Credit constraints and adoption of agricultural technologies in developing countries? Evidence from Nigeria

by Bedru B. Balana and Motunrayo A. Oyeyemi

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ABSTRACT

The agricultural sector in Nigeria is characterized by low productivity, driven partly by low use of modern technologies. Poor access to credit is seen as a key barrier to adoption of these technologies. Policy discourse and literature often associate credit constraints with supply-side factors such as limited access or high borrowing costs. However, demand-side factors, such as borrower's risk-averse behavior, transaction costs and information asymmetry equally play important roles in credit-rationing. Using a nationally representative LSMS-ISA data from 5000 smallholders in Nigeria and seemingly unrelated econometric models, we examine the nature of credit constraints, factors affecting credit constraints, and the effects of credit constraints on adoption of four agricultural technologies – inorganic fertilizer, improved seed, agrochemicals, and mechanization. Contrary to policy discourse, we found that demand-side factors are as important as supply-side constraints. Improving supply-side constraints thus may not necessarily address credit constraints for smallholders. On the supply side, lack of adequate collateral is the key constraints; hence supply-side policies should focus on enhancing smallholders' capacity to possess bankable collateral, such as land titles or assets. On the demand-side, interventions such as crop insurance, information and extension services are needed to increase credit access, technology adoption, and agricultural productivity in Nigeria.

Keywords: Adoption, Agricultural technology, Credit constraints, Smallholder farmers, Nigeria
JEL. Q14, Q12, O16

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1. Introduction

With a population of over 200 million people, Nigeria is the most populous country in Africa and the seventh populous in the world. About 49 percent of Nigeria's population is living below the international poverty line of $1.9 per day (World Bank, 2018). Food insecurity and a shortage of energy and nutrient-rich foods remain the major challenges in Nigeria (FMARD, 2016; NPC and IFC, 2019). Like most other developing countries, agriculture is a major source of employment and economic development in Nigeria, contributing about 23 percent to GDP and a 70 percent share of the labour force. However, the sector suffers from two major challenges: (i) the sector's inability to meet domestic food requirements and (ii) the inability of the sector to export at quality levels required for market success (FMARD, 2016). 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 lack of 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 percent; 84 percent; and 25 percent, 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, inorganic fertilizer, agrochemicals, agricultural machinery, and irrigation, is the major constraint hindering the performance of the agriculture sector in the country. Poor access to financial services 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 agriculture more broadly. According to the APP, insufficient access to 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 (2012), and the Anchor Borrowers' Programme (2015), were instituted by government to mitigate the problem. Though government claims some positive results, e.g., agricultural lending increased from 1 percent in 2011 to 6 percent 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 globally highlights that lack of access to credit forms a major impediment to agricultural technology adoption among smallholder farmers in developing countries (Feder et al. 1990; Feder and Umali 1993; Fernandez-Cornejo and McBird 2002; Carter and Olinto 2003; Guirkinger and Boucher 2008; Abate et al. 2016; Khandker and Koolwal 2016). This research associates the principal credit constraints faced by smallholders 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 credit access through policies that mitigate such supply-side constraints is often recommended as an effective strategy to boost agricultural technology adoption and productivity. However, improving credit access via the easing of supply-side constraints may not necessarily increase credit uptake and the use of modern agricultural inputs without equally addressing demand-side factors and behaviors that constrain smallholders' access to and use of credit (de Janvry et al. 1991; Woutersen and Khandker 2013; Adjognon et al. 2017). Even if the supply-side constraints were removed, e.g., by lowering interest rates, farmers might still may not take loans for several reasons including: (i) farmers' risk-aversion behavior; (ii) collateral requirements and repayment schedule that many smallholders cannot afford; (iii) farmers finding the option of financing input purchases from their own resources through crop sales or other sources of income; and (iv) high transaction costs.

In addition to the supply-side constraints, these demand-side factors can play an important role in the functioning of agricultural credit markets and credit-rationing to smallholder borrowers. Empirical knowledge gaps exist in understanding the nature of credit constraints, whether credit constraints emanate from the supply- or demand-side, and whether credit constraints are a major limiting factor for agricultural technology adoption by smallholders. Using the Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA) data for Nigeria from the 2018/19 survey round and

multinomial probit (MNP) and seemingly unrelated regression (SUR) models, the main aims of this paper are to: (i) Identify the credit-constraint status of smallholder farmers – unconstrained, supply-side constrained, or demand-side constrained; (ii) Examine the factors affecting the credit constraint status of smallholder farmers; and (iii) Investigate the effects of credit constraint on adoption of four agricultural technologies – inorganic fertilizer, improved seed, agrochemicals, and mechanization.

A better understanding of the credit constraint status of smallholders; the factors that affect this status; and whether credit access could enhance technology adoption would provide empirical evidence to support policy decisions to alleviate these constraints on smallholder farmers and enable them to improve their productivity and livelihoods. In terms of 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, 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 brief overview of the research literature on the linkages between credit constraints and agricultural technology adoption. A review of recent agricultural credit policies in Nigeria is summarized in section 3. Section 4 describes the methodologies (data and econometric models) used in the study. Sections 5 and 6 respectively present descriptive and econometric results. The final section concludes the paper with key policy recommendations.

2. Agricultural credit in Nigeria

Given the potentially vital role of agricultural credit markets in spurring broad economic growth and development, the government of Nigeria has established rural finance policies through which numerous formal agricultural finance institutions, schemes, and programmes were developed(Mogues et.al. 2008; Ojiako and Ogbukwa 2012; Adetiloye 2012; Bassey et al. 2016). Table 1 summarizes the key policy interventions and schemes around rural credit in Nigeria over the past two decades.

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	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 percent 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. (2005); Adetiloye (2012); Oparinde et al. (2017)
Commercial Agriculture Credit Scheme (CACS)	2009 to present	To provide finance for country's commercial agricultural value chains. Established jointly by CBN and the Federal Ministries of Agriculture and of Waters 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 percent shared between CBN at 7 percent and the issuing bank at 2 percent.	• 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 & Yaro (2015).
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 percent.	Agricultural industry	Banks reluctant to give loans due to poorly packaged proposals from applicants. Bureaucracy and slow processing of loan applications. Applicants unwilling to pay additional 3 percent guarantee fee. NIRSAL having difficulty in validating information provided by counterparties. Lack of information technology infrastructure.	Olomola & Yaro, (2015).

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 ─ farmer enumeration, input redemption, reconciliation of records, and subsidy payment. Once farmers receive their subsidy support on their mobile phones, they pay 50 percent 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 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 percent. Participating financial institutions receive from CBN a 2 percent 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. Programme supplied expired seedlings. Misunderstandings around the modalities of the programme: • 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.	Odukoya (2020)
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 percent 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 (2019) Ogbette et al. (2019)

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.

Sources: Authors' compilation from documents listed in Sources column.

3. Methodology

4.1 Data

We used the 2018/19 Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA) data, which is the fourth wave of the LSMS-ISA panel dataset for Nigeria, because the earlier waves do not have adequate information on credit. This wave consisted of a nationally representative sample of over 5,000 households sampled across 519 enumeration areas (EAs). Households were visited twice in wave four, in a post-planting and post-harvest visits between July and September 2018 and January or February 2019, respectively. Information on credit consisted of answers to a broad 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.

4.2 Conceptual framework and identification strategy

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 (Boucher et al. 2009; Croppenstedt et al. 2003; Abdulai and Huffman 2014). It is argued that credit access allows farmers to increase their purchases of agricultural inputs and, thus, increase their productivity (Feder et al. 1990). In a competitive market with symmetric information, borrowers can access credit under any interest rate and collateral combination conditional on the borrowers' behavior (Boucher et al. 2009). 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 (Feder et al. 1990; Boucher et al. 2008). Information asymmetry creates adverse selection and moral hazards, which in turn may negatively affect the performance of credit markets (Stiglitz and Weiss 1981). 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 informational 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 (Hoff and Stiglitz 1990).

To guide the empirical analyses of credit constraints and their potential effects on technology adoption, we adapted the Boucher et al. (2009) framework for a household credit constraint identification strategy summarized in Table 2. The credit constraint status of a household can be: (a) 'unconstrained' - households consisted of either satisfied borrowers; or non-borrowers who did not need loans or who preferred to work with their own liquidity; (b) 'supply-side constrained' - consisted of rejected loan applicants; unsatisfied borrowers, that is; or non-borrowers who perceived that their application, if made, would be rejected; and (c) 'demand-side constrained' - are 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.

Table 2. Identification strategy of credit constraints status of smallholders

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 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	**Non-borrowers:**	Do not want to be worried; afraid.	Need to pay bribes, too much politics involved

	credit history; existing outstanding loans; or irregular income

Source: Authors' representation.

The identification strategy of credit constraints depicted in Table 2 is based on the answers of respondents to questions in the LSMS-ISA survey instruments. Such a direct elicitation method approach has been applied in similar studies (Boucher et al. 2009; Ali et al. 2014) and allows us to make comparison between constrained and non-constrained borrowers.

4.3 Econometric approach

4.3.1 Multinomial probit (MNP) model

A multinomial probit (MNP) model is the most used probability model when the outcome 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 or fall under one of the alternatives. The choices can be coded as $j = 0, 1, \dots, m$, where m is the number of categories. In our analysis, we let y_i be the categorical variable that takes values $j = 0, 1, 2$ that represents the credit constraint status, i.e., unconstrained, supply-side constrained, and demand-side constrained, respectively, of the i^{th} household. Defining y_i^* as the unobserved propensity of the i^{th} household to be in credit constraint status j (Equation 1):

$$y_{ij}^* = x_i' \beta + \varepsilon_{ij} \quad (1)$$

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 (Equation 2):

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

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

4.3.2 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 may be affected by several factors, such as socio-demographic factors; endowments; access factors, e.g., to ICT and extension services; financial literacy; and 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 a 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 application of inorganic fertilizer or agrochemicals. Thus, cross-equation error terms of different agricultural technologies may be correlated for the same 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 (Feder et al. 1985; Amare et al. 2012. 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 (Roodmand 2011). Equations in a SUR system seem 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 (Maddala 1983; Greene 2000).

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

$$y' = x'\theta + \varepsilon' \quad (3)$$

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 (Equation 3), the empirical model of the four agricultural technologies is specified as a set of four simultaneous equations (Equations 4a to 4d):

$$AgTec_{i1} = \beta_1 CR_{ssi} + \psi_1 CR_{ddi} + \gamma_1 X_{i1} + \varepsilon_{i1} \quad (4a)$$

$$AgTec_{i2} = \beta_2 CR_{ssi} + \psi_2 CR_{ddi} + \gamma_2 X_{i2} + \varepsilon_{i2} \quad (4b)$$

$$AgTec_{i3} = \beta_3 CR_{ssi} + \psi_3 CR_{ddi} + \gamma_3 X_{i3} + \varepsilon_{i3} \quad (4c)$$

$$AgTec_{i4} = \beta_4 CR_{ssi} + \psi_{41} CR_{ddi} + \gamma_4 X_{i4} + \varepsilon_{i4} \quad (4d)$$

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 Υ_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 (Roodman 2011). 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

5.1 Summary statistics of model variables

Table 3 presents the socio-economic 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 percent), had insurance coverage (6 percent), were members of cooperatives (21 percent), were members of informal saving groups (58 percent). Finally, there is indication of higher wealth status among applicants from the household durable assets and household yearly 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 membership association and informal saving groups were observed among the unconstrained category of households.

Table 3. Descriptive results of major 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 (%)	17.96	20.51	-1.62	20.93	18.49	-1.90*	19.37	17.48	0.91
Married (%)	77.46	72.94	2.61**	72.72	75.54	2.02**	74.35	76.90	-1.10
Literate household head (%)	80.60	71.38	5.27***	71.01	76.26	3.71***	76.67	75.84	0.36
Used hired labor (%)	94.55	94.26	0.23	93.99	94.88	0.85	94.05	95.69	-0.97
Active members (aged between 15 & 65 years)	3.0	2.7	3.38***	2.7	2.9	3.04***	2.8	2.9	-1.58
Household asset ownership:									
Land size (ha)	1.40	1.41	-0.07	1.39	1.47	0.98	1.41	1.53	-0.91
Land title (%)	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	241378	-1.92**	246,793	236,286	0.16
Household durable assets (value)	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)	9,041	7,578	0.42	7,076	8,540	0.54	10,085	6,805	0.77
Household access to:									
ICT (mobile, internet) (%)	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 (%)	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 (%)	12.50	9.33	1.90*	8.26	14.07	3.90***	14.56	13.43	0.39
Member of cooperative (%)	20.59	8.03	7.41***	10.61	9.61	-0.66	7.91	11.57	-1.50
Household has any insurance coverage (%)	6.36	3.43	3.88***	3.92	3.34	-0.96	3.11	3.60	-0.52
Member of informal savings groups (%)	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 (%)	15.63	15.98	-0.20	13.74	21.51	5.53***	21.92	21.06	0.32
Used inorganic fertilizer (%)	39.40	41.98	-1.11	37.28	43.10	-3.10***	36.18	38.27	-0.66
Used agro-chemicals (%)	43.90	50.92	-2.98***	48.59	53.23	2.63***	53.51	52.85	0.30
Used mechanization (%)	12.38	11.32	0.71	11.43	11.21	-0.18	8.99	13.32	-2.09**
Used manure (organic fertilizer) (%)	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.

5.2 Credit constraint situation, by rural and urban

Table 4 presents the differences in household credit status among survey households. There is a low number of agricultural credit loan applications as only about 15 percent of households applied for a loan during the 12-month period preceding the survey.

Table 4. Summary statistics of credit constraints status, by urban and rural

Credit constraint status	Households		Comparisons	
	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 (2,039)	-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.

In terms of the number of loan applications, there is no significant difference between urban and rural sectors. However, the average sizes of loans requested, and loans received were significantly higher among urban households. Higher loan demand from urban areas may be an indication of larger scales of operation often associated with higher profitability (Satterthwaite et al. 2010; Zezza & Tasciotti 2010). It also has been argued that urban applicants have access to a wider pool of credit opportunities, which gives them a competitive edge over their rural counterpart in obtaining credit. Furthermore, distance to lending institutions; low financial inclusiveness; higher transaction costs, literacy levels, and asset endowments; and lack of collateral security have been found to adversely affect credit access in rural areas (Lopez and Winkler 2018;Oyedele et al. 2009; Rajhi and Adeoti 2010; Olomola and Gyimah-

Brempong 2017). Interestingly, we observed no clear difference in the percentage of rejected borrowers between rural and urban households. Both had on average 14.5 percent rejected borrowers. About 69 percent of rural respondents indicated they did not need a loan, while in urban areas 61 percent 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

6.1 **Determinants of credit constraint status of households**

Following the identification strategy shown in Table 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 multinomial probit (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. Hence, the likely effect of each covariate on the credit constraint status of a household is interpreted against this base category.

Table 2. Estimation results of multinomial probit (MNP) regression models[1]

	Supply-side credit constrained households		Demand-side credit constrained households	
Independent variables	**Coefficient**	**Std. Err.**	**Coefficient**	**Std. Err.**
Age of household head (yrs.)	-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	-0.026***	0.010	-0.003	0.010
Log of value of livestock	-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	0.006	0.008	0.002	0.008
Log of non-farm income	0.016**	0.006	0.013**	0.006
Log of remittance income	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: 5,050		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' households

Source: 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.

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 (Feder et al. 1988; Boucher et al. 2009) 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 African smallholder households, 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 (Croppenstedt et al. 2003). 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, three significant factors are their 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. (2017) 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 not be 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.

Based on these findings, 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 to telephones and the internet? How to develop and promote appropriate

insurance products to mitigate risks for smallholders, e.g., risk of crop failure? Addressing these issues will help resolve demand-side credit constraints among smallholders.

Results show that about 27 percent of survey households are likely credit constrained, of which about 13 percent are supply-side constrained, and 14 percent 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 (Abate et al. 2016; Khandker and Koolwal 2016). 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 (de Janvry et al. 1991; Woutersen and Khandker 2013; Adjognon et al. 2017). 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 strong 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 percent less likely to be credit constrained on the supply-side and on the demand-side, respectively. 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 land

title documents or assets can be used as collateral for accessing credit, hence reducing the likelihood of a household being credit constrained (Boucher et al, 2009).

Table 3. Marginal effects of multinomial probit (MNP) regressors on probability of a household being credit constrained

	Credit unconstrained households		Supply-side credit constrained households		Demand-side credit constrained households	
Independent variables	**dy/dx**	**Std. Err.**	**dy/dx**	**Std. Err.**	**dy/dx**	**Std. Err.**
Age of household head (yrs.)	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 (no.)	-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	0.004*	0.002	-0.004***	0.001	0.000	0.002
Log of value of livestock	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	-0.001	0.002	0.001	0.001	0.000	0.001
Log of non-farm income	-0.004**	0.001	0.002**	0.001	0.002*	0.001
Log of remittance income	-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: 5,052. (*) 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

An unexpected result in Table 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 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. Those with any type of insurance coverage are 6.1 percent less likely to be demand-side credit constrained. Similarly, access to information sources reduces demand-side credit constraints by 4.3 percent. Similarly, households with access to extension services are 2.7 percent less likely to be demand-side credit constrained.

6.2 Credit constraint and agricultural technology adoption

Table 7 presents results from the seeming unrelated regression (SUR) model for rural households in our sample. We estimated adoption decisions of four agricultural technologies – use of inorganic fertilizer, improved seed, agrochemicals, and agricultural machines – simultaneously using a seemingly unrelated regression 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 Equations 4a – 4d). This allows joint estimation of the four equations that may or may not have a common set of regressors.

Table 4. Results from seemingly unrelated regression (SUR) models – credit constraints and agricultural technology adoption, rural households

	Used Inorganic Fertilizer		Used Improved Seed		Used Agrochemicals		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 (yrs.)	-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, no.	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	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	0.0316***	0.0020	0.0081***	0.0014	0.0422***	0.0019	0.0084***	0.0014
Log of non-farm income	0.0024	0.0016	0.0043***	0.0013	-0.0011	0.0017	-0.0007	0.0012
Log of remittance income	-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

Source: SUR estimation results using LSMS-ISA (Nigeria) panel wave 4 (2018/19) data.

Note: Observations: 3,427. *** p<0.01, ** p<0.05, * p<0.1

The share of rural farmers adopting the four technologies varies – nearly 50 percent 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 four equations, except for two additional variables (use of organic fertilizer and soil quality) in the equation on 'inorganic fertilizer' and one additional variable (use of hired labor) in the 'mechanization equation' 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 percent 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. 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 (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 that 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 on the variable on the use of hired labor in the mechanization 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 credit constraints for smallholders result not only from supply-side factors but from demand-side factors as well. Our findings show that the demand-side factors appear somewhat stronger than the supply-side factors. 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. (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.

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