Gendered Analysis of Households' Uptake of Agricultural Technology, Production and Food Consumption in Rural Nigeria

Scholastica Ngozi Atata
Belmondo Tanankem Voufo
Uchenna Efobi
Emmanuel Orkoh

Research Paper 554

Bringing Rigour and Evidence to Economic Policy Making in Africa

AFRICAN ECONOMIC RESEARCH CONSORTIUM
CONSORTIUM POUR LA RECHERCHE ÉCONOMIQUE EN AFRIQUE

Gendered Analysis of Households' Uptake of Agricultural Technology, Production and Food Consumption in Rural Nigeria

By

Scholastica Ngozi Atata
Federal University of Agriculture Abeokuta, Ogun State, Nigeria

Belmondo Tanankem Voufo
Ministry of Economy, Planning and Regional Development, Cameroon

Uchenna Efobi
Centre for Economic Policy and Development Research, Nigeria

Emmanuel Orkoh
Nordic Africa Institute, Uppsala, Sweden
School of Economic Sciences, North-West University, Potchefstroom, South Africa

AERC Research Paper 554
African Economic Research Consortium
April 2024

THIS RESEARCH STUDY was supported by a grant from the African Economic Research Consortium. The findings, opinions and recommendations are those of the author, however, and do not necessarily reflect the views of the Consortium, its individual members or the AERC Secretariat.

Published by: The African Economic Research Consortium
P.O. Box 62882 - City Square
Nairobi 00200, Kenya

ISBN 978-9966-61-259-5

Contents

List of tables

List of figures

Abstract

The literature suggests marked gender inequality in the use of agricultural technology despite the availability of evidence that women could be as productive as men when given equal access to agricultural resources. This underscores an urgent need to consider improving women's access to agricultural technology to ensure the sustainable provision of food for all people, and particularly those in developing countries. This study addresses two specific objectives. It: (a) examines gender differences in households' use of farm-level technology (herbicides, pesticides and inorganic fertilizer); and (b) assesses the impact of the uptake of agricultural technology on farm production and food consumption, paying particular attention to the gender of the household head. The results of a three-stage least squares (3SLS) regression reveal that households' uptake of agricultural technology has a significant positive effect on their dietary diversity and food consumption expenditure per capita due to increased farm production. While these results are consistent regardless of the gender of the household head, the extent of effects for female-headed households is almost double that for male-headed households. Therefore, an essential policy implication of our result is that the government could use input subsidies to address some of the gender gaps with regard to agricultural technology access and use. Such efforts should address any entrenched inequalities in women's access to agricultural production resources and consider other socioeconomic factors such as education and landholding, which contribute to gender inequality in agricultural technology uptake.

Keywords: Agricultural technology, gender, food consumption, rural Nigeria

1. Introduction

Many developing countries face the challenge of addressing the combined effects of population growth and climate change on the sustainable provision of food for all people (Hall et al, 2017). Low-income countries, including those in sub-Saharan Africa (SSA) face stagnant agricultural productivity and persistent food insecurity (Takahashi et al, 2020). The uptake of agricultural technology, such as herbicides, pesticides and inorganic fertilizers by smallholder farmers who contribute a significant proportion of food in these low-income countries, has been the most recommended policy option to address the challenges (Duflo et al, 2008; Schneider and Gugerty, 2011; Liverpool-Tasie et al, 2017). However, evidence suggests significant gender inequalities in adopting these technologies due to barriers such as sociocultural norms and beliefs about gender roles, inadequate policies deliberately targeted at gender equality and lack of agency and resources for effective policy implementation (Rola-Rubzen et al, 2020).

It is estimated that approximately 80 per cent of agricultural production in most African countries comes from smallholder farmers who are primarily rural women, but they are less likely to access and utilize improved agricultural technologies than their male counterparts (Doss and Morris, 2001; Odiwuor, 2022). For example, in the Economic Community of West African States (ECOWAS) sub-region, the application of appropriate fertilizers remains low, with an average annual application rate of 12 kilogrammes per hectare. This falls short of the 50 kilogrammes per hectare target by 2015 set by African governments (Falaju, 2016; IFDC, 2016). Such a low uptake rate of agricultural technology can be potentially traced to poor finance, lack of access, and lack of knowledge of farmers regarding these technologies (Ellis et al, 2007).

There is, therefore, rising momentum in policies targeted at improving the rate of agricultural technology uptake by farmers, especially among women in rural Africa. In the ECOWAS sub-region, for example, there are structures set up to improve agrarian technology uptake, such as the West African Fertilizer Programme (WAFP), which is focused on improving agricultural production through the distribution of high-quality and affordable fertilizers to the most constrained farmers (IPES-Food, 2020). In recent years, Nigeria has implemented a farming promotion policy that targets agricultural sector sustainability and rural development by 2020 (FMARD, 2016). This ambitious policy is also targeted at enhancing agricultural technology uptake among farmers in general, and women in particular. It also includes efforts to develop an input market (Druilhe and Barreiro-Hurlé, 2012; FMARD, 2016), which is an essential component of the structural progress of the agricultural sector.

Available statistics on the agriculture sector's contribution to gross domestic product (GDP) for the third quarters of 2016 and 2019 suggest that some progress has been made, notwithstanding the inherent challenges of the policy. While the agricultural sector grew by 8%, crop production, livestock, forestry and fishing grew by 8%, 2%, 10% and 6%, respectively. Despite the efforts made towards developing an input market and improving aggregate production, the gender dynamics of the extent to which the uptake of these technologies has impacted household food production and consumption are still unknown. There is limited literature on how such policies, which are targeted at bridging the gender disparity in adopting agricultural technologies, impact farm production and consumption in male-headed and female-headed households in rural Nigeria, where agriculture remains the main source of economic activity and livelihood.

This paper, therefore, seeks to analyse the effects of technology uptake on farm production and food consumption of households in rural Nigeria. The specific objectives are to: (a) determine the gender differences in households' use of farm-level technology (herbicides, pesticides and inorganic fertilizer); and (b) examine the impact of the uptake of agricultural technology on farm production and food consumption, paying particular attention to the gender of the household head. This study provides a gender-focused assessment of the household farm production and food consumption impact of agricultural technology uptake policies, which are targeted at closing the inequality and poverty gap for rural transformation and sustainability in Nigeria.

Earlier studies concluded that women bear a large proportion of the burden from household food consumption although they earn less than men (UNCTAD, 2011; Amu, 2005; Orkoh, 2018). Consequently, understanding some policies to improve household food capacity, especially for female-headed households, is undertaken in line with the United Nations Sustainable Development Goals (SDGs) 2 and 5, which respectively seek to achieve zero hunger and gender equality and empowerment of women and girls by 2030 (United Nations, 2020). In addition, the statistics on the nutritional outcomes in Nigeria are staggering: Nigeria ranks 107/113, disaggregated as 113, 108, 79 and 57 for affordability, availability, quality and safety, and sustainability and adaptability, respectively, in the Global Food Security Index – GFSI (GFSI, 2022). Therefore, there is a need for a comprehensive assessment of the extent of uptake and the effectiveness of the agricultural policies targeted at addressing this situation.

2. Agricultural activity in Nigeria and the role of women

The agricultural sector contributes significantly to the economy of most African countries. In Nigeria, for example, the agricultural sector contributed about 23.69% to the country's GDP in 2022 and about 35.21% to total employment in 2021 (The World Bank, 2023). Women constitute nearly half of this agricultural sector workforce and are mainly engaged in smallholder activities or subsistence agriculture. In addition to being responsible for taking care of small ruminants and poultry, women are more likely to be responsible for marketing agricultural products and livestock by-products. Those engaged in crop planting mostly grow yams, cassava and maize, while men tend to manage plots that grow sorghum, maize and beans (Oseni et al, 2013). More importantly, the extent of the coping mechanisms of these rural smallholders when confronted with adverse environmental and farm conditions like pests and weed infestations complicates farm processes for rural women considering the high poverty rate and low use of modern agricultural technology, which affects production from year to year (The World Bank, 2014a).

The challenge is great for women whose active participation in agricultural activities is affected by a number of obstacles. Key among these obstacles is excessive workload and social constraints that result in gender-based discrimination, and poor access to agricultural input compared to their male counterparts. In Nigeria, for example, male plot managers are more likely than female plot managers to use fertilizer inputs (42% and 19%, respectively) and herbicides (26% and 6%).[1] The combined effects of gender-based social constraints and limited access to agricultural input means women are more prone to poor nutrition, poor health and poor well-being in Nigeria (Oseni et al, 2013).

As part of the effort to address the aforementioned challenges, the Nigerian Government, together with foreign donors such as the United Nations Development Programme (UNDP), has rolled out some agricultural interventions to improve agricultural output in rural areas through projects and programmes that are gender sensitive. Among the numerous initiatives are the Agriculture Development Programme, Agricultural Credit Guarantee Scheme, Rural Electrification Scheme, National Agricultural Land Development Authority, Strategic Grains Reserves Programmes, Agricultural Transformation Agenda with use of e-wallet, Anchor Borrowers Programme, Agricultural Promotion Policy and the Rural Banking

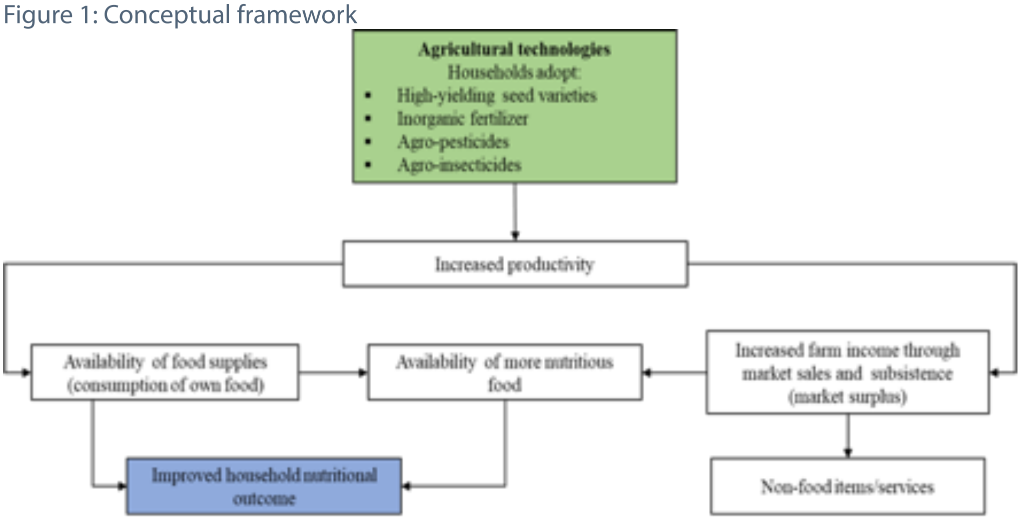
Programme, which are directed at improving the agricultural sector in Nigeria (World Bank, 2014b). Of all these initiatives, the Fadama[2] project stands out as a typical example that creates opportunities for women through domestic, social and productive investments.

The implications of these interventions for the household's well-being will be more effective if they are equally gender-inclusive through targeted programmes to improve the agricultural productivity of women. Women, especially in rural Nigeria, actively participate in agricultural activities through smallholding activities, contract farming and out-grower schemes. Despite women's participation, they earn less than their male counterparts in most aspects (Olayinka, 2014) and are actively engaged in the non-paid labour allocation within the household, which includes home keeping, childcare and food preparation (Orkoh et al, 2020). Focusing on food preparation, women in rural Nigeria, just as in some other African countries such as Cape Verde (see UNCTAD, 2011), are more engaged in activities that ensure sufficient food consumption within households. These input-related interventions by the government will have significant implications for household poverty, food nutrition, and even production, if they are particularly sensitive to inclusive participation; especially in considering females.

3. Conceptual framework

The framework that conceptualizes the connection between the uptake of agricultural technology, household production and food consumption (nutritional outcomes) is displayed in Figure 1. The agricultural technology that is of interest for this study includes the components of Green Revolution Initiatives, such as high-yielding seed varieties, synthetic fertilizers and pesticides/herbicides (Ameen and Raza, 2017). Therefore, encouraging households to adopt this technology is worth considering as females constitute the largest labour input in the agricultural sector in rural Nigeria. The uptake of these technology inputs will enhance farm production and reduce farm losses from pests and weeds. The improved production is expected to enhance households' nutritional outcomes via two channels: 1) increased availability of food supplies and consumption of own produce; and 2) increased farm incomes due to market surplus, which would make it possible for households to buy more nutritious food.

Figure 1: Conceptual framework



Source: Authors' construct

First, depending on the extent to which households consume what they produce, improved production due to households' uptake of agricultural technology would contribute to an increase in the availability of food supplies. A household that consumes a higher proportion of its produce will, in turn, improve the health status of its members and result in a healthy household workforce that would lead to higher agricultural production. Hirvonen and Hoddinott (2017) elaborated on this proposition and its implication for the quality of the health of household members. They observed that increased household production diversity leads to considerable improvements in children's dietary diversity.

The second channel of the effect of agricultural technology uptake is dependent on the extent to which households sell their produce and their decisions about the use of the additional income from a market surplus as a result of increased food production. A household that is able to produce in excess of its consumption due to its uptake of agricultural technology may decide to spend the additional income earned from the sales of the increased food production on non-food items or services. In that case, the increased production may not directly contribute to household nutritional outcomes. However, it may contribute to other welfare indicators, such as health and good living, which may contribute to higher agricultural production and its associated nutritional and non-nutritional outcomes. While production is the main indirect channel of the effect of agriculture technology uptake, we also explore their potential direct effect on nutritional outcomes. As indicated in Equation 1 of the estimation techniques (see Chapter 4 under Estimation technique), these direct and indirect effects of agriculture technology uptake on nutritional outcomes are accounted for in the empirical modelling. Non-food expenses based on income from increased production are captured in the household and individual-level control variables included in the analysis.

In the Nigerian context, women in rural households participate in unpaid care and family work, home improvements and even food consumption within the household (see Uwakwe, 2004; Fapohunda, 2012). This implies that the income they derive from improved agricultural production as a result of adopting agricultural technology will logically be used to increase household food consumption outcomes.

4. Data and estimation

Data

The data for this study are sourced from the World Bank's Living Standards Measurement Study (LSMS) – Integrated Household Survey for Nigeria. The LSMS is a nationally representative survey that includes about 5,000 households from different states in Nigeria for two seasons: post-planting and post-harvest. We rely on the latest wave of the survey to reduce measurement errors that could arise from changes in the gender of the household head status that are evident across different waves of the data. We specifically rely on the 2018/2019 survey period of the LSMS data for this study. This survey contains information relating to agricultural performance, welfare measures, improved agricultural technologies usage/uptake and other household characteristics that are useful for our estimations. The survey also covers different crop categories that are grown by the households and detailed information about the farmlands of the household.

It is important to note that in the context of this study, we focused on households that are located in rural areas where the main activity of the adults in the household is in the agricultural sector. The analysis of this study is at the household level. An earlier study suggests that in Nigeria, the extent of gender involvement in agricultural production and their contribution to the household food basket vary from one ethnic group to another. A review of the literature reveals that women in the Anambra State of Nigeria contribute more than men in terms of labour input in farming and are solely responsible for household management duties. Similarly, between 70 and 80 per cent of the Jukun, nomadic Fulfude and Kulka farmers were found to be women (Mohammed and Abdulquadri, 2012). These differences may reflect differences in household decisions regarding agriculture technology uptake.

Measuring food consumption expenditure and dietary diversity

We measure food consumption using two indicators. The first is the total value of household food expenditure per capita (i.e., total value of food expenditure in the local currency unit, Naira, divided by the size of the household). The second is the dietary diversity index, which captures the household's food access and caloric availability

(Pangaribowo et al, 2013) and is associated with improved birth weight and child anthropometric status (Rao et al, 2001), haemoglobin concentration (Bhargava et al, 2001) and reduced risk of mortality from cardiovascular disease. This variable is therefore computed based on the 12 food categories proposed by Swindale and Bilinsky (2006) in Kennedy et al (2013), as the summation of the household seven-day recall of the consumption of the following food items: cereals; white tubers and roots; vegetables; fruits; meat; eggs, fish and other seafood; legume nuts and seeds; milk and milk products; oils and fats; sweets; spices; and condiments and beverages.[3]

The argument supporting these measures is based on the fact that measuring food consumption, especially at the individual/household level, should include different categories of foods with varied nutritional components. The approach of this study is preferred compared to the use of calorie availability indicators following the argument in Sraboni et al (2014). The descriptive statistics in Table 1 show that, on average, dietary diversity is marginally higher in male-headed households (4.087) than in female-headed households (3.480). However, food consumption expenditure per capita was higher for female-headed households (1471.737 Naira) than for their male counterparts (1024.115 Naira).

Table 1: List of variables for analysis

	Female head		Male head		All household	
	Obs.	Mean/Freq. (Std. Dev.)	Obs.	Mean/Freq. (Std. Dev.)	Obs.	Mean/Freq. (Std. Dev.)
Agricultural technology use						
Herbicide uptake (1 if household adopted it in last planting season)	708	35.7%	5,168	60.6%	5,876	57.6%
Pesticide uptake (1 if the household adopted it in last planting season)	708	16.5%	5,168	36.2%	5,876	33.8%
Inorganic fertilizer (1 if household adopted it in last planting season)	708	40.8%	5,168	28.7%	5,876	26.6%
Value of farm production per hectare of farmland (farm production, in ’000’)	638	15.120 (24.638)	4,992	18.622 (33.069)	5,630	18.230 (32.253)
Dietary diversity (0, low – 12, high)	859	3.480 (1.417)	5,490	4.087 (1.630)	6,349	4.005 (1.616)
Food expenditure (past seven days) per capita	859	1471.737 (1785.918)	5,490	1024.115 (1267.044)	6,349	1084.677 (1357.461)
Remittance (1 if any member of the household received remittances from abroad)	859	5.00%	5,490	15.6%	6,349	14.1%

Credit uptake (percentage of HH members with credit)	858	2.93%	5,488	3.91%	6,399	2.78%
Education of HH head (1 if has primary education and above)	465	49.9%	4,188	67.5%	4,653	65.8%
Household size	859	4.667 (2.996)	5,491	7.436 (3.996)	7,945	6.596 (3.911)
Poor health status (percentage of HH members sick/injured)	859	7.39%	5,490	10.18%	6,349	6.95%
Dependents: share of dependent HH members (<=5 or >=65)	859	0.369 (0.316)	5,491	0.279 (0.207)	7,945	0.434 (0.349)
The community has market access (1=Yes)	829	78.4%	5,400	74.9%	6,229	75.4%
Electricity availability: days per week with electricity	825	5.700 (0.785)	5,379	5.7803 (0.736)	6,204	5.769 (0.744)
Instruments						
Average usage of herbicides in the community	859	12.7%	5,491	23.6%	7,988	17.5%
Average usage of pesticides in the community	859	14.1%	5,491	27.0%	7,988	20.1%
Average usage of inorganic fertilizer in the community	859	19.3%	5,491	40.5%	7,988	29.9%
Hours on agricultural activities in the farmland (per week)	513	16.853 (13.061)	3,547	20.075 (14.769)	4,060	19.668 (14.602)

Note: Values in percentages are frequencies, while the mean and standard deviations are only available for the continuous variable.

Source: Authors' computation from LSMS data.

Measuring agricultural technology uptake

First, we conceptualize agricultural technology uptake to mean the transition of agricultural activities from traditional to modernized processes. This transition can take two forms, especially when considering the context of our study. These include the transition from the use of traditional tools of farming (such as hoes, shovels, cutlasses and wheelbarrows) to more mechanized tools (such as mechanized irrigation and tractors), and from traditional crop production inputs (such as the use of animal dung) to green revolution processes like the use of hybrid seeds, high-yielding seed varieties, synthetic fertilizers and pesticides. For this study, we consider the green revolution elements for two reasons: first, smallholders in rural Nigeria are relatively small farmers with meagre capital input for farming processes. Second, most interventions that are informed by government policies and development donors have encouraged the uptake of green revolution agricultural inputs for improved production. For example, agricultural policies in Nigeria include granting farmers some of these agricultural inputs as it is well known that they can enhance agricultural output even for households that rely on non-mechanized technology for their farmlands (see Liverpool-Tasie et al, 2017).

Generally, we measured the uptake of agricultural input at the household level as a binary indicator which takes the value 1 if a household member used: (i) synthesized fertilizer in the last planting season, 0 otherwise; (ii) herbicide in the last planting season, 0 otherwise; and (iii) pesticide in the last planting season, 0 otherwise. The focus of this study is on responses by adult members of the household, typically those 18 years and above. The choice of the three different measures of agricultural technology input is informed by the availability of data from the main data source. On average, about 57.6 per cent of the sampled households reported that they adopted herbicides, while 33.8 per cent reported the use of pesticides, and 26.6 per cent used inorganic fertilizers on their farm plots. The uptake of herbicides and pesticides (see Table 1) was higher among male-headed households (60.6% and 36.2%, respectively) than female-headed households (35.7% and 16.5%, respectively). However, a higher proportion of female-headed households (40.8%) than male-headed households (28.8%) adopted inorganic fertilizers.

This may be explained by the entrenched gender differences in access to resources and division of labour in agricultural production activities in developing countries (Elias et al, 2015). Peterman et al (2014) suggest that the low adoption of new technologies among females may be explained by their relatively low level of education, cultural bottlenecks, limited access to land and lower ownership of land and farm tools. It can, therefore, be inferred from these statistics that if more female-headed than male-headed households were to adopt the use of herbicides and pesticides their production might be higher. Similarly, if more male-headed households than female-headed households were to adopt inorganic fertilizer they would increase their production. It is, therefore, important that the distribution of agricultural input in developing countries is informed by the principle of equity.

Measuring agricultural production

We measure agricultural production by relying on the survey question about the agricultural yield from the household farm. We focus on the market value of agricultural output from the farmlands of the households because it directly captures the output that the smallholder household derives from the land available for farm production. This variable was divided by the size of the farm of the household, measured in hectares. On average, households' total agricultural production is about 18.230 Naira (local currency unit) per hectare of farmland. Male-headed households have higher production per hectare (18.622) than their female-headed counterparts (15.120).

Control variables

Following the literature, we include covariates that have been shown to influence the uptake of agricultural technology, production and nutrition. For example, studies highlight that finance is an important determinant of the extent to which smallholders use agricultural technology for farm activities (Tadesse, 2014; Smale et al, 2015). We include the following variables: access to finance, including remittance receipts (that is, 1 if the household received remittances in the past 12 months), and the total number of household members with credit from formal or informal sources. From the survey, 14.1% of household members reported receiving remittances (15.6% for male-headed vs. 5% for female-headed households).

The other covariates included in the analysis are the education of the household head, which is a binary indicator that takes the value 1 if the head of the household has at least a primary school education, 0 otherwise. The reference includes those household heads with less than primary school education and no education completion. We also include the size of the household, the health status of the household (number of HH members sick/injured),[4] and the share of household members that are dependent (i.e., those who are in early childhood (younger than 5 years) and those who are outside the active labour force (older than 65).[5] We also include additional covariates measuring community-level or LSMS cluster-level variables, which take a value of 1 if the community has access to a market (market access, that is, the community has a market as indicated in the data) and continuous variable, which measures the number of days in a week that the community had electricity supply. These variables are important determinants of agricultural production in the literature (Fink and Masiye, 2015; Awotide et al, 2016; Headey et al, 2019). The descriptive statistics (mean and standard deviations) of these variables are presented in Table 1.

Estimation technique

The estimation technique used to address the objectives of this study is based on an analytical framework which links agriculture technology uptake with nutritional outcomes through production. This framework requires systems of estimation methods in which all three outcome variables (agricultural technology uptake, production and food consumption) are determined simultaneously. As these models consist of more than one equation, the disturbance terms are likely to be contemporaneously correlated, because unconsidered factors that influence the error term in the equation for either technology uptake, production or food consumption may influence the error terms in other equations. They also contain dependent variables in one equation that appear as explanatory variables in another equation leading to endogeneity (simultaneity) (Henningsen and Hamann, 2006).

Such equations can be estimated separately by ignoring the contemporaneous correlation, but this may lead to inefficient parameter estimates. They can also be estimated simultaneously using seemingly unrelated regressions (SUR), which takes the covariance structure of the residuals into account. However, this may produce efficient but biased and inconsistent parameter estimates due to endogeneity (Henningsen and Hamann, 2006; Friesenbichler and Peneder, 2016). The simultaneity bias can be corrected for each equation using a two-stage least squares (2SLS) method, or for all equations simultaneously using a three-stage least squares (3SLS) estimation of the system of equations. The 3SLS, which is applied in this study to address our objectives, is a combination of 2SLS and SUR in the sense that it generalizes the two-stage least squares method to take account of the correlations between equations in the same way as SUR (Henningsen and Hamann, 2006).

In most studies, estimates of the OLS, 2SLS, SUR and 3SLS are presented for comparison purposes but the 3SLS appears to produce the most efficient and reliable estimates. For example, in their study on how cash transfers affect modern input demand, Prifti et al (2019) found the estimates of the 3SLS to be more robust compared to the other three estimation techniques. In a similar study on the effects of smallholder agricultural involvement on household food expenditure and dietary diversity in Malawi (Benfica and Kilic, 2016) the estimates of the 3SLS were more robust compared to those of the 2SLS.

Following earlier studies (Imbs, 2004, 2006; Sarwar and Anastasopoulos, 2016), we begin the specification of our system of equations with Equation 1, where households' agriculture technology uptake (Ag_Tech) is a function of a vector of individual, household and community level characteristics (ψ), community average of agriculture technology usage (Com_Ag_Tech) and the error term (v). The parameters (α_0), (α_1), and (α_2) represent the constant term, the community average of agricultural technology usage and a vector of the coefficients of the individual, household and community level characteristics, while the subscript (i) represents a particular household. The variable ψ captures the other correlates of agricultural technology uptake (gender of the household head, education of the household head, household size, remittance, number of household members with credit uptake, community's access to market, availability of electricity and geographical location of household – North-Central, North-East, North-West, South-East, South-South and South-West). The symbol $\sum$ is the summation notation while n is the index of the summation of the other correlates.

$$Ag\_Tech_i = \alpha_0 + \alpha_1 Com\_Ag\_Tech_1 + \alpha_n \sum_{n=2}^{10} \psi_{ni} + \nu_i \quad (1)$$

The literature suggests that the uptake of agricultural technology contributes to high production while a strong push for higher production may lead to a greater likelihood of uptake (Baglan et al, 2020). This reverse causal relationship suggests that agricultural technology uptake and agricultural production are endogenous.

We address this potential endogeneity by including the community average (Com_Ag_Tec) of agricultural technology used as an instrument to facilitate the identification process (e.g., Babatunde, 2018). The use of the community average of a variable as its own instrument is supported by literature (Minten and Barrett, 2008; Smale et al, 2015).

In Equation 2, agricultural production ($Ag\_Production$) is specified as a function of agricultural technology uptake (Ag_Tech), hours ($Hours$) spent on agricultural land, a vector of other individual, household and community level correlates (Φ) and the error term (ν). The vector Φ represents the health status of the household head, household size, share of household members outside the working age group (<=5 or >=65 years)/dependants, community's access to the market, hours spent on agricultural activities in the farmland, geographical location of household and gender of the household head.

The literature suggests that agricultural technology uptake is endogenous in the food consumption variables due to measurement error, simultaneity or selection bias (Dillon et al, 2015). Specifically, unobserved factors that predict food consumption might be correlated with households' decision to adopt agricultural technology (Sarwar and Anastasopoulos, 2016). It is also argued that agricultural production is likely to be endogenous in food consumption (Ogundari and Awokuse, 2016). This potential endogeneity is addressed by using hours spent on agricultural land as an instrument for agricultural production. We use hours of work as an instrument based on an earlier study where Smale et al (2015) used a similar farm input variable to moderate the relationship between the endogenous uptake variable and the outcome variable.

$$Ag\_Production = b_0 + b_1 Ag\_Tech_i + b_2 Hours_1 + b_n \sum_{n=3}^{11} \Phi_{ni} + \nu_i \quad (2)$$

We finally specify household food consumption ($Food\_Consumption$), including dietary diversity and food expenditure, as a function of agricultural production ($Ag\_Production$), which has been "purged" of the unobserved confounding influences, a vector of the exogenous variables (X) and the error term (θ). In Equation 3, X represents the community's access to the market, days per week of electricity availability, education of household head, the share of household members outside the working age group (<=5 or >=65years)/dependants, access to credit, geographical location of household and gender of the household head. Unlike the dietary diversity function, the food expenditure function excludes household size because we used expenditure per capita where household size is the denominator. We include electricity in the food consumption equation because it is one of the efficient sources of cooking fuel (Frempong et al, 2021). Households' access to a constant electricity supply enables them to store food (both own produced and purchased) in the fridge to ensure food availability at all times. It is also worth noting that we logged the food consumption expenditure and production variables to smoothen this indicator.

$$Food\_Consumption_i^* = \gamma_0 + \gamma_1 Ag\_\widehat{Production}_i + \gamma_n \sum_{n=2}^{8} X_{ni} + \theta_i \qquad (3)$$

5. Results and discussion

Food expenditure/dietary diversity for all households

In Table 2 we present the results of agricultural technology use, i.e., herbicide, pesticide and inorganic fertilizer use, on food expenditure. Table 3 presents the results of the effect of the same agricultural technology uptake on the second indicator of food consumption dietary diversity. Columns a, b, and c, respectively, display the estimates for the first stage (determinant of agricultural technology uptake), the second stage (farm production function) and the third stage regression (food consumption function). Evidence from columns 1a, 2a and 3a suggests that the instrument, which is the community average rate of agricultural technology uptake (i.e., herbicide, pesticide and inorganic fertilizer usage) has a significant positive effect on households' uptake of such technology. This positive effect feeds into the production functions in columns 2b and 3b, suggesting that with the uptake of herbicides and inorganic fertilizers, the value of farm production by the household increases significantly. We do not find a significant effect for the estimate of the uptake of pesticides (column 2b).

Table 2: Effect of agricultural technology uptake on food expenditure

	Herbicide			Pesticide			Inorganic fertilizer		
	Herbicide use [1a]	Logged production [1b]	Logged food expenditure [1c]	Pesticide use [2a]	Logged production [2b]	Logged food expenditure [2c]	Inorganic fertilizer use [3a]	Logged production [3b]	Logged food expenditure [3c]
Agricultural technology use		1.029***			-0.123			0.624***	
		(0.115)			(0.269)			(0.067)	
Logged production			0.180***			0.200***			0.196***
			(0.032)			(0.032)			(0.018)
Female household head	-0.274***	-0.262***	-0.197**	-0.243*	-0.319***	-0.187**	-0.125	-0.288***	-0.188***
	(0.089)	(0.088)	(0.092)	(0.127)	(0.096)	(0.092)	(0.078)	(0.063)	(0.053)
Education	0.249***	-0.090	0.348***	0.137	-0.041	0.350***	0.279***	-0.125***	0.350***
	(0.074)	(0.078)	(0.071)	(0.087)	(0.085)	(0.071)	(0.052)	(0.042)	(0.035)
Poor health status		0.045			0.040			0.032	
		(0.031)			(0.034)			(0.020)	
Household size	0.019*	0.009		0.013	0.016		0.047***	0.008	
	(0.010)	(0.009)		(0.010)	(0.010)		(0.007)	(0.005)	
Community market	-0.009	-0.039	0.252***	-0.029	-0.210*	0.252***	0.084	-0.255***	0.252***
	(0.064)	(0.098)	(0.097)	(0.050)	(0.112)	(0.097)	(0.058)	(0.045)	(0.040)
Dependents		-0.204	-0.131		-0.221	-0.114		-0.260***	-0.118
		(0.163)	(0.121)		(0.166)	(0.119)		(0.086)	(0.073)
Hours of work		-0.003			-0.005**			-0.006***	
		(0.002)			(0.003)			(0.001)	
Credit uptake	0.054		0.169*	0.109		0.168*	0.060		0.167***
	(0.105)		(0.091)	(0.095)		(0.090)	(0.067)		(0.043)
Remittance	0.065		0.331*	0.249		0.337**	0.084		0.332***
	(0.185)		(0.170)	(0.249)		(0.170)	(0.170)		(0.116)
Electricity availability			0.173***			0.173***			0.173***
			(0.051)			(0.050)			(0.022)

Instrument	3.604***			3.406***			3.637***		
	(0.077)			(0.089)			(0.097)		
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	-1.909***	10.776***	4.904***	-1.762***	11.531***	4.688***	-2.398***	11.575***	4.741***
	(0.124)	(0.238)	(0.518)	(0.096)	(0.248)	(0.522)	(0.173)	(0.117)	(0.256)
Observations	5,778	5,778	5,778	5,778	5,778	5,778	5,778	5,778	5,778

Note: We control for the location fixed effect, and cluster the standard errors at the local government area because the instruments were constructed at this level. The instrument that we use for the uptake models is the ratio of adopters of these technologies to the population of the community. The values in parentheses are the standard errors, while the superscripts are described as follows: ***<0.01; **<0.05.

These first sets of results are similar to those reported in Table 3, which are the results of the effect of agricultural technology on the second indicator of food consumption dietary diversity. Specifically, we find significant effects of the instrument on the likelihood of the household adopting any agricultural technology (columns 1a, 2a and 3a). For the production function, we also find a significant effect on farm production for herbicide and inorganic fertilizer usage (columns 1b and 3b), but not for pesticide usage, for which we find a null effect (column 2b). For the dietary diversity function in columns 1c, 2c, and 3c, we find a consistent increase in household dietary diversity with the increase in farm production from the uptake of any of the agricultural technologies being considered in this study.

Overall, the results suggest a positive effect of increased farm production on food expenditure per capita and dietary diversity due to households' uptake of herbicides, pesticides or inorganic fertilizers (agricultural technologies). However, the effect of farm production on food expenditure is relatively higher than the effect of dietary diversity. This may be explained by the prevailing inflation and households' consumption dynamics. As highlighted in the conceptual framework, increased farm production is either sold for income to purchase other complementary food ingredients or is consumed by households. As expenditure on food is a combination of price and quantity, a disproportionate increase in the prices of those commodities relative to increase in income from farm production will increase households' overall food expenditure. Holding the household size constant, an increase in food expenditure may indirectly limit their ability to consume diversified food. Conversely, if households consume the additional increase in their production without selling any for income to purchase complementary ingredients or food, they will also eat less diversified food. It is possible from the results that when households' farm production increases with the uptake of these technologies, households tend to consume more of their own products or utilize additional income from the sale of their farm products to purchase other household food items. As displayed in Figure 1, these are the two likely channels through which increased production from the uptake of agricultural technologies impact households' food consumption.

Table 3: Effect of agricultural technology uptake on dietary diversity

	Herbicide			Pesticide			Inorganic fertilizer		
	Herbicide use [1a]	Logged production [1b]	Dietary diversity [1c]	Pesticide use [2a]	Logged production [2b]	Dietary diversity [2c]	Inorganic fertilizer use [3a]	Logged production [3b]	Dietary diversity [3c]
Agricultural technology use		1.040***			-0.077			0.653***	
		(0.114)			(0.286)			(0.068)	
Logged production			0.164***			0.155***			0.168***
			(0.049)			(0.051)			(0.024)
Female household head	-0.267***	-0.265***	-0.217**	-0.230*	-0.323***	-0.223**	-0.120	-0.293***	-0.216***
	(0.089)	(0.088)	(0.100)	(0.126)	(0.095)	(0.100)	(0.078)	(0.063)	(0.072)
Education	0.250***	-0.091	0.408***	0.135	-0.045	0.407***	0.282***	-0.129***	0.409***
	(0.074)	(0.079)	(0.105)	(0.087)	(0.085)	(0.105)	(0.052)	(0.042)	(0.047)
Poor health status		0.043			0.033			0.026	
		(0.031)			(0.034)			(0.020)	
Household size	0.021**	0.007	0.027**	0.017*	0.013	0.027**	0.050***	0.006	0.026***
	(0.009)	(0.009)	(0.011)	(0.009)	(0.010)	(0.011)	(0.007)	(0.005)	(0.006)
Community market	-0.009	-0.038	0.159	-0.031	-0.216*	0.157	0.088	-0.260***	0.158***
	(0.065)	(0.098)	(0.143)	(0.050)	(0.113)	(0.143)	(0.058)	(0.045)	(0.054)
Dependents		-0.205	0.035		-0.233	0.029		-0.267***	0.037
		(0.163)	(0.158)		(0.166)	(0.154)		(0.086)	(0.099)
Hours of work		-0.003			-0.006**			-0.006***	
		(0.002)			(0.003)			(0.001)	
Credit uptake	0.055		-0.026	0.111		-0.024	0.050		-0.028
	(0.105)		(0.100)	(0.096)		(0.100)	(0.066)		(0.058)
Remittance	0.063		0.369	0.257		0.379*	0.090		0.372**
	(0.183)		(0.228)	(0.247)		(0.230)	(0.169)		(0.157)

Electricity available			0.129			0.126			0.127***
			(0.084)			(0.083)			(0.029)
Instrument	3.582***			3.350***			3.596***		
	(0.077)			(0.092)			(0.097)		
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	-1.908***	10.784***	0.687	-1.756***	11.547***	0.801	-2.416***	11.608***	0.653*
	(0.126)	(0.240)	(0.852)	(0.095)	(0.251)	(0.869)	(0.173)	(0.117)	(0.341)
Observations	5,778	5,778	5,778	5,778	5,778	5,778	5,778	5,778	5,778

Note: We control for the location fixed effect and cluster the standard errors at the local government area because the instruments were constructed at this level. The instrument that we use for the uptake models is the ratio of adopters of these technologies to the population of the community. The values in parentheses are the standard errors, while the superscripts are described as follows: ***<0.01; **<0.05.

5.2 Food expenditure/dietary diversity for male-headed households

Tables 4 and 5 present the estimates for male-headed households. Overall, the result seems similar to the earlier estimates in Tables 2 and 3. The instrument (community average of agricultural technology use) has a positive impact on the likelihood of the male-headed household adopting any of the agricultural technologies that were of interest (columns 1a, 2a and 3a). Again, we only find significant effects of herbicide and inorganic fertilizer use on farm production, but at varying significant levels, depending on whether we consider food expenditure or dietary diversity outcomes. The effect was significant at the one-per-cent level for estimates from both food expenditure models (Table 4, columns 1b and 3b), and the dietary diversity models (Table 5, columns 1b and 3b), but we do not find a significant effect of pesticide use on farm production.

The estimates of the main outcome variables (food expenditure and dietary diversity) for male-headed households are presented in column c in Tables 4 and 5. The results show that the increased production from the uptake of herbicides, pesticides and inorganic fertilizers led to a 0.132%, 0.154% and 0.149% increase, respectively, in the food expenditure per capita for male-headed households. These effects were significant at the one-per-cent level (Table 4, columns 1c, 2c and 3c). In Table 5 we also find a significant increase in dietary diversity with increased production from the uptake of each agricultural technology. Specifically, an increase in farm production from the uptake of each of the agricultural technologies led to a 0.28%, 0.258% and 0.26% increase in dietary diversity. These effects, again, are significant at the one-per-cent level (Table 5, columns 1c, 2c and 3c).

Table 4: Effect of agricultural technology uptake on food expenditure, male-headed households

	Herbicide			Pesticide			Inorganic fertilizer		
	Herbicide use [1a]	Logged production [1b]	Logged food expenditure [1c]	Pesticide use [2a]	Logged production [2b]	Logged food expenditure [2c]	Inorganic fertilizer use [3a]	Logged production [3b]	Logged food expenditure [3c]
Agricultural technology use		1.050***			-0.147			0.677***	
		(0.116)			(0.273)			(0.072)	
Logged production			0.170***			0.193***			0.187***
			(0.033)			(0.035)			(0.019)
Education	0.260***	-0.118	0.373***	0.137	-0.058	0.376***	0.263***	-0.148***	0.376***
	(0.084)	(0.085)	(0.079)	(0.094)	(0.092)	(0.079)	(0.056)	(0.045)	(0.037)
Poor health status		0.065**			0.060*			0.052**	
		(0.031)			(0.035)			(0.020)	
Household size	0.017	0.007		0.012	0.015		0.046***	0.008	
	(0.011)	(0.010)		(0.010)	(0.011)		(0.007)	(0.005)	
Common market	-0.039	-0.056	0.245**	-0.034	-0.249**	0.247**	0.073	-0.304***	0.247***
	(0.067)	(0.107)	(0.105)	(0.053)	(0.122)	(0.105)	(0.061)	(0.047)	(0.042)
Dependents		-0.019	-0.115		-0.038	-0.096		-0.079	-0.096
		(0.173)	(0.145)		(0.178)	(0.143)		(0.097)	(0.082)
Hours of work		-0.005*			-0.007***			-0.008***	
		(0.003)			(0.003)			(0.001)	
Credit uptake	0.041		0.155	0.134		0.153	0.059		0.151***
	(0.113)		(0.102)	(0.097)		(0.101)	(0.072)		(0.046)
Remittance	0.011		0.430***	0.182		0.439***	-0.146		0.434***
	(0.201)		(0.162)	(0.301)		(0.161)	(0.213)		(0.140)
Electricity availability			0.154***			0.155***			0.154***
			(0.056)			(0.055)			(0.023)
Instrument	3.555***			3.372***			3.636***		

	(0.084)			(0.096)			(0.105)		
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	-1.855***	10.861***	5.080***	-1.825***	11.642***	4.828***	-2.333***	11.683***	4.890***
	(0.126)	(0.242)	(0.565)	(0.106)	(0.271)	(0.573)	(0.177)	(0.122)	(0.273)
Observations	5,090	5,090	5,090	5,090	5,090	5,090	5,090	5,090	5,090

Note: We control for the location fixed effect and cluster the standard errors at the local government area because the instruments were constructed at this level. The instrument that we use for the uptake models is the ratio of adopters of these technologies to the population of the community. The values in parentheses are the standard errors, while the superscripts are described as follows: ***<0.01; **<0.05.

Table 5: Effect of agricultural technology uptake on dietary diversity, male-headed households

	Herbicide			Pesticide			Inorganic fertilizer		
	Herbicide use [1a]	Production [1b]	Dietary diversity [1c]	Pesticide use [2a]	Production [2b]	Dietary diversity [2c]	Inorganic fertilizer use [3a]	Production [3b]	Dietary diversity [3c]
Agricultural technology use		1.064***			-0.121			0.712***	
		(0.115)			(0.295)			(0.073)	
Production			0.158***			0.145**			0.162***
			(0.055)			(0.057)			(0.025)
Education	0.261***	-0.119	0.422***	0.133	-0.057	0.421***	0.265***	-0.151***	0.423***
	(0.085)	(0.086)	(0.113)	(0.094)	(0.093)	(0.113)	(0.056)	(0.045)	(0.052)
Poor health status		0.063**			0.051			0.046**	
		(0.031)			(0.035)			(0.020)	
Household size	0.019*	0.006	0.019	0.016	0.012	0.019*	0.048***	0.005	0.018***
	(0.010)	(0.010)	(0.011)	(0.010)	(0.011)	(0.011)	(0.007)	(0.005)	(0.006)
Community market	-0.041	-0.053	0.175	-0.035	-0.255**	0.173	0.076	-0.309***	0.175***
	(0.069)	(0.107)	(0.152)	(0.053)	(0.123)	(0.152)	(0.061)	(0.047)	(0.058)
Dependents		-0.017	0.070		-0.048	0.057		-0.083	0.074
		(0.173)	(0.198)		(0.178)	(0.193)		(0.097)	(0.114)
Hours of work		-0.005*			-0.008***			-0.008***	
		(0.003)			(0.003)			(0.001)	
Credit uptake	0.041		-0.042	0.139		-0.040	0.049		-0.045
	(0.113)		(0.107)	(0.098)		(0.107)	(0.071)		(0.063)
Remittance	0.012		0.443	0.184		0.456*	-0.141		0.446**
	(0.199)		(0.275)	(0.297)		(0.276)	(0.212)		(0.194)
Electricity availability			0.133			0.131			0.132***
			(0.093)			(0.093)			(0.032)
Instrument	3.529***			3.305***			3.591***		

	(0.084)			(0.102)			(0.105)		
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	-1.850***	10.864***	0.761	-1.813***	11.660***	0.918	-2.346***	11.712***	0.729*
	(0.128)	(0.242)	(0.946)	(0.104)	(0.272)	(0.965)	(0.176)	(0.122)	(0.373)
Observations	5,090	5,090	5,090	5,090	5,090	5,090	5,090	5,090	5,090

Note: We control for the location fixed effect and cluster the standard errors at the local government area because the instruments were constructed at this level. The instrument that we use for the uptake models is the ratio of adopters of these technologies to the population of the community. The values in parentheses are the standard errors, while the superscripts are described as follows: ***<0.01; **<0.05.

Food expenditure/dietary diversity for female-headed households

In Tables 6 and 7 we present the results for food expenditure and dietary diversity with increased farm production from the uptake of each of the agricultural technologies for female-headed households. Again, the instrument remains statistically significant and positive in determining the likelihood of female-headed households adopting each agricultural technology (Table 6, columns 1a, 2a and 3a). However, regarding the implication of agricultural technology uptake on farm production, we only find significant effects for the dietary diversity equation, where an increase in herbicide use was seen to significantly improve farm production (Table 7, column 1a). Apart from this, other coefficients of agricultural technology in the other models show a positive effect, but are not significant at any of the conventional levels.

The estimates of food consumption and dietary diversity also show improvements (Tables 6 and 7, column c) with improved farm production from the uptake of the different types of agricultural technologies. Thus, female households also benefit from adopting these technologies, as their food consumption and dietary diversity also increase with improved farm production. Comparatively, the point estimates of these variables are generally higher for female-headed households than for male-headed households. This suggests that the extent of the effect of uptake of the various categories of agricultural technologies on food consumption is significantly higher for female-headed households than for their male-headed counterparts.

Thus, it is clear from the gender analysis that the effect of agricultural technology application on farm production is statistically significant for herbicide and inorganic fertilizer use, but insignificant for the use of pesticides. The insignificance of pesticide may be explained by the intensity/quantity of its use compared to herbicide and inorganic fertilizer. As presented in Table 1, there is higher adoption of herbicides (58%) and inorganic fertilizer (34%) than pesticides (27%). This distribution of adoption rates reflects the relative difference in the extent to which soil fertility, weeds and pests are a problem for smallholder farmers in developing countries, and Nigeria in particular. Every farmer will need fertilizer and herbicides, but not necessarily pesticides. The use of pesticides is largely dependent on the type of crop produced.

The extent of the effect on agricultural production is higher for male-headed households than for female-headed households. This observation is also consistent with the descriptive statistics in Table 1, which show that a higher proportion of male-headed households than female-headed households adopted herbicides and pesticides, while more female-headed households than their male counterparts adopted inorganic fertilizers. The observed gender differences in the adoption of agricultural technologies could have important implications for agricultural production and food consumption expenditure and dietary diversity. Despite the relative difference in the magnitudes of the production effects of agricultural technology adoption, the effects of improved production on both food consumption expenditure per capita and dietary diversity are markedly higher (almost twice the rate) for female-headed households than for male-headed households.

These results support the assertion in the introduction of this paper that, on average, females earn less from their economic activities than males, but they spend a relatively higher proportion of their low earnings on the provision of household food (UNCTAD, 2011; Amu, 2005; Orkoh, 2018). Consistent with the conceptual framework (see Figure 1), this means that a higher share of income from the sale of improved food production due to females' adoption of agricultural technologies is likely to be spent on purchasing other ingredients for food consumption by household members. This could also explain why female-headed households also have more diversified diets than male-headed households. The other side of the argument is that the additional increase in food production for female-headed households may not be sufficient. As a result, they spend more from other sources of income on the purchase of food. However, the possibility of this second argument holding is low due to the low diversity of income sources of rural households in a developing country such as Nigeria.

Table 6: Effect of agricultural technology uptake on food expenditure, female-headed households

	Herbicide			Pesticide			Inorganic fertilizer		
	Herbicide use [1a]	Production [1b]	Food expenditure [1c]	Pesticide use [2a]	Production [2b]	Food expenditure [2c]	Inorganic fertilizer use [3a]	Production [3b]	Food expenditure [3c]
Agricultural technology use									
		0.712*			0.541			0.325*	
		(0.403)			(0.698)			(0.194)	
Production			0.311***			0.291***			0.290***
			(0.068)			(0.066)			(0.055)
Education	0.142	0.068	0.190	0.026	0.025	0.195	0.360**	0.004	0.189*
	(0.166)	(0.142)	(0.123)	(0.275)	(0.144)	(0.122)	(0.146)	(0.115)	(0.104)
Poor health status		-0.157*			-0.126			-0.173**	
		(0.083)			(0.080)			(0.075)	
Household size	0.061**	0.016		0.030	0.012		0.059**	0.013	
	(0.026)	(0.024)		(0.035)	(0.025)		(0.024)	(0.019)	
Community market	0.266	0.222	0.337*	0.270	0.236	0.343*	0.277	0.215	0.341**
	(0.186)	(0.195)	(0.193)	(0.373)	(0.205)	(0.196)	(0.205)	(0.147)	(0.138)
Dependents		-0.692***	-0.253		-0.755***	-0.241		-0.728***	-0.277*
		(0.252)	(0.233)		(0.256)	(0.230)		(0.185)	(0.167)
Hours of work		0.014***			0.014**			0.012***	
		(0.005)			(0.006)			(0.004)	
Credit uptake	0.115		0.232	0.064		0.238	0.053		0.235*
	(0.187)		(0.174)	(0.429)		(0.175)	(0.193)		(0.132)
Remittance	0.381		0.075	0.380		0.082	0.568*		0.076

	(0.314)		(0.220)	(0.498)		(0.221)	(0.303)		(0.216)
Electricity availability			0.296***			0.291***			0.297***
			(0.073)			(0.073)			(0.061)
Instrument	4.319***			4.086***			3.758***		
	(0.350)			(0.483)			(0.267)		
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	-3.019***	9.913***	3.100***	-1.894***	10.152***	3.286***	-2.768***	10.448***	3.296***
	(0.382)	(0.723)	(0.899)	(0.478)	(0.756)	(0.889)	(0.333)	(0.362)	(0.704)
Observations	688	688	688	679	679	679	679	679	679

Note: We control for the location fixed effect and cluster the standard errors at the local government area because the instruments were constructed at this level. The instrument that we use for the uptake models is the ratio of adopters of these technologies to the population of the community. The values in parentheses are the standard errors, while the superscripts are described as follows: ***<0.01; **<0.05.

Table 7: Effect of agricultural technology uptake on dietary diversity, female-headed households

	Herbicide			Pesticide			Inorganic fertilizer		
	Herbicide use [1a]	Production [1b]	Dietary diversity [1c]	Pesticide use [2a]	Production [2b]	Dietary diversity [2c]	Inorganic fertilizer use [3a]	Production [3b]	Dietary diversity [3c]
Agricultural technology									
use		1.146***			0.647			0.277	
		(0.227)			(0.531)			(0.189)	
Production			0.230**			0.245***			0.246***
			(0.111)			(0.083)			(0.058)
Education	0.147	0.101	0.299*	0.023	0.023	0.301*	0.354**	0.011	0.299***
	(0.167)	(0.108)	(0.177)	(0.270)	(0.141)	(0.176)	(0.147)	(0.114)	(0.111)
Poor health status		-0.242***			-0.110			-0.159**	
		(0.087)			(0.082)			(0.073)	
Household size	0.068***	0.056***	0.137***	0.034	0.010	0.135***	0.070***	0.013	0.135***
	(0.026)	(0.019)	(0.025)	(0.034)	(0.025)	(0.024)	(0.024)	(0.019)	(0.018)
Community market	0.297	0.316**	0.072	0.274	0.231	0.070	0.287	0.210	0.066
	(0.188)	(0.150)	(0.225)	(0.378)	(0.209)	(0.224)	(0.206)	(0.146)	(0.147)
Dependents		-0.359**	-0.178		-0.804***	-0.156		-0.765***	-0.172
		(0.164)	(0.239)		(0.252)	(0.237)		(0.182)	(0.180)
Hours of work		0.025***			0.013**			0.011***	
		(0.004)			(0.005)			(0.004)	
Credit uptake	0.106		-0.102	0.069		-0.057	0.046		-0.066
	(0.191)		(0.202)	(0.397)		(0.197)	(0.193)		(0.141)
Remittance	0.403		0.281	0.396		0.286	0.597**		0.283
	(0.281)		(0.296)	(0.508)		(0.298)	(0.301)		(0.229)
Electricity availability			0.084			0.089			0.089

			(0.099)			(0.101)			(0.065)
Instrument	4.370***			4.109***			3.760***		
	(0.348)			(0.501)			(0.269)		
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	-3.130***	8.095***	-0.363	-1.904***	10.159***	-0.567	-2.831***	10.492***	-0.555
	(0.372)	(0.456)	(1.271)	(0.487)	(0.743)	(1.124)	(0.333)	(0.355)	(0.744)
Observations	688	688	688	679	679	679	679	679	679

Note: We control for the location fixed effect and cluster the standard errors at the local government area because the instruments were constructed at this level. The instrument that we use for the uptake models is the ratio of adopters of these technologies to the population of the community. The values in parentheses are the standard errors, while the superscripts are described as follows: ***<0.01; **<0.05

6. Conclusion

There is evidence of entrenched gender inequality in access to and adoption of agricultural technologies in developing countries. However, empirical analysis of the implications of this inequality for household food consumption and dietary quality remains limited. This study fills this gap in the literature by assessing the food consumption effect of increased agricultural production due to households' uptake of agricultural technology (namely herbicides, pesticides and inorganic fertilizer) in rural Nigeria, with a particular focus on gender. Specifically, the study examines the effects of production as a medium through which agricultural technology uptake affects food consumption of male-headed and female-headed households in rural Nigeria.

The data used for the purpose of the study were taken from the World Bank's Living Standards Measurement Study (LSMS) – Integrated Household Survey for Nigeria. We measured food consumption using two indicators: the total value of household food expenditure per capita, and the dietary diversity index, using a three-stage least squares (3SLS) regression as estimation technique.

The regression estimates show that households' uptake of agricultural technologies has a significant positive effect on their dietary diversity and food consumption expenditure per capita due to increased farm production. While these results are consistent regardless of the gender of the household head, the extent of effects for female-headed households is almost twice that for male-headed households.

These findings underscore the need for the Ministry of Agriculture in Nigeria and its allied ministries such as the Ministry of Gender Affairs to ensure that the distribution of herbicides, pesticides and inorganic fertilizer is gender inclusive. There is a need for a review of existing input subsidy policies to ensure a level playing field for both males and females. In addition to the advantage that males have over females in terms of the share and right of ownership of agricultural land (FAO, 2018), it appears from this analysis that females face numerous barriers in accessing pesticides and herbicides. It is, therefore, important that the government pays particular attention to the distribution of these inputs to make them more accessible to females to improve the quantity and quality of food production and consumption in their households.

Notes

1 These statistics are gotten from the main data source for our analysis, which is the World Bank's Living Standards Measurement Study.

2 Fadama in the local dialect of Northern Nigeria means irrigable land.

3 The 12 food categories are a good indication of household economic access to food compared to an alternative measure that considers only nine food categories, which reflects the probability of micronutrient adequacy (Kennedy et al, 2013).

4 It is important to clarify that this measure is highly subjective, with a wide spectrum of illnesses and ,therefore, their impact on productivity may not be accurately measured.

5 Due to the fact that our sample consists of smallholders who rely on domestic agricultural labour for their farm activities, considering individuals who are neither infants nor older than 65 allows us to identify those who will likely be engaged in farm labour.

References

Ameen, A. and Raza, S. 2017, Green revolution: a review, International Journal of Advances in Scientific Research, 3(12), 129-137.

Amu, N.J. 2005. *The Role of Women in Ghana's Economy*. Friedrich Ebert Foundation, Bonn, Germany.

Awotide, B.A., A.A. Karimov and A. Diagne. 2016. "Agricultural technology adoption, commercialization and smallholder rice farmers' welfare in rural Nigeria". *Agricultural and Food Economics*, 4(3). At https://doi.org/10.1186/s40100-016-0047-8

Babatunde, R.O. 2018. "Impact of remittances on food consumption and nutrition of migrant's household: Empirical evidence from Nigeria". 10th International Conference of Agricultural Economists, July 28-Auguts 2, 2018. Vancouver, Canada. .

Baglan, M., G.E. Mwalupaso, X. Zhou and G. Xianhui. 2020. "Towards cleaner production: Certified seed adoption and its effect on technical efficiency". Sustainability, 12(4): 1344.

Benfica, R. and T. Kilic. 2016. "The effects of smallholder agricultural involvement on household food consumption and dietary diversity: Evidence from Malawi". IFAD Research Series, (4): 1–31.

Bhargava, A., H.E. Bouis and N.S. Scrimshaw. 2001. "Dietary intakes and socioeconomic factors are associated with the haemoglobin concentration of Bangladeshi women". The Journal of Nutrition, 131(3): 758–64.

Dillon, A., K. McGee and G. Oseni. 2015, Agricultural production, dietary diversity, and climate variability, *The Journal of Development Studies*, 51.8 (2015): 976-995.

Doss, C.R. and M. Morris. 2001. "How does gender affect the adoption of agricultural innovations? The case of improved maize technology in Ghana". Agricultural Economics, 25(1): 27–39.

Druilhe, Z. and J. Barreiro-Hurlé. 2012. "Fertilizer subsidies in sub-Saharan Africa". ESA Working Paper No. 12-04, Food and Agriculture Organization, Rome, Italy

Duflo, E., M. Kremer and J. Robinson. 2008. "How high are rates of return to fertilizer? Evidence from field experiments in Kenya". *American Economic Review*, 98 (2): 482-88.

Elias, A., M. Nohmi, K. Yasunobu and A. Ishida. 2015. "Does gender division of labour matter for the differences in access to agricultural extension services? A case study in North West Ethiopia". *Journal of Agricultural Science*, 7(1): 138-147.

Ellis, A., M. Blackden, J. Cutura, F. MacCulloch and H. Seebens. 2007. *Gender and Economic Growth in Tanzania: Creating Opportunities for Women*. Washington, D.C.: The World Bank.

Falaju, J. 2016. USAID, ECOWAS canvass use of fertilizer to boost food production, The

Guardian. At https://guardian.ng/news/usaid-ecowas-canvass-use-of-fertilizer-to-boost-food-production/

Fapohunda, T.M. 2012. "Gender and development: Challenges to women involvement in Nigeria's development". International Journal of Academic Research in Business and Social Sciences, 2(6): 14–28.

Fink, G. and F. Masiye. 2015. "Health and agricultural productivity: Evidence from Zambia". *Journal of Health Economics*, 42: 151–64.

FAO. 2018. Gender gaps in land rights. At https://www.fao.org/3/I8796EN/i8796en.pdf

Federal Ministry of Agriculture and Rural Development (FMARD). 2016. "The Agriculture Promotion Policy (2016–2020): Building on the successes of the Agricultural Transformation Agenda (ATA), closing key gaps". Policy and Strategy Document, Federal Ministry of Agriculture & Rural Development. Abuja, Nigeria. Accessed 20 October 2022. At https://nssp.ifpri.info/files/2017/12/2016-Nigeria-Agric-Sector-Policy-Roadmap_June-15-2016_Final.pdf

Frempong, R.B., E. Orkoh and R.E. Kofinti. 2021. "Household's use of cooking gas and children's learning outcomes in rural Ghana". Energy Economics, 103: 105617.

Friesenbichler, K. and M. Peneder. 2016. "Innovation, competition and productivity: Firm-level evidence for Eastern Europe and Central Asia". Economics of Transition, 24(3): 535–80.

Gebre, G.G., H. Isoda, Y. Amekawa and H. Nomura. 2021. "Gender differences in agricultural productivity: Evidence from maize farm households in southern Ethiopia". GeoJournal, 86(2): 843–64.

Global Food Security Index. 2022. Global Food Security Index 2022.– Rankings and Trends. The Economist Newspaper Limited, London, England Athttps://impact.economist.com/sustainability/project/food-security-index/about.

Hall, C., T.P. Dawson, J.I. Macdiarmid, R.B. Matthews and P. Smith. 2017. "The impact of population growth and climate change on food security in Africa: Looking ahead to 2050". *International Journal of Agricultural Sustainability*, 15(2): 124–35.

Headey, D., K. Hirvonen, J. Hoddinott and D. Stifel. 2019. "Rural food markets and child nutrition". *American Journal of Agricultural Economics*, 101(5): 1311–27. At https://doi.org/10.1093/ajae/aaz032

Henningsen, A. and J. Hamann. 2006. "systemfit: A package to estimate simultaneous equation systems in R". University Library of Munich, Germany.

Hirvonen, K. and Hoddinott, J. 2017, Agricultural production and children's diets: Evidence from rural Ethiopia, Agricultural Economics, 48(4), 469-480.

Imbs, J. 2004. "Trade, finance, specialization, and synchronization". Review of Economics and Statistics, 86(3): 723–34.

Imbs, J. 2006. "The real effects of financial integration". *Journal of International Economics*, 68(2): 296–324.

International Fertilizer Development Centre – IFDC. 2016. "IFDC project charts way forward for West African fertilizer use". At https://ifdc.org/2016/07/25/ifdc-project-charts-way-forward-for-west-african-fertilizer-use/

IPES-Food. 2020. "The added value(s) of agroecology: Unlocking the potential for transition in West Africa". Accessed 16 September 2022. At https://www.ipes-food.org/_img/upload/files/IPES-Food_FullReport_WA_EN.pdf

Kennedy, G., T. Ballard and M.C. Dop. 2013. "Guidelines for measuring household and individual diet diversity". The Food and Agriculture Organization of the United Nations. At http://www.fao.org/3/a-i1983e.pdf

Liverpool-Tasie, L.S., B.T. Omonona, A. Sanou And W.O. Ogunleye. 2017. "Is increasing inorganic fertilizer use for maize production in SSA a profitable proposition? Evidence from Nigeria". Food Policy, 67: 41–51.

Minten, B. and C.B. Barrett. 2008. "Agricultural technology, productivity, and poverty in Madagascar". *World Development*, 36(5): 797–822.

Mohammed, B.T. and Abdulquadri, A.F.. 2012. "Comparative analysis of gender involvement in agricultural production in Nigeria". Journal of Development and Agricultural Economics, 4(8), 240-244 .

Odiwuor, F. 2022. "Women smallholder farmers: What is the missing link for the food system in Africa?" Africa up close. Woodrow Wilson International Center for Scholars, USA. Accessed 20 October 2022. At https://africaupclose.wilsoncenter.org/women-smallholder-farmers

Ogundari, K and Awokuse, T. 2016, Assessing the Contribution of Agricultural Productivity to Food Security levels in Sub-Saharan African countries, In 2016 *Annual Meeting, July 31-August 2, Boston, Massachusetts.* Agricultural and Applied Economics Association. 2-26, DOI. 10.22004/ag.econ.235730

Olayinka, I.K. 2014, The Welfare Impact in Nigeria of the ECOWAS Common External Tariff: A Distributional Effects Analysis, in United Nations (ed.), Trade policies, household welfare and poverty alleviation: Case studies from the Virtual Institute academic network, 273-299, New York and Geneva.

Oldiges, C. 2017. "Measuring malnutrition and dietary diversity: Theory and evidence from India". Oxford Poverty & Human Development Initiative (OPHI) Working Paper No. 108, University of Oxford: 1–30. At https://www.ophi.org.uk/wp-content/uploads/OPHIWP108.pdf.

Orkoh, E., P.F. Blaauw, and C. Claassen, 2020, Relative effects of income and consumption poverty on time poverty in Ghana, Social Indicators Research, 147(2), 465-499.

Orkoh, E. 2018. Gender welfare effects of regional trade integration on households in Ghana, in World Bank Group and World Trade Organization (eds.), Trade and poverty reduction: *New evidence of impacts in developing countries*, 36-57, World Trade Organization, Geneva.

Oseni, G., M. Goldstein, and A. Utah, 2013. "Gender dimensions in Nigerian agriculture". The World Bank Group. Africa Region Gender Practice, Policy Brief: No. 6, World Bank, Washington, DC. Athttps:// openknowledge.worldbank.org/handle/10986/25459.

Pangaribowo, E.H., N. Gerber and M. Torero. 2013, Food and nutrition security indicators: A review, Centre for Development Research, Policy Brief: Issue 108. At https://www.zef.de/fileadmin/webfiles/downloads/zef_wp/wp108.pdf.

Peterman, A., J.A., Behrman and A.R. Quisumbing. 2014. A Review of Empirical Evidence on Gender Differences in Nonland Agricultural Inputs, Technology, and Services in Developing Countries. In: A. Quisumbing, R. Meinzen-Dick, , T. Raney, A. Croppenstedt, J. Behrman, A. Peterman, (eds) Gender in Agriculture. Springer, Dordrecht. https://doi.org/10.1007/978-94-017-8616-4_7

Prifti, E., S. Daidone, N. Pace and B. Davis. 2019. "Unconditional cash transfers, risk attitudes and modern inputs demand". Applied Econometrics, 53: 100–18.

Rao, S., C.S. Yajnik, A. Kanade, C.H. Fall, B.M. Margetts, A.A. Jackson and B. Desai. 2001". "Intake of micronutrient-rich foods in rural Indian mothers is associated with the size of their babies at birth: Pune maternal nutrition study". The Journal of Nutrition, 131(4): 1217–24.

Rola-Rubzen, M, F. T. Paris, J. Hawkins, and B. Sapkota, 2020. "Improving gender participation in agricultural technology adoption in Asia: from rhetoric to practical action". Applied Economic Perspectives and Policy, 42(1), 113-125.

Sarwar, M.T. and P.C. Anastasopoulos. 2016. "Three-stage least squares analysis of post-rehabilitation pavement performance". Transportation Research Record, 2589(1): 97–109.

Schneider, K. and M.K. Gugerty. 2011. "Agricultural productivity and poverty reduction: Linkages and pathways". The Evans School Review, 1(1): 56–74.

Smale, M., M. Moursi and E. Birol. 2015. "How does adopting hybrid maize affect dietary diversity on family farms? Micro-evidence from Zambia". Food Policy, 52: 44–53. At http://dx.doi.org/10.1016/j.foodpol.2015.03.001

Sraboni, E., H.J. Malapit, A.R. Quisumbing and A.U. Ahmed. 2014. "Women's empowerment in agriculture: What role for food security in Bangladesh?" World Development, 61: 11–52.

Swindale, A. and P. Bilinsky. 2006. "Development of a universally applicable household food insecurity measurement tool: Process, current status, and outstanding issues". The Journal of Nutrition, 136(5): 1449S–52S.

Tadesse, M. 2014. "Fertilizer adoption, credit access, and safety nets in rural Ethiopia". Agricultural Finance Review, 74(3): 290–310. At https://doi.org/10.1108/AFR-09-2012-0049

Takahashi, K. R. Muraoka, and K. Otsuka, 2020. "Technology adoption, impact, and extension in developing countries' agriculture: A review of the recent literature". Agricultural Economics, 51(1), 31-45.

The World Bank. 2014a. "Levelling the field: Improving Opportunities for Women Farmers in Africa" Working Paper No. 86039. World Bank, Washington, D.C. At http://documents1.worldbank.org/curated/en/579161468007198488/pdf/860390WP0WB0ON0osure0date0March0180.pdf

The World Bank. 2014b. "Nigeria agriculture and rural poverty: A policy note". Report No. 78364-NG, World Bank, Washington, D.C. Accessed 20 September 2022. At https://openknowledge.worldbank.org/handle/10986/19324

The World Bank. 2023. World Development Indicators. World Bank, Washington, D.C.:. At https://databank.worldbank.org/source/world-development-indicators

United Nations. 2020. The Sustainable Development Goals Report 2020. At https://unstats.un.org/sdgs/report/2020/The-Sustainable-Development-Goals-Report-2020.pdf

United Nations Conference on Trade and Development (UNCTAD). 2011. *Who Is Benefiting from Trade Liberalization in Cape Verde? A Gender Perspective*. Geneva: United Nations.

Uwakwe, M.O. 2004. "Factors affecting women's participation in the labour force". Journal of Agriculture and Social Research, 4(2): 43–5.

Van den Broeck, G. T Kilic, and J. Pieters, 2023. Structural transformation and the gender pay gap in Sub-Saharan Africa. Plos one, 18(4), e0278188.

Mission

To strengthen local capacity for conducting independent, rigorous inquiry into the problems facing the management of economies in sub-Saharan Africa.

The mission rests on two basic premises: that development is more likely to occur where there is sustained sound management of the economy, and that such management is more likely to happen where there is an active, well-informed group of locally based professional economists to conduct policy-relevant research.

Bringing Rigour and Evidence to Economic Policy Making in Africa

- Improve quality.
- Ensure Sustainability.
- Expand influence.

www.aercafrica.org

Learn More

www.facebook.com/aercafrica

twitter.com/aercafrica

www.instagram.com/aercafrica_official/

www.linkedin.com/school/aercafrica/

Contact Us
African Economic Research Consortium
Consortium pour la Recherche Economique en Afrique
Middle East Bank Towers,
3rd Floor, Jakaya Kikwete Road
Nairobi 00200, Kenya
Tel: +254 (0) 20 273 4150
communications@aercafrica.org