The Impact of Agricultural Productivity on Welfare Growth of Farm Households in Nigeria: A Panel Data Analysis

Mulubrhan Amare[a*], Jennifer Denno Cissé[b], Nathaniel D. Jensen[b] and Bekele Shiferaw[a]

[a*]Corresponding author: Research Fellow, Partnership for Economic Policy (PEP), PO.Box:30772-01100, Nairobi, Kenya. E-mail: Mulubrhan.Amare@pep-net.org

[b] Cornell University, Charles H. Dyson School of Applied Economics and Management, Ithaca, New York 14853, USA

Abstract

Empirical studies across many developing countries document that improving agricultural productivity is the main pathway out of poverty. In this paper, we begin by investigating the factors that hinder or accelerate agricultural productivity. Additionally, we seek to understand whether agricultural productivity, measured using land productivity, improves household consumption growth using nationally representative Living Standards Measurement Study - Integrated Surveys on Agriculture (LSMS-ISA) panel datasets from Nigeria, merged with detailed novel climate and bio-physical information. The results show that agricultural productivity is positively associated with labor and farm inputs. Consistent with the inverse land size-productivity relationship so often observed in the literature, land productivity decreases with increasing farm size. We also find that climate risk and bio-physical variables play a significant role in explaining agricultural productivity. Moreover, agricultural productivity has a significant and positive impact on household consumption growth. The results also indicate that while agricultural productivity has a positive impact on welfare growth for non-poor households, it has a negative impact for poor households.

1. Introduction

Agriculture constitutes only about one-fifth of Africa's GDP and about half of the total value of its exports, yet more than two-thirds of the population lives in rural areas and more than 85% of people in these regions depended on agriculture for their livelihoods (World Bank Development Indicators, 2014). Improving the productivity, profitability, and sustainability of smallholder farming is therefore considered the main pathway out of poverty. Agricultural research and development interventions focused on agricultural intensification and modernizing market channels for agricultural products can lead to agricultural productivity growth and thereby both reduce poverty and meet growing demands for food (Ravallion and Datt, 1998; Loayza and Raddatz, 2010; Ravallion and Datt, 1999, Mellor, 2001; Thirtle et al., 2003).

The literature suggests that there are multiple pathways through which increases in agricultural productivity can reduce poverty, including real income changes, employment generation, rural non-farm multiplier effects, and food price effects (Ravallion and Datt, 1999, Gollin et al., 2002; Irz and Tiffin, 2006). Its impact on poverty is both direct, flowing immediately from growth in agriculture by raising real incomes of poor farm (and non-farm) households, and indirect by increasing agricultural outputs which induces job creation in upstream and downstream non-farm sectors as a response to higher domestic demand (Valde´s and Foster, 2007; Gollin et al., 2014). Potentially lower food prices can increase the purchasing power of poor consumers (Olsson and Hibbs, 2005; de Janvry and Sadoulet, 2010). The poverty impact of agricultural productivity can be sizeable mainly because the majority of poor people in sub-Saharan Africa countries directly depend on agriculture for their livelihoods (Foster and Rosenzweig, 2005).

However, agriculture is not a panacea for poverty reduction (Hasan and Quibria, 2004). Agriculture is often associated with economic and natural risks such as price fluctuations, drought, pests and diseases. The poor and small-scale farmers are particularly vulnerable to these risks. A country which relies on agricultural exports can be adversely affected by global economic shocks (Winters et al., 2004; Easterly and Kraay, 2000). A sudden decrease in the prices of agricultural outputs can quickly push small net sellers into losses and poverty. Moreover, poor smallholders face a number of constraints that limit their productivity. Lack of information about production methods and market opportunities, particularly for new crops and varieties prohibit households from intensifying agriculture and producing high-value commodities whose market demand is growing rapidly. Poor access to credit and/or insurance can also limit uptake of new technologies. Smallholder producers are now also facing the growing challenges of recent technological changes and the stringent quality standards for many food products, both of which are associated with the globalization of commodity chains. In addition, high initial inequality in the distribution of assets and especially of land can also be a plausible candidate explanation of why some agricultural productivity change might be less effective in up lifting poor families from poverty (de Janvry and Sadoulet, 2010).

Therefore, the extent to which poor people would gain from agricultural productivity depends on the specific circumstances of initial land distribution, market, infrastructure, institutions and demographic set ups. Our analysis is organized around four questions. First, what are the main production determinants factors associated with of household agricultural productivity? Second, how does agricultural productivity impact household welfare growth? Third, does the relative position of poor people (e.g. the bottom 25%) improve or worsen with productivity change? Fourth, how do different categories of smallholder farmers benefit from agricultural productivity?

The paper contributes to the literature in several respects. First, whereas earlier research has examined the relationship between farm technology and agricultural productivity, and farm technology and household welfare, there is limited evidence on how agricultural productivity change affects household welfare growth. Second, the paper uses panel data from a nationally representative household level survey with rich socio-economic information, merged with detailed novel climate and bio-physical information. The combination of these datasets allows us to assess the role of weather in determining households' agricultural productivity and its impact on household welfare growth. Third, a key issue that has not been adequately addressed in the agricultural productivity and household welfare linkages literature is unobserved heterogeneity which could cause endogeneity. In this paper, we investigate the impact of agricultural productivity on household welfare growth taking explicitly into account the potential endogeneity of agricultural productivity using exogenous climate and bio-physical variables as instrument variables. Fourth, the paper provides evidence on impact of agricultural productivity on different categories of smallholder farmers, such as by welfare status and initial land holdings, with important policy implications in designing specific policies for specific categories of households. We find that agricultural productivity is positively associated with labor and farm inputs. Consistent with the inverse land size-productivity relationship so often observed in the literature, land productivity decreases with increasing farm size. We also find that climate risk and bio-physical variables play a significant role in explaining agricultural productivity. Moreover, agricultural productivity has a significant and positive impact on household consumption growth. The results also indicate that while agricultural productivity has a positive impact on welfare growth for non-poor households, it has a negative impact for poor households.

The paper is organized as follows: Section 2 presents the background on agricultural production and productivity in Nigeria. Section 3 elaborates data and descriptive statistics. Section 4 presents the empirical model and identification strategy. The empirical results are presented in Section 5 before we conclude in the final section, highlighting the main findings and policy implications.

2. **Background: Agricultural Production and Productivity in Nigeria**

Nigeria is the largest country in Africa in terms of population (177 million) and among the largest in terms of land area (910,770 km^2). Nigeria has the 27th biggest economy in the world, with a gross domestic product (GDP) of US$523 billion; its per capita GDP was US$3,010 in 2013 (World Bank 2014). The agricultural sector employs 60 % of Nigeria's working population and accounts for over 40 % of its GDP, although a higher level of poverty is observed among households whose primary source of income is agriculture (World Bank, 2014). As for subsectors, crop production captures the largest share — estimated at 88 % of the total GDP from agriculture (Mogues et al., 2014). The agricultural sector in Nigeria grew by about 5.9 % annually from 2002 to 2012, but it is argued that the growth in the agricultural sector is mainly attributed to population growth and the farming of larger expanses of land, most likely by commercial farmers (Oseni et al., 2014). Nigerian agriculture is primarily rain-fed, which is characterized by low productivity, low technology, and high labor intensity.

This low agricultural productivity has been attributed to the low use of fertilizer, the loss of soil fertility, and traditional, low technology, rain-fed farming systems. The literature has documented that Nigerian farmers across all regions are below their production frontiers, indicating there is room to increase agricultural productivity above existing levels, even without a change in their current levels of input use (Liverpool-Tasie et al., 2011; Oseni and Winters, 2009). Low input use and farm technology, such as improved seed and fertilizer, are among the many reasons for low agricultural productivity in Nigeria. More than 80% of the households in Nigeria relate their poverty status to problems in agriculture, of which lack of agricultural inputs and not being able to afford inputs (such as fertilizers and seeds) accounts for 44 % (Oseni and Winters, 2009). Moreover, the Federal Ministry of Agriculture and Rural Development estimated fertilizer application at 10-15 kg/ha in 2009, far lower than the 200 kg/ha recommended by the United Nations Food and Agriculture Organization (FAO). The huge gap in fertilizer use compared to recommended fertilizer levels is often given as one of the main reasons for low agricultural productivity in Nigeria. It has long been argued that limited access of framer to extension service, an outdated land tenure system, climatic factors, imperfect credit and capital market, spatial inequality distribution of fertilizer, the high prices of other non-fertilizer inputs and an inadequate fertilizer supply are among other constraints to improve fertilizer use in Nigeria (Philip et al., 2009; Oseni et al., 2014).

Nigeria, along with some other Sub-Saharan African countries (e.g., Malawi, Kenya, Tanzania, Zambia, and Zimbabwe), implemented fertilizer subsidy programs in the 1970s where both Federal and State governments directly procured fertilizer from importers and distributed subsidized fertilizer to farmers. The fertilizer subsidy has been central to the policy tool of Nigeria to encourage growth in the agriculture sector and may be justified on many grounds, including market failures (Mogues et al., 2012). Although fertilizer subsidies assisted Nigerian farmers to expand fertilizer use to some extent, findings show that the heavy emphasis on price subsidization to the detriment of other approaches — including complementary actions to improve farmers' fertilizer-use techniques, seeking lower transactions costs, or reducing agricultural risk — has hampered market development in Nigeria (Smith et al. 1994; Yanggen et al. 1998). To address the issues and improve the usage of fertilizer as a means to achieving the region's green revolution objectives, the Federal Government of Nigeria (FGN) decided to disengage from direct procurement of fertilizer in favor of promoting private sector participation and piloted a fertilizer voucher system in selected Nigerian states as an alternative way of administering the fertilizer subsidy. However, the impact of the experimental voucher program on improving fertilizer and other input use, as well as on agricultural productivity are still inclusive.

3. Data and Descriptive Statistics

3.1. Data

The longitudinal data for this paper comes from the Nigerian LSMS-ISA, representing the years 2010 and 2012. The LSMS-ISA datasets are publicly available and were collected in eight African countries. These nationally representative datasets include detailed information on household characteristics such as education, demographic characteristics, household shocks, assets, agricultural production, non-farm income, other sources of income, allocation of family labor, hiring of labor, access to services, and consumption expenditure. The agriculture module includes information on agricultural and livestock production, farm technology, use of modern inputs, and productivity of crops and livestock. The community-level module contains information on local level infrastructure, basic public goods, precipitation and %age of agricultural land that could potentially affect agricultural production and productivity.

In order to control for the effects of rainfall and temperature variations on farmers' adoption agricultural productivity, we merge the Nigeria LSMS-ISA with historical rainfall and temperature data at the enumeration area (EA) level. Rainfall and temperature data come from the daily Africa Rainfall Climatology Version 2 (ARC2) of the National Oceanic and Atmospheric Administration's Climate Prediction Center (NOAA-CPC) summed at decadal (10-day) values and corrected for possible missing daily values. The ARC2 rainfall database contains raster data at a spatial ground resolution of 1/10 of degree for African countries for the period 1983-2012. Our temperature data are decadal surface temperature measurements for the period of 1990-2012.

Similar to previous studies (e.g., Arslan et al., 2016; Asfaw et al., 2016), we construct climate variability using coefficient of variation[1] (CoV) rainfall and average rain shortfall, both computed for the 1983-2012 period. One of the major advantages of the CoV in our context is that, for a given level of standard deviation, it changes as the mean changes, reporting a lower level of variability if the mean increases but the variance remains constant. On the other hand, CoV is scale-invariant. The average rainfall shortfall is the average of the annual total departures from the long run average. We also construct variables for total rainfall and mean monthly temperature (1990-2012). We expect the climate indicators are important determinants of agricultural productivity. To control for bio-physical characteristics and assess the impact of bio-physical variables on agricultural productivity, we construct a variable of soil nutrient availability and soil pH extracted from Harmonized World Soil (HWS) database[2] and ISRIC-World Information

[1]The coefficient of variation (CoV of rainfall) is measured as the standard deviation divided by the mean of the annual rainfall totals for 30 years (1983–2012) of (average/15Km EA radius).

[2]The database has a spatial resolution of 1km (30 arc seconds). http://www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/harmonized-world-soil-database-v12/en/

Service[3], respectively. Soil pH values are at a spatial resolution of 1000 meters for the period 1950-2005.

3.2. Descriptive statistics

As the main objective of this paper is to examine the drivers of agricultural productivity and its impact on household welfare growth, only households who have harvested some crops for both of the two years in the dataset were retained. This procedure resulted in a balanced panel of 2,031 households over two rounds. We measure aggregate household expenditure from both food and non-food expenditures, income, assets and the total value of crops adjusted using regional CPI to 2010 purchasing power parity for Nigeria.

Table 1 reports land productivity by land and consumption quintile. The results indicate that land productivity decreases with land size. Households in the bottom two quantiles exhibit systematically higher productivity as compared to households in the two upper quintiles. The results are consistent with the empirical evidence for the existence of an inverse farm size productivity relationship (e.g. Carletto et al., 2013; Barrett et al., 2010). Table 1 also shows that households in the bottom consumption quintile have lower land productivity. Similarly, Table 2 breaks down land productivity by land quintile and consumption quintile simultaneously. The observations are surprisingly well distributed, although we do see a concentration of households will relatively high (top quintile) consumption but low land holdings. We also see that the least endowed households from a land holdings perspective are the most productive. There is no discernable pattern, however, with regards to consumption. While households in the lowest consumption quintile are never the most productive, we do not see that households with the highest consumption are consistently more productive.

Table 3 describes land productivity and aggregate consumption by regions. There are variations in land productivity across the zones. The South-South zone has the highest land productivity, whereas the South-West and North-East zones have the lowest land productivity. We speculate this may be attributable in part to labor constraints in South-West, including the availability of non-farm employment in urban areas. This is because many of the major industries and cities in the country are located in the South-West due to the presence of crude oil and the

[3]The values are for the 0-5cm depth. The soil pH maps can be downloaded from the ISRIC website at: http://www.isric.org/data/soil-property-maps-africa-1-km

availability of ports whereas in northern parts of Nigeria households are more likely to be engaged in agriculture and have larger farm sizes, as well as higher crop expenses. The infrastructural, institutional, and socio-cultural variations across the zones may also contribute to high regional variations in agricultural productivity.

Similarly, there are variations in aggregate consumption per adult equivalent across the zones (Table 3). Southern zones have the highest aggregate consumption per adult equivalent as compared to the Northern zones. South-West has the highest aggregate consumption per adult equivalent (138,000 Nigerian naira per adult equivalent per year), whereas North-West has the lowest (84,000 per adult equivalent per year). Poverty levels vary across the country with the highest proportion of poor people in the Northern part of Nigeria (e.g. in North-Central about 29 % of the population is poor) and the lowest in the southern part of Nigeria (in South-West only 9 % of the population is poor)

Table 4 reports aggregate consumption by consumption quintile and round. We find that aggregate annual consumption declined significantly in 2012 in all consumption quintiles. The results reveal the %age change (drop) in aggregate consumption increases with aggregate consumption; the highest decline is for the top consumption quintile households (26%).

To confirm that the climate and soil nutrient variables are important variables in explaining agricultural productivity, we regress land productivity on climate variables, soil nutrient indicators and other explanatory variables. Table 5 reports the results of this regression. To control for differences in topology, land fertility, and other agro-ecological factors, state fixed effects are included. We expect a high coefficient of rainfall variation imposes a production risk, which subsequently makes adoption of farm technology riskier and thus reduces agricultural productivity, while rainfall is expected to increase productivity. Land productivity is significantly, negatively associated with rainfall CoV, rainfall shortfall, temperature and soil-nutrients and significantly, positively associated with total rainfall. The coefficients are as expected.

Summary statistics of the variables used in subsequent regression analyses are presented in Table 6, including mean values for aggregate annual consumption per adult equivalent, agricultural productivity, demographic characteristics (household size, education, age, and gender), and wealth indicators including land and livestock, and both total and agricultural assets. Table 6 also reports descriptive results of access to farm technology, infrastructure and financial institutions, as well as climate and soil-nutrient variables. The average annual aggregate consumption per AEU is about 103 (in thousands of Naira) and average land productivity is about

460 (thousand Naira) per hectare. Our key variables of interest are agricultural productivity measured through land productivity (as described in the following section), annual aggregate consumption per adult equivalent, and climate and soil-nutrient variables.

4. Empirical Approach

In this section we discuss the empirical approach to investigate two main objectives stated in the introduction. First, we examine the drivers of household agricultural productivity. Second we address the impact of agricultural productivity on household welfare growth in Nigeria. In particular, we discuss how we control a key problem, endogeneity in agricultural productivity, in estimating the impact of agricultural productivity on household welfare growth.

Given that factor markets are absent or imperfect in rural areas of developing countries, the paper employs a non-separable (between production and consumption decisions) farm household model (Singh et al., 1986; de Janvry et al., 1991) as the key conceptual framework. We assume that households' (denoted by i) objective is to maximize farm profit (π), defined as:

$$\pi_i = \sum p_y Y_i - \sum w_x X_i \tag{1}$$

where p the vector of output prices and w is is a vector of variable input prices. The production function is given:

$$Y_i = f(X_i, k_i, \omega) \tag{2}$$

where Y is the value of output per hectare, X is a vector of quantities of variable inputs, k is a vector of quantities of quasi-fixed inputs, and ω is a vector of environmental variables (climate variables, soil type, location, constraints, policy indicators etc.). Since labor and capital market imperfections are common in developing countries, the shadow cost of labor and shadow cost of capital are endogenous (Sadoulet & De Janvry, 1995). In other words, the shadow cost of labor and capital are affected by household labor and asset endowments, as well as by village capital and accessibility to infrastructure.

We measure agricultural productivity through analysis of the productivity of land. Increasing land productivity is expected to play a significant role in improving household welfare growth where population pressure on the land is high and the intensity of cultivation has increased due to reduced fallow periods. Application of new technology (e.g. using improved seeds and fertilizer) is important for increasing productivity of land as land scarcity increases. We measure land productivity as the ratio of net-value of crop output per unit of land, i.e., net-income of harvested produce per hectare. We use a Cobb-Douglas production function as follows:

$$\ln(Y_{it}) = \gamma_{it} + \ln(X_{it})\,\beta_x + H_{it}\alpha_h + C_{it}\gamma_i + \nu_i + \varepsilon_{it} \quad (3)$$

where X is a vector of quantities of inputs such as: labor inputs, seeds, fertilizer, herbicide and pesticides. We expect all the farm technology variables to contribute positively to the increase productivity. H is a vector household and community characteristics such education, the age, gender of the household head and household size assets and community-characteristics. We expect that households with more labor and educated household heads are more likely to have higher agricultural productivity, because they are better able to employ the new technologies, either because education helps them learn about how to use the technology and\or education is related to other unobserved things that result in variation in production from technology. C is a vector of climate variables and soil type. ν is a household specific fixed effect, and ε is a mean zero, identically and independently distributed random error and is assumed to be uncorrelated to all the explanatory variables.

The problem in estimating the drivers of agricultural productivity on welfare is that agricultural productivity is correlated with the household's level of information about inputs, level of human capital and physical assets and unobserved heterogeneities (unobserved variation in plot characteristics, managerial skill or ability). This correlation between the unobserved individual effect in the error term ε_{it} and agricultural productivity would cause a bias in ordinary least squares (OLS) estimators (Wooldridge, 2010). While the fixed effects model addresses bias caused by time variant and time invariant factors that are endogenous, it only addresses time-invariant unobservable heterogeneities (dimensions of soil quality and geographic variables that might affect agricultural) so that the estimates of the other variables are not biased by time-invariant variables. Thus, we employ the Correlated Random Effects (CRE) model which enables us to address time invariant unobserved household characteristics and still recover the coefficients on time invariant variables (Mundlak 1978; Chamberlain, 1982). The estimation procedure in CRE involves adding the mean of time-varying variables as an extra set of explanatory variables. The inclusion of these mean variables controls for time-constant unobserved heterogeneity (Wooldridge, 2010).

We estimate the impact of agricultural productivity measured using land productivity on household consumption growth using a function of the following form:

$$\Delta C_{it} = \gamma_1 \mathrm{P}_{it-1} + \gamma_2 \mathrm{H}_{it-1} + \gamma_3 W_{it-1} + \gamma_4 L_{it-1} + \gamma_5 C_{it-1} + \varsigma + \lambda_p + \eta_i \tag{4}$$

The dependent variable used in the regression analysis is the adjusted per capita consumption growth(ΔC_{it}). The effect of interest is captured by the coefficients on P_{it-1}, which is land productivity (total net-value of harvest per hectare). H_{it} represents a vector of levels of household demographic characteristics and W_{it} captures household wealth indicators. To explore the effect of extension service and plot characteristics (L_{it}) on consumption and asset, we include information on the frequency of contact with extension agents, the plot slope and potential wetness index.

We also include community characteristic assets (C_{it}) agricultural potential and access to market and road. Community variables are included in the equation because they represent the availability of productive economic infrastructure due to infrastructure investments by service providers which is closely associated with non-farm and other income-generating activities in the local environment. Because similar intrinsic demographic characteristics can lead to different asset distribution patterns, a household fixed effect ς is included to control for time-invariant unobserved demographic characteristics. Furthermore, a state fixed effect (λ_p) is included to control for further geographic diversity in land quality, weather conditions, and distance to markets, local leadership, and for covariate shocks affecting all provinces uniformly in each year. η_i is the error term for which strict a exogeneity condition is assumed to hold; errors are independently and normally distributed with zero mean and constant variance.

It is likely that agricultural productivity is correlated with household level of farm technology information, level of human capital and physical assets and unobserved heterogeneities (e.g., unobserved variation in plot characteristics, managerial skill or ability). This correlation between the unobserved individual effect in the error term η_i and agricultural productivity would cause a bias in ordinary least squares (OLS) estimators (Hausman and Taylor 1981).

To address for this type of endogeneity, we use a set of instrumental variables that influence welfare growth which is measured by changes to consumption only through their effect on the household's agricultural productivity. We construct the instruments by matching our panel household data with the historical rainfall data and soil type. We use the coefficient of variation and the average shortfall of rainfall computed over the period 1983-2012 at EA the level, which are intended to capture the uncertainty about expected climatic conditions, and soil type of the EA. Our justification for using these instruments is that the coefficient of variation of and average shortfall of rainfall and soil-nutrients influence agricultural productivity without directly influencing the welfare growth in the village.

A potential concern with regard to the validity of the instrument is that the use the coefficient of variation of rainfall, the average shortfall of rainfall and soil type of the EA may be correlated with the village's economic activities such as non-farm and self-employment. Thus, the coefficient of variation of rainfall, the average shortfall of rainfall and soil type may directly affect households' welfare growth outcomes. To circumvent this problem, first we include the non-farm and self-employment condition of the household and a wide range of EA-level characteristics as control variables in the identification strategies. Second, we use lagged agricultural productivity levels on the right hand side instead of current agricultural productivity levels to help ensure that agricultural productivity are affected only by subsequent changes in consumption growth.

We separately estimate the asset growth model (equation 4) by initial welfare status and land holdings to control for heterogeneity in the impact of agricultural productivity. In particular, we examine whether agricultural productivity affects the poor differently than non-poor households and whether household with smaller landholdings are less likely to benefit from agricultural productivity than household with larger landholdings. In order to check the robustness of our results to various specifications, we estimate the parameters of model (4) by Ordinary Least Squares (OLS), and Instrumental Variables (IV) with standard 2SLS, and IV for the welfare equation where expected (predicted) values of agricultural productivity serve as an instrument for observed values.

5. Empirical results

In this section, first we discuss the econometric results on the drivers of agricultural productivity measured by land productivity. Second, we examine the impact agricultural productivity on household welfare growth measured by annual aggregate consumption expenditure per AEU.

5.1. Determinants of agricultural productivity

Table 7 reports the estimates of the Cobb-Douglas production function in Equation 3 where outcome variable is the [ln] value of output per hectare. The first column is from pooled OLS, the second and third columns from random-effects (RE) and correlated random-effects (CRE). As Correlated Random Effects (CRE) model enables us to address time invariant unobserved household characteristics and still recover the coefficients on time invariant variables, we will mainly draw our conclusions based on correlated random-effects estimates.

The results indicate that among the household characteristics, we find that family size significantly affect land productivity. The estimates also show the presence of an inverse relation between land size and land productivity which is consistent with many other findings in the literature (Carletto et al., 2013; Barrett et al., 2010). The coefficient of land size is robust to all estimation models. The inverse land size-productivity relation has been mostly explained by market failures (Barrett, 1996).

Results for non-land wealth indicators such agricultural and non-agricultural asset are also in line with expectations and with the existing literature. Household with higher agricultural and non-agricultural assets have higher agricultural productivity, which may indicate that wealthier households are more able to finance the purchase of their farm technology inputs which is consistent with the other findings (e.g., Asfaw et al., 2016; Peterman et al., 2011).

As for inputs use, we find that labor allocated to agriculture production measured in terms of person days has a positive and significant effect on land productivity. The elasticity of land agricultural productivity to person days devoted to agricultural production is about 11%. Similarly, fertilizer use and application of herbicide have significantly positive effect on agricultural productivity. These may suggest that adoption of any of the farm management practices may have a significant role in increasing agricultural productivity. Our results are consistent with a number of studies that have demonstrated that the security of input use has substantial effect on the agricultural performance of farmers (e.g., Ravallion and Datt, 1999; Janvry and Sadoulet, 2010; Mendola, 2007; Amare et al., 2012). We find no evidence of effect access to extension.

We find the distance to nearest road has a significant negative effect on agricultural productivity. Distances to roads affect transaction costs and access to information, which in turn affect agricultural productivity. This result indicates that better infrastructure may help to cut transaction costs, increasing the likelihood of adoption of market-provided inputs and thus increase agricultural productivity. The distance of the plot to the dwelling is positive and significant, contrary to expectation. One would have thought the plots closer to the home would be better managed and thus more productive.

As expected, climate and soil-nutrient variables strongly affect agricultural productivity. We find that farmers located in EAs where the rainfall variability (CoV) is higher have 32% lower agricultural productivity, while higher season rainfall levels increase land productivity. This is because abundant rainfall increases harvests and thus land productivity, consistent with the findings of Asfaw et al. (2016). Rainfall variability, on the other hand, implies increased risk of farm technology adoption particularly in liquidity constraint and market failure setting, and thus reduces production and productivity. The results also show the rainfall shortfall significantly decrease agricultural productivity. Moreover, severe constraints on soil nutrient availability significantly decrease agricultural productivity. We find the presence of soils characterized by higher pH levels (than the average in the sample, about 4.49) is productivity enhancing. This result is expected since most crops grow in a range of soil types but optimally in a well-drained, moist loam with a pH of 5.6 to 6.4.

5.2. The impact of agricultural productivity

5.2.1. Impact of agricultural productivity on household welfare growth

We now turn to an exploration of the impact of agricultural productivity on consumption growth. The results of the first stage that is used in the later IV analysis to explain asset growth are reported in the Table 7 in Column 3. All instruments (CoV rainfall, Rain shortfall and Soil nutrient) are individually and jointly significant at the 5 % level in the first-stage regression, suggesting that the climate and soil nutrient are crucial factors driving land productivity. We estimate the model for consumption growth with both OLS, and IV-OLS estimation; the results are reported in Table 8.

Before turning to the causal effects of agricultural productivity on household welfare growth, we briefly discuss the quality of the selection instruments used. To probe the validity of our selection instruments, we looked at three major tests: the weak identification test, the relevance of our instruments and over identification tests. The test results support the choice of the instruments, as do the F-test values for all of the specifications (bottom of Table 8). The F-statistic of joint significance of the excluded instruments is greater than 10, thus passing the test for weak instruments. We use the Sargan–Hansen test of over identifying restrictions and fail to reject the joint null hypothesis that our instruments are valid instruments. We apply Stock and Yogo to test weak identification test which is based on the Cragg–Donald Statistic, we reject the null hypothesis that a given group of instruments is weak against the alternative that it is strong.

In general, all model estimates for land productivity are similar in sign; the results obtained from both models confirm that land productivity has significant, positive effects on consumption growth. However, the IV estimates for the key variables of interest are much larger than the OLS estimates, implying that correcting for endogeneity affects the results. Therefore, our subsequent discussion focuses on the two-stage IV model estimates[4].

The results of the IV estimation to examine the impact of the agricultural productivity on household consumption growth are reported in column (2) of Table 8. The results reveal that agricultural productivity has a positive, significant impact on consumption growth. Controlling for other factors, we find that a 10 % increase in the level of agricultural productivity in the previous year tends to increase consumption growth by 2 % on average. This result supports the hypothesis that agricultural productivity can facilitate consumption growth by raising the real incomes of households, and perhaps even indirectly by increasing agricultural outputs which induces job creation in upstream and downstream non-farm sectors as a response to higher domestic demand.

Households with more dependents experienced a significantly higher consumption growth. We find that a 10 % increase in years of education of the household head tends to increase consumption growth by 0.8 % on average. We find non-farm employment opportunities improve household consumption growth. For example, the effect of non-farm self-employment participation is particularly strong; consumption growth differs by 3 % between participants and non-participant households. Similarly both access to formal and informal credit and borrowing from friends play a significant role in explaining consumption growth. Controlling for other factors, consumption growth differs by 7 and 4 % between households that have access to borrowing from formal and informal institutions respectively, compared with those that do not. Controlling for other factors, we find that households that use fertilizer and farm equipment exhibit 12% and 17%, respectively higher consumption growth as compared households do not use fertilizer and farm equipment. More important, we find that access to public infrastructure, such as a nearby market and road, plays a significant role in improving consumption growth.

[4] Our results are robust to the use of alternative estimators such as GMM and are available upon request. Moreover, under the assumptions of conditional homoskedasticity and independence, the efficient GMM estimator is the traditional IV/2SLS estimator

5.2.2. Heterogeneous impact of agricultural productivity

We examine whether the magnitude of the coefficient of agricultural productivity varies by initial consumption level by estimating the growth model separately for poor and non-poor households. As is often the case, however, the instruments are not strong as the whole sample for subgroups, and the F statistic on the excluded instruments is only above 10 for the non-poor households. The results (Table 9) indicate that agricultural productivity has a positive significant impact on consumption growth for non-poor and poor households. However, it has a smaller impact on consumption growth for poor households. Controlling for other factors, we find that a 10 % increase in agricultural productivity increases consumption growth by 2 % on average for consumption non-poor households and 0.8 % for poor households. It has is more than two and half times higher for the non-poor households. The results may suggest that poor smallholder face a number of constraints that cause to lower their productivity such as lack of information about production methods and market opportunities, particularly for new crops and varieties prohibit households from intensifying agriculture and producing high-value commodities whose market demand is growing rapidly.

We further allow for heterogeneity in the impact of agricultural productivity by land holdings. Similar to the wealth status, however, the instruments are not strong as the whole sample for subgroup (Table 10). The results show that agricultural productivity have a positive significant impact on consumption growth for all quintiles. However, agricultural productivity have a higher impact for the household in top two land quintiles compared to the bottom two land quintiles. When we compare the impact of agricultural productivity for households in the bottom land quintile and top land quintile, the coefficient for agricultural productivity is approximately two times higher for the latter. The results may indicate agricultural productivity is not pro-poor, with the greater gains enjoyed by those who are initially better off. High initial inequality in the distribution of assets and especially of land may be a plausible candidate in explaining why some of the agricultural productivity change might be less effective in up lifting poor families from poverty in developing countries.

6. Conclusions and policy implications

Improving agricultural productivity is widely considered as the most effective means of addressing poverty and the main pathway out of poverty. However, a key challenge in developing country agriculture is how to increase agricultural productivity to meet food security needs for the growing population while also reducing poverty of smallholder farmers. Investigating the factors that hinder or accelerate agricultural productivity, with a particular focus on the role of different measures of climate variables and soil nutrient data, are priorities in most African national agricultural plans. Additionally, in this paper we seek to understand whether agricultural productivity, measured using land productivity, improves household consumption growth using nationally representative LSMS-ISA panel datasets from Nigeria. We address three important policy questions in the process of addressing the research objectives. First, what are the main determinants of household agricultural productivity? Second, how does agricultural productivity impact household welfare growth? Third, does the relative position of poor people (e.g. the bottom 25%) improve or worsen with productivity change? Fourth, how do different categories of smallholder farmers benefit from agricultural productivity?

To address the first objective, we employ the Correlated Random Effects (CRE) model which involves adding controlling for the household mean of time-varying variables and enables us to address time invariant unobserved household characteristics and still recover the coefficients on time invariant variables. We found that the agricultural productivity decreases with family size and households' access to non-farm self-employment. The estimates also show the presence of an inverse relation between land size and land productivity which is consistent with many other findings in the literature (Carletto et al., 2013; Barrett et al., 2010). We find agricultural and non-agricultural asset have positive and significant effect on agricultural productivity which may indicate that wealthier households are more able to finance the purchase of their farm technology inputs.

We find agricultural productivity increases with increased labor allocated to agriculture production measured in terms of person days, fertilizer use and the application of herbicide, which may indicate that input use and farm technology adoption may have a significant role in increasing agricultural productivity, although we find no evidence of an effect for access to extension (although this is likely due to limited variability in access). Moreover, we find the distance to nearest road distance has a significant negative effect on agricultural productivity which suggests that better infrastructure may help to cut transaction costs increasing the likelihood of adoption of market-provided inputs and thus increase agricultural productivity. In terms of the impact of climate and soil-nutrient variables, we find that farmers located in EAs where the rainfall variability (CoV) is higher have 32% lower agricultural productivity, while higher season rainfall levels increase land productivity. Moreover, severe constraints on soil nutrient availability significantly decrease agricultural productivity, while we find the presence of soils characterized by higher pH levels (than the average in the sample, about 4.49) is productivity enhancing.

To provide rigorous evidence of agricultural productivity impact on household welfare growth and to account for possible endogeneity of agricultural productivity, we applied IV regression estimation techniques. We find that a 10 % increase in the level of agricultural productivity in the previous year tends to increase consumption growth by 2 % on average. We estimate whether the magnitude of the coefficient of agricultural productivity varies by initial consumption level by estimating the growth model separately for poor and non-poor households. We find that a 10 % increase in agricultural productivity increases consumption growth by 2 % on average for consumption non-poor households 0.8 % for poor households. Moreover, we find that agricultural productivity has a positive significant impact on consumption growth for all land quintiles. However, productivity have higher impact for the household in top two quintiles.

We believe that our findings have important policy implications for policy makers and institutions in sub-Saharan Africa at large and in Nigeria in particular. First of all, given the strong role of farm technology, climate variability, access to infrastructure and assets in improving agriculture productivity, better targeting agricultural practices to respond to weather risk exposure and sensitivity, and then building household and system-level capacity to support different interventions are key factors in improving agricultural productivity. Most importantly, the results in this article provide very strong arguments on what seem to be required in order to achieve sustainable pro-poor poverty reduction are integrated interventions that are effective to improve asset, infrastructure, and use of farm technology and to develop formal insurance markets in order to enhance the capabilities to smooth agricultural income risk and choices of the poor.

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Table 1: Land productivity by land and consumption quintile

Land productivity [a] distribution by land quintile		**Land productivity distribution by aggregate consumption quintile**	
1	826.24	1	346.93
2	482.74	2	523.71
3	430.24	3	500.55
4	327.95	4	424.46
5	235.00	5	507.83

Source: Based on LSMS-ISA surveys in Nigeria.
Note: [a] Total value of harvested crops (LU, 1000) per hectare

Table 2: Land productivity by land and consumption quintile (N in parentheses)

Land quintile	Consumption Quintile				
	1	2	3	4	5
1	740.27 (106)	1010.54 (118)	1114.57 (168)	1083.68 (192)	522.75 (230)
2	364.76 (174)	801.092 (188)	493.88 (180)	349.95 (116)	314.39 (154)
3	419.51 (200)	384.65 (182)	427.08 (132)	286.27 (154)	659.63 (144)
4	175.43 (192)	245.76 (170)	348.58 (148)	199.35 (172)	807.34 (130)
5	161.11 (142)	283.23 (154)	121.37 (184)	109.02 (178)	284.18 (154)

Table 3: Land productivity and aggregate consumption by regions

	North-Central	**North-East**	**North-West**	**South-East**	**South-South**	**South-West**
Land productivity [a]	385.63	321.05	436.64	474.81	1180.84	286.86
Consumption/AEU	103.34	111.83	84.20	100.27	124.73	138.42
Poverty headcount	0.29	0.23	0.24	0.19	0.11	0.08
N	782	828	1082	886	304	180

Source: Based on LSMS-ISA surveys in Nigeria.
Note: [a] Total value of harvested crops (LU, 1000) per hectare

Table 4: Household aggregate consumption per AEU by consumption quintile and year

Consumption quintile	2010	2012	% change
1	46.84	40.53	-0.13
2	76.10	62.89	-0.17
3	100.55	83.49	-0.17
4	132.12	105.09	-0.21
5	216.65	160.62	-0.26

Source: Based on LSMS-ISA surveys in Nigeria.
Note: [a]Total value of harvested crops (LU, 1000) per hectare

Table 5: OLS regression of climate variables and soil nutrients on land productivity (UNITS)

	Coef	Se
CoV of annual rainfall	-5.343***	1.534
Total monsoon rainfall(mm)	0.001**	0.000
Rain shortfall(mm)	-0.001**	0.001
Soil nutrient(Sever constraint=1)	-0.335***	0.120
pH	-0.888	0.644
Mean temperature	-1.568*	0.918
Constant	9.776***	3.615
State fixed effects	Yes	Y
N	4,062	

Source: Based on LSMS-ISA surveys in Nigeria.
Note: State fixed effects are included in the specifications. *** p<0.01. ** p<0.05. * p<0.10.

Table 6: Description and Summary Statistics

Variable	Description	All		2010		2012	
		N=4062		N=2031		N=2031	
		Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Consumption	Aggregate consumption per AEU (local unit=LU, 1000)	102.59	66.03	114.62	68.52	90.56	61.14
Value harvest	Total value of harvested crops (LU, 1000)	134.14	619.24	122.60	532.74	145.68	1227.35
Land prod.	Land productivity= (total value of harvested per hectare)	460.64	1955	608.21	2268.34	313.06	1569.37
Household characteristics							
Family size	Family size (adult equivalent unit)	5.41	2.07	5.14	1.95	5.68	2.15
Dependents	Dependent (<15 , >64 years old)	3.24	2.28	3.31	2.30	3.18	2.26
Gender	Gender of the household head	0.89	0.31	0.89	0.31	0.88	0.32
Head educ	Educ. HH head (years)	4.47	4.72	4.60	4.69	4.34	4.75
Head age	Age HH head (years)	51.00	15.05	49.71	15.04	52.28	14.96
Borr. instit.	Borrowing from formal institutions	0.03	0.18	0.03	0.16	0.04	0.21
Borr. infor.	Borrowing from informal institutions	0.20	0.40	0.20	0.40	0.20	0.40
Borr. friends	Borrowing from friends	0.30	0.46	0.30	0.46	0.30	0.46
Wage part	Wage labor employment participation	0.07	0.26	0.02	0.13	0.13	0.33
Self-part	Non-farm self-employment participation	0.52	0.50	0.49	0.50	0.55	0.50
Wealth indicators							
Farm size	Farm size (in hectare)	0.59	0.93	0.62	0.98	0.56	0.85
Livestock	Total livestock -Tropical livestock unit	78.65	1142.10	23.37	924.99	133.92	1322.02
Agr. asset	Value of agricultural assets (LU, 10^)	82.50	528.00	45.17	270.10	119.82	1564.97
Non-agr. asset	Value of total non-agricultural asset (LU, 1000)	562.76	2464.56	648.28	3372.40	477.24	873.71
Farm Inputs							
Person days	Labor (both family & hired labor) allocated to agricultural production person days	198.79	239.65	206.47	243.24	191.10	235.93
Extension	Access to extension (yes=1)	0.10	0.27	0.11	0.26	0.10	0.27
Fertilizer	Fertilizer use indicator(yes=1)	0.48	0.50	0.48	0.50	0.48	0.50
Pesticides	Pesticides use indicator(yes=1)	0.19	0.39	0.18	0.38	0.20	0.40
Herbicide	Herbicide use indicator(yes=1)	0.27	0.44	0.24	0.43	0.29	0.45
Equipment	Equipment use indicator(yes=1)	0.23	0.42	0.21	0.41	0.24	0.43
Plot distance	Plot distance(km)	3.71	44.30	6.01	61.31	1.41	12.54
Plot wetness	Plot potential wetness index	14.37	3.60	14.08	4.18	14.66	2.88
Plot slope	Plot slope	2.83	2.74	2.78	2.98	2.88	2.49
Market	Distance to the market (km)	69.71	37.71	69.74	37.69	69.68	37.74
Road	Distance to the road (km)	13.22	15.11	18.44	18.43	8.00	7.93
Climate and bio-physical variables							
CV rainfall	CoV rainfall (1983-2012) (average/15Km EA radius)	0.22	0.05	0.22	0.05	0.22	0.05
Rain shortfall	Average rain shortfall (1983-2012) (avg/15Km EA radius)	89.37	62.84	114.18	74.98	64.57	32.34
Season rainfall	Season total rainfall(mm)	886.17	236.70	937.55	244.38	834.80	216.97
Soil nutrient	Soil nutrient avail (Severe contraints)	0.25	0.44				
pH	Soil pH (avg/15Km EA radius)	4.49	0.58				
Temperature	Season average temp(1990-2012) (avg/15Km EA radius)	25.63	1.21	25.56	1.22	25.70	1.21

Source: Based on LSMS-ISA surveys in Nigeria.

Table 7: OLS, RE and CRE estimates of determinants of agricultural productivity

	OLS		**RE**		**CRE**	
	Coef	**Se**	**Coef**	**Coef**	**Se**	**Coef**
Family size	-0.331***	0.125	-0.325***	0.124	-0.376***	0.127
Dependents	-0.025	0.082	-0.025	0.081	-0.052	0.082
Gender of hh head	0.193	0.159	0.200	0.159	0.113	0.162
Head education	-0.070	0.056	-0.062	0.055	0.057	0.122
Head age	0.042*	0.025	0.045*	0.025	0.052	0.032
Wage part	0.044	0.159	0.052	0.157	0.104	0.158
Self-part	-0.286***	0.086	-0.272***	0.086	-0.245***	0.086
Borr. Instit.	-0.009	0.216	-0.026	0.213	0.008	0.213
Borr. Infor.	0.025	0.107	0.004	0.107	0.011	0.106
Borr. Friends	0.054	0.086	0.045	0.086	0.057	0.086
Farm size	-3.575***	0.258	-3.614***	0.257	-4.039***	0.420
Livestock	-0.101***	0.031	-0.101***	0.031	-0.111**	0.045
Agr. asset	0.134*	0.080	0.134*	0.078	0.129*	0.078
Non-agr. asset	0.111**	0.048	0.101**	0.048	0.099**	0.048
Labor (Person days)	0.200***	0.027	0.187***	0.027	0.077**	0.039
Extension	-0.091	0.155	-0.091	0.155	-0.092	0.154
Fertilizer	0.281***	0.084	0.260***	0.084	0.254***	0.083
Pesticides	-0.093	0.104	-0.083	0.102	-0.083	0.102
Herbicide	0.524***	0.093	0.507***	0.092	0.469***	0.093
Equipment	-0.057	0.105	-0.028	0.104	-0.033	0.104
Plot slope	0.035*	0.020	0.032	0.020	0.030	0.020
Plot distance	0.175***	0.063	0.180***	0.063	0.172***	0.063
Plot wetness	-0.127	0.096	-0.137	0.095	-0.105	0.094
Distance to market	0.047	0.525	0.038	0.525	0.112	0.564
Distance to road	-0.597***	0.089	-0.605***	0.089	-0.583***	0.089
CoV rainfall	-3.100***	1.081	-3.354***	1.096	-2.837**	1.105
Rain shortfall	-0.004***	0.001	-0.003***	0.001	-0.003**	0.001
Total monsoon rain	0.001***	0.000	0.001***	0.000	0.001***	0.000
pH	0.260***	0.090	0.265***	0.091	0.184**	0.092
Mean temp	-0.250	0.978	-0.231	0.978	-0.344	0.980
Soil nut. (Sever =1)	-0.570***	0.112	-0.576***	0.112	-0.566***	0.112
Constant	4.027	3.229	4.134	3.223	4.566	3.220
N		4,062		4,062		4,062
R^2	0.35		0.26		0.28	

Source: Based on LSMS-ISA surveys in Nigeria.

Note: The mean of time-varying variables, dummy for year and state/regions and are included as additional regressors in this Correlated Random Effect (CRE) model, but they are not reported for brevity. *** p<0.01. ** p<0.05. * p<0.10.

Table 8: Household OLS, IV-OLS Regression Estimates of Consumption Growth

	OLS		IV	
	Coef	**Se**	**Coef**	**Se**
Land productivity	0.010***	0.003	0.196***	0.022
Family size	-0.037	0.094	-0.023	0.097
Family size squared	-0.034	0.031	-0.036	0.032
Dependents	0.095***	0.018	0.097***	0.019
Gender	0.056	0.036	0.059	0.039
Head education	0.069**	0.030	0.077**	0.033
Head age	-0.047**	0.023	-0.021	0.027
Wage part	0.018	0.016	0.011	0.017
Self-part	0.011	0.010	0.031**	0.011
Wage part	0.059	0.037	0.069*	0.041
Self-part	0.036*	0.019	0.039*	0.021
Borr. Instit.	-0.026	0.018	-0.047**	0.021
Farm size	0.278***	0.058	0.447***	0.095
Livestock	-0.061**	0.025	-0.074***	0.028
Agr. asset	0.009	0.015	0.014	0.016
Non-agr. asset	0.015*	0.008	0.013	0.009
Extension	-0.045***	0.017	-0.056***	0.019
Fertilizer	0.123***	0.025	0.123***	0.029
Pesticides	-0.030	0.021	-0.021	0.023
Herbicide	0.053***	0.020	0.016	0.026
Equipment	0.177***	0.020	0.173***	0.021
Dis. market	-0.123**	0.048	-0.122***	0.045
Dis. road	-0.192***	0.020	-0.166***	0.025
Constant	0.345**	0.135	-0.006	0.216
N	2,031		2,031	
R^2	0.31		0.32	
Sargan–Hansen			13.444 ***	
Stock-Yogo (Cragg-Donald Wald F statistic)			13.453 **	
Sanderson-Windmeijer multivariate F test of excluded instruments: F(3, 2003)			15.74***	

Source: Based on LSMS-ISA surveys in Nigeria.

Note: The regression included a dummy for provinces. *** p<0.01. ** p<0.05. * p<0.10.

Table 9: Household IV-OLS Regression Estimates of Consumption Growth by Welfare Status

	Poor		Non-poor	
	Coef	**Se**	**Coef**	**Se**
Land prod	0.083**	0.045	0.202***	0.028
Family size	0.095	0.701	-0.038	0.115
Family size^2	-0.126	0.204	-0.037	0.040
Dependents	0.078	0.063	0.115***	0.025
Gender	-0.158	0.100	0.102**	0.049
Head educ	0.090	0.178	0.088**	0.041
head age	-0.094	0.087	-0.007	0.040
Wage part	0.044	0.049	0.012	0.020
Self-part	-0.060	0.048	0.027*	0.014
Borrow institutional	0.077	0.255	0.068	0.051
Borrow informal	-0.100	0.076	0.038	0.027
Borrow friends	0.054	0.087	-0.031	0.025
Farm size	-1.042*	0.601	0.510***	0.106
Livestock	-0.065	0.074	-0.047	0.029
Agricultural asset	0.102**	0.047	-0.033	0.021
Non-agricultural asset	0.151**	0.062	0.013	0.011
Extension	0.293**	0.131	0.127***	0.035
Fertilizer	0.097	0.063	-0.087***	0.024
Pesticides	-0.277**	0.115	-0.006	0.027
Herbicide	0.278***	0.106	-0.008	0.032
Equipment	0.176**	0.071	0.189***	0.026
Dis. market	-0.526	0.411	-0.164***	0.060
Dis. road	-0.299***	0.062	-0.118***	0.032
Cons	1.536*	0.837	-0.342	0.298
N	450		1,581	
R^2	0.34		0.31	
Sargan–Hansen	10.50		13.00	

Source: Based on LSMS-ISA surveys in Nigeria.

Note: The regression included a dummy for states. *** p<0.01. ** p<0.05. * p<0.10.

Table 10: Household IV-OLS regression estimates of consumption growth by land quintile

Variables	Land quintile									
	1		2		3		4		5	
	coef	se	coef	se	coef	se	coef	se	coef	se
Land prod	0.130*	0.015	0.087**	0.036	0.117**	0.053	0.191***	0.049	0.245***	0.042
Family size	0.102	0.126	0.492*	0.284	-0.223	0.527	-0.350	0.387	-0.503	0.506
Family size^2	-0.064	0.046	-0.152*	0.078	0.027	0.125	0.014	0.098	0.084	0.160
Dependents	0.147***	0.031	0.015	0.045	0.064	0.094	0.069*	0.041	0.212**	0.090
Gender	0.052	0.056	-0.047	0.073	0.075	0.111	0.011	0.093	-0.123	0.301
Head educ	0.069	0.044	0.012	0.076	0.250	0.180	0.056	0.068	0.222	0.264
head age	0.002	0.046	-0.056	0.052	0.105	0.129	-0.050	0.079	0.064	0.133
Wage part	0.014	0.043	-0.022	0.046	-0.010	0.051	-0.017	0.040	-0.144	0.105
Self-part	0.024	0.024	0.002	0.032	0.014	0.034	-0.002	0.023	0.078	0.052
Borrow instit.	0.019	0.097	0.026	0.096	0.175	0.177	0.072	0.088	-0.113	0.162
Borrow infor	0.004	0.041	0.059	0.058	0.155**	0.076	-0.004	0.044	0.019	0.091
Borrow friends	-0.027	0.041	-0.036	0.055	-0.123	0.097	0.047	0.045	-0.014	0.075
Farm size	9.116**	3.792	2.604	2.368	1.267	2.689	-0.957	0.955	0.712**	0.345
Livestock	-0.123**	0.062	-0.049	0.045	-0.210**	0.098	-0.028	0.036	-0.137**	0.065
Agr. asset	-0.029	0.051	-0.040	0.068	-0.064	0.093	0.028	0.033	0.029	0.059
Non-agr. asset	-0.017	0.017	0.026	0.021	0.017	0.025	0.046**	0.021	-0.054	0.053
Extension	-0.189**	0.089	0.147**	0.064	0.237*	0.126	0.136**	0.056	0.072	0.134
Fertilizer	-0.051	0.040	-0.048	0.046	-0.082	0.063	-0.094*	0.049	-0.052	0.065
Pesticides	-0.011	0.061	-0.057	0.068	0.077	0.156	-0.042	0.047	0.106	0.107
Herbicide	-0.028	0.080	0.234**	0.102	0.019	0.141	-0.037	0.046	-0.120	0.086
Equipment	0.349***	0.068	0.179***	0.067	0.037	0.121	0.116***	0.040	0.189**	0.078
Dis. market	-0.072	0.045	0.150	0.245	0.785	0.812	-0.064	0.325	-0.412	0.486
Dis. road	-0.064	0.048	-0.211***	0.049	-0.071	0.138	-0.194***	0.057	-0.003	0.110
Cons	-0.311	0.344	0.181	0.456	-1.237	2.175	0.874	0.693	-0.845	0.953
N	407		406		406		406		406	
R^2	0.24		0.29		0.31		0.32		0.35	
Sargan–Hansen	11.48		11.80		12.51		11.01		12.36	

Source: Based on LSMS-ISA surveys in Nigeria.

Note: The regression included a dummy for states. *** p<0.01. ** p<0.05. * p<0.10.