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

Romain Vignes

Jeffrey Powell

Ruerd Ruben

*LEI Wageningen University Research Centre, the Netherlands*

November27th, 2015

Preliminary version. Do not quote, do not disseminate

**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

**JEL Code:**

1. Introduction

Given the FAO's definition[[1]](#footnote-1) of food security, specifying a single indicator or a reasonable set of indicators which can be used to establish whether an individual enjoys food security or not is a complex task. Suggested measures fall into four general categories: caloric deprivation indicators; monetary poverty indicators; dietary diversity indicators, and; subjective indicators (Headey and Ecker 2013). Carletto, Zezza, and Banerjee (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. In the current paper, we link food security, particularly nutritional security at the level of the household, with household farm production. The overlap between food security and nutritional security is large, our emphasis in on the whether a household consumes the types of food items that will ensure an adequate intake of nutrients. We examine the effects of the diversity of farm production for households in Uganda on their dietary diversity, a measure that has previously been linked to a household’s nutrient adequacy, and caloric intake (Hoddinot and Yohanes , 2020). As will be argued further below, establishing a direct link between a measure of household’s nutrient level and its constituents is difficult and we are apply a second-best technique. Ideally we would have conducted our analysis at the level of the individuals however such diary level data is not available in the data set (e.g., Arimond, M et al., 2010). The principle advantages of the data we analyse over individual, diary level data are its breadth and length.

There is some evidence that diversity of food production at the farm level positively affects diversity of the diet. In particular, recent work by Jones, Shrinivas, and Bezner-Kerr (2014) argues that there is a positive relationship between farm production and the health of household members. We aim to complement the work of Jones et al. in two ways. First, concerning technical matters, we use a panel set of data instead of cross-sectional data and apply more appropriate econometric techniques. Using the World Bank LSMS-ISA panel data set for Uganda, we are better able to test the reported relationships between the DDS measure and consumption diversity as reported in Jones et al. (2014). Panel data allows us to utilize econometric techniques which statistically control for potential problems related to omitted, static, variables which can bias results when only one year of data is used. In addition, we test and, when appropriate, incorporate a more complete set of household variables into the model to better account for household characteristics influencing dietary diversity (e.g. non-agricultural income, investments and transfers). The last technical addition concerns the use of a count model in place of the continuous models used in Jones et al. Our second contribution is that we test whether there is a relationship between farm production diversity and household caloric intake. Therefore, in addition to the relationship between farm production diversity and adequacy of nutrient consumption via diverse consumption, we add the influence of production diversity on caloric intake. Our contention is that an index which combines both nutrient diversity and caloric content will provide a better indication of health than one or the other 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 link we draw between production diversity and nutritional adequacy rests on the link between consumption diversity and nutritional adequacy. There is evidence in the literature that dietary diversity is an important component of health, with several papers arguing that there is a significant relationship between diet diversity and micro-nutrient intake. Nutrient adequacy is commonly calculated using the Nutrient Adequacy Ratio (NAR), a measure that compares an individual’s intake of nutrients to the recommended intake levels of those nutrients. The sum of the NAR by nutrient, divided by the number of nutrients, gives an overall indicator known as the Mean Adequacy Ratio (MAR). Two studies in Mali found a positive relationship between the Food Varity Score (FVS), which corresponds to the number of different food items consumed over a defined period, and the MAR. In addition, it has been shown that a significant level of correlation exists between the Dietary Diversity Score (DDS) which, like the FVS, focuses on nutritional food groups, and the MAR Hatluy, Torheim, and Oshaug 1998; Torheim et al. 2004). (Kennedy et al. 2007). Both the DDS and the FVS have been used as indicators of dietary adequacy of children (Arimond and Ruel (DDS) 2004; Steyn et al. 2006). Steyn (2006), concludes that either the FVS or DDC can be used as a simple and quick indicator of the nutritional adequacy of a diet. In the Philippines, a significant relationship was found between nutrient adequacy intake and the DDS for children which were not breast feed (Kennedy et al. 2007) These studies were run at the individual level with the exception of Torheim et al. (2004), who considered both individual and household levels using both DDS and FVS measures. In contrast, our study examines household dietary diversity as in Thorne-Lyman et al. (2010) and Jones et al. (2014). We assume that within a household food allocation is distributed equitably to optimize the diet of each member according to the total of foods available. Ideally, the individual consumption data would be available; unfortunately they are not in the LSMS-ISA databases. In general, according to Thorne-Lyman (2010), the collection of reliable data on household expenditures is relatively time consuming and complex and therefore dietary diversity scores are increasingly used as measures of food security and as proxies for nutrient adequacy**.**  However, as argued in Pitt, Rosenzweig, and Hassan (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.

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.

1. **Data and Methods**

*Presentation of LSMS-ISA*

The Uganda economy is heavily dependent on agriculture. That sector employed 66% of the population in 2009 (Boysen, Jensen, and Matthews 2014). According to surveys in 2011-2012, half of the surveyed households consider farming to be their main activity and their principle source of income (The Uganda Bureau of Statistics 2015).

Three waves of the LSMS-ISA Uganda National Panel Survey (UNPS), 2009-2010, 2010-2011 and 2011-2012, implemented by the Ugandan Bureau of Statistics, are included in the analysis. The LSMS-ISA UNPS consists of data from two household visits separated by six months to record the activities of the two Ugandan cropping seasons – dry and rainy. The survey is composed of four different questionnaires. We use two of them, namely, the household and the agriculture surveys the first of which contains household socio-economics information and weekly food consumption data and the second which contains descriptions of farm characteristics. Specific variables used in analyses are described below. The households selected by UNPS were selected such that the weight of each region is equally represented and with stratification between rural and urban regions. All three wavers of data were used in the analyses allowing us to construct a balanced panel consisting of 1722 household observations. In addition to data from the LSMS-ISA surveys, we estimate a measure of nutrition based on a household’s total caloric intake. We constructed this measure by calculating calories per kilogram of food item consumed by Ugandans using calorific coefficient data from the World Food Programme and the USDA's National Nutrient Database for Standard (References World Food Programme; USDA, 2013). In most cases, 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. Although in some cases the matching was imperfect given the local food item itself or the non-standard quantity measure.

*Measurement of dietary diversity*

Our study aims to link production diversity and the diversity of household consumption. In keeping with the literature on this topic and to provide a rough crosscheck of outcomes, we use several measures of dietary diversity. In order to make our work comparable with previous results we initially use standard definitions of consumption diversity. 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 (Hatloy, Torheim, and Oshaug, 1998; Arimond and Ruel, 2004; Torheim et al., 2004; Steyn et al., 2006; Kennedy et al., 2007). 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 Food Consumption Score 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 (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. The DDS consists of the following 12 nutritional food groups: cereals, roots and tubers, pulses and nuts, vegetables, fruit, meat, eggs, fish and seafood, milk and dairy products, oil and fats, condiments, and sugar. DDS uses the same food items consumed over the same time span as the FCS (Swindale and Bilinsky 2006).

*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 measures are postulated to be positively linked to our measures of dietary diversity and two of them have been previously used (Jones, Shrinivas, and Bezner-Kerr, 2014). The first measure of farm production diversity simply sums the number of different products from the household farm. That sum takes into account only crops which have been harvested at the time the household was interviewed. Our argument for not counting additional potentially harvestable products is that we cannot be certain that those crops will eventually be consumed or sold for reasons including the ability of the farmer to harvest the crops due to health concerns and the threats of insects, rodents, 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 part of crop *j* in the total area cultivated by the household *i*. Then is the area of the crop *j* used by household *i*, is the total cropped area cultivated by the household *i*. 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. Values approaching zero indicate that a household has an unequal distribution of crops, while a value approaching one reflects an equal crop distribution across cultivated area. 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 intercropping, each crop was taken separately. Given that there is no information on the proportion of an intercropped crop on a plot, we assume that each crop encompasses the entire plot. The two seasons, dry and rainy, were taken in consideration for the Simpson’s index as for the other variables. Both seasons correspond to different varieties and amount of production, consider them together reduce possible errors.

The third production indicator has not previously been used in the literature. It is designed to reflect the effects of farm production diversity on the number of nutritional food groups grown by a household. In an analogous relationship to that between the FVS and DDS measures, 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 consumption diversity. The same nutritional matching and groups are considered as in the DDS and as a result a score is calculated between 0 to 12 inclusive. This new indicator is easy to calculate and could provide policy makers with an additional indicator of health. This variable seems important especially for households consuming their own production and we expect that a production of various nutritional food group should improve the diet quality. A separate exogenous variable indicating whether households raise animals such as chickens or cattle was included in the regressions to test their effect on household consumption diversity.

*Variables description*

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.

*Household characteristics*

Household characteristics clearly have significant effects on the diversity of food consumption. For instance, the number of household members 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), and; 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, Bjørnstad, and Smale (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 age of the household head has also been hypothesized to be positively correlated with dietary diversity because it is seen as a proxy for experience. However, while Abay et al. (2009) found a positive relationship between age and diversity, Jones et al. (2014) found a negative correlation. The argument behind the relationship between age and diversity is not entirely clear. The underlying assumption which we make is that heads of households desire to increase dietary diversity because they assume that it increases health, greater age, which is a proxy for experience, allows better, healthier production decisions to be made. Similarly, the education level of the household head and person primarily responsible for food preparation is presumed to be positively related to the dietary diversity of the household and their caloric intake. A better education level should influence the knowledge about the importance of a good diet. Positive influence of this parameter have been stressed by Benin et al. (2004) and Jones et al. (2014).

*Economics characteristics*

Clearly, the economic characteristics of a household affect food consumption diversity. Total income is an important indicator of the general economic well-being of households, consequently a positive relationship is expected between consumption diversity and total income. A high level of income may permit to the purchase of more food and food of higher nutritional quality. The econometric techniques used will allow us to distinguish between the effects of income on household net of the effects of, for example, household size. In a separate model, we examine the importance of sources of household income on diversity by categorizing income along the following lines: agricultural income, non-agricultural income, property income, investments and transfers. Agricultural and non-agricultural income are expected to be positively related to diversity because they are the main sources of income for the households in our sample. In regards 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. 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 money values have been deflated by taking 2010 as index.

*Agricultural characteristics*

With 66% of the Ugandan population employed in the agricultural sector in 2009 (Boysen, Jensen, and Matthews 2014), agricultural characteristics are an essential component of Ugandan households. The number of household members who have worked in sector other than agriculture is hypothesized to be positively related to dietary diversity because of its positive influence on income. Such jobs are could represent a significant source of income for households and make them economically more independent of the agricultural sector. In addition, the proportion of food items consumed from a household’s own farm production is expected to be positively correlated with dietary diversity of consumption. We hypothesize that a family with a farm has potentially greater access to a diversity of food items not otherwise available through the market or elsewhere. . Whether the head of the household primarily makes economic farm decisions was evaluated. Jones et al. (2014), argue 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. Finally, we test whether a household’s total crop area has an influence on the income of the family and on own farm production consumption. More land and maybe more plots can encourage and allow households to produce a greater diversity of crops. Accordingly, this variable is presumed to be positively correlated with food diversity and caloric intakes of the household.

*Location*

Finally, the location, in terms of western, eastern, northern or central Uganda, of a household was assumed to be an important determinant of dietary diversity. We argue that being in the central region, where Kampala is located, gives a household greater market access for it products and other products and, in addition, increases access to non-agricultural jobs, both of which imply that a household can potentially increase the diversity of the crops it consumes.

*Data characteristics*

Two data analyses are presented in this paragraph, first household data are described for each of the three waves, and secondly, they are split according to their location to stress differences within the country which might then be used to set assistance priorities.

Table 1 presents the characteristics of households variables previously described disaggregated by wave year. 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. Both dietary diversity scores were greater in the central region while the lowest scores were observed in the northern region for the FCS and western region for the DDS. Households from western region spent less for food and consumed more products from their own farm. 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*

*Table 2: Variables characteristics by region*

Other variables, of the hundreds available, 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.

*Analytical methodology*

As mention in the introduction, we aim to complement and extend the work of Jones et al. (2014) in two ways. First, we use a panel set of data which allows us to measure dynamic effects, and we apply more appropriate econometric techniques given that some of the endogenous variable we test are count measures..

The panel data allows us to utilize econometric techniques which statistically control for potential problems related to omitted static endogenous variables which can bias results when only one year of data is available.

In addition to the classic Ordinary Least Square (OLS) regression technique used by Jones et al. (2014), we run panel Poisson regressions. In particular we estimate a Poisson Generalized Panel Linear Model with fixed effects. The fixed effects model assumes that individual household characteristics are important; an assumption which tests, see below, confirm are significant. Finally, a time-fixed effect model is used because it allows us to control for correlation of individual households through time.

We also incorporates a more complete set of household variables into the model to better account for household characteristics influencing dietary diversity. For example, as mentioned we include variables which measure income from different sources, specifically we include measures of income from agricultural, non-agricultural, property, investments and transfers. . We test the quadratic forms of the income and age of the household head to capture non-linear effects of these variables.

Finally, we test whether there is a relationship between farm production diversity and household caloric intake. This is our key exogenous variable in that it links household production and consumption. If that link is robust after having accounted for the other exogenous variables contained in the regressions, then policy implications follow. Our contention is that some combination of nutrient diversity and caloric intake indices will provide a better indication of health than one or the other index alone. At a minimum, it would be worthwhile reporting both measures.

*Measurement of children anthropometric development*

Finally, data in the LSMS-ISA survey allow us to estimate household child development as a measure of child health. Many studies have tested and established a the link between children dietary diversity and the height for age Z-score (HAZ) (Arimond and Ruel, 2004; Steyn et al., 2006; Rah et al., 2010). We use our exogenous variables to test their effect on the HAZ. Once again, we need to make the assumption that dietary diversity is equal across all members of the household. The World Health Organisation anthropometric children data were used as references (World Health Organization, 2006). Two thousand, nine hundred and thirty-two childhood anthropometric parameters from the Uganda LSMS-ISA surveys were used in the HAZ estimation. Weight for age Z-score (WAZ) and weight for height Z-score (WHZ) were estimated using the same method for 2929 and 2964 children respectively.

1. **Results and discussion**

*Table 3: Comparison of different regression methods*

*Technique regression comparison.*

Panel regression results are reported in Table 3. Each of the dependent variables, the Food Consumption Score (FCS), the Dietary Diversity Score (DDS), and Calories are discussed in order of their appearance in the table. For each of these dependent variables panel Ordinary Least Squares (OLS) and within transformed (PLM) regressions were calculated. 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.

Estimated coefficients for the OLS estimator for the FCS model are deceptively encouraging in the sense that nearly all are statistically significant and have the expected, hypothesized, signs as was argued in the variable description section of the paper. The estimates for household characteristics are discussed first followed by estimates for economic characteristics, agricultural and regional characteristics.

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).

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.

In general, the OLS estimates should read with caution to the extent that correlation is present between households and across time. The assumption of the OLS panel model is that this correlation is not affecting estimates and that there are no significant static missing variables. However, the null hypothesis of a common intercept is soundly rejected for both the FCS and Calories models implying that OLS is inappropriate in essence because there are significant differences between households. In addition, the within transformation removes the effects of both observed and unobserved static variables. Time dummies were added to the model in order to capture significant events not captured by the explanatory variables. Finally, a Hausman test rejected the random effects model in favour of the within model (results does not show).

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

A comparison of the results for the OLS and the within panel models for the FCS dependent variable indicates similar coefficients for the variables the number of different crops produced by the household, food expenditures, total crop area and the proportion of food consumed from own production. The signs of the coefficients are identical and their magnitudes similar. Results for the DDS model also show that the coefficient for the number of different crops produced by the household and food expenditures are positive and significant, but coefficients for total crop area and the proportion of food consumed from own production are no longer significant. However, as previously noted, DDS is a count measure so using a continuous measure is not recommended. Before discussing the panel Poisson model for DDS, panel results for the Calories model will be presented. The same four variables are significant in both the FCS and Calories models. Unsurprisingly, the magnitudes of the coefficients are different given the difference in scales of the two dependent variables. In addition, household size is positive and significant, as is the education of the household head. The age of the head of household negatively affects caloric intake, but is only just significant. In short, the results of the Caloric model correspond closely with the FCS measure, and the signs of most of the coefficients conform to hypotheses. 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.

*Regressions with different production count variables*

*Table 4: Time-effect regression results with different production count variables*

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.

*Subdivided income and non-linear variables*

*Table 5: Time-effect regression results with subdivided income*

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.

*Child growth*

The children development indicators have a mean under the anthropometric children references database but they stay at a reasonable level. According to the WHO, the normal standard deviation window is [-2 ; +2]. Respectively for HAZ, WAZ and WHZ the results are -1.58, -1.02 and -0.39. But extremes case of undernourishment are present when we look at the minimum HAZ, WAH and WHZ. The same problem is observed on the other side with unusual maximum Z-scores. According to the Uganda Bureau of Statistics (2012) 13.8% of children under five years old were still underweighted in 2011. Still work have to be done for the purpose of eradicate children anthropometric deficiencies which pass through healthy diet.

1. **Conclusion and policies reflexions**

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

**References**

Abay, Fetien, Asmund Bjørnstad, and Melinda Smale. 2009. “Measuring on Farm Diversity and Determinants of Barley Diversity in Tigray, Northern Ethiopia.” *Momona Ethiopian Journal of Science* 1 (2). http://www.ajol.info/index.php/mejs/article/view/46048.

Arimond, Mary, and Marie T. Ruel. 2004. “Dietary Diversity Is Associated with Child Nutritional Status: Evidence from 11 Demographic and Health Surveys.” *The Journal of Nutrition* 134 (10): 2579–85.

Benin, S., M. Smale, J. Pender, B. Gebremedhin, and S. Ehui. 2004. “The Economic Determinants of Cereal Crop Diversity on Farms in the Ethiopian Highlands.” *Agricultural Economics*, Current Issues in the Economics of Agriculture, Food, and Resources: Reshaping Agriculture’s Contributions to Society, 31 (2–3): 197–208. doi:10.1016/j.agecon.2004.09.007.

Boysen, Ole, Hans Grinsted Jensen, and Alan Matthews. 2014. “Impact of EU Agricultural Policy on Developing Countries: A Uganda Case Study.” IIIS. https://www.gtap.agecon.purdue.edu/resources/download/7200.pdf.

Carletto, Calogero, Alberto Zezza, and Raka Banerjee. 2013. “Towards Better Measurement of Household Food Security: Harmonizing Indicators and the Role of Household Surveys.” *Global Food Security* 2 (1): 30–40. doi:10.1016/j.gfs.2012.11.006.

Greene, William H. 2012. Econometric Analysis, Seventh Edition. International Edition. Pearson Education Limited.

Hatluy, A., L. E. Torheim, and A. Oshaug. 1998. “Food Variety - a Good Indicator of Nutritional Adequacy of the Diet? A Case Study from an Urban Area in Mali, West Africa.” *European Journal of Clinical Nutrition* 52: 891–98.

Headey, Derek, and Olivier Ecker. 2013. “Rethinking the Measurement of Food Security: From First Principles to Best Practice.” *Food Security* 5 (3): 327–43. doi:10.1007/s12571-013-0253-0.

Jones, Andrew D., Aditya Shrinivas, and Rachel Bezner-Kerr. 2014. “Farm Production Diversity Is Associated with Greater Household Dietary Diversity in Malawi: Findings from Nationally Representative Data.” *Food Policy* 46: 1–12. doi:10.1016/j.foodpol.2014.02.001.

Kennedy, Gina L., Maria Regina Pedro, Chiara Seghieri, Guy Nantel, and Inge Brouwer. 2007. “Dietary Diversity Score Is a Useful Indicator of Micronutrient Intake in Non-Breast-Feeding Filipino Children.” *The Journal of Nutrition* 137 (2): 472–77.

Pitt, Mark M., Mark R. Rosenzweig, and Md. Nazmul Hassan. 1990. “Productivity, Health, and Inequality in the Intrahousehold Distribution of Food in Low-Income Countries.” *The American Economic Review* 80 (5): 1139–56.

Rah, J. H., N. Akhter, R. D. Semba, S. de Pee, M. W. Bloem, A. A. Campbell, R. Moench-Pfanner, K. Sun, J. Badham, and K. Kraemer. 2010. “Low Dietary Diversity Is a Predictor of Child Stunting in Rural Bangladesh.” *European Journal of Clinical Nutrition* 64 (12): 1393–98. doi:10.1038/ejcn.2010.171.

Simpson, E. H. 1949. “Measurement of Diversity” 163: 688. doi:10.1038/163688a0.

Steyn, Np, Jh Nel, G Nantel, G Kennedy, and D Labadarios. 2006. “Food Variety and Dietary Diversity Scores in Children: Are They Good Indicators of Dietary Adequacy?” *Public Health Nutrition* 9 (05): 644–50. doi:10.1079/PHN2005912.

Swindale, Anne, and Paula Bilinsky. 2006. “Household Dietary Diversity Score (HDDS) for Measurement of Household Food Access: Indicator Guide.” *Washington, DC: Food and Nutrition Technical Assistance Project, Academy for Educational Development*.

The Uganda Bureau of Statistics. 2015. “The Uganda National Panel Survey (UNPS) 2011/12.” Accessed March 23. http://siteresources.worldbank.org/INTLSMS/Resources/3358986-1233781970982/5800988-1265043582346/UNPS\_2009\_10\_BID\_rev\_2014.pdf.

Thorne-Lyman, Andrew L., Natalie Valpiani, Kai Sun, Richard D. Semba, Christine L. Klotz, Klaus Kraemer, Nasima Akhter, et al. 2010. “Household Dietary Diversity and Food Expenditures Are Closely Linked in Rural Bangladesh, Increasing the Risk of Malnutrition Due to the Financial Crisis.” *The Journal of Nutrition* 140 (1): 182S – 188S. doi:10.3945/jn.109.110809.

Torheim, L. E., F. Ouattara, M. M. Diarra, F. D. Thiam, I. Barikmo, A. Hatløy, and A. Oshaug. 2004. “Nutrient Adequacy and Dietary Diversity in Rural Mali: Association and Determinants.” *European Journal of Clinical Nutrition* 58 (4): 594–604. doi:10.1038/sj.ejcn.1601853.

Verbeek, Marno, 2012. A Guide to Modern Econometrics, Fourth Edition. John Wiley & Sons Ltd.

Weiss, Christoph R., and Wolfgang Briglauer. 2000. “Determinants and Dynamics of Farm Diversification.” FE Working Paper 0002. Christian-Albrechts-University of Kiel, Department of Food Economics and Consumption Studies. http://econpapers.repec.org/paper/zbwcaufew/0002.htm.

1. “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.” (FAO, 1996). [↑](#footnote-ref-1)