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Credit Constraints and Agricultural Technology Adoption

Evidence from Nigeria

Bedru Balana and Motunrayo Oyeyemi

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ABSTRACT

The agricultural sector in Nigeria is characterized by low productivity that is driven by low use of modern agricultural technologies, such as improved seed, chemical fertilizer, agrochemicals, and agricultural machinery. Poor access to credit is claimed to be one of the key barriers to adoption of these technologies. This study examines the nature of credit constraints among smallholder farmers – whether smallholders are credit constrained or not and the extent to which credit constraints emanate from supply-side or demand-side factors. Using multinomial probit and seemingly unrelated simultaneous equations econometric models with data from the 2018/19 Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA) for Nigeria, the study investigates the factors affecting credit access and the effects of these credit constraints on adoption of four agricultural technologies – inorganic fertilizer, improved seed, agrochemicals, and mechanization.

The results show that about 27 percent of survey households were found to be credit constrained – 12.8 percent due to supply-side factors and 14.2 percent due to demand-side factors. Lack of access to information and communication technology, extension services, and insurance coverage are the major demand-side factors negatively affecting smallholder's access to credit. Registered land titles and livestock ownership enhance credit access. Credit constraints manifest themselves differentially on the adoption of different agricultural technologies. While adoption of inorganic fertilizer and improved seed are significantly affected by credit constraints from both the supply and the demand-sides; use of agricultural machinery is affected only by demand-side factors, while use of agrochemicals is not affected from either supply or demand-side credit factors. From a policy perspective, our findings indicate that improving credit access via supply-side interventions alone may not necessarily boost use of modern agricultural technologies by smallholder farmers in Nigeria. Demand-side factors, such as access to information, extension services, and insurance cover, should equally be addressed to mitigate the credit constraints faced by smallholders and increase their adoption of modern agricultural technologies and improve their productivity.

Keywords: adoption, agricultural technology, credit, demand-side constraints, supply-side constraints, smallholders, Nigeria

1. INTRODUCTION

Two key agricultural policy documents for Nigeria – the Agricultural Transformation Agenda (2010/11-2016) and the Agricultural Promotion Policy (2016-2020) – recognize two principal challenges in Nigerian agriculture sector: (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). These policy documents 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. 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 Agricultural Promotion Policy, 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. 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 the absence of accessible credit sources in local areas, available credit products being unsuited for meeting smallholder needs, or high costs of borrowing. Consequently, improving credit access through policies that mitigate such supply-side constraints is often recommended as effective for boosting agricultural technology adoption and productivity. However, improving credit access via the easing of supply-side constraints may not increase 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:

- Risk-aversion – fear inability to pay back the loan and, subsequently, losing collateral or standing and responsibility within group of borrowers;
- Collateral requirements and repayment schedule that many smallholders cannot afford;
- Finding it more attractive to finance 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
- High transaction costs, including complicated loan application procedures.

In addition to supply-side constraints that affect a farmer's decisions to obtain credit, 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 supply- or demand-side, and whether credit constraints are a major limiting factor for agricultural technology adoption by smallholders. A better understanding of the credit constraint status of smallholders; the factors that affect this status; and whether credit access could facilitate 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 profitability. 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.

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:

- Identify the credit-constraint status of smallholder farmers – unconstrained, supply-side constrained, or demand-side constrained;
- Examine the factors affecting the credit constraint status of smallholder farmers; and
- Investigate the effects of credit constraint on adoption of four agricultural technologies – inorganic fertilizer, improved seed, agrochemicals, and mechanization.

Against the claim that credit constraints are generally associated with supply-side factors, our findings show that about 50 percent of the constrained survey respondents face demand-side credit constraints. Poor access to information and communication technology (ICT) and to extension services and a lack of insurance coverage are key demand-side factors limiting credit uptake. Having a registered land title and livestock ownership enhance smallholder's access to credit, as they can be used as collateral to reduce the risk lenders perceive in making a loan to a smallholder farmer. We find that both demand-side and supply-side credit constraints significantly affect adoption of inorganic fertilizer and improved seed. On the other hand, use of agricultural machines is affected only by demand-side credit constraints, while the use of agrochemicals is not affected by credit access.

The remainder of this paper is organized as follows. Section 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 out descriptive and econometric results. The final section concludes the paper with key policy recommendations.

2. CREDIT ACCESS 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 (Petrick 2004), profits (Foltz 2004), and investment (Carter and Olinto 2003). These constraints have been repeatedly linked to credit market imperfections hindering adequate access to credit for farmers (Jack 2013; Abdul-Hanan et al. 2014; Meyers 2015; Abdallah 2016). Credit access offers farming households the liquidity they require to purchase agricultural inputs, adopt technology, or undertake other investments that are associated with higher yields and increase their capacity to make longer term investments. Beyond these credit constraints, some researchers have found that access to interlinked credit and insurance contracts increases the likelihood of technology adoption (Makate et al. 2019).

While also highlighting the role of information asymmetries on improved agricultural technologies (Awotide et al. 2015; Wossen et al. 2017); weak government subsidies (Mogues et al. 2015; Wossen et al. 2017), and attitude towards risk aversion (Simtowe et al. 2006; Liu 2013), the research literature emphasizes that constraints on access to credit are one of the main factors responsible for the low adoption of agricultural technologies in sub-Saharan Africa, particularly for smallholder farmers (Okpukpara 2010; Liu 2013; Bassey et al. 2016; Fletschner et al. 2010). Moreover, access to credit may at times be specifically connected to the use of specific inputs, thus limiting choices across the technologies that farmers might consider (CIMMYT 1993; Poulton et al. 2006; Mogues et al. 2015).

Many empirical studies have shown a positive effect of credit access on technology adoption. The studies of Ali and Deininger (2012) in Ethiopia, Jia et al. (2013) in China, in Kenya, and Shoji et al. (2012) in Sri Lanka highlight that access to credit is a determining factor in the adoption by smallholder farmers of many agricultural technologies and innovations. These deductions have equally been made for sub-Saharan African contexts (Fischer and Qaim 2012; Obuobisa-Darko 2015., Mohamed and Temu 2008, Kudi et al. 2011, Beshir 2014, Donkoh et al. 2011). However, we should not assume that these findings are generic to all countries and are time invariant. Drawing on an extensive review of the literature on the adoption of agricultural technologies, Doss (2006) pointed out that among the limitations of these micro-studies is the rare use of panel data to enable the generation of insights on the dynamics of agriculture technology adoption processes and the lack of variation within the smallholder household samples studied. These data challenges makes it difficult to use the study results to answer policy relevant questions. Moreover, many of these studies used a simple dichotomous variable approach for the definition of adoption, neglecting to recognize that adoption can be only partially implemented, so should be measured on a continuum. Lastly, most of these studies did not examine household collective action around technology adoption or, of interest to our study here, household behavior and how that behavior affects whether the household is credit constrained or not.

It is important to note 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 (Feder et al. 1990; Boucher et al. 2008; 2009). If credit is not a binding constraint to a farmer's agricultural production, credit may be diverted to non-productive activities, such as household consumption or non-agricultural activities. The extent to which credit contributes to agricultural investment and agricultural livelihood outcomes is likely to be higher for smallholders whose production decisions are effectively constrained by credit than for those that are less constrained (Simtowe et al. 2006; Shoji et al. 2012; Jia et al. 2013). Nonparticipation of some smallholders in credit market does not necessarily imply an unmet credit need (de Janvry et al. 1991; Simtowe et al. 2006; Ali and Deininger 2012). 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 the credit constraint status of farming households and whether credit access could enhance technology adoption by those households is also important agricultural development policy and program design. This paper aims to fill some of these knowledge gaps for Nigeria and provide evidence for better decisions around them.

3. AGRICULTURAL CREDIT IN NIGERIA

In the context of developing countries, sources of rural credit consist broadly of formal, semi-formal, and informal credit markets (Boucher and Guirkingner 2007; Barslund and Tarp 2008). 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 (Ghate 1992). In an ideal credit market, loans are traded competitively and interest rates are determined by the forces of supply and demand. However, governments sometimes intervene to correct market failures and to address the needs of disfavored economic sectors and actors. Some credit markets provide loans tailored to cater to the needs of targeted sectors or groups. Examples of such formal financial institutions in Nigeria include registered microfinance institutions, the Nigeria Agricultural Cooperative and Rural Development Bank, the Nigerian Agricultural Cooperative Bank, and the Bank of Agriculture. These institutions are established mainly to improve credit access to the agriculture sector and to ease liquidity constraints for promoting agricultural productivity in Nigeria.

The informal credit market consists of money lenders, cooperatives, family and friends, 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 (Okojie et al. 2010; World Bank 2008).

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. The policies were put in place with a view to guaranteeing sustainable availability and accessibility of credit funds to the Nigerian agricultural sector in order to constructively revitalize the sector, 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 overall economic growth and development (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.

In addition to the array of agricultural financial schemes described in Table 1, 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; Awotide et al. 2015; Wossen et al. 2017), 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; Okpukpara 2010; Ojiako and Ogbukwa 2012; Bassey et al. 2016; Obasi 2015; Awotide et al. 2015; Olomola and Gyimah-Brempong 2014; Olomola & Yaro 2015; Wossen et al. 2017). 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. Broadly, most of the credit schemes were ineffective and characterized by:

- Unequal distribution across sub-sectors and actors, e.g., crop farmers versus livestock farmers, smallholder farmers versus large-scale farmers, or rural versus urban;
- Lengthy bureaucratic problems and high transaction costs;
- Inflexibility in state-contingent credit contracts;
- General information asymmetry leading to problems of adverse selection and moral hazard;
- Poor governance in the context of weak control of corruption; and
- Diversion by officials of funds allocated to agriculture to non-agricultural activities.

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 & 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 (CACCS)	2009 to present	To provide finance for country's 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.	<ul style="list-style-type: none"> • Input supply • Production • Processing • Storage • Marketing 	Criticized for being discriminatory against certain beneficiaries and types of enterprises. Rigid 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: <ul style="list-style-type: none"> • 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. Provides incentives to banks, such as cash awards for successful banks. 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 a systems 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 the seed or fertilizers to agro dealers. Targets 5 million farmers each year– totalling 20 million at the end of four years:	Farmers	Administrative challenges, such as farmers list inundated with errors, 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. Operational constraints – poor mapping of farmers, mishandling identification, and redemption bottlenecks. Political interests interfere, as seek to divert inputs to their states.	Olomola (2016)

Key interventions or schemes	Years	Key objectives & modalities	Target beneficiaries or value chains	Challenges	Sources
Anchor Borrowers' Programme	2015 to present	To create economic linkages between smallholder farmers and large-scale processors in order 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: <ul style="list-style-type: none"> • 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: <ul style="list-style-type: none"> • Cereals, • Cotton, • Roots and Tubers, • Sugarcane, • Tree crops, • Legumes, • Tomato, and • Livestock (fish, poultry, ruminants) 	Exaggeration of successful outcomes. Late disbursement of funds and inputs, with negative implications for production. Supplied expired seedlings. Misunderstandings around the modalities of the programme: <ul style="list-style-type: none"> • 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: <ul style="list-style-type: none"> • 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)

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

Note: Naira (₦) is the currency of Nigeria. The market exchange rate for the Naira in August 2020 was USD 1.00 ≈ ₦ 384.

Agricultural credit made up only 3.4 and 4.0 percent of the total credit released to the private sector in Nigeria in 2017 and 2018, respectively (NBS 2018). 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. While there are a myriads of institutional factors hindering credit supply, as discussed above, credit constraints also emanate from the demand-side (Zeller 1994). Due to limitations on available resources, in theory credit suppliers carry out two types of credit rationing – quantity rationing and risk rationing (Boucher and Guirkingner 2007; Stiglitz and Weiss 1981). Interest rates serve as screening devices for evaluating risk. Because borrowers change their behavior with changing interest rates – being incentivized by lower rates, when coupled with a situation of information asymmetry between lenders and borrowers, credit rationing occurs. Furthermore, imperfections in insurance markets trigger similar reactions – farmers gravitate towards lower risk enterprises despite those enterprises producing lower yielding results (Eswaran & Kotwal 1990). Moreover, the adverse effects of credit rationing on agricultural productivity are situated within a broader context of selection bias by credit suppliers against smallholders in general (Feder et al. 1990; Osabohien et al. 2020).

High transaction costs, such as for loan processing, and the risk aversion behaviors of borrowers are the major demand-side constraints in agricultural credit market participation (Barham et al. 1996; Boucher et al. 2008; Boucher et al. 2009; Carter 1988; Guirkingner and Boucher 2008). 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 (Gray 2006; Kosgey 2013; Hananu, et al. 2015; Mohieldin and Wright 2000; Okurut et al. 2005; 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 (Oyedele et al. 2009; Rajhi and Adeoti 2010; Olomola and Gyimah-Brempong 2014; Aliero & Yusuf 2017; Ololade & Olagunju 2013). For instance, Ugoani et al. (2015) explains 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 (Okojie et al. 2010).

4. METHODOLOGY

4.1 Data

This study uses data from the 2018/19 round of the Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA), which is the fourth wave of the LSAM-ISA panel dataset for Nigeria. Since the earlier waves of the dataset do not have adequate variables on household use of credit, we limited our study to the cross-sectional data of the fourth wave. This wave consisted of over 5,000 households sampled across 519 enumeration areas (EAs). Households were visited twice in a post-planting visit between July and September 2018 and in a post-harvest visit in January or February 2019.

From this rich set of information at community, household, and farm plot level, we extracted information on household demographics, farm and off-farm income activities, remittances, other income (from investments, land rental, asset rental, and cash assistance from safety net programmes), use of credit, ICT, labor use, crop and livestock production, use of agricultural inputs, including land; and use of agricultural technologies. Data from both the post-planting and

post-harvest visits were pooled. Information on credit consisted of answers to a broad range of questions regarding loan applications in the past 12 months, the purpose for which the loan was sought, and general access to credit. The survey also obtained information on household savings and use of insurance. We used these responses to classify farm households by credit constraint status – *supply-side-constrained*, *demand-side-constrained*, or *unconstrained*, as now described.

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). Empirical studies identify lack of access to credit as one of the major barriers to agricultural technology adoption by smallholders (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). 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.

Figure 1. 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	Rejected borrowers: 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, e.g., high-interest rates Lenders not located nearby, e.g., do not know any lenders
Non-borrowers	Do not need a loan	Borrowers	Unsatisfied borrowers: 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, i.e., 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.

In light of this and as a guide to an empirical assessment of the forms of credit constraints and their potential effects on agricultural technology adoption, we develop a framework for a household credit constraint identification strategy. This is depicted in Figure 1. The credit constraint status of a household can be unconstrained, supply-side constrained; or demand-side constrained households.

- Unconstrained households consisted of either satisfied borrowers, i.e., obtained the amount requested, or non-borrowers who did not need loans or who preferred to work with their own liquidity.
- Households with credit constraints from the supply-side consist of a pool of rejected loan applicants, unsatisfied borrowers, i.e., those who received less than the loan amount requested, or non-borrowers who perceived that their application, if made, would be rejected.
- Households with credit constraints from the demand-side combine households that are risk-averse and other non-borrowers that consider the transaction costs of acquiring a loan to be too high and hence not worth it.

Such an identification strategy of credit constraints is based on the answers of respondents to questions in the LSMS-ISA survey instruments. A direct elicitation method, this approach has been applied usefully in several similar studies (Boucher et al. 2009; Ali et al. 2014) and allows us to make comparison between constrained and non-constrained borrowers. Borrowers 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 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, if unrevealed, demand for credit. Such households can also be classified as credit constrained due to demand-side constraints. Using the identification strategy portrayed in Figure 1, 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.

4.3 Econometric approach

4.3.1 Multinomial probit (MNP) model

A multinomial probit (MNP) model is the most commonly used probability model when the outcome (dependent) variable is categorical and takes more than two categories, e.g., the type of insurance contract that an individual selects; the crop type a farmer selects to grow; the fertilizer type a farmer selects. 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. The fundamental assumption of an MNL model is the assumption of standard normal probability density function in the error terms.

In our empirical 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_{ij}^* 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):

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

Where P_{ij} represent the probability of the i^{th} individual falls into the j^{th} category, x_j' is a vector of regressors, β = the parameters to be estimated, and Φ is a probit functional evaluator. The variables included in the empirical model are presented in Table 4.

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, such as 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. 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 or unrelated 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.

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 developed 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 (Roodman 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.

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, $x' = (x_1, \dots, x_k)'$ 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 with zero means and a covariance 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 values of 0 or 1 for unconstrained and constrained households, X_{i1} to X_{i4} , as

described in Table 4, 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 *cmp* (conditional mixed process) model command in the Stata statistical analysis software (Roodman 2011).¹

5. DESCRIPTIVE RESULTS

5.1 Credit constraint situation, by rural and urban

Table 2 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 2. Summary statistics of credit constraints status, by urban and rural

	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.

¹ *cmp* (conditional mixed process) is a very flexible Stata command that is appropriate for estimating broad types of econometric models (single, multivariate, a mix of limited dependent and continuous left-hand variables, selection models, etc.). *cmp* is particularly suitable to model SUR equations when some or all the left-hand (dependent) variables are not continuous variables (Roodman 2011).

5.2 Credit constraint situation, by source – formal, semi-formal, and informal

Table 3 shows that only about 11.5 percent credit seekers applied for loan from formal sources, with 43 percent of these applications being rejected. However, despite catering for only a small portion of credit requests, the sizes of the loan request and the loan received from the formal sector are considerably larger than the loans requested or received from other credit markets. Seventy-six percent of loan applications were made to informal lending sources and only 9.5 percent of applications were rejected. The semi-formal sector stands in between the formal and informal sectors, in both loan requests received and rejected applications – 12 and 19 percent, respectively. It is clear from the high rate of rejection from the formal sector, that credit rationing is more stringent and targeted to a certain household profile. In addition to poor policy implementation, which ideally should incentivize the formal credit sector to disburse funds to the agricultural sector, Olomola and Gyimah-Brempong (2014) pointed out that there are capacity gaps among these financial institutions. This leads them to take inflexible approaches to credit rationing. It is also observed that quantity rationing was more prominent in the formal sector – 16.8, 11.8, and 6.6 percent of borrowers from the formal, semi-formal, and informal sectors, respectively, received less than the amount they requested.

Table 3. Summary statistics of credit constraints status, by loan source

Credit applications and decisions	Formal	Semi-formal	Informal
Applied or attempted to borrow (%)	11.5	12.1	76.4
Average amount for which applied (Naira)	623,691	398,441	165,520
Average amount received (Naira)	483,385	108,625	86,000
Rejected borrowers (%)	42.7	19.3	9.5
Unsatisfied borrowers (%)	16.8	11.8	6.6

Source: Authors' computations from the LSMS-ISA (Nigeria) panel wave 4 (2018/19) data

Table 4 presents the socio-economic characteristics 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 land. However, there is a distinct difference in 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 4. Descriptive results of major variables used in the econometric analysis, by credit constraint status

	Applied/ Attempted	Non- applicants	Difference (t-stat.)	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
Dependency ratio (Dependents/Workers)	1.112	1.010	2.74***	1.033	1.009	-0.80	0.971	1.053	-1.68*
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	241,378	-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 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.

Among the five identified technologies that can boost productivity (Table 4), mechanization is the least used technology (12 percent) among loan applicants. In contrast, 44 percent used agrochemicals, 40 percent used inorganic fertilizers, 28 percent used organic fertilizers, and 16 percent used improved seed. However, despite significant differences in technology use, most households were credit constrained.

6. ECONOMETRIC RESULTS

6.1 Determinants of credit constraint status of households

Following the identification strategy shown in Figure 1, 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 5. Estimation results of multinomial probit (MNP) regression models

Dependent variable: Credit constraint status						
Base category – Credit unconstrained households						
Independent variables	Supply-side credit constrained			Demand-side credit constrained		
	Coefficient	Std. Err.	p-value	Coefficient	Std. Err.	p-value
Age of household head (yrs.)	-0.001	0.002	0.508	-0.002	0.002	0.423
Literate household head (0/1)	0.096	0.078	0.219	0.073	0.079	0.354
Male household head (0/1)	0.063	0.124	0.610	-0.018	0.115	0.877
Married household head (0/1)	0.039	0.110	0.723	0.067	0.105	0.526
Members of working age, no.	0.043**	0.020	0.029	0.033	0.020	0.101
Landholding size of household (ha)	0.026	0.017	0.130	0.018	0.018	0.314
Has land title (0/1)	-0.303***	0.097	0.002	-0.343***	0.095	0.000
Log of value of assets	-0.026***	0.010	0.008	-0.003	0.010	0.727
Log of value of livestock	-0.015**	0.007	0.024	-0.024***	0.007	0.000
Access to ICT (0/1)	0.187	0.151	0.216	-0.323**	0.157	0.040
Access to agricultural extension (0/1)	-0.014	0.099	0.891	-0.173*	0.104	0.097
Has insurance (0/1)	-0.206	0.174	0.239	-0.464***	0.173	0.007
Has formal savings (0/1)	0.000	0.072	1.000	-0.013	0.071	0.853
Has informal savings (0/1)	0.463***	0.064	0.000	0.317***	0.062	0.000
Rural (0/1)	-0.098	0.080	0.219	0.260***	0.075	0.001
Log of farm income	0.006	0.008	0.433	0.002	0.008	0.764
Log of non-farm income	0.016**	0.006	0.012	0.013**	0.006	0.027
Log of remittance income	0.023*	0.014	0.096	0.004	0.014	0.782
Constant	-1.651***	0.219	0.000	-1.504***	0.221	0.000
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			

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, household sociodemographic variables, such as age and marital status, are not statistically significant in determining a household’s credit constraint status. 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. With regard to demand-side constrained households, three significant factors are their level of access to information and communication technology²(ICT²), 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.

This finding highlights several policy relevant issues:

- 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.
- 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.
- There is a need to improve access to agricultural extension, both through improved coverage and improved 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. Overall, we find that rural residents are more likely to suffer demand-side credit constraints compared to their urban counterparts. The greater challenges such households face in accessing information, extension services, and insurance than urban households contribute to this result.

Based on our estimates, 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 – for instance, due to an

² This includes access to phone services, internet, and other information technology sources.

absence of accessible credit sources in local areas, an absence of credit products that are in line with smallholder needs, and high costs of borrowing. Consequently, improving credit access through mitigating such supply-side constraints has been recommended as an effective policy to boost agricultural technology adoption. 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. Marginal effects of multinomial probit (MNP) regressors on probability of a household being credit constrained

Independent variables	Credit unconstrained households			Supply-side credit constrained			Demand-side credit constrained		
	dy/dx	Std. Err.	P>z	dy/dx	Std. Err.	P>z	dy/dx	Std. Err.	P>z
Age of household head (yrs.)	0.000	0.000	0.363	-0.000	0.000	0.627	-0.000	0.000	0.491
Literate household head (0/1)	-0.021	0.016	0.180	0.012	0.012	0.283	0.009	0.013	0.488
Male household head (0/1)	-0.005	0.024	0.834	0.011	0.018	0.562	-0.005	0.019	0.775
Married household head (0/1)	-0.013	0.022	0.537	0.004	0.017	0.823	0.010	0.017	0.558
Members of working age (no.)	-0.010**	0.004	0.020	0.006*	0.003	0.060	0.004	0.003	0.220
Landholding size (ha)	-0.006	0.004	0.135	0.004	0.003	0.174	0.002	0.003	0.471
Has land title (0/1)	0.077***	0.017	0.000	-0.034***	0.013	0.008	-0.044***	0.013	0.001
Log of value of assets	0.004*	0.002	0.076	-0.004***	0.001	0.007	0.000	0.002	0.811
Log of value of livestock	0.005***	0.001	0.000	-0.001	0.001	0.149	-0.004***	0.001	0.001
Access to ICT (0/1)	-0.061**	0.027	0.026	0.018	0.021	0.398	-0.043**	0.021	0.036
Access to agricultural extension (0/1)	0.023	0.020	0.245	0.004	0.015	0.789	-0.027*	0.015	0.072
Has insurance (0/1)	0.077**	0.030	0.010	-0.017	0.024	0.486	-0.061***	0.020	0.002
Has formal savings (0/1)	0.002	0.015	0.906	0.000	0.011	0.965	-0.002	0.011	0.846
Has informal savings (0/1)	-0.099***	0.013	0.000	0.063***	0.010	0.000	0.036***	0.010	0.000
Rural (0/1)	0.047**	0.016	0.004	-0.005	0.012	0.659	-0.042***	0.013	0.001
Log of farm income	-0.001	0.002	0.511	0.001	0.001	0.453	0.000	0.001	0.898
Log of non-farm income	-0.004**	0.001	0.004	0.002**	0.001	0.034	0.002*	0.001	0.085
Log of remittance income	-0.003	0.003	0.251	0.003*	0.002	0.091	-0.000	0.002	0.921
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

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 owning 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).

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 constraints and agricultural technology adoption

Table 7 presents results from the seeming unrelated regression (SUR) model for rural households in our sample. Adoption of different agricultural technologies by smallholder farmers may seem to be independent decisions from each other. But agricultural technologies may complement one other or there may be a degree of substitution among them. For instance, adoption of improved seed may also entail application of inorganic fertilizer or agrochemicals. Thus, joint decisions on technology adoption may be affected by a common set of observable factors or there may be unobserved heterogeneities correlated for these decisions (Feder et al. 1985; Amare et al. 2012). In such cases, estimation of the adoption of one technology with a single equation could cause bias, inconsistency, and inefficiency in parameter estimates (Greene 2000; Maddala 1983). We estimated adoption decisions of four agricultural technologies – use of inorganic fertilizer, improved seed, agrochemicals, and agricultural machines i.e., mechanization – simultaneously using a seemingly unrelated regression equation systems where the errors terms affecting the adoption decision of one technology is allowed to correlate with errors terms affecting adoption decisions of other technologies (as specified in Equations 4a – 4d).³ This allows joint estimation of the four equations that may or may not have a common set of regressors.

³ We originally considered 'use of irrigation technology' as a fifth agricultural technology. However, only 2 percent of sampled farmers used irrigation in the survey period. Also, unlike the other four technologies, use of irrigation technology mainly depends on the availability of water sources and irrigation infrastructure. Thus, we did not include irrigation in our analysis.

Table 7. Results from seemingly unrelated regression (SUR) models – credit constraints and agricultural technology adoption, rural households

Independent variables	Used Inorganic Fertilizer		Used Improved Seed		Used Agrochemicals		Used Agricultural Machinery	
	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 is good (0/1) – in the equation on the use of inorganic fertilizer and one additional variable – use of hired labor – in the mechanization 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), a majority of 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.

7. CONCLUSIONS AND POLICY IMPLICATIONS

This study investigates the agricultural credit-constraint status of smallholder farmers in Nigeria – that is, whether the source of the credit constraints faced by smallholders are driven by supply-side factors or by demand-side factors or, alternatively, whether credit is not a binding factor for smallholder production. Using the 2018/19 LSMS-ISA data for Nigeria, the study examines the factors affecting smallholder's credit-constraint status and the effects of credit constraint on adoption of four agricultural technologies – inorganic fertilizer, improved seed, agrochemicals, and mechanization. Against the claims in the Agricultural Transformation Agenda, the Agricultural Promotion Policy, and the research literature that associates credit constraints smallholders face to supply-side factors, we found that out of all credit-constrained households in the survey sample, about half face credit constraints from the demand-side. These demand-side constraints are due to risk-perceptions, to high transaction costs, to a lack of entrepreneurial skill or business aspirations, or to a combination these factors.

The key findings of the study include:

- Access to information and communication technology (ICT), to extension services, and to insurance coverage are key demand-side factors affecting credit, i.e., households having good access to these three services are less likely to be demand-side credit constrained. A household with any type insurance coverage is 6.1 percent less likely to be demand-side credit constrained, access to information reduces demand-side credit constraint by 4.3 percent, and those households with access to extension services are 2.7 percent less likely to be demand-side credit constrained.
- The area of land a household owns does not have a statistically significant effect on easing the credit constraint status of a household. Rather, having a registered land title and owning livestock enhances smallholder's access to credit by mitigating both supply and demand constraints either by reducing the risk to lenders or by potentially being used as collateral for the borrower. Owning titled land is associated with a lower probability of being either supply-side or demand-side credit constrained.
- Use of agrochemicals and application of inorganic fertilizer are widely used technologies relative to the other technologies. In contrast to the use of inorganic fertilizer, the use of agrochemicals is not affected by credit constraints from either the supply or the demand sides.
- Both demand-side and supply-side constraints significantly affect adoption of inorganic fertilizer and use improved seed. On the other hand, use of agricultural machines is affected only by demand-side credit constraints.

Based on these findings, we suggest the following policy changes:

- Improving credit access via easing supply-side constraints may not necessarily boost agricultural credit use and increase adoption of modern agricultural technologies by smallholder farmers in Nigeria. Demand-side factors should equally be addressed.
- 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.
- Policy needs to pay attention to improving the access of rural farming households to information, extension services, and insurance coverage to mitigate these key demand-side factors hindering smallholders' access to credit.
- Inorganic fertilizer and improved seed are considered to be two key modern agricultural inputs required to increase agricultural productivity (Croppenstedt et al. 2003; Shiferaw et al. 2008; Abate et al. 2016). Unfortunately, adoption of these technologies by farmers in Nigeria is significantly affected by credit constraints. We suggest targeted policy interventions to improve smallholders' access to credit to finance adoption these key agricultural inputs.

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ABOUT THE AUTHORS

Bedru Balana is a Research Fellow in the Development Strategy and Governance Division (DSGD) of the International Food Policy Research Institute (IFPRI) working with IFPRI's Nigeria Strategy Support Program (NSSP), based in Abuja, Nigeria. **Motunrayo Oyeyemi** is a Research Analyst in DSGD of IFPRI working with NSSP, based in Abuja, Nigeria.

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INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

1201 Eye St, NW | Washington, DC 20005 USA
T. +1-202-862-5600 | F. +1-202-862-5606
Email: ifpri@cgiar.org | www.ifpri.org | www.ifpri.info

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c/o International Fertilizer Development Center
No.6 Ogbagi Street | Off Oro-Ago Crescent, Garki II
Abuja | Nigeria
ifpri-nigeria@cgiar.org | nssp.ifpri.org/

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