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Food Consumption–Production Adjustments to Economic Crises under Credit Constraints in Nigeria

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Abstract: Poverty and food security risks are increasing in resource-reliant African countries such as Nigeria. Resultantly, policymakers have attempted to use agricultural policy reforms to boost productivity and increase income. However, macroeconomic instabilities complicate agricultural transformation. Consequently, farm households try to diversify food production to mitigate shock-induced nutrition losses. However, credit constraints disrupt the planting of different crops required for adequate diets. This study investigates food security performance during Nigeria's Agricultural Transformation Agenda. It examines whether credit-constrained households adjust food consumption and production differently from credit-unconstrained families. The aim is to uncover the nutritional implications of the adjustments and evaluate the changes such a linkage has undergone during the commercialization initiative. While credit-unconstrained households diversified food production to mitigate food security risks, credit-constrained households were unable to do so. A policy that improves credit access for farm-input purchases appeared to increase food security. However, macroeconomic shocks disrupt the smooth implementation of the policy. Resultantly, policy decisions on the designation of a financial-support scheme that approves credit to households for operating off-farm enterprises must be considered. The business profits could complement farm income to improve family nutrition. Part of the profits could again be plowed back into farm-input needs to enhance agricultural commercialization.

Keywords: agricultural policy; agricultural transformation; consumption–production linkage; dietary diversity; credit constraint; sustainable economic growth

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1. Introduction

Given the growing population of farm households in Sub-Saharan Africa (SSA), agricultural transformation is one of the top strategies for achieving sustainable economic growth and poverty reduction. Modernizing the agricultural sector is vital to diversifying the SSA economies and increasing food production [1]. The growth in agricultural productivity stems from the presence of enabling structural policy reforms and agricultural sector investments [2]. Policymakers in SSA countries have prioritized support for agricultural commercialization in recent years [3], especially in Nigeria given its large farm households and high poverty rates.

The two most recent agricultural sector initiatives in Nigeria include the 2011–2015 Agricultural Transformation Agenda (ATA) and the 2016–2020 Agricultural Promotion Policy (APP) [4,5]. Implementing the policies requires fund transfers from the federal government, through the state and local governments, to the households in more rural areas of the countries. Public revenues from natural resources, particularly the oil and gas rents, which fluctuate with the prices of oil and gas in the world's market [5], are used for the implementation of such policies. This suggests that countries' macroeconomic and fiscal conditions are significant for modernizing farm production and marketing.

Transforming agricultural activities can help grow farms' income, enabling farm households to consume appropriate food for a healthy life. The growing consumption may stimulate aggregate demand and generate sustainable economic growth. However, specializing in a few profitable crops reduces the production diversity of farms and the food self-sufficiency of households [6]. This has implications for nutritional sustainability. To protect families from food security risks of the unfolding macroeconomic downturns, households often reduce farm specialization to sustain food production diversity [7]. This is consistent with the evidence of diversifying food production for improving nutrition adequacy found in SSA countries [8,9]. Using production diversity to mitigate consumption risks is rational due to the non-separability of farm production decisions and household consumption choices consequent upon the dysfunctional markets in SSA [10].

However, given the poverty rates in SSA countries, planting new crops may require external resources, suggesting the relevance of credit access for increasing the food security of households. Again, macroeconomic and fiscal volatilities complicate policy reforms, with the associated food production and welfare consequences [11]. Most studies investigating the production–consumption relationship in Africa [12,13] used cross-sectional household-survey data or short panel data of one or two years. Such research provided little coverage of the macroeconomic and environmental changes surrounding households. These studies suggested income growth and food production diversification for increasing nutritional quality. However, past studies have not explored how households have performed in securing food for their families in recent years. Do the households actually remedy income losses by increasing food production diversity or obtaining loans to insure their consumption?

Studies attempting to measure the food security performance of African farm households are limited. The work by [14] is notable in this area. It documents that the beneficiaries of Nigeria's Growth Enhancement Scheme (GES)—the ATA's key initiative—witnessed improved food nutrition during the period of ATA. Regarding pooled households, it remains unclear whether the increased consumption was due to the policy program or if households took loans to sustain their consumption in periods of economic crisis. Therefore, evidence from such studies has limited usefulness for policymakers, especially in Africa's context with random failure of the credit markets [15].

To better investigate households' food security conditions, this study uses Nigeria's household panel data that span over seven years and coincide with the ATA periods. In doing it, households are separated based on their credit status to study their relative production–consumption response to macroeconomic and fiscal outcomes. Understanding such consumption and production decisions that farm households use to mitigate food insecurity risks at any credit condition will serve agricultural policy purposes. One way to explain such non-separable decisions is to examine households' dietary changes associated with their consumption and production choices. The aim of this study is to investigate precisely such a link in Nigeria's context. To do it, we address the research questions thus: (1) Do farm households adjust food consumption and production alike regardless of their credit status? (2) Is there a connection between credit positions and dietary implications of such adjustments? (3) How has such linkage changed during the GES agricultural initiative? The empirical answers may be useful for agricultural policymakers in Africa, especially in countries where nutrition-sensitive agricultural policy is a priority. This study's implications will again be relevant to many other countries in Asia and Latin America, facing issues such as lack of access to credit and high poverty rates.

The section describes the ATA's initiative and households' credit status and its linkage with dietary diversity. Thereafter, data construction, descriptive evidence, and the estimation technique are discussed. Immediately following these are interpretations and implications of results, the GES evaluation, and then the conclusions.

2. Literature Review

2.1. ATA and Credit Status of Households in Nigeria

Nigeria is Africa's largest crude oil producer with oil and gas rents as its main revenue source. The share of oil and gas in the country's GDP is volatile and hovered around 3% and 18% between 2011 and 2018 [16]. During that period, agriculture's share in GDP was consistently 21%, and employment declined from 40.2% to 36.6% [17]. However, Nigeria's annual spending on food imports increased to US$6.1 billion in 2018 from US $3.2 billion in 2011 [17]. Nevertheless, about 86.4 million persons in 2017–2019 remained food-insecure [18].

Consequently, the Federal Ministry of Agriculture and Rural Development (FMARD) believed that through agricultural commercialization, locally produced food items could substitute the imported ones, thereby reducing spending on food imports. Additionally, it generates foreign exchange via farm exports and increases food security by making food items accessible to the people [5]. Resultantly, the ATA was initiated in 2011 to increase farm productivity, efficiency, and effectiveness [4]. The ATA enlisted a fresh federal farm scheme on the basis that agriculture has to be a self-surviving venture that is owned and managed by private individuals. Prior to 2011, the world's oil prices rose and Nigeria's GDP growth increased. However, oil prices became stable in 2011 and lower petroleum was produced, reducing oil revenues. Resultantly, Nigeria's economic growth reduced between 2011 and 2012 before it increased above 6% between 2013 and 2014 [16]. During 2015–2016, oil prices fell, Nigeria's terms of trade deteriorated, and oil revenues decreased. These macroeconomic fluctuations increased fiscal deficits starting from 2013 [19].

The GES is the ATA's primary initiative through which FMARD issued e-wallets to over 12 million farmers from 2011 to 2014 to buy inorganic fertilizer at subsidized cost from retailers [11]. It appears that the ATA largely influenced the food production and consumption reactions of families via farm-input supports outlined in the GES. The GES extended earlier reforms in the fertilizer industry that narrowed the government's involvement in inorganic fertilizer's procurement and distribution to alter dissemination mediums of the private sector [14]. During the agricultural input-support schemes that existed before the GES, subsidized fertilizers were physically shared with farm households by public officials [14]. In essence, the e-wallets that the government provided to farm households as a subsidy to purchase urea fertilizer or NPK and enhanced seeds were a substantial improvement from the prior agricultural input-supply interventions. However, input market enhancement was beneficiary to a segment of farmers because of complexities in the policy administration between the central government and the states [5], despite the successful evidence existing for the ATA. Other fertilizer assistance to farmers accompanied the ATA because private farm input markets were strengthened; however, its implementation was reduced under the APP as macroeconomic volatilities worsened [5]. In addition to the increasing macroeconomic shocks at that time, several farm households had binding credit constraints.

Table 1 presents credit questionnaire responses in the Nigeria general household survey (GHS) panel. Roughly 11.7% of Nigerian farm households in wave three, which increased to 27.9% in wave four, were credit constrained, as they needed a loan but did not apply for it (a-1). Additionally, the number of households that were constrained by their inability to repay loans decreased from approximately 64.5% in wave three to roughly 47% in wave four (b-1). However, the number of households that could obtain loans if they wanted to, increased from about 6.1% to around 9.8% (b-2). The credit-constrained households spent less than the credit-unconstrained households in the third wave; however, the increase in the expenditure of the former was more than that of the latter in the fourth wave.

Table 1. Stylized facts about household credit status provided by respondents in Nigeria's GHS-Panel.

				Wave 3 ***			Wave 4 ***		
(a) Out of Total Number of Households Surveyed	**Wave 3**	**Wave 4**	**Credit Status**	**Exp**	**dds**	**fvs**	**exp**	**Dds**	**Fvs**
(a-1) Households that needed a loan but did not applied for it	0.1168	0.2791	constrained	5.05	8.51	16.2	5.57	8.82	17.1
(a-2) Households that did not need a loan and did not apply for it *	0.7066	0.5683							
(b-1) Out of (a-2), those that had low liquid assets as in (f-1)	0.6454	0.4701	constrained	4.88	7.83	13.9	5.62	8.28	15.3
(b-2) Those that had sufficiently high liquid assets as in (f-2)	0.0612	0.0982	not constrained	5.15	8.41	15.4	5.56	8.83	17.4
(a-3) Households that applied for and received loans	0.1674	0.1186							
(c-1) Those that received the amount they applied for **	0.0916	0.0638	not constrained	5.04	8.69	16.0	5.79	8.59	16.2
(c-2) Those that received less than the amount requested	0.0757	0.0548	constrained	5.16	9.03	17.5	6.00	9.66	19.0
(c-3) Households with approved but yet to receive loans	0.0092	0.0049	constrained	5.20	8.00	13.8	6.02	10.2	19.4
(c-4) Households whose loans were not approved	0.0106	0.0221	constrained	4.95	7.98	14.4	5.60	7.89	15.6
(a-4) Households that do not own any asset	0.7824	0.7559	constrained	4.99	8.21	15.0	5.64	8.57	16.2
(a-5) Households that own some assets	0.2176	0.2441							
(f-1) Those with assets less than the mean asset of households	0.8715	0.8143	constrained	4.93	8.04	14.5	5.63	8.49	15.9
(f-2) Those whose liquid assets are at least equal to the mean	0.1285	0.1857	not constrained	5.23	8.70	16.3	5.69	9.24	18.6

* partly self-selected due to inability of paying back the potential amount of loans ** partly reporting enough amount of loan due to self-selection *** sample average expenditure (exp), dietary diversity score (dds), and food variety score (fvs) for the various credit classification of households.

Furthermore, roughly 6.4% of households in wave four, which fell from 9.2% in wave three, witnessed less difficulty in obtaining loans (c-1). Moreover, roughly 7.6% of households received a lesser loan amount than requested in wave three compared to 5.5% in wave four (c-2). Households that managed to obtain the entire loan amount sanctioned to them were not credit constrained unlike those that received a lesser amount than they had applied for. The credit-constrained households spent more than those that were credit unconstrained and also better diversified their diets. Moreover, roughly 0.9% and 0.5% of households in wave three and wave four, respectively, got approval but were yet to receive loans (c-3). Moreover, 1.1% of households in wave three and 2.2% in wave four were denied loans (c-4). These indicate that around 6.34% of households were not credit constrained, whereas about 8.9% were credit constrained based on the past three-year information from the survey.

Inadequate collateral prevented most households from applying for a loan [20,21]. Compared to 2018, there was a decrease in the value of guaranteed loans provided by the agricultural credit guarantee scheme fund (ACGSF) to the extent of NGA N307,594 in 2019 [22]. Following [23,24], self-selected households and those that were denied loans are defined as credit constrained. However, the credit status of households who declared no need for loans for having sufficient income was defined on the basis of their liquid assets (b-1; b-2), in line with [25]. (Some households might become credit-constrained if they witness income shocks.) Notice that Table 1 shows credit information in wave three and wave four because the two waves provide better coverage of credit data due to upgrades in the survey questionnaires [26].

2.2. Dietary Diversity and Credit Constraint's Linkage

Several studies in Africa's context explain dietary diversity's linkage with income changes and food production diversity. The studies in [12,27] focused on Malawi; [28] on Ethiopia, Malawi, and a few other countries; and [13] on Kenya. Studies by [29] on Ethiopia; [30] on Malawi, Tanzania, and Uganda; and [8,9,31] on Nigeria are notable.

The study in [8] estimated Nigeria GHS-Panel data to find that producing 10% more crops led to 2.4% more diverse foods consumed. Using the same database and fixed effects (FE) method, [9] confirmed that dietary diversity increased by roughly 0.019 units consequent upon one additional crop produced. These studies used cross-section data, reflecting inadequate coverage of changes in the environments that households live in. However, [6] on Ghana and [14] on Nigeria are notable exceptions, as these studies utilized panel data that spanned over seven years. The authors in [14] estimated FE models with three dietary indicators: dietary diversity score (DDS), food variety score (FVS), and per capita calorie intake. Similarly, planted food crops and crop groups are indicators of crop production diversity, with per capita expenditure as a surrogate for income.

Their study reported that a 10% increase in income resulted in a 0.24-unit increase in food items consumed and a 0.09-unit increase in food groups consumed. An additional crop planted increased food items consumed by 0.11-units and food groups consumed by 0.09-units. The estimate of a 0.11 increase in food items consumed mirrors the result of [6], which used combined data from 2005 to 2006 and 2012 to 2013 from the Ghana living standard survey (LSS) to analyze the FE model. The study [14] found that any additional food consumed out of a diversified crop was reduced by the related income variability.

However, food production–consumption evidence for Africa remained mixed. For instance, after FE estimation of Tanzanian data, [32] found an insignificant association between crop production indicator of crop species count and the dietary diversity measure of food consumption score. A similar result was found by [33] between crop production and micronutrient consumption. Another subset of research found that access to credit markets diversifies diets more than crop production diversity. Using the instrumental variable (IV) method and Ghana LSS dataset, [34] found that aside from income, a positive association also occurs between access to credit and dietary diversity. The work by [24] classified households by their credit status and analyzed the Rwandan dataset, and [35] emphasized how water and energy are interrelated to increase the food sustainability of households in SSA countries.

They found that credit-unconstrained households had roughly 17% average growth in farm output. Moreover, credit-constrained households had approximately 6.3% lesser chance of operating off-farm businesses, suggesting that credit constraints affect income. This corroborates evidence by [23], which revealed that consumption and production decisions are adversely affected by credit constraints. Results from the switching model by [36] predicted some 60% growth in output by reducing credit constraints in Ethiopia.

Given that credit constraints affect income and food production, how do households' decisions vary with their credit positions? Moreover, is there a link between credit status and dietary implications of such decisions? The empirical analyses below emphasize these issues.

3. Data Construction

This study used the Nigeria GHS panel as the database for empirical analyses [26]. Data were collected from roughly 4167 households that mostly farm small areas of land, after planting periods and the following harvest. The objective was to incorporate crop planting and harvest information within an agricultural year [37]. There are, presently, four panel waves: wave one, 2010–2011; wave two, 2012–2013; wave three, 2015–2016; and wave four, 2018–2019. However, only 1507 households among those originally interviewed in wave one through wave three were assessed in wave four because of insecurities in some regions at that time [26]. Therefore, to investigate this study's hypotheses and simplify comparison with related studies, the first three waves were focused on.

Farm households, defined as those that produce crops, rear livestock, and undertake other agricultural activities [37] were the broad focus of analyses. Following [14], this wider sample was narrowed to include households that cultivated farmlands and consumed food items at home. This gave a balanced panel sample of 2336 households, amounting to 56.1% of the complete balanced panel sample. While 727 households were credit constrained by the inability to obtain loans, 825 households received the full amount of loans they requested and so were not credit constrained. These gave panel data of 1552 households in the loan-application classification.

Moreover, 88 households that partly received loans and 322 households with no loan application had low assets and were credit constrained. Adding these to the previously credit-constrained households gave a balanced panel of 1137 households with binding credit constraints in the joint classification. Likewise, 307 self-selected households and 67 households with incomplete loan receipts, had substantial liquid assets. These, together with the previous credit-unconstrained households, constituted the 1199 households with unbinding credit constraints in the mixed separation. Table 2 summarizes the sample classifications.

Table 2. Sample classification of households using loan-application questionnaire and liquid assets per capita.

	Refused	**Accepted**		**Why No Application?**		**Total**
		Partly	**Fully**	**Satisfied**	**Self-Selected**	
applying for loans	727	980				1707
		155	825			
not applying for loans				629		629
				435	194	
	Constrained HHs			Not constrained HHs		
		value of assets per capita		value of assets per capita		
		less than average	not less than average	less than average	not less than average	
		88	67	322	307	
Total		Constrained HHs	Not constrained HHs	Constrained HHs	Not constrained HHs	2336

Note: There are 727 households that were refused loans and so were credit-constrained and 825 households that received full amount of loans they requested and then were credit-unconstrained. Again, 88 households out of those that partly received loans and 322 households among those that had no need of additional income had low liquid assets and belong to the credit-constrained group. Similarly, 67 households with partial loan receipt and 307 non-participants in the credit market owned sufficiently high liquid assets and so had unbinding credit constraints.

Data were constructed for dietary diversity indicators and the calorie intake indicator. Similar to other studies [6,9], the dietary indicators used were FVS and DDS, with calorie intake per capita as the calorie indicator. In predicting dietary quality and measuring food security, dietary diversity was used [38]. To construct dietary indicators, food items and food groups consumed in the consumption modules were counted. Before counting FVS, the same food recorded for various product forms was unified. Food grouping by [39] was adopted for DDS.

In line with [8,12], food crop variety (FCV) and food crop group (FCG) were used as indicators for food production diversity. Similar to FVS and DDS, food crops and crop groups planted in the agricultural modules were counted as measures for FCV and FCG, respectively. For the income variable which was proxy by the amount of expenditure, food and non-food expenditure of households were aggregated, following [40]. The income data was from the post-planting and post-harvest rounds. Data on food consumption and characteristic variables were from the post-harvest rounds. Food production data was gathered from the post-planting rounds.

Descriptive Evidence

Table 3 presents descriptive analyses of key variables in the mixed classification. Average dietary diversity increased over the survey periods as FVS and DDS show. Credit-constrained households earned a little more income and consumed more food items and food groups than the credit-unconstrained households in wave one. In wave two, the income of the credit-constrained households fell lower than that of the credit-unconstrained households. Meanwhile, the former allowed calorie consumption to fall below that of the latter but sustained an increase in dietary diversification. The income of the credit-constrained households rose in wave three but was lower than that of the credit-unconstrained households. The former increased both calorie consumption and food diversity more than the latter in wave three.

Table 3. Summary statistics for the key variables.

Variables	W1:2010–2011		W2:2012–2013		W3:2015–2016		Compounded Annual Growth Rate		
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**W1–W2**	**W2–W3**	**W1–W3**
PANEL A: Credit-constrained households									
Food variety score (FVS) (max. = 60)	13.2	4.35	14.0	4.62	15.1	4.90	1.48	1.52	1.94
Dietary diversity score (DDS) (max. = 12)	7.69	1.96	7.93	1.93	8.24	1.87	0.77	0.77	0.99
Calorie intake per capita (CIC) (kcal/day; log)	6.90	0.93	6.29	1.13	7.57	0.72	−2.29	3.77	1.33
Total expenditure per capita (EXP) (₦/day; log)	5.02	0.70	4.92	0.70	4.98	0.65	−0.50	0.24	−0.11
Food crop variety (FCV) (max. = 41)	3.34	1.61	3.43	1.56	3.37	1.53	0.67	-0.35	0.13
Food crop groups (FCG) (max. = 7)	2.24	0.96	2.28	0.95	2.19	0.87	0.44	−0.80	−0.32
PANEL B: Credit-unconstrained households									
Food variety score (FVS) (max. = 60)	12.9	4.30	13.7	5.08	14.8	4.88	1.52	1.56	1.98
Dietary diversity score (DDS) (max. = 12)	7.57	1.97	7.83	2.03	8.18	1.89	0.85	0.88	1.11
Calorie intake per capita (CIC) (kcal/day; log)	6.90	0.74	6.39	1.16	7.57	0.72	−1.90	3.45	1.33
Total expenditure per capita (EXP) (₦/day; log)	5.00	0.71	4.96	0.71	5.00	0.67	−0.20	0.16	0.00
Food crop variety (FCV) (max. = 41)	3.27	1.57	3.43	1.52	3.42	1.53	1.20	−0.06	0.64
Food crop groups (FCG) (max. = 7)	2.15	0.90	2.23	0.88	2.19	0.87	0.92	−0.36	0.26

Note: There are 1137 credit-constrained households and 1199 credit-unconstrained households per wave. Again, calorie intake per capita has 1030 credit-constrained households and 1082 credit-unconstrained households. In each panel, the first three variables are dietary diversity indicators and the last two the food production indicators. The expenditure is then an income variable.

Contrarily, credit-unconstrained households increased food items and food groups consumed by almost the same annual rate throughout the survey years as the compounded annual growth rate (CAGR) for FVS and DDS show. However, a decline in income caused credit-constrained households to increase food items consumed at a slower rate between wave one and wave two. When income rose, credit-constrained households maintained the same increment in food variety as the credit-unconstrained households between wave two and wave three, although both the categories increased food groups consumed at almost the same rate. Summary statistics for other variables are in the Appendix A, Table A3.

4. Methodology

Consider a dietary diversity FE model developed by [14]:

$$y_{hast} = \alpha_{h|a|s} + \beta_1 x_{hast} + \beta_2 d_{hast} + \beta_3 d_{hast} \times x_{hast} + F'_{hast}\gamma + Z'_{hast}\delta + \varnothing_t + \varepsilon_{hast},$$

where subscripts h, a, s, and t index the household, the local government area, the state, and the time period, respectively. This relates dietary diversity (y_{hast}) to household income (x_{hast}); food production diversity (d_{hast}); association between food production diversity and income growth ($d_{hast} \times x_{hast}$); household farm characteristics (F_{hast}); and household demographics (Z_{hast}). Table 3 provides the details of the main variables. In addition, the model allows for the presence of two-way fixed effects ($\alpha_{h|a|s}$ and $\varnothing_t$) to capture a heterogeneity specific to a household and a time effect across households.

In the FE model, it is assumed that farm production decisions and household consumption decisions have homogeneous effects on nutritional quality across households. This hypothesis, in Africa's context, especially in Nigeria with idiosyncratic failure of credit markets [41], is severely restrictive. As originally presented (in Table 1), some households experienced income declines but were unable to use credit over the sample periods [26]. The adverse effect of credit constraints on consumption compositions is well documented [23]. Resultantly, differences in dietary diversities consequent upon heterogenous production-consumption reactions are expected between households that are credit constrained and those that are not.

In addition, the FE model captures genuine unobservables by enabling fixed effects but does not control for contingent unobservables due to potential omitted variables. For example, conflicts between herdsmen and farmers, which can lead to the destruction of planted food crops and the death of farm animals, can influence dietary diversity. However, past evidence has shown that endogeneity is not a serious problem in this area of study, particularly in Nigeria [9,14]. Furthermore, instrumenting for the endogenous credit separation of households minimizes the endogeneity problem in our case. Welfare loss due to types of accidents (such as the herders–farmers clash) could be insured if credit markets function properly. However, without well-working credit markets, such unobservables are sources of creating credit constraints, which leads to correlations between welfare (proxied by dietary diversity) and credit constraint status (captured by the error term in the FE model) of a household.

The possible presence of credit constraints for some households leads us to the modified FE model, the switching regression model [42], which can control for the heterogeneity and endogeneity in consumption–production relations due to credit constraints. The model consists of the following three equations:

$$d_{it} = 1\{z'_{it}\gamma + c_{d,i} + v_{it} > 0\}, \tag{1}$$

$$y_{1,it} = x'_{it}\beta_1 + c_{1,i} + u_{1,it}, \tag{2}$$

$$y_{0,it} = x'_{it}\beta_0 + c_{0,i} + u_{0,it}, \tag{3}$$

where i represents a household at a local government area in a state (the triple subscript in [14] is reduced to a single subscript for simplicity), and t represents a time period. The first equation is the selection equation; if a household is classified into the credit-constrained group, the dependent variable d_{it} takes the value of 1. Otherwise, it is assigned a value of 0. The variable z'_{it} includes observable determinants of households' credit status, which includes the liquid asset information. The construction of the dependent variable d_{it} was discussed in Section 2. $c_{d,i}$ is a fixed effect and v_{it} is the error term in this equation.

The second and third equation represents production–consumption relations for the credit-constrained and the credit-unconstrained households, respectively. The dependent variables, $y_{1,it}$ and $y_{0,it}$, are latent variables of dietary diversity for each credit status group, x'_{it} is a vector of explanatory variables, which includes household income, food production diversity, the association between food production diversity and income growth, household farm characteristics, and household demographics. $c_{1,i}$ and $c_{0,i}$ are fixed effects, and $u_{1,it}$ and $u_{0,it}$ are error terms in Equations (2) and (3), respectively.

The difference between coefficient vectors β_1 and β_0 captures heterogeneous production-consumption relations across credit status groups. Recall that the error term v_{it} in (1), $u_{1,it}$ in (2), or $u_{0,it}$ in (3) may be correlated due to uninsured occasional welfare loss events, which leads to a correlation between credit status and household welfare through observed and unobserved factors in these equations.

The researchers in [43] proposed an estimation method of the above switching regression model with fixed effects using a control function (CF) approach. The observed dependent variable is given as:

$$\begin{aligned} y_{1,it} &= d_{it}y_{1,it} + (1-d_{it})y_{0,it} \\ &= d_{it}\left(x'_{it}\beta_1 + c_{1,i} + u_{1,it}\right) + (1-d_{it})\left(x'_{it}\beta_0 + c_{0,i} + u_{0,it}\right) \\ &= x'_{it}\beta_0 + d_{it}x'_{it}(\beta_1 - \beta_0) + p_{it} + d_{it}q_{it}, \end{aligned}$$

where $p_{it} \equiv c_{0,i} + u_{0,it}$ and $q_{it} \equiv c_{1,i} - c_{0,i} + u_{1,it} - u_{0,it}$. When these compounded error terms are projected onto the space spanned by all explanatory variables over the sample period, they consist of two terms: the correlated part with all explanatory variables and the uncorrelated one. Further, following the Mundlak approach adopted by [43], the correlated parts are assumed to be linear functions of the sample averages of all explanatory variables, $p_{it} = \bar{x}'_i\theta_p + \varepsilon_{p,it}$ and $q_{it} = \bar{x}'_i\theta_q + \varepsilon_{q,it}$, where the standard deviation of $\varepsilon_{p,it}$ $(\varepsilon_{q,it})$ is σ_p (σ_q). Therefore, the above observed dependent variable can be written as:

$$\begin{aligned} y_{it} &= x'_{it}\beta_0 + d_{it}x'_{it}(\beta_1 - \beta_0) + \left(\bar{x}'_i\theta_p + \varepsilon_{p,it}\right) + d_{it}\left(\bar{x}'_i\theta_q + \varepsilon_{q,it}\right) \\ &= x'_{it}\beta_0 + d_{it}x'_{it}(\beta_1 - \beta_0) + \bar{x}'_i\theta_p + d_{it}\bar{x}'_i\theta_q + \left(\varepsilon_{p,it} + d_{it}\varepsilon_{q,it}\right) \end{aligned} \tag{4}$$

Similarly, when we assume that the compound error term in the selection Equation (1) can be decomposed into the correlated and the uncorrelated parts with all explanatory variables and that the correlated part can be summarized as the Mundlak type linear function, the compound error term is approximated as $c_{d,i} + v_{it} = \bar{z}_i\theta_r + \varepsilon_{r,it}$ (the standard deviation of $\varepsilon_{r,it}$ is normalized to one for identification) and the selection equation with a fixed effect can be rewritten as follows:

$$d_{it} = 1\left\{z'_{it}\gamma + \bar{z}_i\theta_r + \varepsilon_{r,it} > 0\right\}. \tag{5}$$

Next, assuming that the joint normality of the error terms, $\varepsilon_{p,it}$ and $\varepsilon_{r,it}$ ($\varepsilon_{q,it}$ and $\varepsilon_{r,it}$) with a correlation coefficient ρ_p (ρ_q) and all error terms are independent of $x_{i1}, \ldots, x_{iT}$ and $z_{i1}, \ldots, z_{iT}$, the control functions for the Equation (4), or the generalized residual in (4) is given as, using the results $E\left[\varepsilon_{p,it}\middle|d_{it}\right] = \rho_p\sigma_p h_{it}$ and $E\left[\varepsilon_{q,it}\middle|d_{it}\right] = \rho_q\sigma_q h_{it}$,

$$E\left[\varepsilon_{p,it} + d_{it}\varepsilon_{p,it}\middle|d_{it}\right] = \rho_p\sigma_p h_{it} + \rho_q\sigma_q d_{it}h_{it}, \tag{6}$$

where $h_{it} \equiv h(d_{it}) = d_{it}\frac{\phi\left(z'_{it}\gamma+\bar{z}_i\theta_r\right)}{\Phi\left(z'_{it}\gamma+\bar{z}_i\theta_r\right)} - (1-d_{it})\frac{\phi\left(z'_{it}\gamma+\bar{z}_i\theta_r\right)}{1-\Phi\left(z'_{it}\gamma+\bar{z}_i\theta_r\right)}$.

Finally, combining Equation (4) with Equation (6),

$$\begin{aligned} y_{it} &= x_{it}'\beta_0 + d_{it}x_{it}'(\beta_1 - \beta_0) + \overline{x}_i'\theta_p + d_{it}\overline{x}_i'\theta_q + \rho_p\sigma_p h_{it} + \rho_q\sigma_q d_{it}h_{it} \\ &+ \left(\varepsilon_{p,it} + d_{it}\varepsilon_{q,it}\right) - E\left[\left(\varepsilon_{p,it} + d_{it}\varepsilon_{p,it}\right)\middle| d_{it}\right] \end{aligned}$$

To make the estimation of this equation feasible, we first estimate γ and θ_r using the probit model and constructing the fitted value of h_{it}, $\hat{h}_{it} \equiv d_{it}\frac{\phi\left(z_{it}'\hat{\gamma}+\overline{z}_i\hat{\theta}_r\right)}{\Phi\left(z_{it}'\hat{\gamma}+\overline{z}_i\hat{\theta}_r\right)} - (1 - d_{it})\frac{\phi\left(z_{it}'\hat{\gamma}+\overline{z}_i\hat{\theta}_r\right)}{1-\Phi\left(z_{it}'\hat{\gamma}+\overline{z}_i\hat{\theta}_r\right)}$. Then, we run a linear regression model to obtain the coefficient estimates,

$$y_{it} = x_{it}'\delta_1 + d_{it}x_{it}'\delta_2 + \overline{x}_i'\delta_3 + d_{it}\overline{x}_i'\delta_4 + \delta_5\hat{h}_{it} + \delta_6 d_{it}\hat{h}_{it} + error \quad (7)$$

Therefore, to reproduce the coefficient of the unconstrained group, β_0, we know $\beta_0 = \delta_1$. The coefficient of the constrained group is $\beta_1 = \delta_1 + \delta_2$. The significance of δ_5 and δ_6 is corresponding to the exogeneity test of the selection equation. In the following estimation results, heteroskedasticity-robust standard error estimates are used.

5. Coefficient Estimates and Interpretation

Equations (2) and (3) were estimated by the FE method, and results on FVS and DDS are reported in Tables 4 and 5, respectively. In the tables, columns (i)–(iii) used the loan-classification panel dataset, and columns (iv)–(vi) estimated loan-and-asset classification. Clearly, column (i) and column (iv) do not account for credit constraints and pooled households in the relevant classifications. However, columns (ii) and column (v) show results for credit-unconstrained households. Moreover, columns (iii) and column (vi) report results for households with binding credit constraints. Results are robust across the specifications. As expected, crop production diversity has a positive and significant relation with dietary diversity.

Table 4. Estimation results of the household FE model for the dietary diversity indicator [a].

	Food Variety Score (FVS)					
	Classification on Basis of Loans			Loan and Assets' Classification		
Model Specifications	**(i)**	**(ii)**	**(iii)**	**(iv)**	**(v)**	**(vi)**
Panel A						
Food crop variety	0.212 ***	0.227 ***	0.214 ***	0.170 ***	0.168 ***	0.183 ***
	(0.045)	(0.063)	(0.066)	(0.038)	(0.053)	(0.053)
Expenditure per capita (log)	2.576 ***	2.176 ***	3.100 ***	2.598 ***	2.287 ***	2.950 ***
	(0.119)	(0.152)	(0.189)	(0.099)	(0.133)	(0.146)
Panel B						
Food crop variety	0.188 ***	0.198 ***	0.195 ***	0.152 ***	0.149 ***	0.165 ***
	(0.046)	(0.064)	(0.067)	(0.038)	(0.055)	(0.054)
Expenditure per capita (log)	2.556 ***	2.165 ***	3.081 ***	2.586 ***	2.279 ***	2.927 ***
	(0.119)	(0.151)	(0.190)	(0.099)	(0.133)	(0.146)
Panel C						
Food crop variety	0.474 *	0.586	0.440	0.698 ***	1.047 ***	0.412
	(0.288)	(0.392)	(0.428)	(0.239)	(0.346)	(0.333)
Expenditure per capita (log)	2.749 ***	2.425 ***	3.249 ***	2.952 ***	2.876 ***	3.093 ***
	(0.226)	(0.300)	(0.347)	(0.186)	(0.263)	(0.266)
Food variety × expenditure	−0.057	−0.079	−0.049	−0.110 **	−0.181 ***	−0.050
	(0.057)	(0.079)	(0.084)	(0.048)	(0.069)	(0.066)

[a] The sample has 1552 pooled households (column (i)), 825 credit-unconstrained households (column (ii)), and 727 credit-constrained households (column (iii)) per survey wave in the loan classification. There are 2336 households (column (iv)), 1199 households with unbinding credit constraints (column (v)), and 1137 households with binding credit constraints (column (vi)) per wave in the loan and asset classification. Each regression accounts for household demographics and household and time-fixed effects. Estimation in Panel B further controls for farm characteristics, and Panel C incorporates the association between food production diversity and household income. Standard errors (in parentheses) are clustered at the household level. ***, **, * Coefficient is statistically significant at the 1%, 5%, and 10% level, respectively.

Table 5. Estimation results of the household FE model for the dietary diversity indicator [b].

	Dietary Diversity Score (DDS)					
	Classification on Basis of Loans			Loan and Assets' Classification		
Model Specifications	**(i)**	**(ii)**	**(iii)**	**(iv)**	**(v)**	**(vi)**
Panel D						
Food crop groups	0.142 ***	0.120 **	0.166 ***	0.133 ***	0.110 **	0.159 ***
	(0.035)	(0.052)	(0.048)	(0.030)	(0.043)	(0.042)
Expenditure per capita (log)	1.017 ***	0.874 ***	1.211 ***	1.048 ***	0.898 ***	1.219 ***
	(0.052)	(0.070)	(0.080)	(0.044)	(0.060)	(0.064)
Panel E						
Food crop groups	0.124 ***	0.088 *	0.157 ***	0.116 ***	0.087 **	0.148 ***
	(0.036)	(0.053)	(0.050)	(0.030)	(0.044)	(0.042)
Expenditure per capita (log)	1.008 ***	0.873 ***	1.208 ***	1.042 ***	0.897 ***	1.212 ***
	(0.052)	(0.069)	(0.080)	(0.044)	(0.060)	(0.065)
Panel F						
Food crop groups	0.587 ***	0.478	0.798 ***	0.663 ***	0.565 **	0.780 ***
	(0.217)	(0.314)	(0.305)	(0.183)	(0.268)	(0.252)
Expenditure per capita (log)	1.214 ***	1.042 ***	1.505 ***	1.282 ***	1.102 ***	1.495 ***
	(0.109)	(0.151)	(0.161)	(0.090)	(0.128)	(0.128)
Food groups × expenditure	−0.093 **	−0.079	−0.127 **	−0.110 ***	−0.096 **	−0.127 **
	(0.043)	(0.063)	(0.060)	(0.036)	(0.053)	(0.050)

[b] The sample has 1552 total households (model 1), 825 credit-unconstrained households (model 2), and 727 credit-constrained households (model 3) per survey wave in the loan classification. There are 2336 sampled households (model 4), 1199 households with unbinding credit constraints (model 5), and 1137 households with binding credit constraints (model 6) per wave in the loan and asset classification. Each regression accounts for household demographics and household and time-fixed effects. Estimation in Panel B further controls for farm characteristics with Panel C additionally incorporating the association between food production diversity and household income. Standard errors (in parentheses) are clustered at the household level. ***, **, * Coefficient is statistically significant at the 1%, 5%, and 10% level, respectively.

As Table 4 shows, households that produced one additional crop consumed an average of 0.20 more food items, irrespective of credit status. This suggests that households transfer farm produce such as seeds across agricultural seasons, enabling additional crop production even in periods of binding credit constraints. For credit-unconstrained households, one more crop produced led to, on average, 0.23 improved quality of diets (column ii, panel A). The size of this estimate is larger than that obtained by [14] but mirrors results found by [8]. Accounting for farm variables in Table 5 shows that producing one new crop enabled credit-unconstrained households to consume an average of 0.09 increased food groups (columns ii and v, panel E). This is consistent with the result found by [14] and approximates results by [6]. Consequently, ignoring credit constraints while investigating the effect of diversifying food production on dietary diversity is consistent with estimating the effect for households that are not credit constrained. Accordingly, one new crop produced is as good as 0.10 increased consumption of food groups by credit-unconstrained households (columns ii and v), just as it is by the pooled households (columns i and iv) (Table 5, panels (D)–(E)). However, for credit-constrained households, producing a new crop increased food groups consumed by, on average, roughly 0.20 (columns iii and vi).

Again, income-dietary diversity's estimate follows "a priori" expectation of a positive and significant relationship. This suggests that income changes generate the same direction as changes in dietary diversity. As Table 4 presents, a 10% increase (decrease) in the income of households that had unbinding credit constraints led to roughly ($2.425 \times \ln(100 + 10)/100$) or 0.23 average increase (decrease) in the food items consumed (column ii, panel C). This is consistent with the result in [14]. However, it is shown that the same percentage point change in income of the credit-constrained households generates approximately 0.31 average change in the food items consumed (column iii, panel C). This is clearly larger than the effect for the credit-unconstrained group, and this result remained unchanged after verifying it with the mixed classified panel dataset (columns (iv)–(vi)). It is again shown that income has an average mitigation effect of roughly 0.01 and 0.02 for every positive association between crop production diversity and dietary diversity of the pooled and credit-unconstrained households, respectively (columns (iv)–(v)). This result, which is consistent with [14], does not hold for households with binding credit constraints (column vi). Ignoring credit constraints produces results that lie in-between estimates for the two groups but are closer to the result for the unconstrained credit group than that of the constrained credit group.

The effect of income on DDS is shown in Table 5. While households without difficulty in accessing credit markets were consuming an average of 0.08 more food groups for a 10% income growth (column ii, panel E), those with difficulty were eating about 0.12 more food groups, on average (column iii). The percentage points change yielded roughly 0.10 improvement in the quality of diets consumed by the pooled households (column i). The coefficient estimate for the credit-unconstrained households again mirrors results by [14]. By implication, binding credit constraints affect dietary diversity. This suggests that ignoring credit constraints while investigating the association between income and dietary diversity yields misleading evidence for households with binding credit constraints. While such results retain relevance for households that do not face binding credit constraints, this study further produces evidence for credit-constrained households.

Clearly, a vast majority of credit-constrained households were hand-to-mouth and impatient in their consumption decisions. When income grew, they likely spent much of the increase on consumption. In periods of income decline, they consumed fewer food items and food groups. In line with [44], credit-constrained households adjusted spending to a larger degree through food items and food groups consumed. Any credit-constrained household was, by implication, at a kink of the intertemporal budget constraint and its marginal utilities coincided with intertemporal-food prices as slack conditions [45]. Conversely, credit-unconstrained households increased (decreased) food items and food groups consumed by a smaller margin than credit-constrained households when income increased (decreased). This is consistent with the precautionary saving behavior because it appears that credit-unconstrained households consumed more food items and food groups when income increased, but still saved part of the increased income for later consumption.

Note that error terms in Equations (2) and (3) reflect neglected heterogeneity, which likely includes factors that are correlated with credit status. With such correlated factors, endogenous classification is required. Resultantly, the endogenous switching regression (ESR) Equation (7) was estimated, and the results are reported in Tables 6 and 7. Column (i) and column (iv) control for households demographics, while column (ii) and column (v) account for farm variables. Column (iii) and column (vi) then test for mitigation effect. Meanwhile, panel *G* and panel *I* report the main results and panel *H* and panel *J* present credit constrained-induced behaviors. Table 6 reports that, on average, households ate 0.26 more food items for any additional crop produced (column i, Panel G). Moreover, Table 7 shows that producing one new crop enabled households to consume approximately 0.13 increased food groups, on average (column i, Panel I). The results on FVS mirror [8]'s results, and those on DDS echoed [14]'s results.

Table 6 shows that regardless of credit status, households that witnessed a 10% income change made about 0.22 adjustments in food items consumed (column i, Panel G). Aside from this, credit-constrained households consumed 0.09 additional food items (column i, Panel H). Likewise in Table 7, the percentage point change yielded roughly 0.09 change in food groups (column i, Panel I), around the sample average. Then again, credit-constrained households consumed 0.03 more food groups than credit-unconstrained households (column i, Panel J). Unlike the FEs, results from CF show that mitigation effects do not hold. Again, some FE coefficients lost significance in the CF. Additionally, estimated coefficients on most control variables show statistical significance only in the FE estimations. For example, families that engaged in off-farm employment consumed 0.34 (0.16) more food items (food groups) than those that did not (see the Appendix A, Table A4). This suggests that households that were involved in non-agricultural jobs accessed food markets more frequently than those that could not; the former probably bought food for their families when going to and returning from work. Similarly, households that owned a poultry farm ate 0.57 increased food items and 0.21 extra food groups than those without poultry ownership. Likewise, households that owned cattle consumed 0.34 more food groups than their counterpart non-cattle owners.

These suggest that small-scale livestock husbandry is significant for households' dietary diversity. The point estimate of other control factors is also presented in Table A4 of the Appendix A. Generally, the results of the CF estimation of the ESR model are closer to the results of previous studies than the FEs. This is likely because of correlated effects across the specifications. However, results from both methods are somewhat similar, suggesting that the effects of endogenous selection should not be ignored but the extent is not so severe. Note that similar relationships are found in calorie consumption per capita. To avoid repeating similar discussions, the subsection on calorie consumption is left in the Supplementary Materials.

Table 6. Estimation results of the household ESR model for the dietary diversity indicator [c].

	Food Variety Score (FVS)					
	Classification on Basis of Loans			Loan and Assets' Classification		
Model Specifications	**(i)**	**(ii)**	**(iii)**	**(iv)**	**(v)**	**(vi)**
Panel G						
Food crop variety	0.258 ***	0.222 ***	0.513	0.181 ***	0.156 **	0.970 **
	(0.079)	(0.079)	(0.524)	(0.069)	(0.068)	(0.459)
Expenditure per capita (log)	2.310 ***	2.291 ***	2.487 ***	2.359 ***	2.349 ***	2.892 ***
	(0.225)	(0.221)	(0.439)	(0.197)	(0.193)	(0.383)
Food variety × expenditure			−0.059			−0.164 *
			(0.109)			(0.094)
Panel H						
Credit: food crop variety	−0.068	−0.051	−0.036	−0.001	0.005	−0.527
	(0.114)	(0.112)	(0.744)	(0.096)	(0.095)	(0.616)
Credit: expenditure	0.970 ***	0.967 ***	0.982	0.693 **	0.677 **	0.326
	(0.326)	(0.321)	(0.614)	(0.272)	(0.266)	(0.509)
Credit: (Crop variety × expenditure)			−0.001			−0.107
			(0.153)			(0.126)
Farm characteristics?	No	Yes	Yes	No	Yes	Yes
Correlated effects?	Yes	Yes	Yes	Yes	Yes	Yes

[c] The sample has 825 credit-unconstrained households and 727 credit-constrained households per survey wave in the loan classification of columns (i), (ii), and (iii). There are 1199 households with unbinding credit constraints and 1137 households with binding credit constraints per wave in the loan and asset classification: Column (iv), (v), and (vi). Each regression accounts for household demographics and household and time-fixed effects. Standard errors (in parentheses) are clustered at the household level. ***, **, * Coefficient is statistically significant at the 1%, 5%, and 10% level, respectively.

Table 7. Estimation results of the household ESR model for the dietary diversity indicator [d].

	Dietary Diversity Score (DDS)					
	Classification on Basis of Loans			Loan and Assets' Classification		
Model Specifications	**(i)**	**(ii)**	**(iii)**	**(iv)**	**(v)**	**(vi)**
Panel I						
Food crop groups	0.127 ***	0.090	0.436	0.113 **	0.086	0.543
	(0.061)	(0.063)	(0.448)	(0.052)	(0.052)	(0.357)
Expenditure per capita (log)	0.914 ***	0.910 ***	1.061 ***	0.910 ***	0.909 ***	1.106 ***
	(0.102)	(0.102)	(0.221)	(0.085)	(0.085)	(0.179)
Food groups × expenditure			−0.070			−0.092 *
			(0.093)			(0.073)
Panel J						
Credit: Food crop groups	0.022	0.051	0.371	0.040	0.054	0.261
	(0.084)	(0.084)	(0.566)	(0.070)	(0.070)	(0.451)
Credit: expenditure	0.336 ***	0.337 **	0.496 *	0.319 ***	0.313 ***	0.414 *
	(0.141)	(0.140)	(0.291)	(0.115)	(0.114)	(0.233)
Credit: (Food groups × expenditure)			−0.062			−0.041
			(0.116)			(0.091)
Farm characteristics?	No	Yes	Yes	No	Yes	Yes
Correlated effects?	Yes	Yes	Yes	Yes	Yes	Yes

[d] The sample has 825 credit-unconstrained households and 727 credit-constrained households per survey wave in the loan classification (columns (i), (ii), and (iii)). There are 1199 households with unbinding credit constraints and 1137 households with binding credit constraints per wave in the loan and asset classification: Column (iv), (v), and (vi). Each regression accounts for household demographics and household and time-fixed effects. Standard errors (in parentheses) are clustered at the household level. ***, **, * Coefficient is statistically significant at the 1%, 5%, and 10% level, respectively.

5.1. GES Assessment

To evaluate the GES, farm households that received e-wallets or assistance for inorganic fertilizer they used were differentiated from those that did not. Table 8 shows the descriptive statistics of the beneficiaries versus the non–beneficiaries over the ATA's periods. In the table, credit-constrained farm households (upper panel) were separated from the credit-unconstrained ones (lower panel). As the mean FCV and FCG show, GES recipients had insignificant food production diversity, whether credit-constrained or not. This is in accordance with [11] conclusion that households who benefited from the farm policy reform had increased maize harvest and revenues, suggesting that they planted a few profitable crops. Credit-unconstrained non-beneficiaries of GES clearly produced more crops as the mean FCV shows; it increased from roughly 3.3 crops in 2010–2011 to about 3.5 crops in 2015–2016. This indicates that the reduction in the new crops produced by the credit-constrained non-recipients shown by the mean FCG: from roughly 2.2 crops to approximately 2.1 crops between 2010 and 2016, was due to binding credit constraints. The statistics suggest that GES beneficiaries adjusted land area devoted to nonstable crop production to produce increased profitable crops. It is also shown that GES recipients and non-recipients had slight differences in dietary diversity's increase as the mean FVS and DDS show. In line with the mean FVS, the food varieties consumed by GES beneficiaries increased from about 12.5 items in 2010–2011 to roughly 13.9 items in 2015–2016; that of the non-recipients is even greater in each period as it increased from approximately 13 items to roughly 14.8 items, respectively. Likewise, GES non-beneficiaries consumed about 8 food groups between 2010 and 2016 while the recipients ate up to 8 groups of food only in 2015–2016, as the mean DDS indicates. It appears that non-beneficiaries of the GES consumed more food items and food groups than the recipients through diversifications of food production.

Table 8. Descriptive statistics of the GES beneficiaries and non-beneficiaries between wave one and wave three.

	GES Beneficiaries					GES Non-Beneficiaries				
	Wave 1 (2010–2011)		Wave 3 (2015–2016)		Percentage Point	Wave 1 (2010–2011)		Wave 3 (2015–2016)		Percentage Point
Variables	**Mean**	**SD**	**Mean**	**SD**	**Difference**	**Mean**	**SD**	**Mean**	**SD**	**Difference**
Food variety score (FVS)	12.5	5.09	13.9	3.68	11.9% **	13.0	4.31	14.8	4.71	14.1% ***
Dietary diversity score (DDS)	7.11	2.05	7.80	1.70	9.7% **	7.60	1.99	8.16	1.88	7.4% ***
Total expenditure per capita (₦/day; log)	4.94	0.65	4.77	0.53	−3.4% *	4.98	0.69	4.94	0.63	−0.8%
Food crop variety (FCV)	3.40	1.73	3.46	1.46	1.7%	3.44	1.55	3.43	1.44	−0.1%
Food crop groups (FCG)	2.07	0.89	2.11	0.77	1.9%	2.22	0.91	2.13	0.78	−4.1% **
Food variety score (FVS)	11.8	3.91	13.5	4.76	13.9% **	12.9	4.19	14.5	4.65	12.9% ***
Dietary diversity score (DDS)	7.02	1.93	7.75	2.05	10.74 **	7.49	1.95	8.12	1.82	8.4% ***
Total expenditure per capita (₦/day; log)	5.16	0.64	4.87	0.63	−5.4% **	5.00	0.69	4.98	0.64	−0.4%
Food crop variety (FCV)	3.25	1.46	3.41	1.00	4.6%	3.34	1.57	3.49	1.45	4.5% **
Food crop groups (FCG)	1.92	0.70	2.03	0.64	6.3%	2.10	0.87	2.12	0.78	1.0%

Note: ***, **, * The mean difference is statistically significant per a two-sided *t*-test, at 1%, 5%, and 10% levels, respectively. The top panel is for credit-constrained households while the bottom part is for credit-unconstrained households. There are 70 credit-constrained and 59 credit-unconstrained beneficiaries, amounting to 129 beneficiaries per wave. Likewise, there are 739 credit-constrained and 804 credit-unconstrained non-beneficiaries, which gives 1543 households per wave.

Table 9 presents regression results of the household switching regression models with the dietary diversity indicators and income and food production diversity indicators. Food production diversity had an insignificant association with dietary diversity among GES beneficiaries, regardless of their credit status. This suggests that households that benefited from the agricultural policy specialized in the production of a few profitable crops, supporting [46]'s conclusion. However, GES non-recipients that produced one more crop consumed about 0.24 increased food items, on average (column iv, top panel). Likewise, producing a new crop was associated with consuming an average of roughly 0.20 more food groups (column iv, bottom panel). This point estimate mirrors that of [14] for farm households in non-adopter states of the policy reform. The results suggest a stronger food consumption–production connection among GES non-recipients than the beneficiaries. Clearly, GES enabled beneficiaries to remain positioned for agricultural commercialization goals.

It seems that the amount of money saved by beneficiaries of GES from purchasing agricultural input at a subsidized cost served as credit access to the credit-constrained recipients. This cushioned the effect of binding credit constraints on recipients of the agricultural policy reform. For example, income per capita of the credit-constrained beneficiaries decreased from ($e^{4.94}$) or NGA ₦139.8 per day in wave one to NGA ₦117.9 per day in wave three amounting to a percentage point difference of 3.4% per day over the ATA's period (Table 8, top panel). However, they had ($2.084 \times \ln(100 + 3.4)/100$) or roughly 0.07 average decrease in the food items consumed rather than ($(2.084 + 1.573) \times \ln(100 + 3.4)/100$) or about 0.12 mean decline in the food items they ate (column i, top panel). Similarly, credit-constrained beneficiaries of GES experienced ($0.877 \times \ln(100 + 3.4)/100$) or about 0.03 reduction in the food groups consumed instead of ($(0.877 + 0.760) \times \ln(100 + 3.4)/100$) or about 0.05 decease (column i, bottom panel). It is, therefore, obvious that credit-constrained households that benefited from GES responded to income shocks just like their credit-unconstrained counterparts. Clearly, credit-unconstrained recipients of GES were supposed to have a 0.19 (0.09) decrease in food items (food groups) consumed but might have used credit or saving from the GES supports to maintain their nutritional levels. The income of the GES non-recipients remained unchanged over the agricultural policy periods regardless of the households' credit situations, as the mean EXP presents (see Table 8). Regarding previous studies, the magnitude of estimates on FVS and DDS for GES benefited, and non-benefited farm households approximate the ones obtained by [14] for families in the adopter and non-adopter states, respectively.

Table 9. Estimation results of the household ESR model for the dietary GES evaluation [e].

			Food Variety Score (FVS)			
	GES Beneficiaries			**GES Non-Beneficiaries**		
Model Specifications	**(i)**	**(ii)**	**(iii)**	**(iv)**	**(v)**	**(vi)**
Food crop variety	−0.141	−0.262	0.606	0.235 ***	0.231 ***	0.551
	(0.354)	(0.394)	(2.254)	(0.082)	(0.082)	(0.545)
Expenditure per capita (log)	2.084 **	2.176 **	1.914	2.413 ***	2.413 ***	2.632 ***
	(0.951)	(0.886)	(1.792)	(0.211)	(0.207)	(0.432)
Credit: expenditure	1.573	1.442	0.957	0.770 **	0.765 ***	0.917
	(1.361)	(1.326)	(3.063)	(0.313)	(0.305)	(0.611)
			Dietary diversity score (DDS)			
Food crop groups	0.284	0.195	−1.645	0.195 ***	0.183 **	0.218
	(0.340)	(0.382)	(1.804)	(0.064)	(0.065)	(0.389)
Expenditure per capita (log)	0.877 **	0.877 **	0.088	0.960 ***	0.965 ***	0.980 ***
	(0.428)	(0.434)	(0.932)	(0.093)	(0.092)	(0.195)
Credit: expenditure	0.760	0.744	1.788	0.364 ***	0.358 ***	0.609 **
	(0.561)	(0.578)	(1.377)	(0.133)	(0.131)	(0.276)
Farm characteristics?	No	Yes	Yes	No	Yes	Yes
Correlated effects?	Yes	Yes	Yes	Yes	Yes	Yes

[e] The sample has 70 credit-constrained households and 59 credit-unconstrained households per wave in the beneficiaries' columns (i), (ii), and (iii). There are 739 households with binding credit constraints and 804 households with unbinding credit constraints per wave in the non-beneficiaries: Column (iv), (v), and (vi). Each regression accounts for household demographics and household and time-fixed effects. Standard errors (in parentheses) are clustered at the household level. The estimated coefficient on the interaction term between income and food production diversity is insignificant and excluded in the table. ***, ** Coefficient is statistically significant at the 1% and 5% level, respectively.

In sum, the descriptive evidence and estimation results in this GES assessment indicate that farm households that benefited from ATA separated production and consumption decisions better than the non-participants. Therefore, the agricultural policy reform that allowed households access to increased farm inputs enabled families to be less dependent on food self-sufficiency against food insecurity from adverse macroeconomic changes. Regarding the discontinuity of the ATA, specializing in profitable crop production would make credit-constrained recipients more vulnerable to economic shocks unless they turn to adequately diversify their food production to protect their families' food security from severe macroeconomic shocks. By diversifying food production, non-recipients of the ATA mitigated shock-induced nutrition losses. However, credit-constrained recipients were unable to adequately diversify their food production when compared to credit-unconstrained families.

5.2. Observed Evidence and Implications

It is now clear that food production diversity, income, and credit constraints affect nutritional quality. An example is used below to illustrate how these variables affect nutritional adequacy. Credit-unconstrained households had an increase in crop production from 3.230 crops in wave one to 3.444 crops in wave three (see Table 10), amounting to a 0.999% CAGR in food items consumed over the 7-year period. Using the 0.258 effect of crop production on food items (see Table 6), a compounded annual growth effect of 0.264% was calculated (see Table 10 again). This implies that producing more crops led to 0.26% more food items consumed annually. Again, food items consumed by credit-unconstrained households grew at a CAGR of approximately 2.228% (see Table 10 once again). This altogether implies that [0.264/2.228] or 11.85% growth in consumed food items can be attributed to food production diversity. Similarly, [0.077/1.273] or 6.05% increase in food groups consumed can be linked to the production of new crops (see Table 10). Again, around 0.16% growth in food groups consumed is attributable to income growth (see Table 10).

Table 10 also reports that the per capita income of credit-constrained households declined from NGA ₦203.9 per day in wave one to NGA ₦192.4 per day in wave three, amounting to some 0.83% compounded annual decline rate over the period. Using the 0.0328 estimates on income (Table 6), the compounded annual decline rate was computed to be 0.026% (Table 10). As food items consumed grew at a CAGR of 2.037% (Table 10), it can be inferred that a decrease in income reduced food items consumed by 1.28% annually. In this order, (0.010/1.113) or 0.90% decline in food groups consumed can be due to the income decrease.

It is likely that credit-unconstrained households also experienced reduced income but obtained loans to maintain their nutritional quality. Unfortunately, credit-constrained households did not have sufficient access to loans. Binding credit constraints again affected the dietary diversity of credit-constrained households through the channel of food production. This is due to the negative association between credit constraints and agricultural production [47]. For example, about 2.26% and 5.75% reduction in food items and food groups consumed, respectively, can be believed to be due to less diverse food produced (Table 10). In sum, credit-constrained households might improve nutritional quality like their credit-unconstrained counterparts, if a significant reduction in credit constraints is achieved.

The policy implications of the results above are manifold. First, the income increase in credit-unconstrained households is consistent with Nigeria's ATA–and agricultural policies of other African countries–aimed at farm commercialization. The associated improved dietary diversity implies that agricultural transformation policies improve nutrition through farm profits. Second, credit-unconstrained households diversified food production throughout the sample periods to secure nutritional quality in periods of income losses. Even though this shocks-mitigating strategy does not complement agricultural commercialization efforts, it remains a common reaction for coping with income shocks. This suggests that to realize commercialization goals, households' reactions to macroeconomic changes must be incorporated into agricultural policies. Third, the decline in income of credit-constrained households implies that binding credit constraints decelerate progress toward agricultural transformation and food security. Moreover, the diminished diverse food produced indicates that credit-constrained households were unable to remain positioned for dietary diversification in periods of deteriorating macroeconomic conditions due to income constraints for seed acquisitions. To achieve agricultural transformation and food security, policymakers must use credit policies as a necessary complement to agricultural policies.

Table 10. Effects of farm production diversity and income on dietary diversity in Nigeria [f].

Survey Wave 1 to Wave 3				Compounded Annual Growth Rate			Effects
	w1	**w2**	**w3**	**w1–w2**	**w2–w3**	**w1–w3**	**w1–w3**
Panel K							
Food variety score	**12.34**	**13.17**	**14.40**	**1.629**	**1.808**	**2.228**	$\hat{\beta}_0$ **= (.)**
Food crop variety	3.230	3.444	3.463	1.612	0.112	0.999	0.264
Expenditure per capita	181.9	180.4	184.0	−0.203	0.396	0.166	0.004
Food variety × expenditure	591.4	596.6	629.9	0.221	1.090	0.904	−0.002
Dietary diversity score	**7.343**	**7.633**	**8.023**	**0.972**	**1.002**	**1.273**	$\hat{\beta}_0$ **= (.)**
Food crop groups	2.125	2.219	2.215	1.094	−0.044	0.592	0.077
Expenditure per capita	181.9	180.4	184.0	−0.203	0.396	0.166	0.002
Crop groups × expenditure	394.3	396.3	410.1	0.127	0.687	0.563	−0.001
Panel L							
Food variety score	**13.43**	**14.21**	**15.46**	**1.419**	**1.711**	**2.037**	$\hat{\beta}_1$ **= (.)**
Food crop variety	3.436	3.503	3.393	0.487	−0.636	−0.178	−0.046
Expenditure per capita	203.9	186.2	192.4	−2.251	0.656	−0.830	−0.026
Food variety × expenditure	689.5	618.7	632.2	−2.672	0.435	−1.230	0.002
Dietary diversity score	**7.752**	**8.022**	**8.377**	**0.858**	**0.870**	**1.113**	$\hat{\beta}_1$ **= (.)**
Food crop groups	2.316	2.341	2.234	0.266	−0.934	−0.517	−0.064
Expenditure per capita	203.9	186.2	192.4	−2.251	0.656	−0.830	−0.010
Crop groups × expenditure	475.5	428.9	431.2	−2.544	0.103	−1.389	0.002

[f] Panel K represents credit-unconstrained households and panel L credit-constrained households for loan classification's panel dataset. The compounded annual growth effect of any explanatory variable on any dietary diversity indicator is calculated using the endogenous switching regression (ESR) coefficient estimates on the relevant variable, $\hat{\beta}_1$, for credit-constrained households and $\hat{\beta}_0$ for credit-unconstrained households. The ESR results that control for farm characteristics were used. The compounded annual growth effect can be calculated as $\left\{\left(\frac{x_{w3}-x_{w1}}{x_{w1}}\right)\hat{\beta}_j+1\right\}^{1/7} \forall\, j \in \{0\,1\}; x = (exp,\ fcv,\ fcg,\ fcv\_exp,\ fcg\_exp)'$ where w denotes survey wave and $\hat{\beta}_j$ is the interpreted endogenous switching regression (ESR) estimate of $\hat{\beta}_1$ for the credit-constrained households and $\hat{\beta}_0$ for the credit-unconstrained households.

Note that off-farm jobs play a significant role in input purchase decisions [41], and they was found to improve nutrition in this study. These suggest that households use nonfarm income to diversify diets and settle farm-input needs. Therefore, there is a policy need for interventions that allow households access to loans for nonfarm enterprises. This will enable households to plow back cash partly into farm input needs, thereby improving food security. It again allows households to produce profitable crops and thus promotes agricultural commercialization. This is consistent with the nutrition-sensitive agricultural interventions suggested by [48] for increasing income, generating off-farm income opportunities, and diversifying food production. Rather than recommending [49]'s pathways as Fraval and his coauthors did, we suggest reconciling the specialization–diversification odds by creating access to credits for nonfarm businesses. This is because binding credit constraints affect income diversification into high return off-farm activities [50], which are critical avenues out of poverty [24]. Nonfarm income may serve as an important complement to agricultural income, allowing for a balance between farm commercialization and dietary diversification targets during economic crises.

We recognize the ACGSF—the key agricultural financing policy that the Nigerian government established in 1977 in response to the increasing farm households' credit demands [22]. However, aside from the decrease in the scheme's guaranteed loans in recent times as we previously reviewed, it had repeatedly denied credit to small farm households that dominate Nigeria's agricultural sector [41]. It is additionally evident that the number and value of loans granted in previous years had not improved agricultural productivity because of food insecurities in the country [41]. To mitigate the food security risks and sustainably improve agricultural productivity, a policy initiative that grants households credit access for operating small non-farm businesses should be established alongside the existing agricultural input and credit policies. By owning off-farm enterprises, households could use the business profit to reduce dietary losses induced by shocks to income and plow back part of it into agricultural input needs. Expectedly, this would reposition farm households for the agricultural commercialization target and also improve their nutrition.

6. Conclusions

This study investigates the relationship between food production diversity and income growth and dietary diversity. Nigeria's three-wave survey panel dataset that coincides with ATA's periods was used. The dietary diversity of every household increased during the ATA periods; however, credit-unconstrained households had a larger increase than credit-constrained households. Moreover, food production diversity and income of credit-unconstrained households increased, while those of credit-constrained decreased. This suggests that credit-unconstrained households used credit resources to mitigate food security risks in periods of economic shocks, unlike credit-constrained households. Households prioritized the use of loans for families' food security in periods of economic crisis over agricultural transformation goals. With dysfunctional credit markets, food production diversification does not insure families against income-induced nutrition loss. Binding credit constraints decelerate farm commercialization progress because of discontinuities of agricultural policies during deteriorating macroeconomic conditions.

Again, the food production diversity–dietary diversity positive association found in this study validates the results in [8,9,14]. However, endogenizing credit classification shows that the production–income mitigation effect found by [14] does not hold. This suggests that diversifying food production to mitigate food security risks of income loss is ineffective with binding credit constraints. The major novelty of this study's results is that income changes affect the dietary diversity of credit-constrained households more than that of credit-unconstrained households. This suggests that macroeconomic shocks adversely affect the food security of the former more than that of the latter. It appears that credit constraints do not just impede households from securing food for their families through food production adjustments, but also pull them out of the transformation agenda during the economic downturn.

In the presence of binding credit constraints, future studies should investigate whether partial dietary insurance exists against income shocks associated with deteriorating macroeconomic conditions not just for Nigeria but for other African countries. Additionally, exploring how misclassifications of credit status could alter the dietary effects of income and production variables may be significant in further studies.

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Appendix A. Interpretation of the Estimated Coefficients on Calorie Consumption

Table A1 reports the FE estimation results of the relationship between food production diversity and household income and total calorie intake per capita. The estimated coefficients are robust to any choice of the two classifications, and any specification of the models. As suspected, the calorie intake per capita is significantly related to food production diversity. Specifically, the estimate in the loan classification show that adding one crop to the portfolio of farm crops increased average per capita calorie intake by roughly ($e^{0.06}$) or 6.18% (columns i–iii, panel A). This estimate mirrors the statistically significant relationship between Simpson production diversity index (SPDI) and total calorie consumption per capita found by [14]. The percentage point increase in calorie intake per capita slightly reduced to 4.60% in the mixed classification (columns iv–v). These results imply that households that diversified their food production consumed similar diets irrespective of having binding credit constraints or not. The results again imply that households diversified diets as observed on FVS and DDS with the aim of achieving balanced diets. This estimated effect remained unchanged after investigated it by the CF (see Table A2). However, results from the mixture of loan-and-asset classification slightly reduced in magnitude [columns (iv)–(v), Table A2].

Table A1. Estimation results of the household FE model for the calorie consumption [a].

	Calorie Intake Per Capita (CIC)					
	Classification on Basis of Loans			Loan and Assets' Classification		
Model Specifications	**(i)**	**(ii)**	**(iii)**	**(iv)**	**(v)**	**(vi)**
Panel A						
Food crop variety	0.060 ***	0.062 ***	0.059 ***	0.045 ***	0.045 ***	0.047 ***
	(0.012)	(0.017)	(0.017)	(0.010)	(0.014)	(0.014)
Expenditure per capita (log)	0.358 ***	0.310 ***	0.418 ***	0.352 ***	0.289 ***	0.422 ***
	(0.031)	(0.041)	(0.048)	(0.026)	(0.035)	(0.038)
Panel B						
Food crop variety	0.062 ***	0.065 ***	0.061 ***	0.047 ***	0.048 ***	0.048 ***
	(0.012)	(0.017)	(0.017)	(0.010)	(0.014)	(0.014)
Expenditure per capita (log)	0.360 ***	0.311 ***	0.416 ***	0.351 ***	0.285 ***	0.423 ***
	(0.031)	(0.041)	(0.048)	(0.026)	(0.035)	(0.038)
Panel C						
Food crop variety	0.166 **	0.313 ***	0.036	0.107 *	0.278 ***	−0.017
	(0.076)	(0.106)	(0.109)	(0.062)	(0.091)	(0.087)
Expenditure per capita (log)	0.429 ***	0.477 ***	0.400 ***	0.391 ***	0.438 ***	0.378 ***
	(0.059)	(0.082)	(0.088)	(0.049)	(0.069)	(0.069)
Food variety × expenditure	−0.021	−0.051 **	0.005	−0.012	−0.046 **	0.013
	(0.015)	(0.021)	(0.021)	(0.012)	(0.018)	(0.017)

[a] There are 1391 pooled households [column (i)], 737 credit-unconstrained households [column (ii)], and 654 credit-constrained households [column (iii)] per wave in the loan classification. There are 2,112 total households [column (iv)], 1,082 credit-unconstrained households [column (v)], and 1,030 credit-constrained households [column (vi)] per wave in the loan and asset classification. Standard errors (in parentheses) are clustered at the household level. ***, **, * Coefficient is statistically significant at the 1%, 5%, and 10% level, respectively.

Moreover, the estimated coefficient for the per capita income is positive and significant. This suggests that an increase in income of each household-member generates significant increase in the per capita calorie consumption. Table A1 shows that the point estimate of the elasticity for the estimation that controls for farm characteristics equals 0.311 (column ii, panel B). This implies that a 10% increase in income increases per capita calorie consumption of the credit-unconstrained households by, on average, roughly 31.1%. However, the percentage point change increases average calorie consumption per capita of the credit-constrained households by roughly 41.6% (column iii). The elasticity for the estimation that neglects the presence of credit constraints is roughly 36% (column i), which lies in the middle of the previous elasticities as was observed on dietary diversity indicators. This time, however, estimate for the credit-constrained households is closer in magnitude to the point estimate reported in [14], unlike in the case of dietary diversity indicators. This suggests that stratifying households according to their credit situations is important for improved precision of results for any choice of the household groups selected for investigation. Results from investigation that neglects credit constraints and run a pooled panel dataset appear to be relatively less precise than if households were differentiated by their credit conditions. However, this does not contradict the soundness of findings in the existing studies because there are severe measurement errors in the calorie consumption indicator [20,21], which might have seriously affected the estimated coefficients on the per capita calorie consumption.

As Table A2 shows, after controlling for the correlated effects due to the credit constraints, the income elasticities became 0.44 for the credit-unconstrained households and 0.62 (=0.437 + 0.186) for the credit-constrained households (column ii). Similar to results on dietary diversity's indicators, credit-constrained households appear to be hand-to-mount given the elasticity of calorie consumption with respect to income. Table A2 specifically reports that credit-constrained households were consuming about 18.6% more calorie per capita than their counterpart unconstrained households for every 10% increased per capita income earned (see credit: expenditure, column ii). While credit-constrained households remained impatient, credit-unconstrained households were smoothing consumption as previously observed on FVS and DDS.

As [14] noted, results on calorie consumption should be used with caution. This is because food consumption quantities in the GHS-Panel, from where the per capita calorie consumption indicator was constructed, have serious measurement errors. The errors of measurement were correlated with the inconsistencies in the documentation of food quantities that were reported in nonstandard units such as bowl, heap, piece, and bunch [26].

Table A2. Estimation results of the household ESR model for the calorie consumption [b].

	Calorie Intake Per Capita (CIC)					
	Classification on Basis of Loans			Loan and Assets' Classification		
Model Specifications	**(i)**	**(ii)**	**(iii)**	**(iv)**	**(v)**	**(vi)**
Panel D						
Food crop variety	0.063 ***	0.060 ***	0.075	0.035 **	0.032 **	0.061
	(0.019)	(0.019)	(0.120)	(0.015)	(0.016)	(0.103)
Expenditure per capita (log)	0.436 ***	0.437 ***	0.447 ***	0.400 ***	0.397 ***	0.416 ***
	(0.046)	(0.046)	(0.090)	(0.039)	(0.040)	(0.076)
Food variety × expenditure			−0.003			−0.006
			(0.024)			(0.020)
Panel E						
Credit: Food crop variety	−0.023	−0.020	−0.220	−0.001	0.005	−0.238
	(0.028)	(0.028)	(0.181)	(0.023)	(0.023)	(0.149)
Credit: expenditure	0.190 ***	0.186 **	0.050	0.204 ***	0.212 ***	0.047
	(0.074)	(0.074)	(0.140)	(0.061)	(0.061)	(0.114)
Credit: (Food variety × expenditure)			0.040			0.049 *
			(0.036)			(0.030)
Farm characteristics?	No	Yes	Yes	No	Yes	Yes
Correlated effects?	Yes	Yes	Yes	Yes	Yes	Yes

[b] The sample has 737 credit-unconstrained households and 654 credit-constrained households per wave in the loan classification. There are 1082 credit-unconstrained households and 1,030 credit-constrained households per wave in the loan and asset classification. ***, **, * Coefficient is significant at the 1%, 5%, and 10% level, respectively.

Table A3. Summary statistics for other variables.

Variables	W1: 2010–2011		W2: 2012–2013		W3: 2015–2016		Compounded Annual Growth Rate		
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**W1–W2**	**W2–W3**	**W1–W3**
PANEL A: Credit-constrained households									
Farm household characteristics									
Off-farm employment (OFE) (1 = yes, 0 = no)	0.51	0.50	0.49	0.50	0.46	0.50	−1.00	−1.26	−1.46
Farm size (FS) (acres)	2.54	4.21	2.26	3.49	2.19	3.21	−2.88	−0.63	−2.10
Cash crop production (CCP) (1 = yes, 0 = no)	0.08	0.26	0.10	0.30	0.09	0.28	5.74	−2.09	1.70
Poultry ownership (PWN) (1 = yes, 0 = no)	0.42	0.49	0.47	0.50	0.48	0.50	2.85	0.42	1.93
Cattle ownership (CWN) (1 = yes, 0 = no)	0.15	0.35	0.16	0.36	0.16	0.36	1.63	0.00	0.93
Sheep or goat ownership (SGN) (1 = yes, 0 = no)	0.40	0.49	0.45	0.50	0.47	0.50	2.99	0.87	2.33
Household demographics									
Household size (HSIZE)	6.50	3.11	7.07	3.33	7.88	3.59	2.12	2.19	2.79
Age of the household head (AGE) (years)	54.0	58.1	53.3	14.7	54.3	14.0	−0.33	0.37	0.08
Education of the household head (EDC) (years)	11.9	3.73	12.2	3.89	12.6	3.65	0.62	0.65	0.82
Household-head's sex (SEX) (1 = male, 0 = female)	0.89	0.31	0.89	0.31	0.89	0.31	0.00	0.00	0.00
PANEL B: Credit-unconstrained households									
Farm household characteristics									
Off-farm employment (OFE) (1 = yes, 0 = no)	0.56	0.50	0.52	0.50	0.51	0.50	−1.84	−1.39	−1.33
Farm size (FS) (acres)	2.79	4.52	2.56	3.40	2.57	3.48	−2.12	0.08	−1.17
Cash crop production (CCP) (1 = yes, 0 = no)	0.05	0.22	0.07	0.26	0.09	0.28	8.78	5.15	8.76
Poultry ownership (PWN) (1 = yes, 0 = no)	0.42	0.49	0.48	0.50	0.53	0.50	3.39	2.00	3.38
Cattle ownership (CWN) (1 = yes, 0 = no)	0.22	0.41	0.22	0.41	0.22	0.41	0.00	0.00	0.00
Sheep or goat ownership (SGN) (1 = yes, 0 = no)	0.45	0.50	0.52	0.50	0.55	0.50	3.68	1.13	2.91
Household demographics									
Household size (HSIZE)	6.40	3.06	6.91	3.17	7.80	3.51	1.94	2.45	2.87
Age of the household head (AGE) (years)	49.5	14.7	52.2	14.5	53.8	14.2	1.34	0.61	1.20
Education of the household head (EDC) (years)	12.1	3.76	12.5	3.75	12.7	3.65	1.34	0.32	0.69
Household-head's sex (SEX) (1 = male, 0 = female)	0.91	0.29	0.91	0.29	0.91	0.29	0.00	0.00	0.00

Note: There are 1137 credit-constrained households and 1199 credit-unconstrained households per wave.

Table A4. Estimation results of the household FE model for the control variables.

	Food Variety Score (FVS)					
	Loan Classification			**Mixed Classification**		
Model Specifications	**(i)**	**(ii)**	**(iii)**	**(iv)**	**(v)**	**(vi)**
Off-farm employment	0.338 **	0.164	0.449 **	0.329 ***	0.185	0.437 **
	(0.147)	(0.195)	(0.222)	(0.121)	(0.168)	(0.175)
Farm size	0.034 *	0.029	0.040	0.025 *	0.018	0.032
	(0.018)	(0.023)	(0.030)	(0.015)	(0.020)	(0.022)
Cash crop production	0.266	0.009	0.395	0.163	−0.151	0.389
	(0.264)	(0.384)	(0.366)	(0.212)	(0.311)	(0.292)
Poultry ownership	0.240 *	0.567 ***	−0.163	0.186 *	0.427 ***	−0.087
	(0.137)	(0.177)	(0.214)	(0.113)	(0.153)	(0.167)
Cattle ownership	0.223	0.437	−0.144	0.204	0310	0.088
	(0.217)	(0.273)	(0.350)	(0.179)	(0.238)	(0.270)
Sheep or goat ownership	0.023	0.072	−0.066	−0.023	0.049	−0.114
	(0.151)	(0.195)	(0.235)	(0.125)	(0.170)	(0.183)
Age of the household head	−0.004	−0.006	−0.004	−0.003 *	−0.003	−0.003
	(0.003)	(0.012)	(0.003)	(0.002)	(0.010)	(0.002)
Household head's education	−0.001	0.013	−0.014	−0.023	−0.023	−0.022
	(0.018)	(0.024)	(0.028)	(0.015)	(0.021)	(0.022)
Sex of the household head				0.808		5.738
				(3.897)		(3.969)
Household size	0.320 ***	0.310 ***	0.357 ***	0.357 ***	0.352 ***	0.397 ***
	(0.064)	(0.081)	(0.104)	(0.051)	(0.071)	(0.072)
	Dietary diversity score (DDS)					
Off-farm employment	0.163 **	0.105	0.190 **	0.136 **	0.105	0.150 *
	(0.065)	(0.089)	(0.094)	(0.054)	(0.075)	(0.078)
Farm size	0.015 *	0.014	0.019	0.014 **	0.011	0.016
	(0.008)	(0.011)	(0.013)	(0.007)	(0.009)	(0.010)
Cash crop production	0.146	0.293 *	0.012	0.148	0.166	0.110
	(0.117)	(0.177)	(0.156)	(0.095)	(0.139)	(0.130)
Poultry ownership	0.085	0.213 ***	−0.078	0.058	0.141 **	−0.038
	(0.061)	(0.081)	(0.091)	(0.050)	(0.068)	(0.074)
Cattle ownership	0.205 **	0.342 ***	−0.014	0.110	0.176 *	0.037
	(0.096)	(0.125)	(0.148)	(0.079)	(0.106)	(0.119)
Sheep or goat ownership	−0.059	−0.015	−0.113	−0.015	0.032	−0.066
	(0.066)	(0.089)	(0.099)	(0.055)	(0.076)	(0.081)
Age of the household head	−0.001	0.0003	−0.001	−0.001	−0.0001	−0.001
	(0.001)	(0.005)	(0.001)	(0.001)	(0.005)	(0.001)
Household head's education	0.007	0.006	0.009	−0.0004	−0.001	0.002
	(0.008)	(0.011)	(0.012)	(0.007)	(0.009)	(0.010)
Sex of the household head				3.874 **		3.886 **
				(1.730)		(1.754)
Household size	0.136 ***	0.118 ***	0.171 ***	0.169 ***	0.142 ***	0.197 ***
	(0.028)	(0.037)	(0.044)	(0.023)	(0.032)	(0.632)

***, **, * Coefficient is statistically significant at the 1%, 5%, and 10% level, respectively.

References

1. McMillan, M.; Rodrik, D.; Íñigo, V.G. Globalization, Structural Change, and Productivity Growth, with an Update on Africa. *World Dev.* **2014**, *63*, 11–23. [CrossRef]
2. Jayne, T.S.; Milu, M.; Ayala, W.; Hosaena, G.; Caleb, S.; Stickler, M.; Chapoto, A.; Ward, A.; Divanvan, D.W.; Nyange, D. Are Medium-scale Farms Driving Agricultural Transformation in Sub-Saharan Africa? *Agric. Econ.* **2019**, *50*, 75–95. [CrossRef]
3. Rodrik, D. An African Growth Miracle? *J. Afr. Econ.* **2018**, *27*, 10–27.
4. FMARD (Nigeria Federal Ministry of Agriculture and Rural Development). *Agricultural Transformation Agenda*; We Will Grow Nigeria's Agricultural Sector: Abuja, Nigeria, 2011.
5. FMARD (Nigeria Federal Ministry of Agriculture and Rural Development). *The Agriculture Promotion Policy: Building on the Successes of the ATA*; Closing Key Gaps: Abuja, Nigeria, 2016.

6. Ecker, O. Agricultural Transformation and Food and Nutrition Security in Ghana: Does Farm Production Diversity (Still) Matter for Household Dietary Diversity? *Food Policy* **2018**, *79*, 271–282. [CrossRef]
7. Dillon, B.; Barrett, C.B. Agricultural factor markets in Sub-Saharan Africa: An updated view with formal tests for market failure. *Food Policy* **2017**, *67*, 64–77. [CrossRef]
8. Dillon, A.; Kevin, M.G.; Gbemisola, O. Agricultural Production, Dietary Diversity and Climate Variability. *J. Dev. Stud.* **2015**, *51*, 976–995. [CrossRef]
9. Ayenew, H.Y.; Sibhatu, B.; Lena, S.; Getachew, A.K.; Johannes, S. Production Diversification, Dietary Diversity and Consumption Seasonality: Panel Data Evidence from Nigeria. *BMC Public Health* **2018**, *18*, 988.
10. Poulton, C.; Dorward, A.; Kydd, J. The future of small farms: New directions for services, institutions, and intermediation. *World Dev.* **2010**, *38*, 1413–1428. [CrossRef]
11. Wossen, T.; Tahirou, A.; Arega, A.; Shiferaw, F.; Jacob, R.G.; Manyong, V.; Bola Amoke, A. Productivity and Welfare Effects of Nigeria's E-Voucher-Based Input Subsidy Program. *World Dev.* **2017**, *97*, 251–265. [CrossRef]
12. Jones, A.D.; Shrinivas, A.; Bezner-Kerr, R. Farm production diversity is associated with greater household dietary diversity in Malawi: Findings from nationally representative data. *Food Policy* **2014**, *46*, 1–12. [CrossRef]
13. Romeo, A.; Meerman, J.; Demeke, M.; Scognamillo, A.; Asfaw, S. Linking farm diversification to household diet diversification: Evidence from a sample of Kenyan ultra-poor farmers. *Food Secur.* **2016**, *8*, 1069–1085. [CrossRef]
14. Ecker, O.; Hatzenbuehler, P.L. Food consumption–production response to agricultural policy and macroeconomic change in Nigeria. *Appl. Econ. Perspect. Policy* **2022**, *44*, 982–1002. [CrossRef]
15. Davis, B.; Winters, P.; Reardon, T.; Stamoulis, K. Rural nonfarm employment and farming: Household-level linkages. *Agric. Econ.* **2009**, *40*, 119–123. [CrossRef]
16. EIA (US Energy Information Administration). International Energy Statistics. 2019. Available online: https://catalog.data.gov/dataset/international-energy-statistics (accessed on 12 April 2019).
17. World Bank. World Development Indicators Databank. 2019. Available online: https://databank.worldbank.org/source/world-development-indicators (accessed on 12 April 2019).
18. FAO; IFAD (International Fund for Agricultural Development); UNICEF (United Nations Children's Fund); WFP (World Food Programme); WHO (World Health Organisation). The State of Food Security and Nutrition in the World 2020. In *Transforming Food Systems for Affordable Healthy Diets*; FAO: Rome, Italy, 2020.
19. IMF (International Monetary Fund). *Nigeria 2017 Article IV Consultation*; IMF Country Report No. 17/80; IMF: Washington, DC, USA, 2017.
20. NBS (Nigeria National Bureau of Statistics); World Bank. *LSMS-Integrated Surveys on Agriculture: General Household Survey Panel 2015/16*; Survey Report; NBS: Abuja, Nigeria; World Bank: Washington, DC, USA, 2016.
21. NBS (Nigeria National Bureau of Statistics); World Bank. *Basic Information Document: Nigeria General Household Survey—Panel 2015/16*; NBS: Abuja, Nigeria; World Bank: Washington, DC, USA, 2016.
22. CBN (Central Bank of Nigeria). *Statistical Bulletin*; Central Bank of Nigeria: Abuja, Nigeria, 2020.
23. Kumar, C.S.; Turvey, C.G.; Kropp, J.D. The Impact of Credit Constraints on Farm Households: Survey Results from India and China. *Appl. Econ. Perspect. Policy* **2013**, *35*, 508–527. [CrossRef]
24. Ali, D.A.; Deininger, K.; Duponchel, M. *Credit Constraints, Agricultural Productivity, and Rural Nonfarm Participation: Evidence from Rwanda*; World Bank Policy Working Paper 6769; The World Bank: Washington, DC, USA, 2014.
25. Zeldes, S.P. Consumption and Liquidity Constraints: An Empirical Investigation. *J. Polit. Econ.* **1989**, *97*, 305–346. [CrossRef]
26. NBS (Nigeria National Bureau of Statistics); World Bank. Living Standards Measurement Study–Integrated Surveys on Agriculture: Nigeria, 2018, Datasets. Available online: http://surveys.worldbank.org/lsms/programs/integrated-surveys-agriculture-ISA/nigeria (accessed on 12 April 2019).
27. Koppmair, S.; Kassie, M.; Qaim, M. Farm production, market access and dietary diversity in Malawi. *Public Health Nutr.* **2017**, *20*, 325–335. [CrossRef]
28. Sibhatu, K.T.; Krishna, V.V.; Qaim, M. Production diversity and dietary diversity in smallholder farm households. *Proc. Natl. Acad. Sci. USA* **2015**, *112*, 10657–10662. [CrossRef]
29. Hirvonen, K.; Hoddinott, J. Agricultural production and children's diets: Evidence from rural Ethiopia. *Agric. Econ.* **2017**, *48*, 469–480. [CrossRef]
30. Carletto, C.; Corral, P.; Guelfi, A. Agricultural commercialization and nutrition revisited: Empirical evidence from three African countries. *Food Policy* **2017**, *67*, 106–118. [CrossRef]
31. Sani, Y.; Miklas, S. Interplay of Water–Energy Security and Food Consumption Patterns towards Achieving Nutrition Security in Katsina State, North-Western Nigeria. *Sustainability* **2022**, *14*, 4478. [CrossRef]
32. Habtemariam, L.; Gornott, C.; Hoffmann, H.; Sieber, S. Farm Production Diversity and Household Dietary Diversity: Panel Data Evidence from Rural Households in Tanzania. *Front. Sustain. Food Syst.* **2021**, *5*, 151. [CrossRef]
33. Sinyolo, S.; Murendo, C.; Nyamwanza, A.M.; Sinyolo, S.A.; Ndinda, C.; Nwosu, C.O. Farm Production Diversification and Dietary Diversity among Subsistence Farming Households: Panel Data Evidence from South Africa. *Sustainability* **2021**, *13*, 10325. [CrossRef]
34. Annim, S.K.; Frempong, R.B. Effects of access to credit and income on dietary diversity in Ghana. *Food Secur.* **2018**, *10*, 1649–1663. [CrossRef]

35. Lukwa, A.T.; Feyisayo, O.W.; Estelle, V.L.; Olufunke, A.A. On behalf of the "Savings for Health" IDRC Collaborators. Can Informal Savings Groups Promote Food Security and Social, Economic and Health Transformations, Especially among Women in Urban Sub-Saharan Africa: A Narrative Systematic Review. *Sustainability* **2022**, *14*, 3153. [CrossRef]
36. Mukasa, A.N.; Simpasa, A.M.; Salami, A.O. *Credit Constraints and Farm Productivity: Micro-Level Evidence from Smallholder Farmers in Ethiopia*; Working Paper Series, 247; African Development Bank: Abidjan, Côte d'Ivoire, 2017.
37. NBS (Nigeria National Bureau of Statistics); World Bank. *Basic Information Document: Nigeria General Household Survey—Panel 2018/19*; NBS: Abuja, Nigeria; World Bank: Washington, DC, USA, 2019.
38. Ruel, M.T. Operationalizing dietary diversity: A review of measurement issues and research priorities. *J. Nutr.* **2003**, *133*, 3911S–3926S. [CrossRef] [PubMed]
39. Swindale, A.; Paula, B. *Household Dietary Diversity Score (HDDS) for Measurement of Household Food Access: Indicator Guide*; Version 2; Academy for Educational Development: Washington, DC, USA, 2006.
40. Deaton, A.; Salman, Z. *Guidelines for Constructing Consumption Aggregates for Welfare Analysis*; World Bank: Washington, DC, USA, 2002.
41. Adjognon, S.G.; Lenis Saweda, O.L.; Reardon, T.A. Agricultural input credit in Sub-Saharan Africa: Telling myth from facts. *Food Policy* **2017**, *67*, 93–105. [CrossRef] [PubMed]
42. Wooldridge, J.M. Control Function Methods in Applied Econometrics. *J. Hum. Resour.* **2015**, *50*, 420–445. [CrossRef]
43. Murtazashvili, I.; Wooldridge, J.M. A control function approach to estimating switching regression models with endogenous explanatory variables and endogenous switching. *J. Econom.* **2015**, *190*, 252–266. [CrossRef]
44. Aguiar, M.; Bils, M.; Boar, C. Who Are the Hand-to-Mouth? NBER Working Paper 26643. 2020. Available online: https://ssrn.com/abstract=3518256 (accessed on 14 February 2022).
45. Attanasio, O.P.; Weber, G. Consumption and Saving: Models of Intertemporal Allocation and Their Implications for Public Policy. *J. Econ. Lit.* **2010**, *48*, 693–751. [CrossRef]
46. Pingali, P.L.; Mark, W.R. Agricultural Commercialization and Diversification: Processes and Policies. *Food Policy* **1995**, *20*, 171–185. [CrossRef]
47. Guirkinger, C.; Boucher, S.R. Credit constraints and productivity in Peruvian agriculture. *Agric. Econ.* **2008**, *39*, 295–308. [CrossRef]
48. Fraval, S.; Hammond, J.; Bogard, J.; Ng'endo Kanui, M.; van Etten, J.; Herrero, M.; Oosting, S.; Boer, I.J.M.; Lannerstad, M.; Teufel, N.; et al. Food Access Deficiencies in Sub-saharan Africa: Prevalence and Implications for Agricultural Interventions. *Front. Sustain. Food Syst.* **2019**, *3*, 104. [CrossRef]
49. Fraval, S.; Hammond, J.; Lannerstad, M.; Oosting, S.J.; Sayula, G.; Teufel, N.; Silvestri, S.; Poole, E.J.; Herrerog, M.; van Wijka, M.T. Livelihoods and food security in an urban linked, high potential region of Tanzania: Changes over a three year period. *Agric. Syst.* **2018**, *160*, 87–95. [CrossRef]
50. Woldenhanna, T.; Oskam, A. Income diversification and entry barriers: Evidence from the Tigray region of northern Ethiopia. *Food Policy* **2001**, *26*, 351–365. [CrossRef]