Farm Production Diversity: Is it Important for Food Security, Dietary Diversity and Nutrition? Panel Data Evidence from Uganda

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and
Shamim Nalunga

Research Paper 396

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AFRICAN ECONOMIC RESEARCH CONSORTIUM
CONSORTIUM POUR LA RECHERCHE ÉCONOMIQUE EN AFRIQUE

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AERC Research Paper 396
African Economic Research Consortium, Nairobi
June 2020

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

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

ISBN 978-9966-61-090-4

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Abstract

Improved food security (quantities of food available to households for consumption) and nutrition security (quality of food available to households) remain global problems. Yet, food and nutrition security are areas of strategic importance with regard to the UN's Sustainable Development Goals. The changing global food production systems pose a threat to sustainable improved food and nutrition security. Consequently, a significant population globally remains chronically hungry. Some evidence points to market access as pivotal to enhancing food and nutrition security, whereas other evidence points to own farm production diversity. Mixed evidence creates knowledge gaps that worsen with disjointed insufficient empirical works on the global agriculture-nutrition nexus. Using national household panel survey data from Uganda, and panel regression models, we find that farm production diversity is associated with both improved food and nutrition security. We identified that markets and own farm production are two important food security pathways through which households secure their nutrition. Own farm production was associated with larger effects. Patterns by which these pathways influenced household dietary diversity were similar to those for daily energy, iron and zinc intake, except for vitamin A. We also found gender effects with regard to household nutrition security. Findings could have broader implications for several countries practising smallholder agriculture.

Key words: Farm production diversity, food and nutrition security, dietary diversity, panel data, Uganda.

JEL Codes: C33, C55, D02, Q12, Q18

1. Introduction

Improved food security (quantities of food available to households for consumption) and nutrition security (quality of food available to households) remain a problem in much of the developing world. Yet, improved food and nutrition security is an area of strategic importance as regards the UN's Sustainable Development Goals (SDGs). The world over, about 800 million people are still chronically hungry. Chronic hunger has been attributed to food access being dependent on income access (FAO, 2015; United Nations, 2017). However, income access and distribution is largely unequal, thus enhancing poverty, hunger and malnutrition (Reardon et al., 2000; Van Campenhout et al., 2016). The implication of unequal income distribution is that market access may not be a sufficient pathway for food security and against malnutrition. Therefore, farm production diversity remains an option to enhance household food and nutrition security, and would lessen the effects of unequal income distribution (Minten and Barrett, 2008; Godfray et al., 2010; Jones et al., 2014). In recent decades, various national policies have been used to define the type of crops farmers grow. This has given a stronger indication that farm production diversity is still an important focus for policy. Through such policies and related initiatives (for instance the Poverty Eradication Action Plan – PEAP), the Presidential Initiative on Banana Industrial Development – PIBID, and others in Uganda), a number of crops have been prioritized or introduced by the government to households, for instance bananas, bio-fortified sweet potatoes, vanilla, and so on. Other crops have also been promoted alongside the dominant crops in given agro-ecological zones. Therefore, these policies have dictated household farm production diversity (agriculture), hence food and nutrition security. Consequently, a complex nexus of agriculture, food security and nutrition has been created, which requires proper understanding to ensure sustainable household nutrition security.

Unfortunately, there have been knowledge gaps in understanding the farm production diversity – food and nutrition security linkages. These knowledge gaps have been more evident with regard to small-sector farm households that make up the largest proportion of the chronically hungry population. Some evidence points to market access being more important than farm production diversity towards food and nutrition security (Sibhatu et al., 2015). However, in the context of smallholder farmers in the developing world, where market infrastructure is poor and incomes unequally distributed, such evidence could be largely unrepresentative. Moreover, other evidence points to farm production diversity being more important (Haddinott, 2012; Jones et al., 2014). Therefore, evidence is mixed. In general, although recent efforts have tried to address this nexus of agriculture and nutrition (for instance, Jones et al., 2014; Whitney et al., 2018; Islam et al., 2018; and others), empirical evidence linking agriculture (farm production diversity) and nutrition security is disappointingly still scanty, infrequent, insufficient and disjointed (Shariff and Khor, 2005; Mello et al., 2010; Webb and Kennedy, 2014). Yet, agriculture and nutrition security are of central importance in eliminating severe hunger, chronic poverty and malnutrition (FAO, 2015; Webb and Kennedy, 2014). Therefore, understanding agriculture-nutrition linkages in a jointed framework is of strategic importance.

Disjointed efforts studying the agriculture-food security-nutrition nexus have been more evident in literature. Arndt et al. (2016) and Arndt and Tarp (2017) analyze food security (food poverty) in Sub-Saharan Africa (SSA) but show no clear linkages between food security and farm production diversity. Sibhatu et al. (2015) show evidence of association between market access and dietary diversity. Van Campenhout et al. (2016; 2017) studied food poverty in Uganda but did not cover farm production diversity or nutrition. Sekabira and Qaim (2017b) studied dietary diversity singly and used data from only two districts in central Uganda. A more jointed effort was by Jones et al. (2014) and Islam et al. (2018) who associated farm production diversity to household dietary diversity in Malawi and Bangladesh, respectively. However, Jones et al. (2014) used cross-section data and made no causal inferences. Although Islam et al. (2018) used panel data, they did not explore micronutrient links. Yet, Haddinott (2012) and Jones et al. (2014) agreed that comprehensively studying diets and nutrition is important in understanding agriculture-nutrition linkages of farm households.

Therefore, a significant gap exists in literature and in appropriate policy guidance with regard to farm production diversity (agriculture), food security and nutrition security nexus. We addressed the gap by focusing on the following research objectives and questions.

Research objectives and questions

We sought to understand linkages between farm production diversity (agriculture) within farm households in Uganda, specifically focusing on household: a) Food security and b) Nutrition security. While using panel data, we empirically answered the following research questions:

(i) How does farm production diversity influence household:
   (a) Food security (quantities of food available to households for consumption)?
   (b) Nutrition security (quality of foods/diets available to households)?

(ii) Between farms' generated food security (FFS – food security (daily consumption) achieved by households from consuming their own farm produce) and the income generated one through market access (MFS – food security achieved by households from consuming foods purchased or given from markets) – which one was a more important pathway through which farm production diversity contributed to household nutrition security?

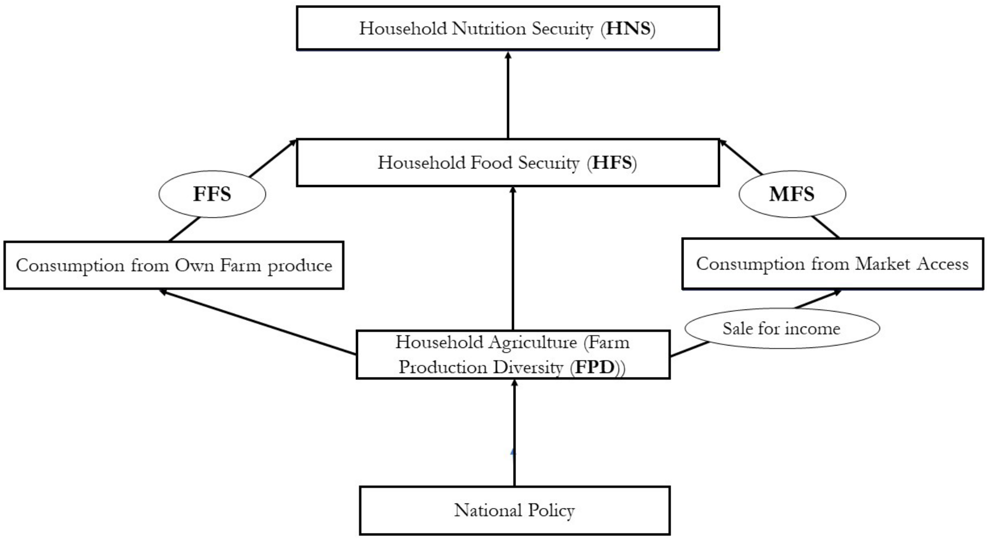
2. Conceptual framework

Overview

Households can satisfy their consumption needs majorly from own farm production or buying consumables from markets. By diversifying what they grow on their farms, households can consume from these plants or livestock species or sell these produce to access income to buy consumables from food markets. This, therefore, creates two major consumption pathways from household farm production diversity. These are: 1) Own farm produce consumption and 2) market access-based consumption. In the context of this study, own farm produce consumption is a consumption pathway where households get their consumables (plant or livestock species eaten within the households) directly from the farm. Market access based consumption is the consumption pathway where households get what to eat (plants or livestock species) through various market channels that include raw food purchases from markets, which is prepared in homes for consumption, ready-to-eat cooked foods bought and consumed in market places (restaurants, hotels, kiosks, and so on) and food accessed in kind.

For this study, therefore, because farm production diversity (FPD) can help households access foods either directly from farms (Farm food security pathway – FFS) or indirectly through farm incomes from crop or livestock sales through markets (Markets food security pathway – MFS), we hypothesized that farm production diversity bears a positive influence on household food security (HFS) and, subsequently, household nutrition security (HNS). We illustrate these linkages in Figure 1 to establish farm production diversity (agriculture) – nutrition linkages through both food security pathways, for a comprehensive understanding of the agriculture–food–nutrition security nexus.

Figure 1: Conceptual framework for the agriculture–food security–nutrition nexus



NB: FFS is Food Security achieved through consumption of own farm produce; MFS is Food security from market consumables.

Specifically, we hypothesized that households with higher farm production diversity would have better food security and thus better nutrition security. We also hypothesized that households with more diverse farm production would have more opportunities for marketed farm items, thus improving their incomes and subsequently their food and nutrition security. To compare pathways, we hypothesized that own farm generated food security (FFS) is more important than market generated food security (MFS) towards enhancing household nutrition security, as also established by Islam et al. (2018).

Data used

We use nationally representative panel survey data to study farm production diversity (agriculture) – nutrition linkages in Uganda. This comprised the Uganda National Panel Survey (UNPS); a yearly survey data collected by Uganda Bureau of Statistics (UBOS), collected with support from the World Banks's Living Standards Measurement Study – Integrated Surveys on Agriculture (LSMS – ISA) project. We used three waves: (2009/10, 2010/11 and 2011/12) that were available and possible to manage using unique identifiers within the data. The data covers about 3,300 households consecutively. The UNPS is a subset of the nationally representative 2005/6 Uganda National Household Survey (UNHS) of 6,775 households.

We chose Uganda as the case study country because cleaned panel data existed. We have also earlier done sufficient work on Uganda's food security using utility consistent poverty lines. Studying food poverty using utility consistent poverty lines takes into account region-specific differences in food prices, consumption bundles, cultural and traditional differences (Van Campenhout et al., 2016; 2017). We relied on the rationality assumption to guide us through the utility theory and to derive utility consistent poverty lines, a methodology we elaborate in Van Campenhout et al. (2016). Therefore, creating understandable farm production diversity–food security–nutrition security linkages using Uganda was relatively easier and comprehensively informative.

Measurement of farm production diversity, food security and nutrition security

Farm production diversity (FPD) has been measured using the household biodiversity index (HBI), which is a simple count of all crops and livestock produced on the farm. The household biodiversity index has been used by Di Falco and Chavas (2009), Jones et al. (2014), and more recently by Sibhatu et al. (2015). The formula for calculating HBI and meanings of variables used therein are provided in Appendix A.

Household Food Security (HFS) has been measured relying on empirical works of Van Campenhout et al. (2017), who established utility consistent food poverty levels for specific regions in Uganda (Kampala 2,336; Central 2,099; Northern 1,653; Eastern 1,668; and Western 1,990). Utility consistent lines render the food security indicator inclusive of region-specific social and cultural aspects, food consumption bundles and food prices. Lines are measured in Uganda shillings (UGX), (1 US$ = 3,500 UGX), and values for earlier years have been deflated using the official consumer price index (CPI) following UBOS (2015) to make food consumption values comparable across households. Therefore, our food security indicator measurements are comprehensive in addressing region-specific food security issues. Food and dietary assessments that reflect region specificity, societal diets and behaviour are more appropriate than aggregated assessments (Haddinott, 2012; Jones et al., 2014; Sibhatu et al., 2015; Van Campenhout et al., 2016). As a brief highlight on the theory underlying the construction of region-specific utility consistent poverty levels, we relied on the rationality assumption where economic agents desire to consume more to less if these agents derive utility from consumption. Therefore, a representative consumer in a given region will merely select that consumption bundle that maximizes his utility against his expenditure. The novelty of region-specific food poverty lines is that they portray the cost of basic needs (minimum energy requirements in kilocalories for an average adult to live), hence giving a clearer assessment of this consumer's food security (Arndt and Simler, 2010; Van Campenhout et al., 2016). These food poverty lines have been used to define households that are food secure or insecure. Specifically, a household whose cost of daily consumption requirements is above its region's utility consistent food poverty line will be food secure, and otherwise food insecure.

Household Nutrition Security (HNS) has been measured using the household dietary diversity score (HDDS), which reflects the dietary quality of foods available to households and; selected micronutrients (daily energy, iron, zinc and vitamin A intake). The HDDS is also measured using the aggregated food consumption index, which measures the sum of groups of foods consumed within a household. These are twelve (12) food groups: cereals, white roots and tubers, vegetables, fruits, meat and its products, eggs, fish, legumes nuts and seeds, dairy and its products, oils and fats, sweets and sugars, and spices, condiments and beverages. However, Swindale and Bilinsky (2006), Jones et al. (2014), and Sibhatu et al. (2015) state that various approaches can be used to measure dietary diversity and these should reflect comparative available qualities of particular foods, diets and societal food behaviour. Therefore, the dietary diversity index (HDDS) is appropriate. The methodology has also been used by Jones et al. (2014), Sibhatu et al. (2015), Koppmair et al. (2016), Sekabira and Qaim (2017b), and most recently by Islam et al. (2018). The formulae for computation of HDDS are availed as Appendix A and are clearly detailed in Swindale and Bilinsky (2006). Earlier literature such as Arimond et al. (2010) have validated HDDS as a good proxy for micronutrient adequacy for women's and children diets, while Koppmair et al. (2016) and Fongar et al. (2018) have validated HDDS as a good proxy for individuals' dietary quality for children, female and male adults. Fongar et al. (2018) add that, at individual level, dietary diversity scores are a good proxy of micronutrient intakes.

Nevertheless, given considerable differing debates on the appropriateness of the HDDS proxy to reflect a finer picture of micronutrient intake, selected micronutrients, including iron, zinc, vitamin A, and energy have been further used in this study. Computations of these micronutrients and energy have been based on Hotz et al. (2012), and compared to FAO recommended thresholds (FAO, WHO, UNU, 2001). Energy and micronutrients will help to assess nutrition security with regard to strategic micronutrients' intake. About two (2) billion people globally, most of whom are in developing countries, suffer deficiencies in these micronutrients (iron, zinc, and vitamin A). Yet, these micronutrients are central in improving physical and mental developments to avoid human vulnerability to diseases and early deaths (IFPRI, 2016).

Empirical model for the impact of farm production diversity on food security and nutrition

We implemented the following specification of panel regression models to address this objective.

$$FNSI_{it} = \chi_0 + \chi_1 FPD_i + \chi_2 \mathbf{X}_i + \alpha T_t + \varepsilon_i \quad (1)$$

Where $FNSI_{it}$ is food/nutrition security indicator (food consumption, HDDS or energy or micronutrient intake) of household i in year t. χ_0 is the constant. χ_1

is the effect of farm production diversity FPD_{it} that we established. χ_2 is a vector of coefficients for observed household, farm and contextual characteristics. 'T' is year (time) identifier variable, and α is the time fixed effects parameter. ε_{it} is the normally distributed error term. FPD_{it} is farm production diversity index of household i in year t. $\mathbf{X}_{it}$ is the vector of observed household (education, gender and age of head, distance to market centres, size, farm size, and so on), and contextual (location dummies, and others) characteristics. These characteristics, alongside farm production diversity, influence food and or nutrition security. t is the year identifier variable capturing yearly time fixed effects.

We followed equation (1) to assess the influence of farm production diversity on food, and nutrition security (HDDS, energy and micronutrient daily intake). However, since households chose to farm or not farm particular plant or livestock species, there might have been endogeneity concerns stemming from observed and unobserved heterogeneity, which may bias estimates. Therefore, all models are estimated with RE estimators. However, the assumption of the RE estimator that FPD is uncorrelated with any unobserved factors that may also impact on outcome variables is a stringent one. Since households self-select which species of crops or livestock to produce, violation of this assumption is highly likely, thus potentially leading to biased estimates. We, therefore, further estimate a pseudo fixed-effects model – the Mundlak (MK) estimator (Mundlak, 1978). The MK estimator contains covariate mean values of explanatory variables as additional covariates, hence controlling for possible biases arising due to time-invariant unobserved heterogeneity (Cameron and Trivedi, 2005). This helps us control unobserved heterogeneity of time-invariant covariates as would be done by the real fixed effects (FE) estimator (Wooldridge, 2010). We do not use the real FE estimator because some households changed headship (due to deaths, migration, divorce, and so on) over the three waves used, thus varying gender of some heads and education for given households. Therefore, these would be time-invariant variables (gender of head and education of head) turn variant and are not dropped when we run the FE estimator. Failure to drop (due to changing household headship over the years) such usually time invariant covariates by the FE estimator may confuse the readership, hence finding the MK specifications more plausible for this data. We interpret coefficients of the MK estimator that are more likely to yield efficient estimates given relaxation of the RE estimator strict assumption mentioned above. However, we present both RE and MK models for comparison. Nevertheless, in equations where we only control for only key food security variables, we use FE estimator along with the RE estimator, and use the Hausman test value to guide interpretations.

Modelling impact pathways of farm production diversity towards nutrition

We aimed to analyze impact pathways of farm production diversity on household nutrition security (HNS), yet a reduced model specification as in (1) was insufficient for such. Therefore, alongside reduced form models, we also implemented a pooled least squares estimator, which is a simultaneous equations procedure specified in equations (2) to (5), to analyze impact pathways. These are a three-stage least squares (3SLS) estimation system. Here, we estimated individual reduced equations at the first stage, then individual structural equations were estimated singly in the second stage; that is, estimates of (5) used in (3) and (4). Finally, in the third stage, the estimates from the two-stage least squares (2SLS) of equations (3) and (4) were used in the main equation (2), and then the entire system of equations was estimated simultaneously. This mechanism is based on elaborations by Zellner and Theil (1962), and Arellano and Bover (1995), and applications of Shankara and Mannering (1998) who used 3SLS approach to study endogeneity between lane-mean speeds and lane-speed deviations. Tests of identification have also been done to ascertain feasibility of variables used as instruments in the system.

$$HNS_{it} = \alpha_0 + \alpha_1 FFS_t + \alpha_2 MFS_t + \alpha_3 \mathbf{X}_t + \alpha_4 T_t + \varepsilon_{t\,2} \tag{2}$$

$$FFS_{it} = \beta_0 + \beta_1 FPD_t + \beta_2 \mathbf{Y}_t + \beta_3 T_t + \varepsilon_{t\,3} \tag{3}$$

$$MFS_{it} = \chi_0 + \chi_1 FPD_t + \chi_2 \mathbf{Z}_t + \chi_3 T_t + \varepsilon_{t\,4} \tag{4}$$

$$FPD_{it} = \delta_0 + \delta_1 \mathbf{K}_t + \delta_2 T_t + \varepsilon_{t\,5} \tag{5}$$

Where HNS_{it} is represented by HDDS and in other cases energy or micronutrient intakes (iron, zinc, or vitamin A) is the household nutrition security indicator of household i in year t, FFS_{it} is the own farm-generated food security indicator of household i in year t, presented as the daily per capita food consumption expenditure on food stuffs consumed directly from own farm production and measured in Uganda Shillings. MFS_{it} is the market-generated food security indicator, presented as the daily per capita food consumption expenditure on foodstuffs consumed by the household from market channels (direct purchases consumed at home, those purchased and consumed away from homes, and consumption from in-kind sources), also measured in Uganda shillings. FPD_{it} is farm production diversity of household i in year t. Equation (2) was the main estimation equation, (3) and (4) fed into (2) and (5) fed into (3) and (4).

For equation (2), α_0 is the constant. α_1 is the effect of own farm-generated food security on nutrition security, α_2 is the effect of market generated food security on nutrition security, α_3 is a vector of coefficients for the vector of household characteristics $\mathbf{X}_{it}$ that affect nutrition security. These characteristics include age, gender and education of the head, household size, farm size, accessibility to markets, agricultural extension access, and others, while is a time fixed effects parameter, and is a year identifier. ε_{it2} was the random error term.

For equation (3), β_0 is the constant. β_1 is the effect of farm production diversity on own farm generated food security, β_2 is a vector of coefficients for the vector of household characteristics $\mathbf{Y}_{it}$ that affect own farm generated food security. These characteristics include age, gender, and education of the head, household size, farm size, and others. β_3 is a time fixed effects parameter, is a year identifier. ε_{it3} was the random error term.

For equation (4), χ_0 is the constant. χ_1 is the effect of farm production diversity on market generated food security, χ_2 is a vector of coefficients for the vector of household characteristics $\mathbf{Z}_{it}$ that affect market generated food security. These characteristics include age, gender and education of the head, household size, farm size, distance to nearest market, possession of a mobile phone and others. χ_3 is a time-fixed effects parameter, and is a year identifier. ε_{it4} was the random error term.

For equation (5), δ_0 is the constant. δ_1 is a vector of coefficients for the vector of household characteristics $\mathbf{K}_{it}$ that affect farm production diversity. These characteristics include age, gender and education of the head, household size, farm size, and access to agricultural extension, annual precipitation, elevation, regional dummies, and others. δ_2 is a time-fixed effects parameter, and is a year identifier. ε_{it5} is the random error term.

We hypothesized that farm production diversity (FPD) is associated with a positive impact on household own farm-generated food security (FFS) and market-generated food security (MFS) that were both associated with a positive impact on household nutrition security (HNS). We also hypothesized that farm or market-generated food security is endogenous, since both could be influenced by farm production diversity. The HNS is also endogenous since the nutrition indicator can be influenced directly by either FFS or MFS while FFS and MFS each can also be influenced by HNS. For instance, if a household has better or worse HNS, this can influence the scale of the household's investment (expenditure) through either MFS or FFS. The Three Stage Least Squares (3SLS) approach that we employed allowed for specification of all endogenous variables, as endogenous. Endogenous variables were then instrumented by other explanatory variables to control for endogeneity. With such specification, equations were then solved jointly, producing error terms that were consecutively independent, with zero mean, and are homoscedastic (Zellner and Theil, 1962). For this system, exogenous variables included: elevation, annual precipitation, type of land tenure, distance to nearest market, location dummy, year dummy, household size, gender, age, education of household head, land size, if a household ever experienced consumption shocks or had access to extension services, and value of productive assets. The system is built to select instruments automatically from available exogenous variables to instrument specified endogenous variables.

3. Results and discussions

In this section, both descriptive and empirical results are presented and discussed, and we also highlight policy implications here.

Descriptive statistics

In Table 1, descriptive statistics of the pooled sample are presented. We do not explore the heterogeneity of the sample with regard to years of observations or regions of household locations. However, we used these descriptively to portray general similarities or differences of the findings with those in literature. This aimed to highlight new general knowledge and existing agreements or gaps within literature.

From Table 1, on average a household consumed 7.5 food groups of the 12 maximum possible, implying a shortage of about 4 food groups. These results are quite similar to those of Sekabira and Qaim (2017b), and those of Sserunkuuma and Omiat (2018) whose average HDDS for Uganda using UNPS data from 2009 to 2014 ranged between 7.2 and 8.1 food groups. From Figure 2, protein-dense food groups were the least consumed, including eggs, fish, dairy and its products, and meat and its products. This may reflect the prevailing dominance of government initiatives and poverty eradication programmes in Uganda. These initiatives have been largely bent towards crop production, and mainly focused on maximizing food quantities over quality to support livelihoods. This was also supported by heavy contributions towards the household dietary diversity score (HDDS) mean by: cereals, roots and tubers, legumes, nuts and seeds, and vegetables that are mostly grown for commercial purposes. Perhaps future policy must as well equally and intensely as with crops, also advocate poultry and livestock farming to improve contributions towards protein-based foods.

In Table 1, we also show results depicting household food security both qualitatively (food security dummy) and quantitatively (daily per capita consumption). Results show that only about 24% of sample was food secure based on a utility consistent national food poverty line that has been corrected with national consumer price index (CPI) for comparability across years. Results are consistent with Van Campenhout et al. (2017), who found a national poverty head count of 33% based on a utility consistent poverty line but with a food component of 71% for Uganda. Results of the utility consistent food poverty line, and the daily per capita consumption are also similar to those of Van Campenhout et al. (2017).

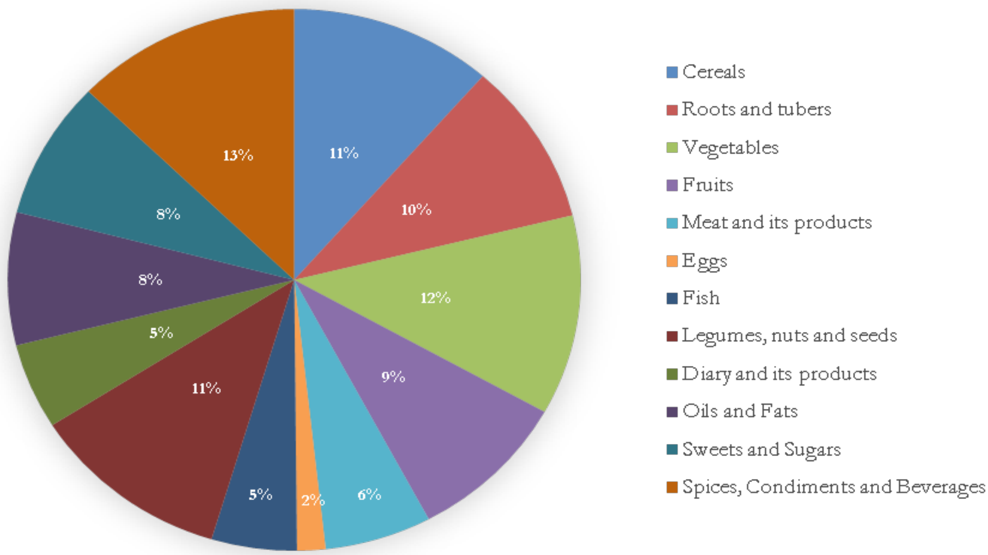
Table 1: Pooled sample (N = 8617) descriptive statistics for key variables used in empirical estimations

Variable	Mean	Std. Dev.
Dependent Variables		
Nutrition (HDDS considering 12 food groups) (proxy for HNS)	7.462	2.515
Food secure households (% under CPI weighted utility consistent national food poverty line)	23.674	42.511
Utility consistent national food poverty line (UGX)	1,092.73	170.553
Farm production diversity (biodiversity index)	8.863	6.215
Explanatory Variables		
Distance to nearest market (kilometres)	29.543	20.016
Annual precipitation (mm)	1,237.61	182.572
Elevation (metres)	1,228.23	231.368
Urban households (percentage)	22.995	42.082
Male headed households (percentage)	70.286	45.703
Household size (persons)	6.956	3.639
Education (years)	5.335	3.996
Heads using mobile phones (percentage)	55.971	49.645
Productive assets (millions UGX)	19.700	93.900
Experienced shocks (percentage)	46.854	49.904
Land size (Acres measured by GPS)	3.282	20.217
Free/lease hold land holders (percentage)	33.678	47.264
Accessed extension services	18.255	38.632
Pathways Analysis Variables		
Daily household per capita food consumption (UGX)	2,440.29	2,313.11
Daily per capita consumption through markets (UGX) (proxy for MFS)	1,819.62	2,204.26
Daily per capita consumption from own production (UGX) (proxy for FFS)	888.24	841.14

Source: Authors calculations from UNPS data waves 2009, 2010, and 2011.

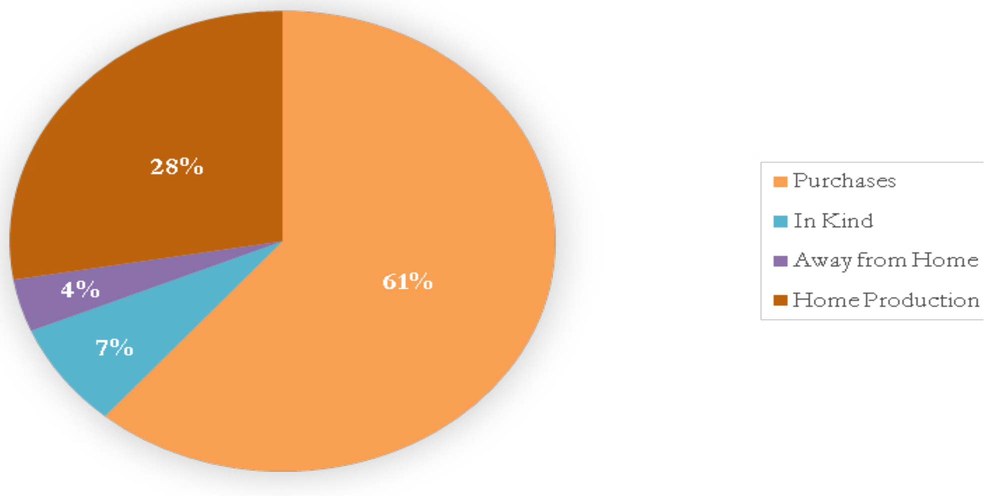
With regard to farm production diversity (FPD), results from Table 1 show that each household on average kept 9 species of crops and livestock. However, the largest proportion of the FPD index, following results from Figure 4, is contributed by crop species (47%), followed by animal (pack and small) species (28%), and least is by poultry species (25%). This largest contribution of crop species may still reflect a heavier bias of policy interventions towards increasing and diversifying crop species produced by households, than towards livestock.

Figure 2: Mean percentage composition of nutrition (HDDS) in terms of the 12 food groups



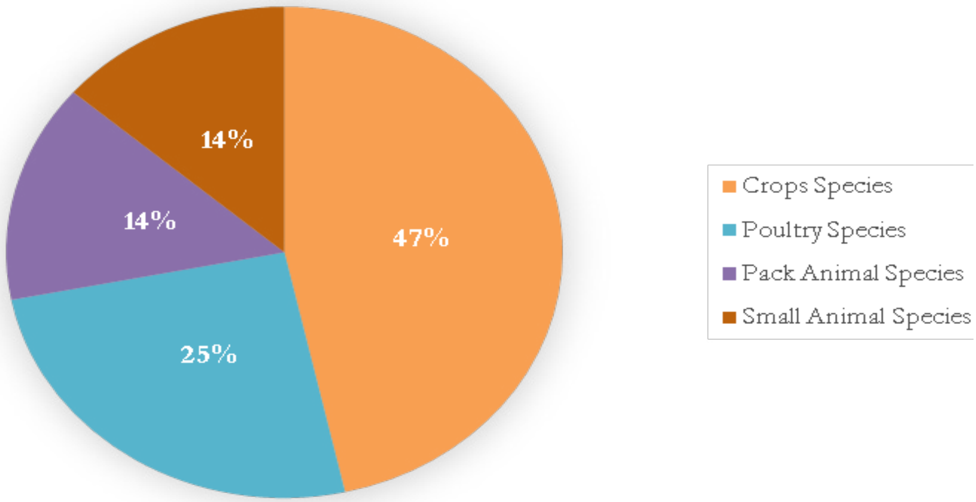
In Figure 2, we decomposed the mean value of household nutrition (HDDS) presented in Table 1 into its contributing 12 food groups – showing percentage contributions of each group. Surprisingly, the less nutritious food group of spices, condiments, and beverages contributed the largest proportion (13%) of HDDS across all households. This means that, on average, this food group was consumed across the largest number of sample households (95%). Another two less nutritious food groups, oils and fats, and sweets and sugars, each contributing 8% to HDDS, were also largely consumed across households. Yet, these may not even have contributed seriously towards food and nutrition security. Therefore, current policy that may be favouring easy access to certain foods such as alcohol, sodas, sweets, sugar, and so on, that are less nutritious may have to be more restrictive. Policy may have to divert effort towards the lacking more nutritious foods such as eggs, fish, and dairy and its products. These results are in line with FANTA-2 (2010), who assessed the food and nutrition situation in Uganda and found that cereals, roots and tubers, and matooke were the most consumed foods in Uganda while eggs, meat, and milk products were consumed rarely. McKinney (2009) and more recently Kilimani et al. (2018) and Whitney et al. (2018) also found similar consumption patterns.

Figure 3: Mean percentage composition for daily per capita consumption in UGX



From Figure 3, we aimed at understanding the impact of various food security pathways towards improved nutrition. We presented mean percentage contributions of each food security pathway towards the average daily per capita consumption expenditure. Foods purchased directly from markets contributed the highest composition (61%) of the daily per capita consumption expenditure. This was followed by foods from own production, then foods received in kind, and least those purchased but consumed away from home (4%). Foods consumed and purchased directly from markets, those consumed away from home, and those received in kind (indirect markets) were contributing towards daily per capita consumption through the markets pathway. Foods consumed from home production were contributing towards daily per capita consumption through the own production pathway. From Figure 3, the largest monetary value spent by households towards food security is through the market pathway. These results are consistent with Sibhatu et al. (2015) who associated the market pathway to being the more important food security pathway. However, market value may not necessarily mean quantity or quality of food, since farm gate prices are usually lower than market prices. Also, if the less nutritious food groups (sweets and sugars, oils, and beverages and condiments) would be excluded, home food consumption expenditure valued at market prices may outweigh market food consumption expenditure, thus agreeing with FANTA-2 (2010), and Kabunga et al. (2014).

Figure 4: Mean composition of farm production diversity (biodiversity index)



In Figure 4, we decomposed the mean value of FPD index in Table 1 to its contributing category species. Since much of agricultural policy initiatives in Uganda have aimed mostly towards crops such as bananas, potatoes, coffee and cassava, therefore attracting more households to diversify with these crops, crop species contributed most towards the FPD index.

The lower part of Table 1 displays average values of other explanatory variables used in empirical estimations. The sample was mostly rural (77%), male-headed (70%) and above half of the population used mobile phones (56%). Households, on average, had 7 persons, a land size of 3 acres, and heads spent only 5 years in school (primary level). However, only 18% of households accessed agricultural extension services. This probably implied that a number of agricultural policy initiatives that aimed at increasing diversification for even targeted crops still lacked average intensity towards extension services. Further still, only 34% of the sample had reliable land tenure (free/leasehold) and this may have limited land available for more crops and livestock species diversification. Also, 47% of households suffered production shocks such as drought, floods, mudslides, pests and disease, which may have limited species produced on farms, hence affecting household food security and nutrition. Uganda had in place policy initiatives against these shocks; however, only severe impact shocks had been addressed, for instance mudslides in Buduuda. Such selective antidotes to shocks left out other regions suffering average shocks of drought, diseases, deaths, and so on, that affect most farming households. To the best of our knowledge, as novelty to this study, this kind of household consumption disaggregation (by species groups eaten) has only been done by this study at least for Uganda.

In Table 2, we present means of household daily energy, and micronutrient intake per adult equivalent. Still, the presentation is made based on our target food security pathways (markets versus own farm production) in terms of their contribution to the total daily mean intake.

Table 2: Descriptive statistics for daily household energy and micronutrient intake per adult equivalent (AE)

Nutrients intake per AE	Mean	Std. dev.
Market-sourced component (N=8,311)		
Energy (kilocalories)	1,726	1,481
Iron (milligrams)	11.74	10.66
Zinc (milligrams)	9.270	8.302
Vitamin A (RAE – micrograms)	145.7	205.9
Own farm production sourced component (N=6,374)		
Energy (kilocalories)	1,227	1,133
Iron (milligrams)	11.26	9.403
Zinc (milligrams)	5.914	5.490
Vitamin A (RAE – micrograms)	249.0	314.1
Total nutrients consumed (all sources) (N=8,574)		
Energy (kilocalories)	2,636	1,567
Iron (milligrams)	19.70	11.02
Zinc (milligrams)	13.36	8.156
Vitamin A (RAE – micrograms)	331.9	329.7
Sample nutrient consumption deficiency, 0 – 1 scale (N=8,574)		
Energy	0.502	0.500
Iron	0.504	0.500
Zinc	0.655	0.476
Vitamin A	0.849	0.358
Household size (Adult Equivalents – AE)	4.241	2.285
FAO recommended minimum thresholds per AE		
Energy (kilocalories)	2,400	
Iron (milligrams)	18.27	
Zinc (milligrams)	15.00	
Vitamin A (RAE – micrograms)	625.0	

Source: Authors' calculations from UNPS data waves 2009, 2010, and 2011.

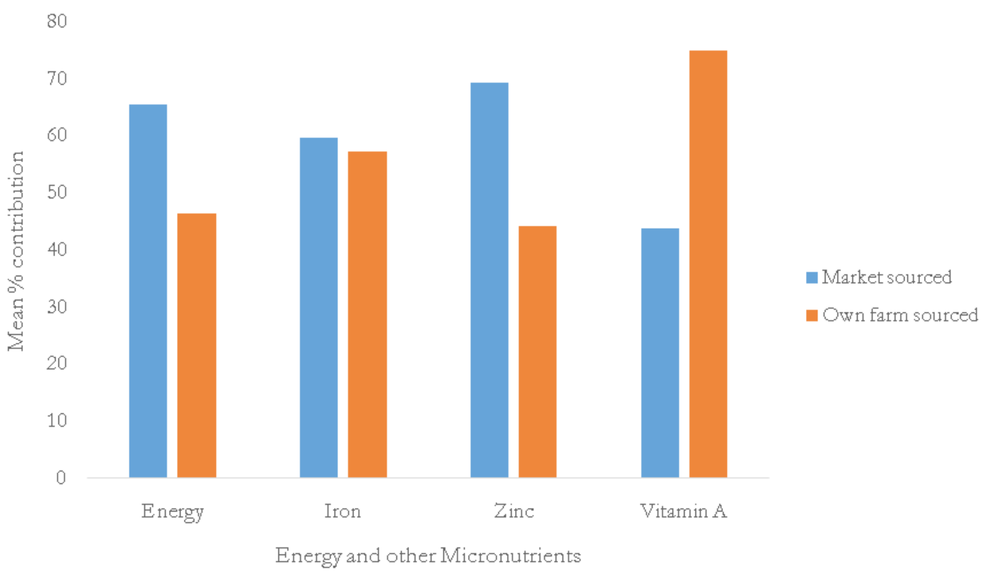
NB: RAE is retinal activity equivalents.

From Table 2, generally the sample was deficient in energy and other micro nutrients when compared with the FAO-recommended minimum thresholds. From Table 2, in the sample nutrient consumption deficiency section, deficiency proportions varied across micronutrients, with households being more deficient in vitamin A

(85%), then zinc (66%), and least iron (50%). Over 50% of households were also deficient in energy. The average household daily energy intake is 2,636 kilocalories per Adult Equivalent (AE). This figure nearly tallies with the 2,220 kilocalories per capita for Uganda (Wikipedia, 2018). FAOSTAT (2010) also quotes a similar figure (2,220 kilocalories per person per day). The tally is based on an average household size of 5 persons (UBOS, 2015), and an average size of 4.2 adult equivalents established by this study. Household averages of daily energy and micronutrient intakes are sourced from two food security pathways: markets and own farm production. In Figure 5, we show mean percentage contributions of each pathway towards the household daily mean intake for energy and respective micronutrients. The high micronutrient deficiency levels for Uganda are not surprising. The Uganda demographic household survey (UDHS) of 2006 in a supplementary study revealed that 88% of women were iron deficient (FANTA-2, 2010).

From Figure 5, as expected, energy intake is mostly from market-purchased foods. However, iron and zinc too are mostly sourced from markets for the sample households. In contrast, vitamin A is largely sourced from own farm production sources. This may be explained by the cultural and social behaviour that foods such as vegetables and fruits, which are a big source of vitamin A, are not bought. Also, consumption of these foods is usually termed as a reflection of poverty (Kilimani et al., 2018) while other households would mostly grow them for selling (Kabunga et al., 2014). That may explain the far much below average (331.9 Rae-mcg per AE) vitamin A intake for the sample, compared to the FAO recommended minimum threshold of 625 RAE-mcg per AE.

Figure 5: Source (markets or own farm) mean percentage contribution to the overall daily mean intake per AE



We must, however, stress the fact that these form a very small proportion of several micronutrients necessary for daily consumption for healthy human development, alongside other macronutrients not included here. We may not at this stage also conclude that the markets pathway is generally the more reliable pathway for all micronutrients. As another novelty, to the best of our knowledge, ours is the first study exploring such decomposition of energy and micronutrients intake by households based on their sources.

Empirical results

Direct impact of farm production diversity on food and nutrition security in Uganda

In Table 3, results of panel regression models for the impact of farm production diversity on household food and nutrition security are presented. We use panel logit regression models for the food security dummy variable of value 1 if household was food secure, and 0 if food insecure. Focusing on the MK model in column 2 of Table 3, results imply that the probability of households becoming food secure significantly decreased with increasing FPD. These results were the opposite of what we hypothesized. However, since only about 24% of the sample was food secure, the qualitative food security variable could be hugely biased towards the food insecure category. In column 3 and 4 of Table 3, we estimate the model using a household specific continuous variable (daily per capita expenditure in UGX) to proxy food security, and in both cases the impact is positive and significant. From column 4, an increase by one species of crops or livestock produced on the farm led to an associated increase of 8.5 UGX in the daily per capita expenditure. This implies a 0.4 percentage point increment, considering a sample average of 2,440 UGX.

FPD also bears a positive and significant associated impact with the nutrition security indicator for dietary quality (HDDS). Results of model 6 in Table 3 showed that adding a single species of plants or livestock to a household's species produced on farm was associated with about 0.04 increments in the food groups consumed by households. This implied a nearly 1 percentage point associated increment, considering the sample average of 7.5 food groups consumed per household. Such small increments are not surprising, especially with dominantly subsistence farm household samples. Islam et al. (2018) also found small but positive and significant associations between farm production diversity and HDDS in Bangladesh. Whitney et al. (2018) also found farm production diversity to be positively associated with HDDS in Uganda, and Jones et al. (2014) and Koppmair et al. (2016) in Malawi. Sibhatu et al. (2015) also found similar results in other developing countries. Our results, therefore, also indirectly imply that policies aimed towards increasing farm production diversity in Uganda are positively associated with improvements in household nutrition security.

Other than farm production diversity, Table 3 results (models 4 and 6) also excavated other factors with notable influences on household food and nutrition security. Notably, increases in the distance to nearest market significantly increased both household food and nutrition security. This implies that the more remote a household was (further away from markets that are usually in town centres) the more food and nutrition secure the household was likely to be. This may be due to associated increases in land available for farming and less dependency on markets that require incomes to buy food in the poverty-stricken rural areas. This may make more sense for households that are dominantly subsistence. Moreover, Sekabira and Qaim (2017b) also found a positive relationship between markets distance and HDDS. However, Sibhatu et al. (2015) and Koppmair et al. (2016) found an opposite direction association in Malawi, and Islam et al. (2018) in Bangladesh.

Personal characteristics of the household head, such as possession of a mobile phone, age and education years were all associated with positive and significant impacts towards household food and nutrition security. Mobile phone (MP) use influences food and nutrition security through the income, information and knowledge mechanisms. Mobile phones enable and enhance access to remittances and smooth consumption expenditure. They also enable communication to relatives or colleagues for business from which incomes are made to smooth consumption, and information and knowledge about types, content and quality of foods eaten. With such remittances, information and knowledge, households may access various food types and become aware of particular importance of specific foodstuffs. Nutrition awareness, and knowledge enhance consumption of good quantities and qualities of foods and therefore enhancing food (dietary quantity) and nutrition security (dietary quality). The results are in agreement with Sekabira and Qaim (2017b), who found that use of mobile phones positively influences HDDS in Uganda. Melese and Melak (2018) found nutrition knowledge to be an important determinant of nutrition outcomes in Ethiopia.

An increasing age of the household head was also associated with improved household food and nutrition security. This is not surprising, since with increasing age usually heads learn through personal experiences and social networks. Such learning benefits heads with vital nutrition knowledge accumulated over time, hence guiding them on proper household food and nutrition security. However, very old age impacts negatively. The results are in line with findings of Koppmair et al. (2016) in Malawi, and Sekabira and Qaim (2017b) in Uganda, and Islam et al. (2018) in Bangladesh who also established a positive association between age of house heads and HDDS. Kasiwa and Muzabedi (2018) also found similar results with regard to child dietary diversity score in the DR Congo. Olomola (2018) found mixed results while studying HDDS for farmers subscribed to input-subsidy schemes versus non-subscribers in Nigeria. Jones et al. (2014) found an inverse relationship between age of household head and HDDS in Malawi.

Table 3: Impact of farm production diversity on household food and nutrition security

Variables	Food security (Dummy)		Daily per capita consumption (UGX)		Nutrition indicator (HDDS) 12 food groups	
	Logit-RE (1)	Logit-MK(3)	RE (5)	MK (6)	RE (7)	MK (8)
FPD (biodiversity index)	-0.045***	-0.043***	6.695*	8.509**	0.034***	0.036***
	(0.008)	(0.009)	(3.712)	(3.703)	(0.006)	(0.006)
Distance to market (kilometers)	0.003	0.020*	-1.048	7.324*	-0.001	0.011*
	(0.002)	(0.012)	(0.934)	(4.114)	(0.002)	(0.007)
Mobile phone use (dummy)	-0.881***	-0.372***	654.1***	303.2***	0.977***	0.486***
	(0.077)	(0.114)	(34.13)	(45.87)	(0.056)	(0.075)
Household size (persons)	0.143***	0.144***	-112.0***	-66.63***	0.115***	0.181***
	(0.011)	(0.036)	(5.394)	(13.77)	(0.009)	(0.022)
Male heads (dummy)	-0.215**	0.122	69.60*	-97.55	-0.205***	-0.318**
	(0.083)	(0.245)	(40.36)	(97.67)	(0.068)	(0.159)
Age of head (years)	0.009	0.002	58.88***	53.71***	0.084***	0.069***
	(0.009)	(0.018)	(4.241)	(7.385)	(0.007)	(0.012)
Age of head squared (years)	-8.9e-6	1.5e-5	-0.567***	-0.462***	-0.001***	-0.001***
	(9.8e-5)	(0.0002)	(0.044)	(0.093)	(7.4e-5)	(0.0002)
Education (years)	-0.069***	0.001	60.68***	30.79***	0.102***	0.055***
	(0.009)	(0.015)	(4.118)	(5.630)	(0.007)	(0.009)
Shock experience (dummy)	0.013	-0.108	90.75***	133.9***	0.158***	0.169***
	(0.068)	(0.085)	(29.04)	(33.62)	(0.048)	(0.055)
Land size (GPS acres)	-0.015*	0.003	1.121	0.432	0.002	0.002
	(0.008)	(0.009)	(0.792)	(0.875)	(0.001)	(0.001)
Year 2010	0.295***	0.289***	-8.131	-19.63	-0.345***	-0.364***
	(0.075)	(0.079)	(30.36)	(31.45)	(0.049)	(0.051)
Year 2011	-0.142*	-0.174*	377.7***	356.7***	-0.135***	-0.168***
	(0.079)	(0.091)	(30.71)	(34.74)	(0.050)	(0.057)
Means of Variables		YES		YES		YES
Constant	-1.631***	-1.329***	5,222***	5,093***	3.705***	3.259***
	(0.248)	(0.293)	(105.0)	(130.6)	(0.175)	(0.221)
Observations	8,616	8,616	8,616	8,616	8,616	8,616
No. of households	3,300	3,300	3,300	3,300	3,300	3,300
Wald Chi^2 value	458.66***	487.94***	1,463.06***	1,677.90***	1,611.65***	1,787.80***

Notes: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1, FPD is Farm Production Diversity. See full table in Appendix B.

All other variables (MP use and increasing age) linked to information and knowledge access, and increases in education, were associated with improved household food and nutrition security. With sufficient education, household heads can learn and know feeding basics, requirements, compositions of foods in terms of quality (macro and micronutrient content), thus achieving nutrition knowledge. Such knowledge drives households to feed on sufficient quantities (food security) that are nutritionally quality, hence improving both food and nutrition security. Away from the knowledge pathway, education can bear an income pathway. With good education, household heads can access well-paying employment, whose incomes can be used to purchase sufficient and quality foods. These findings are in line with our a priori expectations and existing empirical evidence including Jones et al. (2014) and Koppmair et al. (2016) for Malawi, Sekabira and Qaim (2017b) for Uganda, and Islam et al. (2018) for Bangladesh.

With regard to shocks (drought, floods, persistent illnesses, death of household head, and so on), we had primarily expected these to impact negatively on household food and nutrition security. However, from results in Table 3, increased experiences of shocks were instead associated with better food and nutritional security. Moreover, given the high poverty levels in Uganda, shocks may instead help households improve their already worse food and nutrition security. In times of household specific shocks such as persistent illnesses or deaths of household heads, these households are exposed to daily routines of remittances and other consumption support from other family members or community. In times of community or regional shocks, for instance floods or droughts, households are usually exposed to national, regional, or international support. Such support usually provides not only reasonable quantities but also quality and diverse foods, even with supplements. However, these findings must be interpreted with caution since this was 7-day recall data (one week), which may not represent a year scenario. Nevertheless, the panel nature (3 waves across 3 years) may make the results more reliable in depicting a nearly true household yearly scenario. In such a case, the remittances pathway may be a more reliable pathway than national or international interventions against shocks. This study seems to be the first one exploring relationships between such shocks and HDDS.

Increases in household size were associated with significant decreases in food security and significant increases in nutrition security; the latter was unexpected. However, through the labour provision pathway, an increased household size may provide more labour available for food production, and hence better nutrition security. However, some household members such as the elderly and very young children may be unable to provide labour, yet must feed, thus increasing the burden on available food, as found by Whitney et al. (2018). Therefore, in such a situation (larger dependent household size), household size impacts negatively on the available food quantities, hence affecting food security negatively. The results (positive association between household size and HDDS) are in agreement with Jones et al. (2014) and Islam et al. (2018) who found household size to be positively associated with HDDS in Malawi, and Bangladesh, respectively, and Sekabira and Qaim (2017b) for Uganda. However, Koppmair et al. (2016) found an inverse relationship between household size and HDDS in Malawi.

Table 4: Impact of farm production diversity (FPD) on household daily energy, iron, zinc and vitamin A intake per AE

Variables	Energy (Kilocalories)		Iron (milligrams)		Zinc (milligrams)		Vitamin A (RAE – mcg)	
	(1) RE	(2) MK	(3) RE	(4) MK	(5) RE	(6) MK	(7) RE	(8) MK
FPD (biodiversity index)	7.711**	6.535*	0.114***	0.102***	0.066***	0.058**	5.004***	4.704***
	(3.868)	(3.906)	(0.030)	(0.031)	(0.022)	(0.023)	(0.873)	(0.900)
Distance to nearest market (kilometers)	-1.493*	2.275	0.006	-0.006	-0.003	-0.0001	0.963***	-1.408
	(0.897)	(3.918)	(0.007)	(0.032)	(0.005)	(0.021)	(0.182)	(1.087)
Head uses mobile phone (dummy)	217.8***	-23.11	0.627**	-0.557	1.442***	-0.007	-27.05***	-7.935
	(35.10)	(50.66)	(0.276)	(0.420)	(0.203)	(0.292)	(7.991)	(13.51)
Household size (Adult Equivalent)	-126.9***	-194.5***	-0.877***	-1.382***	-0.691***	-0.994***	-9.353***	-15.16***
	(7.907)	(18.45)	(0.061)	(0.145)	(0.045)	(0.100)	(1.696)	(4.266)
Male heads (dummy)	23.79	279.9**	-0.046	1.642**	0.352	1.574**	-6.288	0.855
	(39.41)	(110.5)	(0.302)	(0.783)	(0.224)	(0.627)	(8.148)	(31.37)
Age of head (years)	1.905	15.58**	0.033	0.129**	0.001	0.084**	-0.919	2.078
	(4.593)	(7.575)	(0.036)	(0.065)	(0.026)	(0.041)	(1.025)	(2.282)
Age squared of head (years)	-0.028	-0.214**	-0.0004	-0.001	-0.0001	-0.001**	0.015	-0.025
	(0.047)	(0.097)	(0.0004)	(0.001)	(0.0003)	(0.001)	(0.010)	(0.031)
Education of head (years)	-16.53	-36.64**	0.004	-0.274**	-0.097	-0.300***	2.884	0.999
	(11.45)	(17.24)	(0.089)	(0.137)	(0.066)	(0.099)	(2.587)	(4.353)
Education squared of head (years)	2.625***	3.696**	0.007	0.027**	0.016***	0.024***	-0.155	0.100
	(0.893)	(1.441)	(0.007)	(0.011)	(0.005)	(0.008)	(0.200)	(0.344)
Shock experience (dummy)	-69.56**	-45.74	0.007	-0.107	-0.219	-0.197	-5.570	-16.05
	(30.80)	(37.53)	(0.245)	(0.308)	(0.180)	(0.226)	(7.406)	(10.23)
Land size (GPS meters)	1.188	-0.926	0.026	-0.002	0.027*	-0.001	0.650	-0.195
	(2.449)	(2.930)	(0.019)	(0.026)	(0.014)	(0.017)	(0.572)	(0.791)
Land size squared (GPS meters)	-0.004	-0.002	-5.4e-5*	-1.8e-5	-4.9e-5**	-1.3e-5	-0.001	-0.0001
	(0.004)	(0.004)	(3.1e-5)	(4.0e-5)	(2.3e-5)	(2.7e-5)	(0.001)	(0.001)
Year 2010	34.99	57.38*	0.264	0.295	-0.018	0.049	-18.11**	-21.14**
	(33.28)	(33.87)	(0.271)	(0.271)	(0.197)	(0.197)	(8.868)	(9.143)
Year 2011	9.166	49.32	0.227	0.301	-0.146	-0.006	-16.91*	-21.48**
	(33.37)	(34.52)	(0.271)	(0.277)	(0.197)	(0.203)	(8.818)	(9.088)
Means of Variables		YES		YES		YES		YES
Constant	4,757***	4,795***	20.53***	21.33***	14.76***	14.74***	322.5***	337.8***
	(115.1)	(145.8)	(0.892)	(1.196)	(0.657)	(0.900)	(25.50)	(31.11)
Observations	8,574	8,574	8,574	8,574	8,574	8,574	8,574	8,574
No. of households	3,258	3,258	3,258	3,258	3,258	3,258	3,258	3,258
Wald Chi^2 value	358.80***	368.45***	229.67***	262.13***	344.79***	409.63***	138.00***	158.75***

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1; RE is Random Effects, and MK is Mundlak approach (Pseudo-fixed effects model); RAE-mcg is Retinal activity equivalents-micrograms. See Appendix C for full table.

Models 6 and 8 of Table 3 show clear associated gender influences on both household food and nutrition security. Male household headship (70% of the sample in Table 1) was associated with significantly poorer food security (at 10% significance level) and nutrition security (at 1% significance level). Results imply that the effect was worse for nutritional security. Traditionally, women are responsible for feeding patterns of households. But incomes or decisions for which foodstuffs should be farmed or bought for consumption rest with the heads (mostly males). Therefore, household food and nutrition security gets to be negatively affected. Males may be unaware of sufficient food quantities, feeding patterns of household members, or appropriate foods. Yet, males make decisions affecting types, quantities and qualities of food consumed (61% of foods purchased – Figure 3). These results support recent conclusions by Sekabira and Qaim (2017b), who found existence of gender-related differences with regard to household nutrition, where male headship impacted HDDS negatively. Jones et al. (2014) and Islam et al. (2018) also found similar results in Malawi, and Bangladesh, respectively. However, Koppmair et al. (2016) found positive but insignificant associations in Malawi. Therefore, policies need to be gender informed and inclusive with regard to nutrition interventions to avoid such negatively impacts.

To further disentangle HDDS (dietary quality indicator) to components possible for us to cover under this study, we present in Table 4 results for the impact of FPD on daily energy, iron, zinc and vitamin A intake. We expected the direction of effect of FPD on micronutrients to be similar to that of FPD towards HDDS. As novelty, to the best of our knowledge, this is the first study exploring empirical association of farm production diversity with regard to energy and micronutrient daily intake for farm households.

As had been expected from results in Table 4, columns 2, 4, 6, and 8, farm production diversity (FPD) is positively and significantly associated with household daily intake of energy, iron, zinc and vitamin A. Specifically, a one species increase in the number of crops and livestock produced on farm is associated with increments of 6.5 kilocalories, 0.1 milligrams, 0.06 milligrams, and 4.7 RAE – micrograms of energy, iron, zinc and vitamin A, respectively. These incremental associations imply, respectively, 0.3, 0.5, 0.4, and 1.4 percentage point increases in energy, iron, zinc and vitamin A household daily intake. The trend may not be surprising since, from Figure 2, the most consumed foods are the energy dense ones, hence the unit incremental effects are smallest for energy. Unit incremental effects are largest for micronutrients because micronutrient rich foods are less consumed. For instance, eggs, meat and its products, and fish, are less consumed, while others such as fruits and vegetables are only moderately consumed, as also depicted in Figure 2. These findings agree with existing literature. For instance, McKinney (2009) established that households in Uganda across various regions dominantly consume staples (cereals, roots and tubers or matooke) daily, but micronutrient dense foods such as milk, eggs, meat, vegetables and fruit are consumed infrequently. FANTA-2 (2010) found that meals were inadequately varied in Uganda especially for children, and fruits and vegetables were rarely fed to children. More recently, Kilimani et al. (2018) identified socio-cultural tendencies that deter households from consumption of micronutrient dense foods in Uganda. Yet, recent evidence points to home production of food groups such as fruits and vegetables being associated with more diversity in dietary intakes (Kabunga et al., 2014; Whitney et al., 2018).

A number of factors that were important for the nutrition indicator (HDDS) remain important for daily household energy, iron, zinc and vitamin A intake. Due to space limitation, we do not re-explain them. Because we are more interested in the detailed analysis of pathways (markets or own production) through which FPD affects nutrition, in Table 5 we estimate equation (1) for insights in direct associations between FPD and daily household energy, iron, zinc and vitamin A intake sourced through each pathway. We use the Mundlak approach.

From results of Table 5, FPD is negatively and significantly associated with daily household intake for energy, iron, zinc and vitamin A sourced from markets. The sample is predominantly made of subsistence farmers who produce crops and livestock mostly for consumption. Less is sold in markets for income towards food consumption. Instead, when such produce is sold, incomes are mostly diverted to other long-term household investments, for instance school fees payments, building, health financing, and so on. Therefore, it may not be surprising to see such strong negative direct associations between FPD and energy, iron, zinc and vitamin A intake. On the other hand, FPD is positively and significantly associated with daily intake of energy, iron, zinc and vitamin A intake sourced from own farm production. This is not surprising especially with our knowledge of subsistence farming of the sample households. They mostly consume what they produce, hence the strong positive associations with daily consumptions through the own farm production pathway.

Essentially, FPD reduces household market reliance for both daily energy and micro-nutrient consumption while FPD enhances consumption of daily energy and micro-nutrients from own farm production sources. Therefore, direct positive impacts of FPD towards daily energy and micronutrient intake are more realizable through consumption of on-farm produce. This agrees with Benson (2008) and FANTA-2 (2010) who established that most households in Uganda, especially rural ones, mostly consume from own production sources. The results are not surprising given the heavily subsistence (largely produce for food) nature of the sample households. To the best of our knowledge, this is the first study to document such differential effects of FPD by consumption pathways for energy and micronutrients intake, more so while using panel data. Related efforts have been done by Islam et al. (2018) but they only explore FPD associations with HDDS in Bangladesh. Other factors are also differently important in the daily consumption of energy and individual micronutrients.

Table 5: The impact of FPD on household daily energy, iron, zinc and vitamin A intake per AE by food security pathway

Variables	Energy (kilocalories)		Iron (milligrams)		Zinc (milligrams)		Vitamin A (rae-mc)	
	Markets	Own farm	Markets	Own farm	Markets	Own farm	Markets	Own farm
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Farm production D (biodiversity index)	-74.58***	20.75***	-0.208***	0.179***	-0.099***	0.098***	-2.535***	4.057***
	(10.94)	(2.423)	(0.029)	(0.023)	(0.020)	(0.012)	(0.507)	(0.927)
Distance to nearest market (kilometers)	-8.043	4.222*	-0.017	0.014	-0.015	0.014	0.291	-2.215
	(10.43)	(2.450)	(0.028)	(0.026)	(0.019)	(0.013)	(0.995)	(1.636)
Head uses mobile phone (dummy)	104.7	-34.70	0.224	-0.391	0.272	-0.158	4.798	-10.80
	(142.4)	(33.79)	(0.378)	(0.303)	(0.256)	(0.161)	(7.200)	(14.71)
Household size (Adult Equivalents)	-358.7***	-98.36***	-0.519***	-0.932***	-0.434***	-0.493***	-13.84***	-7.768
	(45.89)	(10.69)	(0.114)	(0.099)	(0.077)	(0.053)	(2.444)	(4.779)
Male heads (dummy)	444.7	111.8	1.232*	0.652	0.825*	0.529	1.182	11.39
	(280.4)	(76.69)	(0.740)	(0.690)	(0.495)	(0.374)	(14.91)	(36.30)
Age of head (years)	15.90	1.514	0.005	0.059	0.008	0.021	0.824	0.368
	(21.55)	(4.757)	(0.058)	(0.047)	(0.039)	(0.024)	(1.499)	(2.331)
Age squared of head (years)	-0.215	-0.002	-8.6e-5	-0.0003	-7.9e-5	-0.0002	-0.016	0.008
	(0.263)	(0.060)	(0.001)	(0.001)	(0.001)	(0.0003)	(0.022)	(0.027)
Education of head (years)	-33.75	-8.453	-0.090	-0.115	-0.123	-0.049	-2.612	3.381
	(47.40)	(11.47)	(0.124)	(0.106)	(0.084)	(0.056)	(2.686)	(4.895)
Education squared of head (years)	6.028	0.535	0.012	0.007	0.012*	0.003	0.467**	-0.357
	(3.925)	(1.002)	(0.010)	(0.009)	(0.007)	(0.005)	(0.226)	(0.397)
Shock experience (dummy)	5.254	-54.36**	-0.009	-0.389*	-0.009	-0.227*	-5.863	-9.351
	(103.6)	(24.82)	(0.273)	(0.228)	(0.189)	(0.119)	(6.238)	(10.59)
Land size (GPS meters)	5.714	-2.876	0.024	-0.027*	0.017	-0.015**	0.216	-1.185*
	(6.710)	(1.777)	(0.020)	(0.015)	(0.013)	(0.007)	(0.779)	(0.660)
Land size squared (GPS meters)	-0.015	0.004	-4.9e-5	3.9e-5*	-3.6e-5*	2.3e-5**	-4.8e-5	0.001
	(0.009)	(0.003)	(3.1e-5)	(2.2e-5)	(2.1e-5)	(1.0e-5)	(0.001)	(0.001)
Year 2010	-25.37	61.01***	-0.232	0.363*	-0.219	0.304***	-11.41**	-17.34*
	(92.81)	(23.16)	(0.248)	(0.210)	(0.169)	(0.111)	(5.689)	(10.08)

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Table 5 Continued

Variables	Energy (kilocalories)		Iron (milligrams)		Zinc (milligrams)		Vitamin A (rae-mc)	
	Markets	Own farm	Markets	Own farm	Markets	Own farm	Markets	Own farm
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Year 2011	184.9*	-18.24	0.371	-0.220	0.173	-0.078	-9.840*	-19.02*
	(95.15)	(23.09)	(0.252)	(0.211)	(0.171)	(0.110)	(5.869)	(9.923)
Means of Variables	YES	YES	YES	YES	YES	YES	YES	YES
Constant	13,104***	1,632***	18.97***	9.411***	11.15***	3.092***	250.4***	270.6***
	(437.1)	(103.4)	(1.183)	(0.927)	(0.829)	(0.499)	(19.40)	(37.68)
Observations	8,310	6,373	8,310	6,373	8,310	6,373	8,310	6,373
No. of households	3,207	2,633	3,207	2,633	3,207	2,633	3,207	2,633
Wald Chi^2 value	929.55***	278.44***	542.38***	275.79***	623.55***	275.61***	347.1***	337.03***

Robust standard errors in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$; RAE-mc is Retinal Activity Equivalents – micrograms; FPD is Farm Production Diversity; AE is Adult Equivalent. See appendix D for full table details.

Farm production diversity and food security impact pathways towards nutrition

In this section, we show food security impact pathways that households used to achieve better nutrition security. We identify two pathways, namely: markets, and own farm production. However, these may not be the only pathways through which households may have achieved nutritional security. Nevertheless, these two explained the largest component possible to achieve nutrition security. In Table 6, we use both qualitative and quantitative food security variables for clearer associated influences of FPD on food, and nutrition security (using dietary quality indicator HDDS). We estimate both RE and FE models following equation (1)

From models 1 and 2 of Table 6, we used a qualitative food security dummy, which showed a negative association between food security and HDDS. However, as earlier highlighted, the dummy could be biased towards food insecure households. Additionally, the dummy captures, qualitatively, the quantities of foods available to households. A quantitative measure for a more reliable associated impact was estimated in models 3-6 of Table 6, using daily per capita consumption in Uganda shillings (UGX). Results showed an associated significant positive impact of food security towards household nutrition. These results rhymed with our hypothesis and existing literature in general as earlier documented. Jones et al. (2014) found exactly that food expenditure per capita in Malawi was positively and significantly associated with HDDS, while using income as a proxy for consumption expenditure, Sibhatu et al. (2015) and Koppmair et al. (2016) found off-farm income to be significantly and positively associated with HDDS. Sekabira and Qaim (2017b) found similar associations using total household income.

Table 6: Food security impact pathways influencing household nutrition security (indicator HDDS) using reduced equations

Variables	Household Nutrition (HDDS) with 12 food groups					
	RE (1)	FE (2)	RE (3)	FE (4)	RE (5)	FE (6)
Food security (dummy)	-2.042***	-1.742***				
	(0.055)	(0.064)				
Daily per capita consumption (UGX)			0.0005***	0.0005***		
			(1.05e-5)	(1.35e-5)		
Daily per capita consumption through markets (UGX)					0.0004***	0.0004***
					(1.18e-5)	(1.59e-5)
Daily per capita consumption from home production (UGX					0.0006***	0.0006***
					(2.93e-5)	(3.53e-5)
Year 2010	-0.137***	-0.195***	-0.249***	-0.286***	-0.243***	-0.282***
	(0.046)	(0.047)	(0.043)	(0.044)	(0.045)	(0.046)
Year 2011	0.058	0.047	-0.142***	-0.158***	-0.143***	-0.160***
	(0.045)	(0.047)	(0.043)	(0.045)	(0.045)	(0.046)
Constant	7.904***	7.921***	6.346***	6.358***	6.402***	6.434***
	(0.045)	(0.035)	(0.049)	(0.044)	(0.052)	(0.046)
Observations	8,616	8,616	8,616	8,616	8,616	8,616
No. of households	3,300	3,300	3,300	3,300	3,300	3,300
Wald χ^2 value	1433.14***		2107.79***		1514.98***	
F-value		270.68***		503.88***		279.36***
Hausman test value		110.94***		45.81***		35.07***

Notes: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1; HDDS is Household Dietary Diversity Score.

In an effort to explore food security pathways for nutrition improvements, we disentangled daily per capita expenditure into its largest two components (markets and own farm production). Results from Table 6, models 5 and 6, showed that improved household food security through both the markets and own farm production pathways were significantly and positively associated with household nutrition. The smaller sizes of the coefficients of food security (daily per capita consumption) achieved through markets or own farm production only reflected the weak value of the Uganda currency (UGX). Moreover, small size coefficients could also be due to the subsistence nature of farm households in the sample (Islam et al., 2018).

Nevertheless, the size of associated increments towards household nutrition per 1,000 UGX increments in food security expenditure through the markets or own production pathways was different. Due to a significant Hausman test, following model 6 in Table 6, increasing food security expenditure by 1,000 UGX through the markets pathway was associated with an increase of 0.4 in the number of food groups consumed by a household. This implied an increase of 5.3 percentage points. A similar incremental expenditure through the own farm production pathway was associated with an increase of 0.6 in number of food groups, implying an 8 percentage point increment. This is against an average HDDS of 7.5 food groups consumed per household. Therefore, policies that targeted increased household food security through access to food markets, for instance road infrastructure development and policies focused on increasing household farm production through special crops producing initiatives (banana, coffee, cassava, potatoes, and so on), NAADS programmes (input use, improved planting materials, extension services, and so on), were impacting positively on household nutrition. Our results generally agree with Jones et al. (2014) who found per capita food expenditures to be positively associated with HDDS in Malawi.

From Table 6 results, the own farm production food security pathway seemed slightly more important towards household nutrition security (relying on the dietary quality indicator HDDS) than the markets pathway. The results are in total agreement with Islam et al. (2018) who explored these pathways in Bangladesh. However, we contradicted findings of Sibhatu et al. (2015), who identified the market pathway as a slightly better alternative. This could be explained by the fact that Sibhatu et al. (2015) considered more than one country, including Kenya, Uganda and Indonesia whose samples may have been more urban than Uganda's. Being more urban with a better market infrastructure makes it easier to be food secure through markets than own farm production. For a more rural sample (70%) such as Uganda's (relying more on the farm for food security) with relatively poorer market infrastructure (which inhibits market access), makes it easier to be food secure through the own farm production pathway. Moreover, Benson (2008) and FANTA-2 (2010) also established that most households in Uganda consume from home production. Therefore, for Uganda given the status quo (more rural with relatively poorer market infrastructure) policies focusing on increasing own farm production have been more important towards improving household nutrition. Inferences can be made to other countries of similar status. Nevertheless, even policies bettering markets have contributed positively and significantly. However, it must be understood that daily per capita consumption is measured in UGX (based on food prices) and therefore lower farm-gate prices (compared to market prices) may have a role to play.

In Table 7, we used simultaneous equations to model these impact pathways and looked at a holistic system of interactions as usually exists naturally between farm production diversity, food security and nutrition (using HDDS). Coefficients of key interest are shaded in grey. These depict the associated impact of FPD on food security and the resultant associated impact of food security on household nutrition (dietary quality indicator – HDDS). Since the 3SLS presented us with an opportunity of instrumenting numerous endogenous variables, endogenous variables were specified and numerously instrumented. Resulting F statistics and other statistical tests showed no evidence of either over identifying (Sargan, and Basmann Chi-square statistics) nor weakly identifying (F statistic at first stage, Anderson-Rubin Wald test F, Chi-square statistics, and the Kleibergen-Paap Chi-square statistic) the instrumented variables.

As in Table 6, results in Table 7 also showed that both markets and own farm production pathways were associated with a positive significant impact on household nutrition. These results collaborate Sibhatu et al. (2015) and Islam et al. (2018). However, as earlier established, the respective incremental effects per 1,000 UGX increases in food security expenditure (daily per capita consumption) are different for markets pathway (2.9 food groups, implying a 39 percentage points increments) and the own farm production pathway (4.1 food groups, implying a 55 percentage points increment).

Therefore, Table 7 results confirm earlier findings in Table 6 that for Uganda, own farm production remained a more important food security pathway for household nutrition (with regards to dietary quality indicator – HDDS) than the markets pathway. The added importance measured up to 16 percentage points. These findings agree with what Islam et al. (2018) found in Bangladesh. Table 7 results also showed that increments in FPD were associated with significant positive increments in own farm production consumption, whereas increments in FPD were associated with significant negative increments in markets sourced foods' consumption. However, these decreases were at a very low significance level (10%) yet increases were at high significance (1%). This may further imply the subsistence nature of our sample, meaning that production for markets is minimal. This may also imply that incomes from sold farm produce is mostly spent on non-food consumption goods such as school fees, housing, medical, etc especially if controlled by men (World Bank, 2005).

Table 7: Food security impact pathways influencing nutrition security (indicator HDDS) using simultaneous equations

Variables	(1)	(2)	(3)	(4)
	Household nutrition (HDDS)	Daily per capita consumption through markets (UGX)	Daily per capita consumption from Home Production (UGX)	Farm production diversity (biodiversity index)
Daily per capita consumption through markets (UGX)	0.0029***			
	(0.0001)			
Daily per capita consumption from home production (UGX)	0.0041***			
	(0.0003)			
Farm production diversity (biodiversity index)		-43.84*	240.2***	
		(24.03)	(11.67)	
Distance to nearest market (kilometres)	-0.004*	-6.198***		
	(0.002)	(1.364)		
Head uses mobile phone (dummy)	-7.243***	1,114***	-587.8***	
	(0.592)	(416.4)	(126.5)	

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Table 7 Continued

Variables	(1) Household nutrition (HDDS)	(2) Daily per capita consumption through markets (UGX)	(3) Daily per capita consumption from Home Production (UGX)	(4) Farm production diversity (biodiversity index)
Household size (persons)	0.829***	-168.4***	-70.14***	0.281***
	(0.038)	(13.34)	(7.016)	(0.013)
Male heads (dummy)	-0.513***	133.0**	-49.13*	0.702***
	(0.084)	(52.51)	(27.48)	(0.100)
Age of head (years)	-0.036***	-3.879	-3.239***	0.020***
	(0.003)	(2.496)	(0.846)	(0.003)
Education of head (years)	0.075***	49.77***	13.52**	0.023**
	(0.016)	(14.35)	(5.700)	(0.012)
Shock experience (dummy)	-0.375***	53.70	-34.34	0.433***
	(0.082)	(46.89)	(23.07)	(0.093)
Land size (GPS metres)	-0.005***		-2.283***	0.017***
	(0.002)		(0.648)	(0.003)
Year 2010	-0.476***	140.5**	286.0***	-1.224***
	(0.085)	(65.24)	(29.97)	(0.110)
Year 2011	-1.703***	485.5***	260.9***	0.053
	(0.129)	(65.16)	(28.42)	(0.111)
Urban household (dummy)		1,104***		
		(119.2)		
Productive assets (UGX)			2.4e-7**	-1.1e-9**
			(1.1e-7)	(4.7e-10)
Access to extension services (dummy)				1.196***
				(0.105)
Free/lease hold land tenure (dummy)				1.416***
				(0.091)
Annual precipitation (mm)				0.002***
				(0.0002)
Elevation (meters)				-0.001***
				(0.0002)
Constant	0.410	2,334***	-1,115***	5.321***
	(0.341)	(234.1)	(131.5)	(0.391)
Observations	8,491	8,491	8,491	8,491
Chi^2 value	1,323.95***	2,561.88***	1548.53***	1,578.21***

Notes: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

To try and understand these food security pathways for nutrition in more detail with regard to nutrition, we estimated equations 2 to 5 simultaneously for energy, iron, zinc and vitamin A as independent components of nutrition. We present summarized results in tables 8, 9, 10, and 11 while details are presented in appendix E, F, G and H respectively.

In Table 8, we present food security impact pathways for household daily energy intake per AE. From Table 8, we see a pattern similar to that in Table 7 where we used HDDS. Both food security pathways (markets and own production) are strongly associated with a positive and significant influence on household daily energy intake.

Table 8: Food security impact pathways influencing nutrition (daily energy intake per AE) using simultaneous equations

Variables	Energy (kilocalorie)	Daily per AE consumption through markets (UGX)	Daily per AE consumption from home production (UGX)	Farm production diversity (biodiversity index)
	(1)	(2)	(3)	(4)
Daily per AE consumption through markets (UGX)	0.842***			
	(0.063)			
Daily per AE consumption from home production (UGX)	5.129***			
	(0.447)			
Farm production diversity (biodiversity index)		-70.63***	67.30***	
		(21.45)	(1.940)	
Other variables	YES	YES	YES	YES
Constant	518.2	5,184***	-336.2***	6.399***
	(324.6)	(205.7)	(24.77)	(0.344)
Observations	8,490	8,490	8,490	8,490
Chi^2 value	568.58***	2,795.66***	4,371.26***	1,708.34***

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; see full table in Appendix E.

However, the own farm production pathway bears the heavier impact. It bears increments of 5.1 (0.4 percentage points) as opposed to 0.8 kilocalories per AE (0.1 percentage points) added for each shilling spent through markets in daily consumption. This pattern is generally similar to th at found in Bangladesh by Islam et al. (2018) who used HDDS. FPD is also associated with a positive significant impact towards daily per AE consumption from own farm production and a negative association on such consumption through markets.

In Table 9, we present food security impact pathways for household daily iron intake per AE. From Table 9, both markets and own production food security pathways are associated with significant increases in the amount of household daily iron intake per AE. This pattern is similar to that in Table 7 where we used HDDS.

Table 9: Food security impact pathways influencing nutrition (daily household iron intake per AE) using simultaneous equations

Variables	Iron (milligrams)	Daily per AE consumption through markets (UGX)	Daily per AE consumption from home production (UGX)	Farm production diversity (biodiversity index)
	(1)	(2)	(3)	(4)
Daily per AE consumption through markets (UGX)	0.008***			
	(0.001)			
Daily per AE consumption from home production (UGX)	0.047***			
	(0.005)			
Farm production diversity (biodiversity index)		-55.01**	67.39***	
		(21.61)	(1.940)	
Other variables	YES	YES	YES	YES
Constant	-1.101	5,091***	-337.2***	6.417***
	(3.542)	(206.1)	(24.78)	(0.345)
Observations	8,490	8,490	8,490	8,490
Chi^2 value	291.58***	2,794.26***	4,372.02***	1,706.00***

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; see full table results in Appendix F.

Still, the own farm production pathway shows a stronger impact, with 0.05 milligrams of iron per AE (0.4 percentage points) added for each shilling spent through own farm production pathway for daily consumption, as opposed to 0.01 milligrams (0.1 percentage points) added for equal expenditure through markets. The pattern is similar to what Islam et al. (2018) found in Bangladesh using HDDS. Farm production diversity is associated with positive significant impact towards own farm produced daily consumption, whereas the association is negative and significant with consumption through markets.

In Table 10, we present food security impact pathways for household daily zinc intake per AE. Results in Table 10 also maintain a pattern by both food security pathways over daily zinc intake, as did the general nutrition indicator, HDDS in Table 7.

Both markets and own production food security pathways are associated with a positive and significant impact on daily zinc intake per AE. The impact is also stronger through the own-farm production pathway, to tunes of 0.02 milligrams of zinc (0.3 percentage points) added for each shilling spent through own farm production consumption. This is opposed to only 0.004 milligrams (0.04 percentage points) added for each shilling spent through markets. Again, FPD is associated with positive and significant impact towards daily consumption from own production. Such association is negative and significant with regard to consumption through markets. It is not surprising that the own farm production pathway contributes more towards micronutrient intake, since most households consume from home production (Benson, 2008; FANTA-2, 2010).

Table 10: Food security impact pathways influencing nutrition (household zinc intake per AE) using simultaneous equations

Variables	Zinc (milligrams)	Daily per AE consumption through markets (UGX)	Daily per AE consumption from home production (UGX)	Farm production diversity (biodiversity index)
	(1)	(2)	(3)	(4)
Daily per AE consumption through markets (UGX)	0.004***			
	(0.0003)			
Daily per AE consumption from home production (UGX)	0.019***			
	(0.002)			
Farm production diversity (biodiversity index)		-61.46***	67.35***	
		(21.70)	(1.940)	
Other variables	YES	YES	YES	YES
Constant	-2.381	5,121***	-336.5***	6.427***
	(1.677)	(206.4)	(24.78)	(0.345)
Observations	8,490	8,490	8,490	8,490
Chi^2 value	432.04***	2,791.94***	4,372.63***	1,706.12***

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; see Appendix G for full table.

In Table 11, we present food security impact pathways for household daily vitamin A intake per AE. As a diversion away from the trend of HDDS, as with energy, iron and zinc, the two food security pathways impact on daily household vitamin A consumption differently.

Whereas own farm production consumption expenditure is associated with a positive and significant impact (0.97 rae-mcg, implying a 0.4 percentage point increment) on daily vitamin A intake per AE, increments in market expenditure bear a negative and significant associated impact (0.10 rae-mcg, implying a 0.1 percentage point decrease). These results are not surprising. This may be attributed to both cultural and expenditure behaviour. Traditionally, there has been limited awareness of consuming vitamin A rich foods (especially vegetables and fruits) on daily meals (Kilimani et al., 2018; Whitney et al., 2018). Households mind more on having solid foods (staples) and legumes in stock for daily meals and when financial resources are limiting – consumption of vegetables and fruits would largely be seen as luxury (FANTA-2, 2010; Kilimani et al. 2018). Therefore, such behaviour may explain the reductions in vitamin A intake, with increased food expenditures through markets. Nevertheless, own farm production bears the expected positive effect. This effect may, however, be limited during dry seasons when farm production is water-constrained. These results are supported by those in Table 4, where FPD's direct associated impacts towards energy and micronutrient intakes were strongest (1.4 percentage points) with regard to vitamin A intake, further implying the cultural underpinning that most vitamin A sources (usually vegetables and fruits) are mostly consumed from own production (Kabunga et al., 2014; Whitney et al., 2018; Kilimani et al., 2018). Nevertheless, even with vitamin A analysis, the own farm production consumption food security pathway remains the more important pathway for household daily vitamin A intake, as with energy, iron, and zinc. This trend is similar to what was found in Bangladesh when HDDS was used (Islam et al., 2018).

Table 11: Food security impact pathways influencing nutrition (daily vitamin A intake per AE) using simultaneous equations

Variables	Vitamin A (RAE – micrograms)	Daily per AE consumption through markets (UGX)	Daily per AE consumption from home production (UGX)	Farm production diversity (biodiversity index)
	(1)	(2)	(3)	(4)
Daily per AE consumption through markets (UGX)	-0.102**			
	(0.044)			
Daily per AE consumption from home production (UGX)	0.972***			
	(0.302)			
Farm production diversity (biodiversity index)		-59.20***	67.38***	
		(22.01)	(1.940)	
Other variables	YES	YES	YES	YES
Constant	3,435***	5,110***	-336.8***	6.409***
	(221.6)	(207.3)	(24.78)	(0.346)
Observations	8,490	8,490	8,490	8,490
Chi^2 value	234.77***	2,791.83***	4,373.51***	1,705.59***

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; see full table details in Appendix H.

4. Conclusions

The study used the Uganda national household panel survey data of three waves (2009, 2010, and 2011) to study the nexus of farm production diversity, food security and nutrition. Descriptively, the spices, condiments and beverages food group, which is a less nutritious food group, contributed the largest proportion (13%) of the sample's household dietary diversity score (HDDS). This implies that it was the commonest food group across sample households. Protein dense food groups such as eggs, fish, dairy and its products, and meat and its products, were the least consumed by the sample population. About 24% of the sample was food secure – considering a CPI weighted utility consisted food poverty line. The markets pathway (direct purchases, in kind access, away from home consumption) accounted for the largest proportion (72%) of expenditure towards daily per capita household consumption. Crops species contributed the largest composition (47%) of the farm production diversity index and minimal contributions were allocated to livestock species. At least 50% of households were deficient in daily intakes for any of energy, iron, zinc, or vitamin A. The deficiency was worse for vitamin A, which was mostly sourced from own farm production consumption.

Empirically, the study explored the impact of farm production diversity on food security and nutrition. We used panel regression models to establish existence of an associated positive impact between farm production diversity and food security, and nutrition. The study also used both reduced form and simultaneous equations to establish that there are two dominant food security pathways (markets, and own farm production) to securing household nutrition. Although households gained positive increments towards their nutrition security through both pathways (markets: 5–39, and own farm production: 8–55 percentage points for HDDS, and 0.04–0.1 and 0.3–0.4 percentage points increments for markets and own production, respectively, for energy, iron, zinc and vitamin A intake), the own farm production pathway had the larger associated increments, with differences ranging between 0.3 and 16 percentage points. The study also found significant gender effects regarding household food security and nutrition. Male-headed households associated with poorer food and nutrition security compared to female-headed households.

The study concluded that policies that have focused on enhancing farm production diversity have, relative to those focused on markets, more positively enhanced household food and nutrition security in Uganda. The study also concluded that policies that have enhanced own farm production and markets access food security pathways have both yielded positively towards enhancing household nutrition security. However, the study also found that all these increments were mostly still below the average (50 percentage points), hence established that there was substantial room for improvement. The study also explores a limited number of micronutrients and extending such studies to other micro and macronutrients would help understand agriculture-nutrition linkages more comprehensively.

References

Arellano, M. and Bover, O. 1995. "Another look at the instrumental variable estimation of error-components models". Journal of Econometrics, 68(1), 29–51.

Arimond, M., Ruel, M., Dewey, K., Chung, E., Swindale, A., Lutter, C., Briend, A., Daelmans, B. and Martines, J. 2010. Working Group on Infant and Young Child Feeding Indicators, 2006

Arndt, C., McKay, A. and Tarp, F. 2016. Growth and poverty in Sub-Saharan Africa. Oxford, UK: Oxford University Press.

Arndt, C. And Simler, K. R. 2010. "Estimating utility–consistent poverty lines with applications to Egypt and Mozambique". Economic Development and Cultural Change, 58(3), 449–474.

Arndt, C. and Tarp, F. 2017. Measuring poverty and well-being in developing countries. Oxford, UK: Oxford University Press.

Benson, T. 2008. "Improving nutrition as a development priority: Addressing under nutrition in national policy processes in Sub-Saharan Africa". IFPRI Research Report 156.

Cameron, A.C. and Trivedi, P.K. 2005. Microeconometrics: Methods and applications. Cambridge: Cambridge University Press.

Di Falco, S. and Chavas, J. P. 2009. "On crop biodiversity, risk exposure and food security in the highlands of Ethiopia". American Journal of Agricultural Economics, 91, 599–611.

FANTA-2. 2010. The analysis of the nutrition situation in Uganda. Food and Nutrition Technical Assistance II Project (FANTA-2). FHI 360, Washington, DC, USA.

FAO, WHO and UNU. 2001. Human energy requirements: Report of a joint FAO/WHO/UNU (Food and Agriculture Organization, World Health Organization and United Nations University). Rome: Food and Agriculture Organization (FAO).

FAO (2015). FAO and the 17 Sustainable Development Goals. Rome: Food and Agriculture Organization of the United Nations.

FAOSTAT (2010). 2008 Food security statistics. Rome: FAO. http://www.fao.org/economic/ess/food-security-statistics/en/

Fongar. A., Gödecke. T., Aseta. A. and Qaim. M. (2018). "How well do different dietary and nutrition assessment tools match? Insights from rural Kenya. Public Health Nutrition.

Godfray, H.C.J., Beddington, J.R., Crute, I.R., Haddad, L., Lawrence, D., Muir, J.F. Pretty, J., Robinson, S., Thomas, S., M. and Toulmin, C. 2010. "Food security: The challenge of feeding 9 billion people". Science, 327: 812–818.

Haddinott, J. 2012. "Agriculture, health, and nutrition: Towards conceptualizing the linkages". In: Fan, S., Pandya-Lorch, R. (eds), Reshaping agriculture for nutrition and health. Washington DC: International Food Policy Research Institute (IFPRI).

Hotz C., Lubowa, A., Sison, C., Moursi, M. and Loechl C.A. 2012. Food composition table for Central and Eastern Uganda. Harvest Plus Technical Monograph 9. HarvestPlus/ International Food Policy Research Institute/International Center for Tropical Agriculture, 2012. Available at: http://www.harvestplus.org/sites/default/files/Tech_Mono_9_Web_1.pdf. Accessed 24 July 2018.

International Food Policy Research Institute – IFPRI. 2016. Global Nutrition Report 2016. "From promise to impact: Ending malnutrition by 2030". Washington, DC: International Food Policy Research Institute.

Islam, A.H.M.S., von Braun, J., Thorne-Lyman, L.A. and Ahmed, U.A. 2018. "Farm diversification and food and nutrition security in Bangladesh: Empirical evidence from nationally representative household panel data". Food Security, 10:701–720.

Jones, A.D., Shrinivas, A. and Bezner-Kerr, R. 2014. "Farm production diversity is associated with greater household dietary diversity in Malawi: Findings from nationally representative data". Food Policy, 46: 1–12.

Kabunga, N., Ghosh, S. and Griffiths, J. 2014. Can smallholder fruit and vegetable production systems improve household food security and nutritional status of women? Evidence from rural Uganda. IFPRI Discussion Paper No. 01346). Washington, DC: International Food Policy Research Institute (IFPRI).

Kasiwa, M. J. and Muzabedi, E. 2018. "Access to agricultural land and nutritional outcomes at the household level: A gender perspective analysis in DR Congo". Final Report presented at the African Economic Research Consortium (AERC) 49th Biannual Research Workshop in Nairobi, Kenya.

Kilimani, N., Buyinza, F. and Guloba, M. 2018. "Agricultural commercialization and nutrition outcomes in Uganda". Report presented at the African Economic Research Consortium (AERC) 49th Biannual Research Workshop in Nairobi, Kenya.

Koppmair, S., Kassie, M. and Qaim, M. 2016. "Farm production, market access and dietary diversity in Malawi". Public Health Nutrition, 20(2): 325–335.

McKinney, P. 2009. Comprehensive food security and vulnerability assessment: Uganda. VAM Food Security Analysis. Rome: World Food Programme.

Melese, B. M., Melak, S. 2018. "Nutrition knowledge, women's empowerment and nutrition outcomes in rural Ethiopia". Work in Progress Report presented at the African Economic Research Consortium (AERC) 49th Biannual Research Workshop in Nairobi, Kenya.

Mello, J.A., Gans, K.M., Risica, P.M., Kirtania, U., Strolla, L.O. and Fournier, L. 2010. "How is food insecurity associated with dietary behaviors? An analysis with low-income, ethnically diverse participants in a nutrition intervention study". Journal of the American Dietetic Association, 110: 1906–1911.

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

Mundlak, Y. 1978. "On the pooling of time series and cross section data". Econometrica 46(1), 69–85.

Olomola, S.A. 2018. "Evaluating the impact of agricultural input subsidy scheme on farmers' productivity, food security and nutrition outcomes in the north central and southwest regions of Nigeria". Report presented at the African Economic Research Consortium (AERC) 49th Biannual Research Workshop in Nairobi, Kenya.

Reardon, T., Taylor, J.E., Stamoulis, K., Lanjouw, P. and Balisacan, A. 2000. "Effects of non-farm employment on rural income inequality in developing countries: An investment perspective". Journal of Agricultural Economics, 51(2): 266–288.

Sekabira, H. and Qaim, M. 2017a. "Mobile money, agricultural marketing, and off-farm income in Uganda". Agricultural Economics, 00: 1–15.

Sekabira, H. and Qaim, M. 2017b. "Can mobile phones improve gender equality and nutrition? Panel data evidence from farm households in Uganda". Food Policy, 73: 95–103.

Shankara, V. and Mannering, F. 1998. "Modeling the endogeneity of lane-mean speeds and lane-speed deviations: A structural equations approach". Transportation Research Part A: Policy and Practice, 32(5): 311–322.

Shariff, Z.M. and Khor, G.L. 2005. "Obesity and household food insecurity: Evidence from a sample of rural households in Malaysia". European Journal of Clinical Nutrition, 59: 1049–1058.

Sibhatu, K.T., Krishna, V.V. and Qaim, M. 2015. "Production diversity and dietary diversity in smallholder farm households". Proceedings of the National Academy of Sciences, 112: 10657–10662.

Sserunkuuma, D. and Omiat, G. 2018. "Women's response to market-oriented production policy: Impact on income and nutrition outcomes in Uganda". Report presented at the African Economic Research Consortium (AERC) 49th Biannual Research Workshop in Nairobi, Kenya.

Swindale, A. and Bilinsky, P. 2006. Household Dietary Diversity Score (HDDS) for measurement of household food access: Indicator guide. Food and Nutrition Technical Assistance Project (FANTA). Washington DC: Academy for Educational Development.

UBOS. 2015. Statistical Abstract. Kampala: Uganda Bureau of Statistics.

United Nations. 2017. Sustainable Development Goals. Retrieved from https://sustainabledevelopment.un.org/sdgs.

van Campenhout, B., Sekabira, H. and Aduayom, H.D. 2016. "Poverty and its dynamics in Uganda: Explorations using a new set of poverty lines". In Arndt, C., McKay, A., and Tarp, F. (eds). Growth and poverty in Sub-Saharan Africa. Oxford, UK: Oxford University Press.

van Campenhout, B., Sekabira, H. and Nattembo, F. 2017. "Uganda: A new set of utility-consistent poverty lines". In Arndt, C. and Tarp, F. (eds), Measuring poverty and well-being in developing countries. Oxford, UK: Oxford University Press.

Webb, P. and Kennedy, E. 2014. "Impacts of agriculture on nutrition: Nature of the evidence and research gaps". Food and Nutrition Bulletin, 35(1): 126–132.

Whitney, C.W., Lanzanova, D., Muchiri, C., Shepherd, K., Rosenstock, T., Krawinkel, M., Tabuti, J.R.S. and Luedeling, E. 2018. "Probabilistic decision tools for determining impacts of agricultural development policy on household nutrition". Earth's Future, 6(3): 359–372.

Wikipedia. 2018. List of countries by food energy intake. Accessed on 13th November 2018 from https://en.wikipedia.org/w/index.php?title=List_of_countries_by_food_energy_intake&oldid=868688953.

Wooldridge, J.M. 2010. Econometric analysis of cross section and panel data (2nd edition), Cambridge, London: MIT.

World Bank. 2005. Uganda: From periphery to centre: A strategic country gender assessment. Washington, DC: World Bank.

Zellner, A. and Theil, H. 1962. "Three-Stage Least Squares: Simultaneous estimation of simultaneous equations". Econometrica, 30(1): 54–78.

Appendix

Appendix A: Formulas for computing biodiversity index and household dietary diversity score

Household Biodiversity Index (HBI): This is a simple count of crops and livestock species produced on the household farm. Crops include those that are farmed for purposes of food consumption or income generation. Each crop species and livestock species would take a quantitative value of 1; the count would be cumulative and the sum of all these crops farmed by the household would generate the household crops biodiversity index (CBI) and otherwise the livestock biodiversity index (LBI). The sum of these two indices (CBI and LBI) would give the household biodiversity index (HBI) that is used in this paper as the proxy for farm production diversity. These formulae are illustrated below in equations 1a–3a:

$$\sum_{1}^{k} CropSpecies_i = CBI_i \qquad \text{1a}$$

$$\sum_{1}^{J} LivestockSpecies_i = LBI_i \qquad \text{2a}$$

$$CBI_i + LBI_i = HBI_i \qquad \text{3a}$$

Where crop species are numbering from 1 to K for household i while livestock species are numbering from 1 to J for the same household i. Crops grown in the sample include: avocado, bananas, beans, cabbage, cassava, chicken peas, coco yam, cocoa, coffee, cotton, cow peas, dodo, eggplants, fallow trees, field peas, ginger, groundnuts, improved pastures, Irish potatoes, jackfruit, maize, mango, millet, natural pastures, oil palm, onions, oranges, forest trees, other shrubs, passion fruit, papaya, pigeon peas, pineapples, plantation trees, pumpkins, rice, simsim, sorghum, soya beans, sugarcane, sunflower, sweet potatoes, tea, tobacco, tomatoes, vanilla, wheat and yam. In total, there were forty-eight (48) crops species considered in the sample and this would be the maximum number of CBI or K for any single household. Livestock species include cattle, donkeys, mules or horses (park animals); goats, sheep, pigs (small animals) and; rabbits, chicken, turkeys, ducks, bees (poultry and others). In total, there were eleven (11) livestock species, and this would be the maximum value of LBI (J) for any single household. Therefore, the maximum possible number of crops and livestock species – the household biodiversity index (HBI) for any single household – was the sum of the two (CBI and LBI) maxima (48+11), which was fifty-nine (59). This was the maximum possible value of Farm Production Diversity (FPD) possible for any single household.

Household Dietary Diversity Score (HDDS): This was a cumulative score of food groups consumed per household i . It was a total of twelve (12) food groups that included: cereals, white roots and tubers, vegetables, fruits, meat and its products, eggs, fish, legumes, nuts and seeds, dairy and its products, oils and fats, sweets and sugars, and spices condiments and beverages. For each of these food groups basing on formulae 1b–12b, a particular food group would be given a quantitative value of one (1) for any household if any of the food types in the formula was consumed by that household (had a qualitative value of one (1)). Then HDDS was computed cumulatively as a sum of the various food groups that had a value of one as shown in equation 13b, implying that the maximum possible value of HDDS per household was 12.

$$Cereals_i = 1f \ (foodtype)_i^{(Rice|Maize, Millet|Sorghum|Simsim|Bread)=1} \quad \text{1b}$$

$$Roots \,\&\, Tubers_i = 1f \ (foodtype)_i^{(SweetPotatoes|Cassava|IrishPotatoes)=1} \quad \text{2b}$$

$$Vegetables_i = 1f \ (foodtype)_i^{Onions|Cabbages|Tomatoes|Dodo|othervegetables)=1} \quad \text{3b}$$

$$Fruits_i = 1f \ (foodtype)_i^{(Bananas|Passionfruit|Jackfruit|Mangoes|Oranges|Otherfruits)=1} \quad \text{4b}$$

$$Meat_i = 1f \ (foodtype)_i^{(Beef|Goatmeat|Chicken|Othermeat|Pork)=1} \quad \text{5b}$$

$$Eggs_i = 1f \ (foodtype)_i^{(Eggs)=1} \quad \text{6b}$$

$$Fish_i = 1f \ (foodtype)_i^{(Fish)=1} \quad \text{7b}$$

$$Legumes \,\&\, Seeds_i = 1f \ (foodtype)_i^{(Beans|Groundnuts|Peas)=1} \quad \text{8b}$$

$$Dairy_i = 1f\ (foodtype)_i^{(Milk|Infantformulamilk|Ghee|Butter|Margerine)=1} \quad 9b$$

$$Oil\ \&\ Fats_i = 1f\ (foodtype)_i^{(CookingOil)=1} \quad 10b$$

$$Sweets\ \&\ Sugars_i = 1f\ (foodtype)_i^{(Sugar|Sweets)=1} \quad 11b$$

$$Spices\ \&\ Beverages_i = 1f\ (foodtype)_i^{(Coffee|Tea|Salt|Soda|Alcohol|Cigarettes)=1} \quad 12b$$

$$HDDS_i = \sum Foodgroups_i^{1b,2b,3b,4b,5b,6b.7b.8b.9b,10b,11b,12b} \quad 13b$$

NOTE: All structural forms for instance (fresh, dried, flour) of a particular food type, for instance cassava, consumed by a particular household i are considered as one food type Cassava for limitations of space for these equations. $1b-12b$ in equation $13b$ are outputs of equations $1b-12b$

Appendix B: Impact of FPD on food and nutrition security

Variables	Food security (Dummy)		Daily per capita consumption (UGX)		Nutrition indicator (HDDS) 12 food groups	
	Logit-RE (1)	Logit-MK(3)	RE (5)	MK (6)	RE (7)	MK (8)
FPD (biodiversity index)	-0.045***	-0.043***	6.695*	8.509**	0.034***	0.036***
	(0.008)	(0.009)	(3.712)	(3.703)	(0.006)	(0.006)
Distance to market (kilometers)	0.003	0.020*	-1.048	7.324*	-0.001	0.011*
	(0.002)	(0.012)	(0.934)	(4.114)	(0.002)	(0.007)
Mobile phone use (dummy)	-0.881***	-0.372***	654.1***	303.2***	0.977***	0.486***
	(0.077)	(0.114)	(34.13)	(45.87)	(0.056)	(0.075)
Household size (persons)	0.143***	0.144***	-112.0***	-66.63***	0.115***	0.181***
	(0.011)	(0.036)	(5.394)	(13.77)	(0.009)	(0.022)
Male heads (dummy)	-0.215**	0.122	69.60*	-97.55	-0.205***	-0.318**
	(0.083)	(0.245)	(40.36)	(97.67)	(0.068)	(0.159)
Age of head (years)	0.009	0.002	58.88***	53.71***	0.084***	0.069***
	(0.009)	(0.018)	(4.241)	(7.385)	(0.007)	(0.012)
Age of head squared (years)	-8.9e-6	1.5e-5	-0.567***	-0.462***	-0.001***	-0.001***
	(9.8e-5)	(0.0002)	(0.044)	(0.093)	(7.4e-5)	(0.0002)
Education (years)	-0.069***	0.001	60.68***	30.79***	0.102***	0.055***
	(0.009)	(0.015)	(4.118)	(5.630)	(0.007)	(0.009)
Shock experience (dummy)	0.013	-0.108	90.75***	133.9***	0.158***	0.169***
	(0.068)	(0.085)	(29.04)	(33.62)	(0.048)	(0.055)
Land size (GPS acres)	-0.015*	0.003	1.121	0.432	0.002	0.002
	(0.008)	(0.009)	(0.792)	(0.875)	(0.001)	(0.001)
Year 2010	0.295***	0.289***	-8.131	-19.63	-0.345***	-0.364***
	(0.075)	(0.079)	(30.36)	(31.45)	(0.049)	(0.051)
Year 2011	-0.142*	-0.174*	377.7***	356.7***	-0.135***	-0.168***
	(0.079)	(0.091)	(30.71)	(34.74)	(0.050)	(0.057)

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Appendix B Continued

Variables	Food security (Dummy)		Daily per capita consumption (UGX)		Nutrition indicator (HDDS) 12 food groups	
	Logit-RE (1)	Logit-MK(3)	RE (5)	MK (6)	RE (7)	MK (8)
Means of Variables						
Distance to market (kilometers)		-0.019		-7.334*		-0.010
		(0.012)		(4.226)		(0.007)
Mobile phone use (dummy)		-0.791***		673.0***		0.987***
		(0.158)		(69.63)		(0.116)
Household size (persons)		0.013		-63.42***		-0.097***
		(0.038)		(15.00)		(0.025)
Male heads (dummy)		-0.299		159.1		0.079
		(0.262)		(107.3)		(0.176)
Age of head (years)		0.007		1.992		0.016
		(0.022)		(9.192)		(0.015)
Age of head squared (years)		-4.6e-5		-0.051		-0.0001
		(0.0003)		(0.108)		(0.0002)
Education (years)		-0.104***		42.67***		0.077***
		(0.020)		(8.382)		(0.014)
Shock experience (dummy)		0.242*		-78.37		0.088
		(0.145)		(65.51)		(0.110)
Land size (GPS acres)		-0.036**		3.747*		-0.001
		(0.015)		(1.968)		(0.003)
Constant	-1.631***	-1.329***	5,222***	5,093***	3.705***	3.259***
	(0.248)	(0.293)	(105.0)	(130.6)	(0.175)	(0.221)
Observations	8,616	8,616	8,616	8,616	8,616	8,616
No. of households	3,300	3,300	3,300	3,300	3,300	3,300
Wald Chi^2 value	458.66***	487.94***	1,463.06***	1,677.90***	1,611.65***	1,787.80***

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Appendix C: Impact of farm production diversity on daily household energy, iron, zinc and Vitamin A intake

Variables	Energy (kilocalories)		Iron (milligrams)		Zinc (milligrams)		Vitamin A (Rae-mcg)	
	(1) RE	(2) MK	(3) RE	(4) MK	(5) RE	(6) MK	(7) RE	(8) MK
FPD (biodiversity index)	7.711**	6.535*	0.114***	0.102***	0.066***	0.058**	5.004***	4.704***
	(3.868)	(3.906)	(0.030)	(0.031)	(0.022)	(0.023)	(0.873)	(0.900)
Distance to nearest market (kilometres)	-1.493*	2.275	0.006	-0.006	-0.003	-0.0001	0.963***	-1.408
	(0.897)	(3.918)	(0.007)	(0.032)	(0.005)	(0.021)	(0.182)	(1.087)
Head uses mobile phone (dummy)	217.8***	-23.11	0.627**	-0.557	1.442***	-0.007	-27.05***	-7.935
	(35.10)	(50.66)	(0.276)	(0.420)	(0.203)	(0.292)	(7.991)	(13.51)
Household size (Adult Equivalents)	-126.9***	-194.5***	-0.877***	-1.382***	-0.691***	-0.994***	-9.353***	-15.16***
	(7.907)	(18.45)	(0.061)	(0.145)	(0.045)	(0.100)	(1.696)	(4.266)
Male heads (dummy)	23.79	279.9**	-0.046	1.642**	0.352	1.574**	-6.288	0.855
	(39.41)	(110.5)	(0.302)	(0.783)	(0.224)	(0.627)	(8.148)	(31.37)
Age of head (years)	1.905	15.58**	0.033	0.129**	0.001	0.084**	-0.919	2.078
	(4.593)	(7.575)	(0.036)	(0.065)	(0.026)	(0.041)	(1.025)	(2.282)
Age squared of head (years)	-0.028	-0.214**	-0.0004	-0.001	-0.0001	-0.001**	0.015	-0.025
	(0.047)	(0.097)	(0.0004)	(0.001)	(0.0003)	(0.001)	(0.010)	(0.031)
Education of head (years)	-16.53	-36.64**	0.004	-0.274**	-0.097	-0.300***	2.884	0.999
	(11.45)	(17.24)	(0.089)	(0.137)	(0.066)	(0.099)	(2.587)	(4.353)
Education squared of head (years)	2.625***	3.696**	0.007	0.027**	0.016***	0.024***	-0.155	0.100
	(0.893)	(1.441)	(0.007)	(0.011)	(0.005)	(0.008)	(0.200)	(0.344)
Shock experience (dummy)	-69.56**	-45.74	0.007	-0.107	-0.219	-0.197	-5.570	-16.05
	(30.80)	(37.53)	(0.245)	(0.308)	(0.180)	(0.226)	(7.406)	(10.23)
Land size (GPS meters)	1.188	-0.926	0.026	-0.002	0.027*	-0.001	0.650	-0.195
	(2.449)	(2.930)	(0.019)	(0.026)	(0.014)	(0.017)	(0.572)	(0.791)
Land size squared (GPS meters)	-0.004	-0.002	-5.4e-5*	-1.8e-5	-4.9e-5**	-1.3e-5	-0.001	-0.0001
	(0.004)	(0.004)	(3.1e-5)	(4.0e-5)	(2.3e-5)	(2.7e-5)	(0.001)	(0.001)
Year 2010	34.99	57.38*	0.264	0.295	-0.018	0.049	-18.11**	-21.14**
	(33.28)	(33.87)	(0.271)	(0.271)	(0.197)	(0.197)	(8.868)	(9.143)
Year 2011	9.166	49.32	0.227	0.301	-0.146	-0.006	-16.91*	-21.48**
	(33.37)	(34.52)	(0.271)	(0.277)	(0.197)	(0.203)	(8.818)	(9.088)

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Appendix C Continued

Variables	Energy (kilocalories)		Iron (milligrams)		Zinc (milligrams)		Vitamin A (Rae-mcg)	
	(1) RE	(2) MK	(3) RE	(4) MK	(5) RE	(6) MK	(7) RE	(8) MK
Means of Variables								
Distance to nearest market (kilometres)		-3.289		0.012		-8.6e-5		2.344**
		(4.030)		(0.033)		(0.022)		(1.112)
Head uses mobile phone (dummy)		414.1***		1.812***		2.307***		-26.88
		(70.06)		(0.559)		(0.401)		(16.83)
Household size (Adult Equivalents)		83.07***		0.630***		0.347***		7.138
		(20.59)		(0.162)		(0.115)		(4.865)
Male heads (dummy)		-321.8***		-2.184**		-1.623**		-8.542
		(118.8)		(0.849)		(0.675)		(32.82)
Age of head (years)		-21.40**		-0.168**		-0.124**		-3.682
		(9.323)		(0.081)		(0.054)		(2.571)
Age squared of head (years)		0.266**		0.002		0.001**		0.046
		(0.111)		(0.001)		(0.001)		(0.034)
Education of head (years)		28.52		0.442**		0.335**		3.065
		(23.36)		(0.181)		(0.132)		(5.239)
Education squared of head (years)		-2.068		-0.032**		-0.016		-0.341
		(1.859)		(0.015)		(0.011)		(0.405)
Shock experience (dummy)		-62.43		0.355		0.072		20.04
		(64.66)		(0.507)		(0.372)		(15.06)
Land size (GPS meters)		4.323		0.052		0.057*		1.322
		(5.002)		(0.038)		(0.029)		(1.004)
Land size squared (GPS metres)		-0.005		-5.8e-5		-6.9e-5		-0.001
		(0.008)		(6.4e-5)		(4.8e-5)		(0.002)
Constant	4,757***	4,795***	20.53***	21.33***	14.76***	14.74***	322.5***	337.8***
	(115.1)	(145.8)	(0.892)	(1.196)	(0.657)	(0.900)	(25.50)	(31.11)
Observations	8,574	8,574	8,574	8,574	8,574	8,574	8,574	8,574
No. of households	3,258	3,258	3,258	3,258	3,258	3,258	3,258	3,258
Wald chi^2 value	358.80***	368.45***	229.67***	262.13***	344.79***	409.63***	138.00***	158.75***

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Appendix D: Impact of farm production diversity (FPD) on energy and micro-nutrient intake through main food security pathways/ sources (markets vs own production) – a Mundlak Approach modelling

Variables	Energy (kilocalories)		Iron (milligrams)		Zinc (milligrams)		Vitamin A (rae-mc)	
	Markets	Own farm	Markets	Own farm	Markets	Own farm	Markets	Own farm
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Farm production (biodiversity index)	-74.58***	20.75***	-0.208***	0.179***	-0.099***	0.098***	-2.535***	4.057***
	(10.94)	(2.423)	(0.029)	(0.023)	(0.020)	(0.012)	(0.507)	(0.927)
Distance to nearest market (kilometres)	-8.043	4.222*	-0.017	0.014	-0.015	0.014	0.291	-2.215
	(10.43)	(2.450)	(0.028)	(0.026)	(0.019)	(0.013)	(0.995)	(1.636)
Head uses mobile phone (dummy)	104.7	-34.70	0.224	-0.391	0.272	-0.158	4.798	-10.80
	(142.4)	(33.79)	(0.378)	(0.303)	(0.256)	(0.161)	(7.200)	(14.71)
Household size (Adult Equivalents)	-358.7***	-98.36***	-0.519***	-0.932***	-0.434***	-0.493***	-13.84***	-7.768
	(45.89)	(10.69)	(0.114)	(0.099)	(0.077)	(0.053)	(2.444)	(4.779)
Male heads (dummy)	444.7	111.8	1.232*	0.652	0.825*	0.529	1.182	11.39
	(280.4)	(76.69)	(0.740)	(0.690)	(0.495)	(0.374)	(14.91)	(36.30)
Age of head (years)	15.90	1.514	0.005	0.059	0.008	0.021	0.824	0.368
	(21.55)	(4.757)	(0.058)	(0.047)	(0.039)	(0.024)	(1.499)	(2.331)
Age squared of head (years)	-0.215	-0.002	-8.6e-5	-0.0003	-7.9e-5	-0.0002	-0.016	0.008
	(0.263)	(0.060)	(0.001)	(0.001)	(0.001)	(0.0003)	(0.022)	(0.027)
Education of head (years)	-33.75	-8.453	-0.090	-0.115	-0.123	-0.049	-2.612	3.381
	(47.40)	(11.47)	(0.124)	(0.106)	(0.084)	(0.056)	(2.686)	(4.895)
Education squared of head (years)	6.028	0.535	0.012	0.007	0.012*	0.003	0.467**	-0.357
	(3.925)	(1.002)	(0.010)	(0.009)	(0.007)	(0.005)	(0.226)	(0.397)
Shock experience (dummy)	5.254	-54.36**	-0.009	-0.389*	-0.009	-0.227*	-5.863	-9.351
	(103.6)	(24.82)	(0.273)	(0.228)	(0.189)	(0.119)	(6.238)	(10.59)
Land size (GPS metres)	5.714	-2.876	0.024	-0.027*	0.017	-0.015**	0.216	-1.185*
	(6.710)	(1.777)	(0.020)	(0.015)	(0.013)	(0.007)	(0.779)	(0.660)

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Appendix D Continued

Variables	Energy (kilocalories)		Iron (milligrams)		Zinc (milligrams)		Vitamin A (rae-mc)	
	Markets	Own farm	Markets	Own farm	Markets	Own farm	Markets	Own farm
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Land size squared (GPS metres)	-0.015	0.004	-4.9e-5	3.9e-5*	-3.6e-5*	2.3e-5**	-4.8e-5	0.001
	(0.009)	(0.003)	(3.1e-5)	(2.2e-5)	(2.1e-5)	(1.0e-5)	(0.001)	(0.001)
Year 2010	-25.37	61.01***	-0.232	0.363*	-0.219	0.304***	-11.41**	-17.34*
	(92.81)	(23.16)	(0.248)	(0.210)	(0.169)	(0.111)	(5.689)	(10.08)
Year 2011	184.9*	-18.24	0.371	-0.220	0.173	-0.078	-9.840*	-19.02*
	(95.15)	(23.09)	(0.252)	(0.211)	(0.171)	(0.110)	(5.869)	(9.923)
Means of Variables								
Distance to nearest market (kilometers)	-10.29	-2.665	-0.019	-0.004	-0.004	-0.006	-0.266	2.483
	(10.77)	(2.520)	(0.029)	(0.026)	(0.019)	(0.013)	(1.004)	(1.660)
Head uses mobile phone (dummy)	1,624***	58.38	2.876***	0.434	2.577***	0.326	11.95	-12.25
	(198.4)	(46.05)	(0.528)	(0.409)	(0.361)	(0.217)	(9.596)	(18.49)
Household size (Adult Equivalents)	15.05	55.85***	-0.099	0.479***	-0.033	0.268***	-0.190	6.113
	(53.05)	(12.33)	(0.135)	(0.113)	(0.092)	(0.059)	(2.867)	(5.455)
Male heads (dummy)	-888.8***	-33.60	-1.989**	-0.378	-1.015*	-0.278	-13.15	-20.22
	(308.0)	(81.26)	(0.818)	(0.731)	(0.549)	(0.396)	(16.13)	(38.07)
Age of head (years)	-38.30	-2.190	-0.038	-0.058	-0.042	-0.020	-0.718	-3.337
	(28.30)	(6.153)	(0.076)	(0.059)	(0.053)	(0.031)	(1.720)	(2.623)
Age squared of head (years)	0.331	0.019	0.0002	0.0004	0.0002	0.0002	0.012	0.028
	(0.323)	(0.071)	(0.001)	(0.001)	(0.001)	(0.0004)	(0.024)	(0.029)
Education of head (years)	-133.9**	30.01*	-0.234	0.297**	-0.018	0.131*	-7.511**	9.263
	(64.72)	(15.83)	(0.173)	(0.143)	(0.118)	(0.076)	(3.285)	(6.172)
Education squared of head (years)	14.54***	-3.371***	0.033**	-0.030**	0.015*	-0.014**	0.641**	-0.798
	(5.108)	(1.307)	(0.014)	(0.012)	(0.009)	(0.006)	(0.263)	(0.499)
Shock experience (dummy)	-269.9	-15.99	0.323	-0.321	0.042	-0.063	-2.804	2.583
	(183.7)	(42.90)	(0.479)	(0.384)	(0.330)	(0.203)	(9.538)	(16.37)
Land size (GPS metres)	-39.00**	11.92***	-0.102**	0.093***	-0.052*	0.058***	0.001	1.065
	(16.49)	(2.852)	(0.042)	(0.020)	(0.028)	(0.011)	(1.005)	(1.083)
Land size squared (GPS metres)	0.066***	-0.019***	0.0002***	-0.0002***	9.2e-5**	-9.1e-5***	0.0003	-0.001
	(0.023)	(0.004)	(6.3e-5)	(3.6e-5)	(4.1e-5)	(1.8e-5)	(0.001)	(0.002)
Constant	13,104***	1,632***	18.97***	9.411***	11.15***	3.092***	250.4***	270.6***
	(437.1)	(103.4)	(1.183)	(0.927)	(0.829)	(0.499)	(19.40)	(37.68)
Observations	8,310	6,373	8,310	6,373	8,310	6,373	8,310	6,373
No. of households	3,207	2,633	3,207	2,633	3,207	2,633	3,207	2,633
Wald Chi^2 value	929.55***	278.44***	542.38***	275.79***	623.55***	275.61***	347.1***	337.03***

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; RAE-mc is Retinal Activity Equivalents – micrograms

Appendix E: Impact pathways of food security towards daily household energy intake using simultaneous equations

Variables	Energy (kilocalories)	Daily per AE consumption through markets (UGX)	Daily per AE consumption from home production (UGX)	Farm production diversity (biodiversity index)
	(1)	(2)	(3)	(4)
Daily per AE consumption through markets (UGX)	0.842***			
	(0.063)			
Daily per AE consumption from home production (UGX)	5.129***			
	(0.447)			
Farm production diversity (biodiversity index)		-70.63***	67.30***	
		(21.45)	(1.940)	
Distance to nearest market (kilometres)	-4.965***	-0.376		
	(1.044)	(1.130)		
Head uses mobile phone (dummy)	-1,122***	1,502***	-290.0***	
	(248.0)	(338.3)	(22.33)	
Household size (Adult Equivalents)	78.52***	-232.4***	-14.05***	0.424***
	(20.59)	(16.48)	(1.947)	(0.020)
Male heads (dummy)	-79.48**	66.80	-17.34***	0.655***
	(36.45)	(42.80)	(5.614)	(0.099)
Age of head (years)	-6.928	-1.963	-1.746***	0.017***
	(4.757)	(2.083)	(0.178)	(0.003)
Age squared of head (years)	0.041			
	(0.046)			
Education of head (years)	-26.36**	42.32***	4.855***	0.027**
	(12.99)	(11.60)	(1.058)	(0.011)
Education squared of head (years)	1.414*			
	(0.859)			
Shock experience (dummy)	-248.1***	106.3***	-14.60***	0.437***
	(36.96)	(38.59)	(4.894)	(0.092)
Land size (GPS metres)	-3.814		-0.677***	0.017***
	(2.489)		(0.137)	(0.003)

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Appendix E Continued

Variables	Energy (kilocalories)	Daily per AE consumption through markets (UGX)	Daily per AE consumption from home production (UGX)	Farm production diversity (biodiversity index)
	(1)	(2)	(3)	(4)
Land size squared (GPS metres)	0.001			
	(0.004)			
Year 2010	-147.3***	165.8***	81.90***	-0.913***
	(40.13)	(54.16)	(5.906)	(0.108)
Year 2011	-540.7***	518.7***	36.78***	0.607***
	(57.12)	(58.67)	(6.525)	(0.109)
Urban household (dummy)		747.5***		
		(100.8)		
Productive assets (UGX)			1.3e-7***	-1.4e-9***
			(2.5e-8)	(4.7e-10)
Access to extension services (dummy)				0.779***
				(0.088)
Free/lease hold land tenure (dummy)				1.759***
				(0.079)
Annual precipitation (mm)				0.002***
				(0.0002)
Elevation (metres)				-0.001***
				(0.0001)
Constant	518.2	5,184***	-336.2***	6.399***
	(324.6)	(205.7)	(24.77)	(0.344)
Observations	8,490	8,490	8,490	8,490
Chi^2 value	568.58***	2,795.66***	4,371.26***	1,708.34***

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Appendix F: Impact pathways of food security towards daily household iron intake using simultaneous equations

Variables	Iron (milligrams)	Daily per AE consumption through markets (UGX)	Daily per AE consumption from home production (UGX)	Farm production diversity (biodiversity index)
	(1)	(2)	(3)	(4)
Daily per AE consumption through markets (UGX)	0.008***			
	(0.001)			
Daily per AE consumption from home production (UGX)	0.047***			
	(0.005)			
Farm production diversity (biodiversity index)		-55.01**	67.39***	
		(21.61)	(1.940)	
Distance to nearest market (kilometres)	-0.035***	-0.715		
	(0.011)	(1.132)		
Head uses mobile phone (dummy)	-14.44***	1,399***	-289.2***	
	(2.701)	(339.4)	(22.34)	
Household size (Adult Equivalents)	0.962***	-235.7***	-14.13***	0.423***
	(0.225)	(16.49)	(1.947)	(0.020)
Male heads (dummy)	-0.707*	62.52	-17.42***	0.655***
	(0.394)	(42.80)	(5.614)	(0.099)
Age of head (years)	-0.052	-2.742	-1.745***	0.017***
	(0.052)	(2.091)	(0.178)	(0.003)
Age squared of head (years)	0.0001			
	(0.001)			
Education of head (years)	0.026	44.23***	4.817***	0.027**
	(0.142)	(11.62)	(1.059)	(0.011)
Education squared of head (years)	-0.002			
	(0.009)			
Shock experience (dummy)	-1.604***	100.0***	-14.58***	0.435***
	(0.400)	(38.61)	(4.894)	(0.092)
Land size (GPS metres)	-0.020		-0.682***	0.017***
	(0.027)		(0.137)	(0.003)

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Appendix F Continued

Variables	Iron (milligrams)	Daily per AE consumption through markets (UGX)	Daily per AE consumption from home production (UGX)	Farm production diversity (biodiversity index)
	(1)	(2)	(3)	(4)
Land size squared (GPS metres)	-6.8e-6			
	(4.4e-5)			
Year 2010	-1.179***	188.9***	81.96***	-0.913***
	(0.434)	(54.33)	(5.906)	(0.108)
Year 2011	-4.149***	527.0***	36.65***	0.605***
	(0.619)	(58.73)	(6.526)	(0.109)
Urban household (dummy)		805.6***		
		(101.5)		
Productive assets (UGX)			1.3e-7***	-1.4e-9***
			(2.6e-8)	(4.7e-10)
Access to extension services (dummy)				0.813***
				(0.089)
Free/lease hold land tenure (dummy)				1.745***
				(0.079)
Annual precipitation (mm)				0.002***
				(0.0002)
Elevation (meters)				-0.001***
				(0.0001)
Constant	-1.101	5,091***	-337.2***	6.417***
	(3.542)	(206.1)	(24.78)	(0.345)
Observations	8,490	8,490	8,490	8,490
Chi^2 value	291.58***	2,794.26***	4,372.02***	1,706.00***

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Appendix G: Impact pathways of food security towards daily household zinc intake using simultaneous equations

Variables	Zinc (milligrams)	Daily per AE consumption through markets (UGX)	Daily per AE consumption from home production (UGX)	Farm production diversity (biodiversity index)
	(1)	(2)	(3)	(4)
Daily per AE consumption through markets (UGX)	0.004***			
	(0.0003)			
Daily per AE consumption from home production (UGX)	0.019***			
	(0.002)			
Farm production diversity (biodiversity index)		-61.46***	67.35***	
		(21.70)	(1.940)	
Distance to nearest market (kilometres)	-0.011**	-0.547		
	(0.005)	(1.133)		
Head uses mobile phone (dummy)	-4.276***	1,466***	-289.8***	
	(1.277)	(340.0)	(22.34)	
Household size (Adult Equivalents)	0.383***	-235.3***	-14.10***	0.423***
	(0.107)	(16.49)	(1.947)	(0.0202)
Male heads (dummy)	-0.079	63.01	-17.38***	0.655***
	(0.185)	(42.80)	(5.614)	(0.0994)
Age of head (years)	-0.025	-2.308	-1.748***	0.0167***
	(0.025)	(2.095)	(0.178)	(0.00294)
Age squared of head (years)	0.0001			
	(0.0002)			
Education of head (years)	-0.058	42.68***	4.838***	0.027**
	(0.067)	(11.63)	(1.059)	(0.011)
Education squared of head (years)	0.003			
	(0.005)			
Shock experience (dummy)	-0.799***	103.2***	-14.59***	0.435***
	(0.189)	(38.62)	(4.894)	(0.092)
Land size (GPS meters)	0.002		-0.681***	0.017***
	(0.013)		(0.137)	(0.003)

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Appendix G Continued

Variables	Zinc (milligrams)	Daily per AE consumption through markets (UGX)	Daily per AE consumption from home production (UGX)	Farm production diversity (biodiversity index)
	(1)	(2)	(3)	(4)
Land size squared (GPS meters)	-1.9e-5			
	(2.1e-5)			
Year 2010	-0.793***	178.0***	81.95***	-0.913***
	(0.204)	(54.43)	(5.906)	(0.108)
Year 2011	-2.386***	520.4***	36.75***	0.605***
	(0.292)	(58.77)	(6.526)	(0.109)
Urban household (dummy)		774.5***		
		(102.0)		
Productive assets (UGX)			1.3e-7***	-1.4e-9***
			(2.6e-8)	(4.7e-10)
Access to extension services (dummy)				0.810***
				(0.089)
Free/lease hold land tenure (dummy)				1.746***
				(0.079)
Annual precipitation (mm)				0.002***
				(0.0002)
Elevation (meters)				-0.001***
				(0.0002)
Constant	-2.381	5,121***	-336.5***	6.427***
	(1.677)	(206.4)	(24.78)	(0.345)
Observations	8,490	8,490	8,490	8,490
Chi^2 value	432.04***	2,791.94***	4,372.63***	1,706.12***

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Appendix H: Impact pathways of food security towards daily household vitamin A intake using simultaneous equations

Variables	Vitamin A (RAE – micrograms)	Daily per AE consumption through markets (UGX)	Daily per AE consumption from home production (UGX)	Farm production diversity (biodiversity index)
	(1)	(2)	(3)	(4)
Daily per AE consumption through markets (UGX)	-0.102**			
	(0.044)			
Daily per AE consumption from home production (UGX)	0.972***			
	(0.302)			
Farm production diversity (biodiversity index)		-59.20***	67.38***	
		(22.01)	(1.940)	
Distance to nearest market (kilometres)	1.862***	-0.604		
	(0.696)	(1.137)		
Head uses mobile phone (dummy)	223.8	1,444***	-289.6***	
	(168.2)	(342.1)	(22.35)	
Household size (Adult Equivalents)	-63.20***	-235.5***	-14.12***	0.423***
	(14.11)	(16.51)	(1.947)	(0.020)
Male heads (dummy)	-6.315	62.77	-17.40***	0.655***
	(24.06)	(42.81)	(5.614)	(0.099)
Age of head (years)	0.246	-2.454	-1.747***	0.017***
	(3.303)	(2.109)	(0.178)	(0.003)
Age squared of head (years)	0.002			
	(0.032)			
Education of head (years)	-17.96**	43.19***	4.829***	0.027**
	(8.908)	(11.66)	(1.059)	(0.011)
Education squared of head (years)	1.991***			
	(0.600)			
Shock experience (dummy)	-24.47	102.1***	-14.59***	0.435***
	(24.54)	(38.66)	(4.894)	(0.092)

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Appendix H Continued

Variables	Vitamin A (RAE – micrograms)	Daily per AE consumption through markets (UGX)	Daily per AE consumption from home production (UGX)	Farm production diversity (biodiversity index)
	(1)	(2)	(3)	(4)
Land size (GPS metres)	1.435		-0.682***	0.017***
	(1.715)		(0.137)	(0.003)
Land size squared (GPS meters)	-0.003			
	(0.003)			
Year 2010	-56.89**	181.7***	81.97***	-0.913***
	(26.53)	(54.77)	(5.906)	(0.108)
Year 2011	-57.21	522.6***	36.71***	0.605***
	(38.15)	(58.90)	(6.526)	(0.109)
Urban household (dummy)		785.0***		
		(103.5)		
Productive assets (UGX)			1.3e-7***	-1.4e-9***
			(2.6e-8)	(4.7e-10)
Access to extension services (dummy)				0.814***
				(0.089)
Free/lease hold land tenure (dummy)				1.744***
				(0.079)
Annual precipitation (mm)				0.002***
				(0.0002)
Elevation (meters)				-0.001***
				(0.0002)
Constant	3,435***	5,110***	-336.8***	6.409***
	(221.6)	(207.3)	(24.78)	(0.346)
Observations	8,490	8,490	8,490	8,490
Chi^2 value	234.77***	2,791.83***	4,373.51***	1,705.59***

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Mission

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

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

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