**The influence of household farming systems on dietary diversity and caloric intake: the case of Uganda**

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# Abstract

The relationship between farm production diversity at the plot level and diversity of household consumption and caloric intake are econometrically estimated. Our results confirm previous findings that an increase in production diversity increases consumption diversity and thereby, presumably, household nutritional levels. In addition, we find a positive relationship between diversity of farm production and caloric intake. Three waves of the World Bank LSMS-ISA database for Uganda were used to create a panel data set. Both fixed effects and limited dependent variable panel models, including time, were estimated. Results indicate that households that produce a greater diversity of crops, have higher food expenditures, have larger farms, and consume more from their own production have higher consumption diversity and caloric intake. Policy implications are that strategies aimed at increasing household production diversity may have positive effects on household nutritional levels and caloric intake.

**Keywords:** dietary diversity, panel data, farm production diversity, caloric intakes, Uganda

**JEL Code:**

# 1. Introduction

According to Rome Declaration on World Food Security, “Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life” (World Food Summit in 1996). Given this definition of food security, the construction of a single indicator a or a reasonable set of indicators for security is a complex task. Indicators suggested in the literature can be categorised into four categories: caloric deprivation indicators; monetary poverty indicators; dietary diversity indicators, and subjective indicators (Headey and Ecker 2013). Carletto et al. (2013) compiled the following list of the most common indicators of food security: measures of undernourishment, food consumption scores, household food security access scales, coping strategy indices, food adequacy factors and non-food factors.

The overlap between food security and nutritional security is large. Agriculture produces much of the world’s food (Hawkes and Ruel 2006), and nearly three-quarters of the poor people live in rural areas of developing countries where agricultural production and livelihoods may be especially influential on diets (Haddad 2000; Pinstrup-Andersen 2007). The positive relationship between farm diversity and dietary diversity was found for households in central Kenya and northern Tanzania (Herforth 2010). Similar finding were found for households in rural highlands of Ecuador (Oyarzun et al. 2013), in western Mali (Torheim et al. 2004), and in Malawi (Jones et al. 2014).

Results from (Kumar 1994) showed that the promotion of hybrid seed use by maize growing smallholders in Eastern Province of Zambia has increased their productivity of maize, increased their reliance on maize products in their food consumption, and declined their dietary diversity. This latter result was surprising, because it contradicted with the historical development in the region where maize growing smallholders maintained to grow local maize varieties due to local preferences for those varieties. In a recent study, Smale et al. (2015) reinvestigated the impact of hybrid seeds on dietary diversity and they concluded that women in maize growing households have more diverse diets. There is some evidence that diversity of food production at the farm level positively affects diversity of the diet.

For Uganda, there has not been an investigation on the link between the use of hybrid seeds, crop production diversity (or productivity) and dietary diversity. This paper links nutrition diversity at the household level to farm production diversity. We examine the effects of the diversity of farm production for households in Uganda on their dietary diversity such as nutrition diversity and caloric intake (Hoddinott and Yohannes 2002). Ideally, the dietary diversity indicator would have been analysed at the individual level, but such data is not available in the data set used (Arimond and Ruel 2004). For children of 5 years or younger, anthropometric indicators are available for Uganda.

This paper will explore the impact of production diversity when explaining the determinants of dietary diversity. We will base our analyses on the work of Jones et al. (2014) for Malawi and we will extend their work in two ways. Firstly, we use panel data on farmers households instead of cross-section data. Panel data allows us to control for unobserved heterogeneity. Next to the two dietary diversity indicators used by Jones et al. (2014) namely Dietary Diversity Score (DDS), and the Food Consumption Score (FCS), we add a dietary diversity indicator that links household caloric intake to farm production diversity. Our hypothesis is that an index which combines both nutrient diversity and caloric content will provide a better indication of health than either a nutrient diversity or caloric content index alone. By doing so, we hope to provide a convenient, first approximation of the level of household food security and allow policy makers to better target potential policies.

The remainder of the paper is organized as follows, the next section describes the data and methods used, emphasizing the process of selecting the variables eventually used in the analysis and the panel techniques employed. Thereafter follows the results and discussion sections. Finally, the conclusions section describes general conclusions and suggests policy implications.

# 2. Methodology

The link we draw between production diversity and nutritional adequacy rests on the link between food consumption diversity and nutritional adequacy. There are several papers arguing that there is a significant positive relationship between diet diversity and micro-nutrient intake (Katz 1994; Rose et al. 2002) and even between diet diversity and anthropometric outcomes for adults and children (Arimond and Ruel 2004; Rah et al. 2010; Hawkes and Ruel 2006).

Ideally, the nutrient adequacy is measured for individuals. Unfortunately, individual consumption data is not available in the LSMS-ISA surveys in Uganda. Therefore, we examine household dietary diversity and we assume that household distribute food equitably to optimize the diet of each member according to the total of foods available (Thorne-Lyman et al. 2010; Jones, Shrinivas, and Bezner-Kerr 2014). According to Thorne-Lyman et al. (2010), dietary diversity scores are increasingly used as measures of food security and as proxies for nutrient adequacy because the collection of reliable household expenditures data is relatively time consuming and rather complex. However, as argued in (Pitt et al.(1990), although intra-household calories allocation varies between members, especially in relationship to gender, the work and other activities of each household member can explain those differences. According to the authors, *“household are averse to inequality”*. Accordingly, as a second best solution we take household consumption as imperfectly reflecting the dietary condition of individual household members.

in developing countries

*Measurement of dietary diversity*

For nutrition diversity in Uganda, we use the same indicators as Jones et al. (2014) for Malawi. We test two commonly accepted measures of dietary diversity which have been linked to a healthy nutrient diet, namely, the FVS and DDS measures previously presented (Hatluy et al. 1998; Arimond and Ruel 2004; Torheim et al. 2004; Steyn et al. 2006; Kennedy et al. 2007).

The DDS is the count of the number of nutritional food groups consumed by a household in a reference period (Swindale and Bilinsky 2006). The maximum score for a household is 12 as there are 12 nutritional food groups: *i*. cereals, *ii*. roots and tubers, *iii*. pulses and nuts, *iv*. vegetables, *v*. fruit, *vi*. meat, *vii*. eggs, *viii*. fish and seafood, *ix*. milk and dairy products, *x*. oil and fats, *xi*. condiments, and *xii*. sugar. It is highly correlated with factors such as caloric and protein adequacy, and household income. Furthermore, i.

The Food Variety Score counts individual food items (Torheim et al. 2004) in a given reference period. Each food groups consists of a number of food items, see Torheim et al. The calculation of the FVS score requires more detailed data on food items. As the DDS, the FVS score does not take into account the frequency of consumption of food items given a reference period.

However, in order to approximate the results in (Jones et al. 2014), we use a derivate of the FVS known as the Food Consumption Score (FCS). The FCS uses weighted food groups, the Dietary Diversity Score uses also uses food groups but with weights set to one and the Food Variety Score counts individual food items. Therefore, while both the FVS and FCS measure the number of different food items consumed over a defined period, the FCS weights each food item according to its nutritional contribution to the diet (United Nations World Food Programme 2008). Households were interviewed in regards to their consumption of 69 food items over the last 7 days before the interview date.

Measurement of farm production diversity

In addition to the three measures of dietary diversity, three indicators were used to estimate farm production diversity; recall that farm production diversity is an exogenous variable in our model. All three production diversity indicators are postulated to be positively linked to our measures of dietary diversity and two of them have been previously used (Jones et al. 2014).

The first farm production diversity indicator is the crop count, which is the count of the number of different crops harvested by the household farm:

with *j* the different crops grown by household *i*. It only takes into account crops which have been harvested at the time the household was interviewed. Current crops on the plots were not taken into account, because we cannot be certain that those crops will eventually be consumed or sold due to health concerns of the farmer, and the threats of insects, rodents, droughts, floods, other pests and thefts.

The second measure of production diversity is the Simpson’s index which was initially used in ecology to define the diversity of a given population (Simpson 1949).

with

Where is the area of the crop *j* used by household *i*, is the total cropped area cultivated by the household *i* and is the share of cultivated land with crop *j* in the total area cultivated by the household *i* with *j*=1,..,12. The Simpson’s index was estimated for a household for each of the three years of the panel. The index is bounded by 0 and 1 and allows us to measure the diversity of farm production. If a household cultivated one single crop, the value of the Simpson’s index is zero. Values approaching zero indicate that a household cultivates one main crop with small plots with other crops. has an unequal distribution of crops, while a value approaching one reflects an equal crop distribution across cultivated area.

The third production indicator is the *own production ratio* which has not been used in the literature before.

with *j* is the production of crops from different food groups. It is designed to reflect the direct link between farm production diversity on the number of nutritional food groups grown by a household. In an analogous relationship to that between the nutrition diversity indicators FVS and DDS, our third indicator counts the number of food items *from different nutritional groups* produced by a household. In short, it distinguishes between crops based on their contribution to nutritional diversity.

All three production diversity measures are designed to estimate the effect of production diversity on dietary diversity. A separate exogenous variable indicating whether households is involved in livestock activities will be included in the regressions to test their effect on nutrition diversity.

*Empirical strategy*

We estimate linear models that regress production diversity indicators and other characteristics on nutrition diversity indicators similar to Jones et al. (2014). We use panel data sample for Uganda which allows us to control for unobserved heterogeneity at the household level. We distinguish three nutrition diversity indicators, namely DDS, FFS and caloric intake. For the production diversity indicators, we use crop count, Simpson’s index, and the own production ratio. In addition to the linear model regressions, we estimate a Poisson Generalized Panel Linear Model with fixed effects for the DDS indicator, because the DDS indicator is a count variable ranging from 1 to 12, which is likely to have a skewed distribution.

We test whether there is a relationship between farm production diversity and household caloric intake. For convenience, we assume that production diversity indicators are exogenous. Since nutrient diversity indicators are complex and multidimensional, we choose to use a combination of nutrient diversity indicators to be explored. Either the analyses of multiple indicators might give us significant and robust results or it might give us insight in the relationship between nutrition diversity indicators.

Furthermore, we also incorporate socio-economic and demographic household variables into the model to control for household characteristics influencing dietary diversity, such as household size, age, gender and education of the household head as well as income-related variables. Those income related variables include different sources of income, property, investments and transfers.

# 3. Data

For our analyses, we use three waves of the LSMS-ISA Uganda National Panel Survey (UNPS) implemented by the Ugandan Bureau of Statistics. The LSMS-ISA survey for Uganda combines information on socioeconomic information including food consumption and anthropometric characteristics, with agricultural characteristics. In our sample, we only take into account the rural households that claim to explore agricultural activities because we research the direct relationship between production diversity and nutrition diversity. For the agricultural part, households are visited twice to record the agricultural activities in both growing seasons (dry and rainy seasons). The food consumption information is based on registering the food consumption in one week.

The LSMS-ISA survey is a stratified survey of households in rural and urban districts. When using weights, it can produce representative results at the national level or the level of four regions. Our sample is based on three waves of the LSMS-ISA survey for Uganda. We constructed a balanced panel of 1,722 rural smallholders. Urban households were not considered, because we cannot establish a relationship between agricultural production diversity and nutrition diversity.

For nutrition diversity we use three different indicators namely DDS, FCS and caloric intake. The latter indicator is constructed by multiplying the weights of food items consumed with the calorific coefficient data from the World Food Programme and the USDA's National Nutrient Database for Standard (References World Food Programme; USDA, 2013). For most food items, we were able to match the food products consumed in Uganda with the caloric coefficient of each product to make the link between quantity consumed by the household and its total caloric intake.

In addition to the three measures of production diversity discussed above, many other variables were considered for inclusion into our model to explain household dietary diversity. The number of potential variables in the World Bank survey meant that we were able to test many potential variables. In practice, our task was to choose a subset of variables that best explains dietary diversity. The variable selection criteria we used was first to consult the literature to get an overview of the set of variables commonly used with the addition of other variables which are commonly used in the micro-economics. Finally, a third condition for deciding whether a variable was chosen for inclusion in the model was the condition of parsimony. The following paragraphs discuss potential variables considered for inclusion into out model and our hypotheses concerning its potential effect on dietary diversity. To ease the flow of the discussion, each variable was placed into one of the following four categories: household characteristics, economics characteristics, agricultural characteristics and location.

Cultivated areas were calculated by GPS data recorded in the surveys. When the GPS data was not available, the farmer plot size estimation was considered, estimations available in the LSMS-ISA survey. In cases of mixed cropping, each crop was taken separately. Given that there is no information on the proportion of crops on a mixed-cropping plot, we assume that each crop encompasses the entire plot. Both growing seasons within a year were included in the calculations of the productivity diversity indicators.

Household characteristics clearly have significant effects on the diversity of food consumption. For instance, household size has previously been hypothesized to directly influence the household dietary diversity and caloric intakes by, for example, influencing the number of members who are potentially able to work. Following previous studies, we believe that this variable will be positively related to the diversity of consumption and the quantity of caloric intakes (Weiss and Briglauer 2000; Benin et al. 2004; Jones et al. 2014). The gender of the head of the household has been argued to be positively related to dietary diversity. For instance, Abay et al. (2009) found a positive correlation with a male household head in Ethiopia link to their contribution to certain tasks associated with strong physical labour such as ploughing. The results on the relationship between age of the household head and nutrition diversity are mixed. While Abay et al. (2009) found a positive relationship (experience), (Jones et al. 2014) found a negative correlation (risk averse). Similarly, the education level of the household head. Benin et al. (2004) and Jones et al. (2014) found a positive relationship. Higher education of the household head, which is primarily responsible for food preparation in the household, take into account nutrition diversity and their caloric intake better.

Total income is an important indicator of the general economic well-being of a household, consequently a positive relationship is expected between consumption diversity and total income. A high level of income allows a household to the purchase of more food and food with higher nutritional quality. With respect to the expenditures of households, we expect food expenditures to be positively correlated with diet diversity because of its direct link to the quantity and the diversity of the food products consumed. Non-food expenditures are assumed to reflect the socio-economic situation of a household. Note that food expenditures might be related to income, but they are not the same. According to Thorne-Lyman et al. (2010), non-food expenditures have a positive effect on the household dietary diversity, however, surprisingly Jones et al. (2014) found a negative relationship. All monetary income and expenditure variables are expressed in 2010 prices.

With 66% of the Ugandan population employed in the agricultural sector in 2009 (Boysen et al., 2014), agricultural characteristics are an essential component of Ugandan households. Most of them are smallholders. Wor not cultivated dietary diversity through grow more different Jones et al. (2014) argued that dietary diversity increases when the head of the household controls agricultural earnings decisions. The underlying assumption, presumably, is that the head of the household has as an aim high dietary diversity.

On average, households consume food from more than 7 different food groups per week (DDS score). For food items, the average is more than 55 food items per week (FCS score). In caloric terms, households take 67,400 calories per week in 2010/2011, and 73,100 calories in 2009/2010. Given the increase in household size from 6.87 in 2009/2010 to 8.15, there is a clear decline in the amount of calories per household member per week from 10,600 calories in 2009/2010 to 8,700 calories in 2011/2012. For all dietary diversity indicators, their scores were largest in the central region, see Table 2. Both DDS and FCS were lowest in the northern region, but the caloric intake is lowest in the western region.

The crop count of smallholders in Uganda also slightly declines over time from 5.15 to 4.83, see Table 1. In addition, the cultivated area per household declined by 20% over time. In Central region, the crop count is highest, and in Eastern region lowest, see Table 2. The total cultivated area per smallholder is largest in Northern Uganda.

Most important changes were observed for the household size which increased from 2009 to 2012 and the cultivated area which decreased over the same period. Table 2 presents the sample variables split by region. Their farms were the smallest of the country; the biggest were located in northern region. The central region, which includes the Ugandan capital Kampala and surrounding regions, had the highest incomes per household.. Standard deviations are large and stress the existence of large gaps between the poorest and richest households. These large differences were observed after removing outliers. But standard deviations for income and expenditures remained still significantly elevated.

*Table 1: Variable characteristics by year*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | 2009/2010 | | 2010/2011 | | 2011/2012 | |
| Characteristics | mean | SD | mean | SD | mean | SD |
| *Nutrition diversity* |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
| FCS | 56.84 | 21.72 | 55.50 | 21.92 | 59.34 | 21.34 |
|  |  |  |  |  |  |  |
| Calories per HH (x 1,000) | 73.1 | 57.4 | 67.4 | 75.,3 | 70.9 | 73.1 |
| Calories per household member (x 1,000) | 10.6 |  | 9.0 |  | 8.7 |  |
| *Production diversity* |  |  |  |  |  |  |
| Crop count | 5.15 | 2.10 | 5.12 | 2.09 | 4.83 | 1.97 |
| Own production ratio | 0.37 | 0.19 | 0.34 | 0.20 | 0.39 | 0.20 |
|  |  |  |  |  |  |  |
| *Household characteristics* |  |  |  |  |  |  |
| Household size | 6.87 | 3.23 | 7.53 | 3.49 | 8.15 | 3.80 |
| Age head household | 47.15 | 15.01 | 47.82 | 15.01 | 48.67 | 14.77 |
| Education level head household | 20.64 | 10.78 | 21.10 | 11.86 | 20.61 | 11.22 |
| Food expenditure | 250.2 | 365.1 | 273.0 | 428.8 | 297.0 | 464.6 |
| Non-food expenditure | 201.7 | 537.3 | 144.5 | 363.4 | 148.4 | 701.3 |
| *Income sources* |  |  |  |  |  |  |
| Total household income | 1,754.9 | 6,484.9 | 1,739.9 | 7,515.3 | 1,807.6 | 5,011.4 |
| # sources of non-agricultural income | 0.10 | 0.35 | 0.31 | 0.66 | 0.29 | 0.60 |
| Agricultural income | 730.4 | 4752.4 | 633.8 | 1624.6 | 781.3 | 1919.2 |
| Non-agricultural income | 3.09 | 116.84 | 0.23 | 5.37 | 3.54 | 92.63 |
| Property income | 451. 6 | 2044.6 | 648.3 | 6791.1 | 558. 5 | 3321.5 |
| Investments | 66.1 | 514.7 | 126.6 | 1463.4 | 99.1 | 1200.0 |
| Transfers | 189.6 | 810.4 | 254.0 | 1202.2 | 276.2 | 1538.3 |
|  |  |  |  |  |  |  |

SD = Standard Deviation

*Table 2: Variables characteristics by region over all three waves*

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Eastern | |  | | Western | |  | | Northern | |  | | Central | |  | |
| Characteristics | Mean | | SD | | Mean | | SD | | Mean | | SD | | Mean | | SD | |
| *Nutrition diversity* |  | |  | |  | |  | |  | |  | |  | |  | |
| DDS | 7.64 | | 1.94 | | 6.53 | | 1.97 | | 7.46 | | 1.96 | | 7.94 | | 1.97 | |
| FCS | 58.23 | | 22.78 | | 58.60 | | 20.39 | | 52.27 | | 20.18 | | 60.63 | | 22.54 | |
| Calories by HH (x 1,000) | 83.34 | | 86.40 | | 55.88 | | 55.23 | | 67.44 | | 54.76 | | 74.01 | | 69.77 | |
| *Production diversity* |  | |  | |  | |  | |  | |  | |  | |  | |
| Crop count | 4.65 | | 1.85 | | 5.35 | | 1.96 | | 4.73 | | 2.09 | | 5.55 | | 2.22 | |
| Own pratio | |  | |  | |  | |  | |  | |  | |  | |  |
| *Household characteristics* |  | |  | |  | |  | |  | |  | |  | |  | |
| Household size | 7.71 | | 3.61 | | 7.15 | | 3.15 | | 7.13 | | 3.16 | | 8.17 | | 4.21 | |
| Age of the household head | 48.43 | | 14.16 | | 47.81 | | 15.07 | | 46.14 | | 14.75 | | 49.40 | | 15.80 | |
| Education level of the household head | 20.86 | | 11.39 | | 20.18 | | 10.82 | | 21.45 | | 11.91 | | 20.57 | | 10.95 | |
|  |  | |  | |  | |  | |  | |  | |  | |  | |
| Food expenditure | 249.58 | | 322.24 | | 198.09 | | 306.55 | | 305.48 | | 490.42 | | 350.61 | | 528.95 | |
| Non-food expenditure | 129.05 | | 231.86 | | 122.77 | | 243.21 | | 181.64 | | 474.18 | | 238.55 | | 1002.71 | |
| *Income sources* |  | |  | |  | |  | |  | |  | |  | |  | |
| Incomes | 1474.03 | | 4591.61 | | 1546.88 | | 3272.15 | | 1720.66 | | 5025.95 | | 2426.33 | | 10908.34 | |
| # sources of non-agricultural income | 0.20 | | 0.49 | | 0.25 | | 0.63 | | 0.22 | | 0.55 | | 0.27 | | 0.58 | |
|  |  | |  | |  | |  | |  | |  | |  | |  | |
| Agricultural incomes | 672.65 | | 3194.08 | | 656.98 | | 1244.83 | | 699.52 | | 983.48 | | 856.60 | | 5389.51 | |
| Non-agricultural incomes | 4.24 | | 100.29 | | 0.00 | | 0.00 | | 4.06 | | 131.84 | | 0.09 | | 1.84 | |
| Property incomes | 332.54 | | 1597.02 | | 427.60 | | 1736.77 | | 614.79 | | 3607.21 | | 902.61 | | 8490.77 | |
| Investments | 81.80 | | 1249.88 | | 102.16 | | 1232.88 | | 101.73 | | 1153.51 | | 105.66 | | 751.63 | |
| Transfers | 166.23 | | 765.75 | | 236.38 | | 1204.97 | | 200.22 | | 1357.20 | | 389.17 | | 1496.80 | |
|  |  | |  | |  | |  | |  | |  | |  | |  | |

Other variables were considered for inclusion in the regressions to explain dietary diversity but were left out due to poor quality due mainly missing values, and because they were highly correlated with variables included in the regressions For example, the number of farm plots could be linked to production diversity because it potentially encourages the production of a range of different crops. It was not included because it was found to be highly correlated with production diversity. A quantile measure of income, used in Jones et al. (2014), was replaced with the correlated measure of income types because these types include more information in terms of the sources of an income.

# 4. Results and discussion

*Panel data results*

We regress productivity diversity and other characteristics on nutrition diversity. Table 3 presents the panel data regression results (transformed PLM regressions). For each dependent variable, DDS, FCS and calories there are three regressions presented which differ across the indicator used for production diversity. For convenience, we assume that the production diversity is exogenous. for fixed effects was not

For the nutrition diversity indicators DDS (columns 1, 4 and 7 in Tables 3) and FCS (columns 2, 5 and 8), all production diversity indicators have significantly positive coefficients, see Table 3. The magnitude of the production diversity coefficients for the DDS and FCS equations ware largest for the Simpson’s index. In the case of calories (columns 3, 6 and 9), only the crop count variables (column 3) showed a significant positive coefficient. The Simpson’s index and own production ratio were not significant in the caloric intake equations. The result confirm the findings of Jones et al. (2014).

The results for the DDS models (columns 1, 4 and 7 in Tables 3) show that the coefficient for food expenditures are positive and significant. Also, three time period dummies are significantly positive as well. Note that we use three period dummies and ignore the intercept in the panel models. The switch between production diversity indicators did not affect the significance levels of the coefficients of the variables. Male household heads showed a significantly negative coefficient in the DDS with own production ratio. As noted above, the DDS indicator is a count variable with a minimum of 1 and a maximum of 12. Moreover, it is likely that the distribution of the counts is skewed.

Tindicator (column 2, 5 and 8)show significant coefficients for and Also, three time period dummies are significantly positive as well. and the magnitude significant weall in the same range. Male household heads showed a significantly negative coefficient in the DDS with own production ratio. The socioeconomic variables such as household size, age of the household head, education of the household head and the gender of the household head were insignificant. This might be due to the fixed effects estimation. Our results do not support the earlier findings of Jones et al.

the Variables

The results of the caloric intake models show that the same variables as the FCS model show significantly positive coefficients. Additionally, household size and education of the household head have also significantly positive while age of the household head has significantly negative coefficient. The total cultivated area is only significant is the count crop and Simpson’s index as proxies for production diversity were used.

,

Old

The coefficient for the size of the household , an indicator of potential labour, is positive indicating that more labour increases dietary diversity. A male head of household has been associated with higher diversity; however, in both the FCS and DDS models the coefficient is far from reaching a statistically significant level. The age of the household head, reflecting greater experience and thereby increasing, for examples, management skills, is negative and insignificant in the FCS model. This is a counter-intuitive result, but corresponds to the findings of Jones et al. (2014). The education level of the household head, hypothesized to reflect better knowledge of the benefits of consuming a nutritious diet, is positive and significant.

In general, the economic characteristic coefficients move as hypothesized, i.e., higher levels of income lead to greater quantity and quality of food consumption. Both the coefficients for food and non-food expenditures are positive and significant. Income, perhaps surprisingly, is insignificant. Its insignificance might be due in part to the fact that the expenditure coefficients are picking-up its correlation with dietary measures. However, regression diagnostics such as measures of correlation between the exogenous variables and variance in inflation factors indicate that excessive collinearity is not a problem for any of the variables selected for analysis.

The income of a household is further distinguished into income from agriculture sources and income from non-agricultural sources. As expected, the higher food expenditures, the higher measures of dietary diversity. Those households spending more on food buy items that increase diversity and thereby improve their health. Greater non-food expenditures, perhaps a further reflection of a households economic standing, increase dietary diversity, but the coefficient's magnitude is much smaller.



The household's total land area devoted to agricultural production is positively associated with dietary diversity. More available land improves diversity. Similarly, the greater the proportion of food consumed from a household's own production, the great the dietary diversity. Given more land, Ugandan households appear to choose a greater diversity of production and consumption. However, in contrast to Jones et al. (2014), our results do not indicate that control of agricultural decisions by the head of a household increases diversity; the coefficient is insignificant in our model. Finally, the Northern region appears to be strongly associated with decreased dietary diversity. This might be due to violence in that part of the country.

Results for the DDS measure closely resemble those of the FCS with the exception of the age of the head of the household, the proportion of food consumed from a household's own production and the significance of the Eastern Region. Differences in the signs and magnitudes of the coefficients might be due to the fact that the DDS measure is a rougher measure than the FCS in the sense that it simply counts the number of items consumed in a time period rather than adjusting the consumption of those items to reflect their nutrient contribution to the diet. The DDS measure imposes a stricter structure on the data which in some cases might distort coefficients. Another explanation is that OLS is an inappropriate technique for count measures such as the DDS because it will lead to inconsistent estimates (Greene, 2012 chapter 17).

*Count model*

Following this reasoning, it is best to compare the Calories model with the FCS model because both are continuous variables. Again, the coefficients of the two models are similar. In contrast to the FCS model, the gender of the head of household is significant in the Calories models. Furthermore, its sign corresponds to its hypothesized sign. However, the coefficient for the education of the head of the household in the Calories model is negative. The more educated the head of the household, the few calories consumed, although this result should be read with caution given that it is just significant.

Results for the FVS and Calories models are less impressive than their respective OLS models in that far fewer coefficients are significant.

Finally, a Poisson panel regression was estimated for the DDS dependent variable. In that regression only food expenditures were found to be significant. As mentioned, the DDS model is rough in that it is a step function.

Table 3: Fixed-effects regression results for three nutrition indicators and three production diversity indicators.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | DDS | | FCS | | Calories | | DDS | | FCS | | Calories | | DDS | | FCS | | Calories | |
|  | (1) | | (2) | | (3) | | (4) | | (5) | | (6) | | (7) | | (8) | | (9) | |
|  | Crop count | | Crop count | | Crop count | | Simpson' s index | | Simpson' s index | | Simpson' s index | | Own production ratio | | Own production ratio | | Own production ratio | |
| Production diversity | 0.046 | \*\*\* | 0.668 | \*\*\* | 1.599 | \*\* | 0.364 | \*\* | 3.585 | \*\* | -2.688 |  | 0.059 | \* | 0.844 | \*\* | 0.971 |  |
| Household size | 0.008 |  | 0.113 |  | 3.549 | \*\*\* | 0.016 |  | 0.281 |  | 3.985 | \*\*\* | 0.009 |  | 0.131 |  | 3.626 | \*\*\* |
| Household head gender - Male | -0.316 |  | -1.435 |  | 12.034 |  | -0.449 | \* | -4.451 | \* | 15.448 |  | -0.332 |  | -1.664 |  | 11.396 |  |
| Age of the household head | -0.006 |  | 0.032 |  | -0.932 | \* | -0.001 |  | 0.163 |  | -1.177 | \*\* | -0.005 |  | 0.038 |  | -0.919 | \* |
| Education level of the household head | 0.004 |  | 0.076 |  | 0.589 | \*\* | 0.008 |  | 0.123 | \* | 0.818 | \*\*\* | 0.004 |  | 0.078 |  | 0.601 | \*\* |
| Food expenditure | 0.001 | \*\*\* | 0.021 | \*\*\* | 0.054 | \*\*\* | 0.002 | \*\*\* | 0.022 | \*\*\* | 0.056 | \*\*\* | 0.001 | \*\*\* | 0.021 | \*\*\* | 0.054 | \*\*\* |
| Non-food expenditure | -0.000 |  | 0.000 |  | 0.001 |  | 0.000 |  | -0.001 |  | -0.003 |  | -0.000 |  | 0.0001 |  | 0.001 |  |
| Incomes | 0.007 |  | -0.029 |  | 0.110 |  | 0.006 |  | -0.029 |  | -0.010 |  | 0.007 |  | -0.024 |  | 0.123 |  |
| Total cropped area | 0.001 |  | 0.024 | \* | 0.101 | \* | 0.001 |  | 0.025 | \* | 0.062 |  | 0.001 |  | 0.023 | \* | 0.100 | \* |
| Proportion of own production | -0.303 |  | 10.624 | \*\*\* | 39.812 | \*\*\* | -0.345 |  | 11.244 | \*\*\* | 39.764 | \*\*\* | -0.275 |  | 11.037 | \*\*\* | 41.325 | \*\*\* |
| # non-agricultural income sources | 0.011 |  | -0.838 |  | -0.157 |  | 0.008 |  | -0.986 |  | -1.147 |  | 0.011 |  | -0.842 |  | -0.129 |  |
| Agriculture Decision - Household Head | 0.048 |  | 1.066 |  | 0.559 |  | 0.154 |  | 1.516 |  | -0.086 |  | 0.056 |  | 1.183 |  | 0.978 |  |
| Year 2009-10 | 7.414 | \*\*\* | 42.121 | \*\*\* | 32.840 |  | 7.069 | \*\*\* | 36.972 | \*\*\* | 45.926 |  | 7.416 | \*\*\* | 42.214 | \*\*\* | 36.066 |  |
| Year 2010-11 | 7.227 | \*\*\* | 39.955 | \*\*\* | 23.489 |  | 6.890 | \*\*\* | 34.672 | \*\*\* | 36.314 |  | 7.229 | \*\*\* | 40.049 | \*\*\* | 26.620 |  |
| Year 2011-12 | 7.494 | \*\*\* | 43.794 | \*\*\* | 25.399 |  | 7.136 | \*\*\* | 38.320 | \*\*\* | 37.343 |  | 7.484 | \*\*\* | 43.721 | \*\*\* | 28.085 |  |
| Observations | 3,941 | | 3,941 | | 3,939 | | 3,596 | | 3,596 | | 3,594 | | 3,941 | | 3,941 | | 3,939 | |
| R2 | 0.12 | | 0.176 | | 0.086 | | 0.125 | | 0.186 | | 0.085 | | 0.119 | | 0.174 | | 0.085 | |
| Adjusted R2 | 0.074 | | 0.108 | | 0.053 | | 0.075 | | 0.111 | | 0.051 | | 0.073 | | 0.107 | | 0.052 | |
| F Statistic | 27.59 | \*\*\* | 43.24 | \*\*\* | 19.080 | \*\*\* | 25.578 | \*\*\* | 40.787 | \*\*\* | 16.600 | \*\*\* | 27.263 | \*\*\* | 42.575 | \*\*\* | 18.751 | \*\*\* |

*Note: \*p<0.1; \*\*p<0.05; \*\*\*p<0.01, Calories intakes are estimated by household. Standard errors and t-values are available upon request with the corresponding author.*

Recall that one of the aims of the paper is to develop an easy to implement indicator that can be used to establish the nutritional health of an individual. So, in addition to testing several endogenous measures, three exogenous production count variables were tested as well to determine if they lead to significantly different overall model estimates. The number of different crops produced, the number of different *nutritional groups* produced, and the Simpson’s index were tested using the fixed-time effects (PLM) method (Table 4). These main variables were significant and positive for our three endogenous variables except for production by nutritional group and Simpson’s index, which were not significant in explaining caloric intakes. Results for the entire model were in line with previous results across the different production count variables and thereby suggest that the most parsimonious exogenous production count indicator in a given situation should be used

The first crop count model, the number of different crops produced, reproduces the results in table 3 and so will not be discussed in the this section. The three models run with different *nutritional groups* (second three columns in the table) as an exogenous variable produce similar results. Its estimate is highly significant in all three models. Two interesting points of comparison are the results for household size and the education level of the head of household. As opposed to the other two models, the estimate for household size is highly significant in the caloric model, indicating that a larger household significantly increases the number of calories consumed by the household. While not in itself surprising, it does raise the question of why a larger household size does not increase household nutritional levels. Similarly, the estimate for the educational level of the household head is also significant in explaining calories consumed by a household, but is not in either of the other two models. In general, the two indices, the number of crops produced and the number of different nutritional food groups produced, yield similar results.

Results for the model using the Simpson’s index were somewhat different than the previous two estimators. Its estimate was also significant for the FCS and DDS models, but insignificant in the Caloric model. The estimate for the variable male head of household for the FCS and DDS models was negative in contrast to the other model. Perhaps male household heads focus on food quantity instead of nutritional diversity.

In general, results across the three models testing different exogenous food count measures show similar results. The Caloric model consistently has more significant variables than the other two models. This might be due to the fact that calories are more closely linked to the quantity of food consumed which we suppose is easier to influence than the nutritional diversity of crops grown. In addition, in none of the models were the time estimates significant for the Calories model. Calories consumed appear to be unaffected through time, as opposed to nutritional intake. This surprising conclusion needs to be further investigated. Of the three exogenous variables tested, the number of different crops shows significant results for each model and similar results for the other exogenous variables in the model. We therefore recommend using it as a measure of the overall nutritional and caloric health of a household.



In our final set of regressions, we split the different sources of income available to a family in order to try to disentangle how sources of household income affect our three endogenous variables with the number of different crops as our main exogenous count of food diversity (Table 5). The five income variables we examine are agricultural income, non-agricultural income, property income, investments, and transfers. Results are mixed and inconsistent across models. Agricultural income is significant in both the FCS and DDS models, but its magnitude is small in comparison to the other estimates in the models. Non-agricultural income is insignificant in all three models, while income from property and income from investments have negative effects in the Calories model. More income from property and investments reduces calories after accounting for the effects of the other variables in the model. However, the magnitudes are small in comparison the many of the other significant variables in the mode. The effects of squaring the following variables was tested in order to check nonlinear effects: age of the household head, income, food and non-food expenditures. Results were insignificant.

*Poisson model for DDS*

In addition, for each model a Poisson model was run, although it is only appropriate for the DDS because it alone is a count measure.

# 5. Conclusions and discussion

Our preliminary results aim at reproducing and extending the model found in Jones, et al. (2014), using more data and improved techniques. In addition, we test several measures of food counts and estimate a model which attempts to explain household variations in calories consumed

Our hypotheses were twofold: to test whether farm production diversity by households effects their consumption diversity using appropriate regression techniques, and; to test whether farm production diversity leads to higher household caloric intake. We were able to confirm both hypotheses. Both hypotheses were confirmed. The panel approach allows the reduction of correlation across time and within the same household. It is therefore preferable to a cross-sectional approach. The exogenous variable, number of different crops produced by a household, was found to outperform the other two variables tested and should be the preferred measure.

The analyses emphasize that farm production diversity increases consumption diversity and therefore nutrient intake and caloric intake. This result was robust across models. Therefore, policies aimed at increasing farm production diversity are likely to improve the overall health of farm households. Given more land, famers in Uganda choose to plant a greater diversity of crops and raise their nutritional health, indicating that they are aware that greater crop diversity leads to greater health. The same appears to be true for

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