cmp) model command in the Stata statistical analysis software [75]. Conditional mixed process (cmp) is a flexible Stata command particularly suitable to model SUR equations when some or all the left-hand (dependent) variables are not continuous variables.

4. Descriptive results

4.1. Summary statistics of model variables

Table 3 presents the socioeconomic characteristics of households and the descriptive statistics of the variables used in econometric models. To examine the mean differences of the variables, t-tests were conducted among the three groups of respondents – loan applicants vs. non-applicants, credit constrained vs. non-constrained, and supply-side constrained vs. demand-side constrained households. Significant differences were observed in the mean values of several variables among applicants and non-applicants, on the one hand, and between constrained and unconstrained households, on the other. For instance, the mean values of certain demographic variables, such as literacy and the number of economically active household members, are statistically different between the constrained and unconstrained groups. In terms of their agricultural profile, loan applicants had an average landholding size of 1.4 ha, earned an estimated income of ₦170,678 from livestock and ₦149,031 crop income for the production season of the survey. When juxtaposing applicants with non-applicants, there are some distinct differences. For example, a higher proportion of applicants had land title documents (26%), had insurance coverage (6%), were members of cooperatives (21%), and were members of informal saving groups (58%). Finally, there is indication of higher wealth status among applicants in terms of household durable assets and annual household income. It is not unusual for wealth disposition to influence credit access. Irrespective of credit constraint status, households had access to agricultural land. However, there is a distinct difference in land tenure security between credit-constrained and credit-unconstrained households. A lower proportion of credit-constrained households had land title documents, suggesting one reason for their inaccessibility to credit. Likewise, higher participation in local associations and informal saving groups were observed among the unconstrained category of households.

4.2. Credit constraint situation of smallholders

Table 4 shows a low number of loan applications as only about 15% of smallholders applied for a loan during the 12-month period preceding the survey.

In terms of the number of loan applications, there is no significant difference between peri-urban and rural sectors. However, the average sizes of loans requested, and loans received were significantly higher among peri-urban farming households. Higher loan demand from peri-urban areas may be an indication of more intensive operations often associated with production of high-value cash crops [76,84]. It also has been argued that peri-urban applicants have access to a wider pool of credit opportunities, which gives them a comparative advantage over their rural counterpart in accessing credit. Furthermore, distance to lending institutions; low financial inclusiveness; higher transaction costs, literacy levels, asset endowments, and lack of collateral security have been found to adversely affect credit access in rural areas [51,67,71,74]; Olomola and Gyimah-Brempong 2017). Interestingly, we observed no clear difference in the percentage of rejected borrowers between rural and peri-urban smallholders. Both had on average 14.5% rejected borrowers. About 69% of rural smallholders indicated they did not need a loan, while in peri-urban areas 61% reported not needing a loan. This may indicate a high degree of risk-averse behavior or a lack of business aspiration among farming households in Nigeria.

5. Econometric results

5.1. Determinants of credit constraint status of households

Following the conceptual approach developed in Section 3.2, households were classified into three distinct groups in terms of their credit constraint status, viz., supply-side constrained, demand-side constrained, or unconstrained households. Table 5 reports the results from the MNP regression model. A set of explanatory covariates, including household demographics, asset ownership, household income level by source, access-related variables (e.g., ICT and extension services), and social and financial capital variables were used in the model. The 'unconstrained' households were used as a base category in the MNP model.

Table 4
Summary statistics of households' credit constraints status, by location.

Credit constraint status	Smallholders (by location)		Comparisons	
	peri-urban (n)	Rural (n)	difference	t-statistic
Applied or attempted to borrow agricultural credit (%)	16.0 (260)	14.9 (511)	−1.10	−1.02
Average amount for which applied (Naira)	362,135 (260)	187,671 (511)	174,464	3.01***
Average amount received (Naira)	191,769 (194)	73,891 (401)	117,878	5.50***
Supply-sided constrained households:				
Rejected borrowers (%)	14.6 (38)	14.5 (74)	0.13	0.05
Unsatisfied borrowers (%)	10.8 (28)	7.2 (37)	3.539	1.67*
Perceived "certainly rejected" nonapplicants (%)	9.4 (152)	9.8 (336)	−0.44	−0.50
Demand-side constrained households:				
Due to risk-aversion behavior (%)	8.5 (138)	3.6 (123)	4.91	7.40***
Due to high transaction cost (%)	10.2 (165)	9.1 (313)	1.03	1.17
Unconstrained households:				
Received full amount wanted (%)	10.2 (166)	10.6 (364)	−0.40	−0.43
Borrowers who did not need loan (%)	61.0 (832)	69.9 (2039)	−8.90	−5.80***

Source: Authors' computations from LSMS-ISA (Nigeria) panel wave 4 (2018/19) data.
Note: Numbers in parentheses are the number of survey sample households. *** $p<0.01$. ** $p<0.05$. * $p<0.10$.

Table 5
Estimation results of multinomial probit regression model[1].

	Supply-side credit constrained smallholders		Demand-side credit constrained smallholders	
Independent variables	Coefficient	Std. Err.	Coefficient	Std. Err.
Age of household head (years.)	−0.001	0.002	−0.002	0.002
Literate household head (0/1)	0.096	0.078	0.073	0.079
Male household head (0/1)	0.063	0.124	−0.018	0.115
Married household head (0/1)	0.039	0.110	0.067	0.105
Members of working age, (number)	0.043**	0.020	0.033	0.020
Landholding size of household (ha)	0.026	0.017	0.018	0.018
Has land title (0/1)	−0.303***	0.097	−0.343***	0.095
Log of value of assets (Naira)	−0.026***	0.010	−0.003	0.010
Log of value of livestock (Naira)	−0.015**	0.007	−0.024***	0.007
Access to ICT (0/1)	0.187	0.151	−0.323**	0.157
Access to agricultural extension (0/1)	−0.014	0.099	−0.173*	0.104
Has insurance (0/1)	−0.206	0.174	−0.464***	0.173
Has formal savings (0/1)	0.000	0.072	−0.013	0.071
Has informal savings (0/1)	0.463***	0.064	0.317***	0.062
Rural (0/1)	−0.098	0.080	0.260***	0.075
Log of farm income (Naira)	0.006	0.008	0.002	0.008
Log of non-farm income (Naira)	0.016**	0.006	0.013**	0.006
Log of remittance income (Naira)	0.023*	0.014	0.004	0.014
Constant	−1.651***	0.219	−1.504***	0.221
Mean dependent variable:	0.424		SD dependent variable:	0.733
Observations:	5050		Chi-square:	183.5
Prob > chi2:	0.000		Akaike information criterion (AIC):	7805.7

[1] The dependent variable is 'credit constraint status' of households and the base category is 'credit unconstrained' householdsSource: MNP regression results using data from the LSMS-ISA (Nigeria) panel wave 4 (2018/19) data*** $p<0.01$, ** $p<0.05$, * $p<0.1$.

The likely effect of each covariate on the credit constraint status of a household is interpreted against this base category.

As shown in Table 5, the two important variables that affect the credit constraint status of both supply-side and demand-side constrained households are whether the household has a title to their land and whether the household owns livestock, both having significant negative coefficients. This result implies that households who possess legal titles to their lands are less likely to fall into either the supply-side or demand-side credit constraint categories. This is consistent with previous studies [21,32] that found that titles to land can be used as formal collateral to reduce the risk the lender faces, on the one hand, and eases the collateral constraints of the borrower, on the other. The combined effect for a household with a land title is increased access to credit. In the context of rural Africa, ownership of livestock is an important measure of household assets or wealth that could either substitute for credit or can serve as an indicator of the household's capacity to bear risks [25]. Similarly, households with a greater value of assets are significantly less likely to be supply-side constrained. A possible explanation for this relationship is that such assets can be used as collateral and, hence, remove supply-side related credit constraints.

The MNP results further reveal that there are specific sets of factors that differentially affect demand-side and supply-side constrained households. Regarding demand-side constrained households, the three important factors include the level of access to information and communication technology (ICT) such as phone and internet services, to extension services, and to insurance coverage. Households having good access to these three services are less likely to suffer demand-side credit constraints. Similar findings have been reported in previous studies in Nigeria. For instance, Wossen et al. [81] show a positive relationship between credit access and extension services. On the other hand, these three factors are not significant in determining the credit access to supply-side constrained households.

In terms of policy evidence relevant to the demand-side credit constraints, these findings highlight: (i) Rural borrowers appear to be not

Table 6
Marginal effects of MNP regressors on probability of a smallholder being credit constrained.

	Unconstrained smallholders		Supply-side credit constrained smallholders		Demand-side credit constrained smallholders	
Independent variables	dy/dx	Std. Err.	dy/dx	Std. Err.	dy/dx	Std. Err.
Age of household head (years.)	0.000	0.000	−0.000	0.000	−0.000	0.000
Literate household head (0/1)	−0.021	0.016	0.012	0.012	0.009	0.013
Male household head (0/1)	−0.005	0.024	0.011	0.018	−0.005	0.019
Married household head (0/1)	−0.013	0.022	0.004	0.017	0.010	0.017
Members of working age (number)	−0.010**	0.004	0.006*	0.003	0.004	0.003
Land size of household (ha)	−0.006	0.004	0.004	0.003	0.002	0.003
Has land title (0/1)	0.077***	0.017	−0.034***	0.013	−0.044***	0.013
Log of value of assets (Naira)	0.004*	0.002	−0.004***	0.001	0.000	0.002
Log of value of livestock (Naira)	0.005***	0.001	−0.001	0.001	−0.004***	0.001
Access to ICT (0/1)	−0.061**	0.027	0.018	0.021	−0.043**	0.021
Access agric. extension (0/1)	0.023	0.020	0.004	0.015	−0.027*	0.015
Has insurance (0/1)	0.077**	0.030	−0.017	0.024	−0.061***	0.020
Has formal savings (0/1)	0.002	0.015	0.000	0.011	−0.002	0.011
Has informal savings (0/1)	−0.099***	0.013	0.063***	0.010	0.036***	0.010
Rural (0/1)	0.047**	0.016	−0.005	0.012	−0.042***	0.013
Log of farm income (Naira)	−0.001	0.002	0.001	0.001	0.000	0.001
Log of non-farm income (Naira)	−0.004**	0.001	0.002**	0.001	0.002*	0.001
Log of remittance income (Naira)	−0.003	0.003	0.003*	0.002	−0.000	0.002
Pr(credit constraint status):		0.729		0.128		0.142

Source: Post-estimation marginal effects (after MNP regression) using data from the LSMS-ISA (Nigeria) panel wave 4 (2018/19) data.
Note: Observations: 5052. (*) dy/dx is for discrete change of dummy variable for a unit change in a regressor. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

well connected to information sources that would inform their credit decision. They may lack adequate information on sources of credit, on the terms and conditions for obtaining the credit, or on interest rates. Thus, even if they need to borrow credit, they do not have sufficient information to do so. (ii) Insurance coverage, such as crop or health insurance, could mitigate risk perceptions and may change household's behavior towards risk. With adequate insurance coverage, households may develop a 'risk-neutral' or 'risk-taker' behavior and engage in borrowing to undertake somewhat riskier but also more rewarding farming activities. (iii) There is a need to improve access to agricultural extension, both through improved coverage and content of the extension packages.

Results show that about 27% of survey households are likely to be credit constrained, of which about 13% are supply-side constrained, and 14% are demand-side constrained households (Table 6). This is an interesting finding in that many studies highlight that credit constraints smallholders face are associated with supply-side factors and recommend improving credit access through mitigating supply-side constraints to boost agricultural technology adoption [1,47]. However, our findings show that credit constraints for smallholders are not only from supply-side factors but from demand-side factors as well. In our data, the demand-side factors appear even stronger than the supply-side factors. Thus, improving credit access via easing supply-side constraints may not necessarily address the problem of credit access for Nigerian smallholders without equally addressing demand-side factors [7,26,82]. The reason some non-borrowers do not participate in the credit market may not necessarily be because they cannot obtain credit, but, rather, because they may be risk-averse or do not have access to adequate information on potential sources of credit or on the terms of the credit that is available. Our empirical findings provide evidence on the wide prevalence of demand-side credit constraints among smallholders in Nigeria.

Table 6 reports the predicted marginal effects of the regression covariates, i.e., the effect of a one-unit change in an explanatory variable on the percentage probability of a household being in each of the credit constraint categories. First, looking at the supply-side constrained households, possessing a title to land, owning high value assets, having informal savings, and earning income from non-farm sources are the key variables with statistically significant marginal effects. Having title to land is associated with a lower probability of being either supply-side or demand-side credit constrained. A household with a land title is 3.4 and 4.4% less likely to be credit constrained on the supply-side and on the demand-side, respectively. Studies [45]; Ghebru et al. 2016) argue that land tenure security (defined as the certainty that a person's land rights including use, control, and transfer rights) is important to provide an assurance that a given land unit has an identifiable owner and the title holder has the authority to administer, use and transfer the land. In Nigeria, land rights are mainly secured through recognition by the local authorities or through the state. This confers ownership and use rights that are officially documented and verifiable and is considered formal tenure security. Ghebru et al. [38] show that as of 2014, less than three percent of the land in Nigeria was formally registered with a proof of certificate of occupancy. The statistically significant empirical relationship between a household's credit constraint and land title revealed in this study highlights the importance of land tenure security to improve credit access to smallholders. Households owing durable assets or valuable personal assets, such as jewelry, are less likely to be credit-constrained from the supply-side. A plausible explanation for this result is that these assets can be used as collateral for accessing credit, hence reducing the likelihood of a household being credit constrained [21].

An unexpected result in Tables 5 and 6 is the positive coefficients associated with having informal savings and earning income from non-farm sources for both the supply-side and demand-side constrained households. The positive coefficients imply that households having savings in the informal sector and earning incomes from non-farm sources are more likely to be credit constrained from both the supply-side and the demand-side. This seems implausible against our *a priori* expectation that having savings and non-farm income may enhance access to credit. Possible explanations could be, first, since we have not differentiated loans by lending source, informal savings and non-farm income may not be important factors for formal lenders, such as commercial banks. Secondly, there may be reverse causality between these two factors and the credit variable, i.e., these households might have already experienced credit constraints and, hence, pursue non-farm income generating activities to mitigate the credit constraints they face or draw from their informal savings to fill their financing gap. Finally, we find that rural households are more likely to be demand-side constrained compared to their peri-urban counterparts.

A remarkable result in Table 6 is seen in relation to the marginal impacts of insurance coverage and access to information on the credit constraint position of a household. In Nigeria, conventional insurers are generally unwilling to indemnify agriculture to the high risks associ-

Table 7
Estimation results of SUR models – credit constraints and agricultural technology adoption.

	(1)Used Inorganic Fertilizer		(2)Used Improved Seed		(3)Used Agrochemicals		(4)Used Agricultural Machinery	
Independent variables	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.
Supply-side credit constrained (0/1)	−0.0473**	0.0214	−0.0523***	0.0169	0.0232	0.0226	0.0164	0.0151
Demand-side credit constrained (0/1)	−0.0458**	0.0215	−0.0522***	0.0170	0.0068	0.0227	−0.0253*	0.0152
Age of household head (years.)	−0.0014***	0.0004	0.0000	0.0004	−0.0025***	0.0005	−0.0007**	0.0003
Literate household head (0/1)	0.0766***	0.0167	0.0563***	0.0132	−0.0310*	0.0176	0.0214*	0.0118
Male household head (0/1)	−0.0178	0.0283	−0.0314	0.0224	0.0950***	0.0300	0.0100	0.0200
Married household head (0/1)	0.0106	0.0267	0.0023	0.0212	0.0325	0.0283	0.0058	0.0189
Members of working age (number).	0.0156***	0.0048	0.0051	0.0038	0.0073	0.0051	0.0048	0.0034
Landholding size of household (ha)	0.0224***	0.0081	−0.0047	0.0064	−0.0003	0.0086	−0.0005	0.0057
Has land title (0/1)	0.0048	0.0036	−0.0089***	0.0028	0.0263***	0.0038	0.0145***	0.0025
Log of value of assets	0.0039	0.0215	0.0079	0.0170	−0.0720***	0.0228	8.0035	0.0152
Log of value of livestock (Naira)	0.0073***	0.0021	0.0024	0.0017	−0.0039*	0.0023	−0.0019	0.0015
Access to ICT (0/1)	0.0042***	0.0014	−0.0002	0.0011	−0.0034**	0.0015	−0.0007	0.0010
Access to agricultural extension (0/1)	0.0007	0.0284	−0.0017	0.0225	0.0282	0.0301	−0.0284	0.0201
Has insurance (0/1)	0.0672***	0.0209	0.0332**	0.0165	0.0333	0.0221	0.0827***	0.0147
Has formal savings (0/1)	0.0327	0.0613	−0.0601	0.0485	0.0223	0.0648	0.0022	0.0433
Has informal savings (0/1)	−0.0366**	0.0173	0.0133	0.0136	−0.0103	0.0182	0.0083	0.0121
Rural (0/1)	0.0034	0.0146	0.0120	0.0116	0.0204	0.0154	−0.0041	0.0104
Log of farm income (Naira)	0.0316***	0.0020	0.0081***	0.0014	0.0422***	0.0019	0.0084***	0.0014
Log of non-farm income (Naira)	0.0024	0.0016	0.0043***	0.0013	−0.0011	0.0017	−0.0007	0.0012
Log of remittance income (Naira)	−0.0033	0.0037	0.0060**	0.0029	−0.0037	0.0039	−0.0047*	0.0027
Use organic fertilizer (0/1)	0.2701***	0.0018	–	–	–	–	–	–
Soil quality is good (0/1)	−0.0314**	0.0155	–	–	–	–	–	–
Use hired labor (0/1)	–	–	–	–	–	–	−0.0306***	0.0111
Constant	−0.1004**	0.0463	−0.0288	0.0365	−0.0287	0.0365	0.0567*	0.0326
Mode diagnostics: RMSE	0.4107		0.3254		0.4342		0.2903	
R-squared	0.2768		0.0368		0.2337		0.0568	
Chi2	1347.47		130.95		1045.16		209.25	
p>chi2	0.000		0.000		0.000		0.000	
Error correlations (rhos): r_{12}=0.216, r_{13}=0.184, r_{14}=0.0263, r_{23}= −0.077, r_{24}= −0.139, r^{34}=0.1197. Breusch–Pagan test of independence: chi2(6) = 169.958, Pr = 0.000								

Note: Observations: 3427. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

ated to agricultural activities. To fill this gap the Federal Government of Nigeria established the Nigerian Agricultural Insurance Scheme (NAIS) in 1987 through which agricultural insurance program was made available to Nigerian farmers. One of the key features of the scheme was the provision of financial support by the government in the form of 50% premium subsidies for most classes of agricultural insurance. However, due to several challenges including low awareness of farmers and agribusiness about the insurance products, inadequate infrastructure and support services, lack of actuarial data, and delays in subsidy premium payments; only less than 5% of Nigerian smallholders are under agricultural insurance coverage. Those with insurance coverage are 6.1% less likely to be demand-side credit constrained. The explanation for this could be that insurance coverage may change household's behavior towards risk perception, hence households may engage in borrowing to undertake somewhat riskier but more rewarding farming activities. Similarly, access to information sources reduces demand-side credit constraints by 4.3% and households with access to extension services are 2.7% less likely to be demand-side credit constrained. Access to information sources and extension services reduce information asymmetry and enable smallholders to understand the terms and sources of credit, thereby improve access to credit.

5.2. Credit and agricultural technology

Table 7 presents results from the SUR model for smallholders in our sample. We estimated adoption decisions of four agricultural technologies – use of inorganic fertilizer, improved seed, agrochemicals, and agricultural machines – simultaneously using a SUR equation systems where the errors terms affecting the adoption decision of one technology are allowed to correlate with errors terms affecting adoption decisions of other technologies (as specified in Eqs. (4.1)–(4.4). This allows joint estimation of the four equations that may or may not have a common set of regressors.

The share of smallholder farmers adopting the four technologies varies – nearly 50% adopted agrochemicals and 41 percent applied inorganic fertilizer. However, as far as the use of improved seed and mechanization are concerned, only 16 and 12 percent adopted these two technologies, respectively. Although we included several control variables to examine how adoptions of these technologies are conditioned, our main interest in this study is to examine the effect of credit constraints on the adoption of these technologies. We used the same set of control variables in all the four equations, except for two additional variables (use of organic fertilizer and soil quality) in the equation for 'inorganic fertilizer' and one additional variable (use of hired labor) in the 'agricultural machinery' equation.

The results in Table 7 indicate that use of agrochemicals is not affected by constraints to credit access, neither from the supply or the demand sides. That may be why more than 50% of the sampled farm households apply agrochemicals. The most plausible explanation for this could be that the total costs of agrochemicals per hectare are generally lower than the costs of the other three technologies analyzed. On the other hand, credit constraints from both the demand-side and the supply-side significantly affect adoption of inorganic fertilizer and improved seed. As these are the two costly but key yield enhancing agricultural inputs, credit constraints could have adverse effects on farm output [72] and profits [36]. Past studies [24,54,73] reported similar findings that access to credit may be connected to the use of specific agricultural inputs. Our findings on the adverse effects of credit constraints on adoption of major agricultural inputs such as inorganic fertilizer and modern seed varieties in the developing countries are consistent with several existing

empirical literature. Ali and Deininger [10] in Ethiopia, Jia et al. [46] in China and Kenya, and Shoji et al. [77] in Sri Lanka highlight that access to credit is a key factor in the adoption of agricultural technologies and innovations. Similar findings were reported in the contexts of sub-Saharan African [17,27,33,49,56,59]. Use of agricultural machines is affected only by demand-side credit constraints, implying that, while agricultural machines may be available for hiring from the supply-side (for cash payment or in-kind credit), most smallholders prefer their tradition manual farm operations in lieu of mechanizing their farm operations. This lack of demand for mechanized operations may be associated with risk-averse behavior or attributable to the subsistence nature of most farming in Nigeria and a lack of entrepreneurial capacity and business aspirations.

The use of inorganic fertilizer and manure (organic matter) are seen to be complementary. Farmers who adopt inorganic fertilizer also are more likely to apply organic matter to their crops. We also see those farmers having good soil quality tend to apply less inorganic fertilizer to their crops. An implication of this result is that investing in soil quality improvement could reduce the costs of applied inputs in agricultural production, making agriculture more profitable and sustainable in the long run. Lastly, the negative coefficient of the variable 'use of hired labor' in the 'agricultural machinery' equation implies that hired labor and the use of agriculture machines serve as substitutes for each other.

6. Conclusions and policy implications

This study examines the nature of credit constraints among smallholder farmers – whether smallholders are credit-constrained or not, the extent to which credit constraints emanate from supply-side or demand-side factors, the factors affecting credit constraints to smallholders, and the effects of these constraints on adoption of four agricultural technologies – inorganic fertilizer, improved seed, agrochemicals, and mechanization. While improving credit access of smallholder farmers in Nigeria through mitigating supply-side constraints has often been recommended as an effective policy for boosting agricultural technology adoption and increase agricultural productivity, our findings show that demand-side factors are equally important to address the credit constraints thatsmallholders encounter. We found that out of all credit-constrained households in the survey sample, over half face credit constraints from the demand-side. Thus, improving credit access via easing supply-side constraints may not necessarily address the problem of credit access for smallholders in Nigeria. The reason some smallholders do not participate in the credit market may not necessarily be because they cannot obtain credit, but, rather, because they may be risk-averse or do not have access to adequate information on potential sources of credit or on the terms of the credit that is available. Addressing demand-side factors, such as access to information, extension services, and insurance cover, will mitigate the credit constraints faced by many smallholders, increase their adoption of modern agricultural technologies, and improve their productivity.

Based on these findings, we suggest the following policy changes: (i) The key supply-side constraints are related to lack of adequate collateral. Policies should focus on mechanisms for enhancing smallholders' capacity to possess bankable collateral, such as land titles or assets. (ii) Besides improving credit access via easing supply-side constraints, demand-side factors should equally be addressed to boost agricultural credit use and increase adoption of modern agricultural technologies by smallholder farmers in Nigeria. (iii) Policy needs to pay attention to improving the access of rural farming households to information, extension services, and insurance coverage to mitigate key demand-side factors hindering smallholders' access to credit. The key policy questions include: How to improve rural information systems, including for agricultural production and marketing? How to enhance household's access to information technologies, including access to telephone and internet? How to promote insurance products that suit smallholders needs to mitigate agricultural risks, e.g., risk of crop failure? How to improve the quality and outreach of extension services to smallholders? Addressing these issues could help resolve demand-side credit constraints among smallholders. (iv) Adoption of the two key modern agricultural inputs, inorganic fertilizer and improved seeds, in Nigeria is significantly affected by both supply-side and demand-side credit constraints. Targeted policy interventions are needed to improve smallholders' access to credit to finance adoption these key agricultural inputs, increased productivity and improve rural livelihoods.

Finally, we would like to highlight some limitations of the present paper and areas for future research to strengthen the evidence base on the nature and relationship between rural credit and agricultural technology adoption by smallholders in developing countries. Firstly, due to the unavailability of credit information in waves 1–3 surveys of the LSMS-ISA in Nigeria, our analysis was based on cross-section data extracted from the wave 4 of LSMS-ISA data for Nigeria. Future research could explore panel data sets, potentially integrating the existing wave-4 data with the upcoming wave-5 LSMS-ISA data to shed further light on the nature and effects of credit constraints on agricultural technology adoption. Secondly, our findings were based on observational survey data. Future research could explore the possibility of designing and generating experimental data. Thirdly, the direct elicitation method (DEM) used in this paper to identify a household's credit constraint status is subject to further scrutiny. Future research could explore alternative approaches to improve the identification strategy.

Declaration of Competing Interest

None! The authors declare that they have no conflict of interest.

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