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Farm production diversity and dietary quality: Linkages and measurement issues

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Abstract

Recent research has analyzed whether higher levels of farm production diversity contribute to improved dietary quality in smallholder households. We add to this literature by using different indicators, thus testing the robustness of previous findings and helping to better understand the underlying linkages. The analysis builds on data from Indonesia, Kenya, and Uganda. Farm diversity measured through a simple species count has a small positive effect on dietary quality, either expressed in terms of dietary diversity scores or micronutrient consumption levels. However, when measuring production diversity in terms of the number of food groups produced, the effect turns insignificant in most cases. Further analysis suggests that diverse subsistence production contributes less to dietary quality than cash income generated through market sales. Much of the food diversity consumed in farm households is purchased from the market. If farm diversification responds to market incentives and builds on comparative advantage, it can contribute to improved income and nutrition. This may also involve cash crop production. On the other hand, increasing the number of food groups produced on the farm independent of market incentives will foster subsistence, reduce cash incomes, and thus rather worsen dietary quality. We conclude that from a nutrition perspective improving market access is more important than farm diversification as such.

***Key words**: dietary diversity; micronutrients; nutrition-sensitive agriculture; smallholder farm households; developing countries*

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1. Introduction

Agricultural modernization over the last few decades has primarily focused on a few crop species, especially cereals. The resulting production increases have contributed considerably to reducing hunger and improving peoples' access to calorie-dense staple foods (Pingali, 2015; Khoury et al., 2014; Godfray et al., 2010). However, in addition to calories, healthy nutrition requires access to a wide range of nutrients. Micronutrient deficiencies in particular are still widespread, causing multiple serious health problems and significant economic and humanitarian costs (IFPRI, 2015; Horton and Steckel, 2013). To improve nutrition more broadly, stronger emphasis needs to be on promoting dietary quality and diversity.

Many of those people globally affected by nutritional deficiencies live in smallholder farm households in developing countries (Barrett, 2010; Muller, 2009). These households largely depend on agriculture for their livelihoods. Against this background, the question how to make smallholder agriculture more nutrition-sensitive has recently gained significant interest among researchers and policymakers (Pinstrup-Andersen, 2013, Keding et al., 2012; Remans et al., 2011). Often, the promotion of production diversity on smallholder farms is seen as a promising strategy (Powell et al., 2015; Fanzo et al., 2013; Burlingame and Dernini, 2012). As small farm households typically consume a substantial share of what they produce, production diversity could directly translate into consumption diversity and thus improved dietary quality through this subsistence pathway. Several recent studies have empirically analyzed the relationship between farm production and dietary diversity (Sibhatu et al., 2015; Snapp and Fisher, 2015; Jones et al., 2014; Pellegrini and Tasciotti, 2014). Most of these studies suggest that farm production diversity has a positive influence on people's diets, although the magnitude of the estimated effect varies. Sibhatu et al. (2015) used data from various countries and showed that the production diversity effect tends to be small in general, and sometimes insignificant. Results from Sibhatu et al. (2015) and Snapp and Fisher (2015) also suggest that access to markets may be more important for nutrition than increasing farm production diversity. However, various questions remain, especially concerning the indicators used to measure production diversity and nutritional quality. The choice of indicators may possibly affect the relationship in important ways (Luckett et al., 2015; Berti, 2015).

In order to design policies towards more nutrition-sensitive agriculture, it is important to better understand the role of production diversity for farm household nutrition. Should further diversification of smallholder production systems be promoted, and – if so – what kind of diversification? Here, we contribute to this research direction by using data from different countries and comparing alternative indicators.

On the consumption side, previous studies used the household dietary diversity score (HDDS) or related measures as indicators of dietary quality (Sibhatu et al., 2015; Snapp and Fisher, 2015; Jones et al., 2014). HDDS counts the number of different food groups consumed by the household over a certain period of time. This food group count is generally accepted as a good and easy-to-measure proxy for dietary quality, as it was found to be correlated with various nutrition outcomes in many situations (Headey and Ecker, 2013; Ruel, 2003). However, eventually it is not the number of food groups that matters for healthy nutrition, but the supply of all essential nutrients in sufficient quantities. Hence, in addition to using the HDDS, we also examine how production diversity contributes to consumption levels of various important micronutrients.

On the production side, previous studies used a simple count of all crop and livestock species produced on a farm as the main indicator of production diversity (Sibhatu et al., 2015; Snapp and Fisher, 2015; Jones et al., 2014). However, different species have different nutritional functions, so that the type of farm diversification can matter for effects on household diets (Berti, 2015; Remans et al., 2014; De Clerck et al., 2011). For instance, the dietary quality effect of growing sorghum in addition to maize may be smaller than that of adding a pulse or vegetable crop to a cereal-dominated production system. Hence, in addition to using a simple species count, we also employ an indicator that explicitly considers the nutritional functions of the different commodities produced on a farm. Comparison of results across the different indicators also helps to shed more light on the mechanisms underlying the production and dietary quality link.

The empirical research builds on survey data from Indonesia, Kenya, and Uganda. The data from all three countries were collected in specific regions and are not nationally representative. Nevertheless, the farming and socioeconomic conditions captured in the overall sample vary widely, so that the analysis may offer some broader insights that also hold beyond a particular context. For the comparisons it is advantageous that the relevant data on farm production and household food consumption in all three countries were collected using the same survey format. This also allows us to pool the data for some of the analyses, in addition to looking at each country subsample separately.

2. Materials and methods

The main research objective pursued in this study is to better understand the relationship between production diversity and dietary quality in smallholder farm households and the underlying mechanisms. We use different indicators of production diversity and dietary quality that are described in the following, before introducing the statistical approaches and the surveys carried out in Indonesia, Kenya, and Uganda.

2.1. Indicators of dietary quality

Simple indicators such as household dietary diversity scores (HDDS) are frequently used to measure dietary quality from survey data. HDDS is a categorical measure of the number of different food groups consumed by the household during a specified period of time, like the last

24 hours or the last seven days prior to the survey interviews. Data for calculating HDDS are relatively easy to collect, because no quantity measures of the different food items consumed are required. HDDS are generally considered a useful proxy for dietary quality (Maxwell et al., 2014; Ruel, 2003). The larger the number of different food groups consumed, the more likely it is that household members are supplied with all the nutrients needed for healthy nutrition. HDDS can also be used as an indicator of food security from a calorie perspective (Headey and Ecker, 2013). Poor households usually try to satisfy their calorie needs with cheaper staple foods before diversifying their diets towards higher-value products. Hence, higher levels of dietary diversity indicate that a household is likely already better supplied with calories.

While there is no international standard on how many food groups to include in the calculation of the HDDS, many studies use 12 different groups (FAO, 2011). We follow this approach and use the following 12 food groups for the calculation of HDDS in this study: cereals; white tubers and roots; legumes, legume products, nuts, and seeds; vegetables and vegetable products; fruits; meat; eggs; fish and fish products; milk and milk products; sweets, sugars, and syrups; oils and fats; and spices, condiments, and beverages.

However, in spite of their usefulness for a first general assessment of dietary quality, HDDS also have a few drawbacks (Hirvonen et al., 2015; Maxwell et al., 2014; Coates, 2013). In particular, not all food groups considered contribute to the supply of essential nutrients in the same way. Moreover, food groups are counted regardless of the actual quantities consumed; very small quantities of certain foods may not add much to healthy nutrition. To address these shortcomings, more comprehensive data about the food quantities and nutrients consumed are required (de Haen et al., 2011). We use detailed food consumption recall data collected during the surveys to calculate the daily quantities of calories and various micronutrients consumed by the household (see below for details). To make the values comparable across households of different size, these quantities are expressed per adult equivalent (AE). In terms of micronutrients, we particularly concentrate on iron, zinc, and vitamin A. Deficiencies in these three micronutrients are responsible for the most important nutritional disorders in large parts of the developing world (Barrett and Bevis, 2015; IFPRI, 2015). Recent studies have used calorie and micronutrient consumption levels to assess nutritional impacts of innovations in African food supply chains (Chiputwa and Qaim, 2016; Chege et al., 2015). We are not aware of any previous research that has used such quantity-based indicators to analyze dietary effects of farm production diversity.

2.2. Indicators of production diversity

A common indicator of production diversity on a farm is a simple count of the different species produced (Sibhatu et al., 2015). This indicator is taken from the agro-biodiversity literature. Sometimes the area under a crop is used for weighting purposes, although a common weighting scheme is more difficult when livestock production is also involved. We use an unweighted count of all crop and livestock species produced on a farm as one measure of production diversity. However, different species have different nutritional functions, which is important to consider when analyzing the production-consumption diversity link. When non-food cash crops are grown, the nutritional value is zero regardless of the number of different species produced. But also when food crops are grown, increasing the number of species within the same food group (e.g., different types of cereals) may have smaller nutritional benefits than when species of a different food group are added to the production portfolio (e.g., adding pulses, vegetables, or fruits). The reason is that products within the same food group tend to provide a similar range of nutrients.

A recent body of literature has developed new diversity scores trying to account for the nutritional functions of different types of food crops produced (Luckett et al., 2015, Remans et al., 2014; DeClerck et al., 2011). The nutritional functional diversity score proposed by Luckett et al. (2015) counts a farm species only as additional when its nutritional profile is sufficiently different from the other species that were already counted on the same farm. Otherwise, the species is considered nutritionally redundant. While this approach has some intuitive appeal, it also has its problems, as judging on the similarity in the nutritional profile always involves some degree of subjectivity. For instance, it depends on the range of different nutrients considered. Even if all common nutrients are taken into account, differences in other nutritionally valuable substances – such as fiber or secondary metabolites – may complicate the concept of nutritional redundancy.

While further work into this interesting line of research is required, we decided to use a simpler and more transparent approach to account for differences in nutritional functions between the species produced on a farm. In particular, we calculate what we call the production diversity score as an alternative measure to the simple species count. The production diversity score builds on the same 12 food groups used for calculating HDDS on the consumption side (see above), hence it is an indicator of the number of different food groups produced on a farm. That is, different species produced on the farm count as one when they all belong to the same food group (e.g., maize, wheat, and sorghum all belong to the group of cereals). On the other hand, one and the same species can count as two when it delivers products that belong to different food groups (e.g., chicken that deliver eggs and meat).

2.3. Analytical framework

We want to estimate the effect of farm production diversity on household dietary quality by estimating regression models of the following general form:

$$D_i = \beta_0 + \beta_1 P_i + \beta_2 X_i + \varepsilon_i$$

where D_i is a measure of dietary quality, P_i is a measure of production diversity, and X_i is a vector of other covariates that may influence dietary quality, all referring to farm household i. Variables included in vector X_i include farm characteristics such as land area, market access, and sociodemographic characteristics such as household size, age, gender, and education. β_0, β_1, and β_2 are coefficients to be estimated, and ε_i is a random error term.

We estimate different specifications of this model, using the various indicators of dietary quality and production diversity that were introduced above. A comparison of the estimates of β_1 across the specifications helps to test how sensitive the results are to issues of measurement. Comparing the coefficients for the two production diversity indicators can also provide insights into the potential mechanisms underlying the relationship in different situations. For instance, in subsistence settings the coefficient of the production diversity score is expected to be larger than that of the simple species count, because the number of food groups produced will translate more directly into the number of food groups consumed. However, in more market-oriented settings the comparison is less clear and may even be reversed: households that try to produce many of the food groups consumed themselves may forego cash income gains from focusing on those species for which they have a comparative advantage in the market.

2.4. Data sources

We use data from surveys of smallholder farm households in Indonesia, Kenya, and Uganda. All three surveys were conducted in 2012 and used structured questionnaires with the same format for the production and consumption related aspects of relevance in this study. In all three countries, the surveys are not nationally representative but focus on specific regions in which smallholders produce food and cash crops to varying degrees. Within the selected regions, a multistage sampling procedure was used, with random selection of individual farm households at the last stage.

In Indonesia, we surveyed 672 farm households in Jambi Province on Sumatra Island. Farmers in Jambi are often specialized on plantation cash crops, notably rubber and oil palm (Euler et al., 2015). Some of the sample farmers do not grow any food, others have small plots with maize, rice, and horticultural crops, sometimes supplemented with livestock and aquaculture production. In Kenya, the sample comprises 395 farm households from Kiambu County, an important vegetable-growing area in Central Kenya (Chege et al., 2015). Sample farms grow different types of green leafy vegetables (e.g., kale, spinach, black nightshade) in addition to other food crops such as maize and banana and non-food cash crops such as coffee and tea. Some of the farmers are also involved in small-scale livestock production. The data from Uganda were collected in Luwero and Masaka, two districts in the Central Region where a lot of coffee is grown (Chiputwa et al., 2015). The sample comprises 417 farm households that grow coffee in addition to food crops such as plantains, cassava, sweet potatoes, different types of cereals, and legumes such as beans and groundnuts. Some fodder crops are grown as well for the households' small-scale livestock enterprises.

In all three surveys, a wide range of socioeconomic data was captured, including details of agricultural production and food consumption at the household level. To capture dietary patterns we used a 7-day consumption recall, involving quantity data for a large number of food items from own production, market purchases, or any other source. Calculation of calorie and micronutrient consumption levels are based on local and international food composition tables (SMILING, 2013; FAO, 2010; USDA, 2005). In the surveys, we also collected detailed data on agricultural market sales and on total household income, including from farm and off-farm income sources. Consumption and income data are expressed per AE to facilitate comparisons.

Cash values were converted from local currencies to US dollars using official exchange rates at the time of the surveys.

3. Results and discussion

3.1. Descriptive statistics

Table 1 shows descriptive statistics of the variables used in this study. The average farm household in the pooled sample, comprising observations from all three countries, cultivates an area of 6.8 acres. Yet, there is considerable heterogeneity in the area cultivated across countries and also within countries. The largest average farm size is observed in Indonesia (11.1 acres), the smallest in Kenya (2.2 acres). Sample farmers in Indonesia primarily grow non-food cash crops such as rubber and oil palm, on average only 6% of the farm area is cultivated with food crops. In contrast, 74% of the area of Kenyan sample farms is cultivated with food crops. This does not imply that farms in the Kenyan sample are primarily subsistence-oriented. Vegetables, which we count under food crops, are largely grown for commercial purposes in Kiambu County, as is also reflected in sizeable cash revenues for Kenyan farm households. Sample farms in Uganda are much more subsistence-oriented. Apart from coffee as their main source of agricultural cash revenues, Ugandan farm households produce food and feed crops primarily for domestic use.

Table 1. Descriptive statistics

Variables	Pooled	Indonesia	Kenya	Uganda
Farm characteristics				
Cultivated land area (acres)	6.83	11.14	2.16	4.30
	(13.17)	(18.35)	(2.93)	(3.06)
Share of land under food crops (%)	35.94	5.99	74.12	48.04
	(37.55)	(19.71)	(30.14)	(23.67)
Agricultural cash revenues per year (US$/AE)	1468.22	2537.74	1017.06	172.03
	(3819.48)	(5208.99)	(2166.42)	(264.82)
Species count on farm (crop + livestock)	5.16	1.73	7.83	7.99
	(3.53)	(0.91)	(2.59)	(2.01)
Production diversity score (12 food groups)	2.91	0.46	4.36	5.52
	(2.60)	(1.15)	(1.62)	(1.00)
Dietary quality characteristics				
Household dietary diversity score (HDDS)	10.19	10.01	11.39	9.33
	(1.53)	(1.29)	(0.97)	(1.63)
Calorie consumption per day (kcal/AE)	3148.72	3124.08	3297.86	3047.28
	(1373.36)	(1475.34)	(1171.24)	(1371.08)
Iron consumption per day (mg/AE)	19.64	19.61	16.86	22.33
	(11.04)	(12.29)	(7.41)	(11.14)
Zinc consumption per day (mg/AE)	13.94	11.07	21.20	11.69
	(7.84)	(5.52)	(8.10)	(6.29)
Vitamin A consumption per day (µg RE/AE)	1227.55	1127.00	1389.73	1236.46
	(1358.68)	(1633.52)	(965.51)	(1161.25)
Other household characteristics				
Total household income per year (US$/AE)	3384.42	3460.11	2286.00	4302.89
	(77140)	(6789.35)	(3542.06)	(9670.22)
Distance to market (km)	4.85	6.56	3.11	3.74
	(6.02)	(7.41)	(3.59)	(4.42)
Household size (number of members)	4.93	4.20	4.67	6.60
	(2.40)	(1.52)	(1.71)	(3.20)
Age of household head (years)	49.32	45.72	52.05	52.54
	(13.59)	(12.18)	(13.65)	(14.29)
Education level of household head (years)	7.81	7.50	9.63	6.57
	(3.82)	(3.63)	(3.71)	(3.63)
Male household head (dummy)	0.88	0.95	0.88	0.76
Number of observations	1484	672	395	417

Notes: Mean values are shown with standard deviations in parentheses. AE stands for adult equivalent. RE stands for retinol equivalent.

In terms of production diversity, farmers in Kenya and Uganda have a much larger species count than their colleagues in Indonesia. Interestingly, farm households in Uganda produce the largest number of species and food groups, but they are performing worst in terms of dietary diversity and calorie consumption. This is a first indication that production diversity is not necessarily a good predictor of consumption diversity and dietary quality. This relationship is analyzed further in the following.

3.2. Production diversity and dietary quality

We now use the regression models described above to analyze the relationship between production diversity and dietary quality more formally. As explained, we employ different indicators of dietary quality as dependent variable and of production diversity as explanatory variable. The results are summarized in Table 2. In this summary table, we only show the estimates for production diversity, as this is the explanatory variable of primary interest. Full results of the different models with other covariates included are shown in Tables A1 to A8 in the Appendix.

We estimated models for the individual countries, as well as pooled models with all observations combined. The pooled data models include country dummies to account for country fixed effects, in addition to the other explanatory variables. In column (1) of Table 2, we use the household dietary diversity score (HDDS) as dependent variable. Since this is a count variable, the underlying models were estimated with a Poisson estimator. In Poisson models, the estimated coefficients can be interpreted as semi-elasticities. In columns (2) to (5), with calorie and micronutrient consumption levels as dependent variables, the models were estimated with ordinary least squares (OLS), hence the estimates can be interpreted as marginal effects. All models were estimated with robust standard errors to account for heteroscedasticity.

In the upper part of Table 2, we use the simple species count as the indicator of production diversity. The positive and significant coefficients in column (1) suggest that household dietary diversity increases with the number of different species produced on the farm. Yet the effect is relatively small. After controlling for other factors, producing one additional crop or livestock species increases the number of food groups consumed by only 1% in the pooled sample. In other words, diverse and balanced diets would require extremely diverse production patterns when relying on own farm production alone. The individual country models reveal that the magnitude of the estimates varies. But even the effect of 2.1% in Uganda is relatively small.

Small positive effects of production diversity on dietary diversity are consistent with findings by Sibhatu et al. (2015).

Table 2. Effect of farm production diversity on dietary quality

	(1) HDDS	(2) Calories (kcal/AE)	(3) Iron (mg/AE)	(4) Zinc (mg/AE)	(5) Vitamin A (µg/AE)
Species count (crop + livestock)					
Pooled	0.010***	67.499***	0.506***	0.251**	30.965
	(0.002)	(19.095)	(0.142)	(0.101)	(19.517)
Indonesia	0.015***	300.402***	2.499***	1.006***	204.475**
	(0.005)	(66.202)	(0.546)	(0.249)	(84.544)
Kenya	0.004**	-2.972	0.028	0.046	-31.527
	(0.002)	(25.358)	(0.165)	(0.173)	(21.179)
Uganda	0.021***	83.035**	0.470*	0.301**	35.618
	(0.004)	(33.648)	(0.255)	(0.152)	(30.738)
Production diversity score (food groups)					
Pooled	0.008***	30.382	0.140	0.157	-31.662
	(0.003)	(28.238)	(0.212)	(0.145)	(23.545)
Indonesia	0.002	12.793	0.088	-0.019	-33.383
	(0.005)	(48.037)	(0.410)	(0.179)	(40.762)
Kenya	0.004	37.246	0.088	0.308	-69.592**
	(0.003)	(46.244)	(0.297)	(0.294)	(33.458)
Uganda	0.033***	108.229	0.835	0.599*	49.277
	(0.009)	(70.622)	(0.547)	(0.321)	(55.715)

Notes: The coefficient estimates are based on regression models as shown in Tables A1 to A8 in the Appendix. Robust standard errors are given in parentheses. Coefficients in column (1) were estimated with Poisson models. Coefficients in columns (2) to (5) were estimated with OLS models. *, **, *** denote significance at the 10%, 5%, and 1% level, respectively. HDDS stands for household dietary diversity score. AE stands for adult equivalent.

In columns (2) to (5) of the upper part of Table 2, where we use different indicators of dietary quality as dependent variables, we also see predominantly positive effects. Many of these effects are statistically significant. We infer that the number of species produced on the farm also contributes to higher calorie and micronutrient consumption. For instance, the pooled model results suggest that one additional crop or livestock species produced increases daily calorie consumption per AE by 67.6 kcal, iron consumption by 0.51 mg, and zinc consumption by 0.25 mg. Comparing with sample mean consumption levels, these estimated marginal effects correspond to changes of less than 3%, again with some differences observed between countries. With the exception of Indonesia, the effects of species diversity on vitamin A consumption are not statistically significant.

We conclude that – even though effects are relatively small – farm species diversity can contribute to dietary quality, measured either in terms of HDDS or calorie and micronutrient consumption levels. But the underlying mechanisms are still unclear. The lower part of Table 2, where we measure farm diversity in terms of production diversity scores helps to gain further insights. As explained, instead of a simple species count, production diversity scores count the number of different food groups produced. That is, the production of non-food crops or of several food crops within the same food group does not influence this measure. If subsistence production is an important source of food in the household, we would expect a strong association between the numbers of food groups produced and consumed. In that case, switching from the simple species count to production diversity scores should lead to larger coefficient estimates. However, the results in Table 2 indicate that the opposite is true. In most cases, the effects in the lower part Table 2 are smaller than those in the upper part. Many of the estimates also turn insignificant, especially when looking at dietary quality in terms of calorie and micronutrient consumption. These results suggest that the subsistence pathway is not of major importance.

A more likely mechanism to explain the positive association between production diversity and dietary quality is the cash income pathway. Farm diversification may add to cash incomes, when farmers respond to market price incentives. Rather than trying to maximize the number of food groups produced it is economically more rational to diversify following the principles of comparative advantage. This may include diversifying into non-food cash crops. A case in point is Indonesia, where many farmers could increase their cash incomes by adding oil palm to their production portfolio (Krishna et al., 2015). Among other things, the higher cash income is used to improve dietary quality through the purchase of more diverse and nutritious foods from the market. Adding additional food groups to the production portfolio instead would not have the same nutritional effect, which is why the significantly positive effects in the upper part of Table

2 turn insignificant in the lower part. One exception is Uganda, where the role of subsistence is still more pronounced and cash revenues are relatively small.

The important role of markets and cash incomes for household dietary quality is also underlined by some of the other covariates included in the different models, which are shown in Tables A1 to A8 in the Appendix. Market distance has a negative effect on dietary diversity and nutrient consumption in most of the models. Interestingly, the share of land under food crops also has negative effects in some cases. In other words, cash crop production and market sales are sometimes more important for household nutrition than food crop production. On the other hand, total farm size and educational levels contribute to higher dietary quality, as one would expect.

3.3. Role of agricultural cash revenues

The above analysis suggests that cash incomes may play a more important role for farm household dietary quality than diverse subsistence production. This is now analyzed further by regressing the different dietary quality indicators on agricultural cash revenues. Cash revenues are endogenous, so the estimation results should not be interpreted as causal. We are primarily interested in the association, which is also why we do not control for other factors in these models. Several other factors are correlated with cash revenues, so their inclusion would make interpretation of the association less straightforward. Results are shown in Table 3. Agricultural cash revenues are positively associated with all dietary quality indicators, and most of these associations are statistically significant. The magnitude of the coefficients may seem small, but this is due to the fact that cash revenues are expressed in US dollars per year. Scaling this variable changes the picture. For instance, in the pooled model 1000 dollars of additional cash revenues per year would be associated with 3-6% higher calorie and micronutrient consumption. These results support our hypothesis that market transactions and cash revenues matter for household dietary quality.

Table 3. Association between agricultural cash revenues and dietary quality

	(1) HDDS	(2) Calories (kcal/AE)	(3) Iron (mg/AE)	(4) Zinc (mg/AE)	(5) Vitamin A (µg/AE)
Pooled	3.8E-06***	0.093***	0.001***	3.4E-04***	0.070***
	(5.5E-07)	(0.021)	(1.5E-04)	(8.7E-05)	(0.016)
Indonesia	3.7E-06***	0.095***	0.001***	3.4E-04***	0.074***
	(5.8E-07)	(0.022)	(1.6E-04)	(9.4E-05)	(0.017)
Kenya	3.6E-06**	0.052***	2.6E-04**	2.7E-04	0.035
	(1.4E-06)	(0.016)	(1.2E-04)	(1.6E-04)	(0.024)
Uganda	3.5E-05	1.072***	0.005***	0.004***	0.144
	(2.5E-05)	(0.240)	(0.002)	(0.001)	(0.194)

Notes: The coefficient estimates are based on regression models as shown in Table A9 in the Appendix. Robust standard errors are given in parentheses. Coefficients in column (1) were estimated with Poisson models. Coefficients in columns (2) to (5) were estimated with OLS models. *, **, *** denote significance at the 10%, 5%, and 1% level, respectively. HDDS stands for household dietary diversity score. AE stands for adult equivalent.

Farm diversification and increasing cash revenues are not necessarily contradictory strategies. As discussed above, it much depends on whether or not diversification is a response to market incentives. In Table 4, we correlate the two different production diversity indicators with agricultural cash revenues and total household incomes. In the pooled sample, the species count and the production diversity score are both uncorrelated with total household income, but negatively correlated with agricultural cash revenues. This suggests that diverse production systems are typically associated with lower market sales and higher subsistence orientation. However, the subsample from Kenya with positive correlation coefficients indicates that this is not always the case. Farmers in Kenya have diversified into different horticultural crops, which are in high demand in the market and therefore help to increase market sales and household incomes.

Table 4. Correlation between production diversity, agricultural cash revenues, and household income

	Pooled	Indonesia	Kenya	Uganda
Species count (crop + livestock)				
Agricultural cash revenues (US$/AE)	-0.173***	0.132***	0.199***	-0.004
Total household income (US$/AE)	0.030	0.036	0.129**	0.091*
Production diversity score (food groups)				
Agricultural cash revenues (US$/AE)	-0.232***	-0.073*	0.22***	0.028
Total household income (US$/AE)	0.012	-0.100***	0.18***	0.049

Notes: *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively. AE stands for adult equivalent.

Of particular interest is the analysis for Indonesia, where agricultural cash revenues are positively and negatively associated with the farm species count and the production diversity score, respectively. The reason for this switch in the sign is that cash crop diversification helps to increase farm revenues and incomes, whereas growing additional food groups is against comparative advantage in this context and hence associated with income losses.

3.4. Further discussion

The analysis suggests that farm diversification can be positively associated with household dietary quality, but that fostering market access and cash revenues are more promising avenues. The important role of markets for household nutrition can also be seen in Figure 1, which compares mean dietary diversity scores and production diversity scores across the different study countries. In the pooled sample, households consume 10.2 food groups, while only producing 2.9 food groups on average. In other words, own farm production accounts for less than 30% of the dietary diversity consumed in the households. Depending on climatic conditions, this number may vary seasonally. In the dry season, the contribution of own production may be lower still; especially fresh horticultural produce cannot be easily stored at home over longer periods of time.

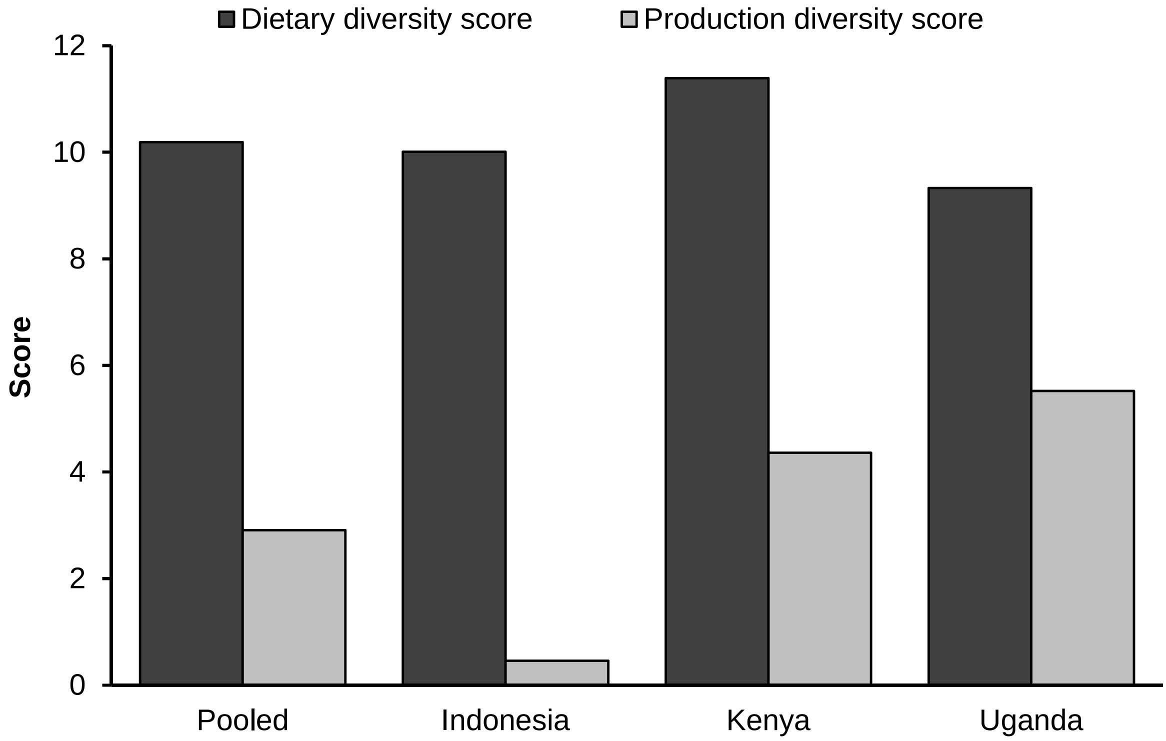

Figure 1. Mean dietary diversity scores and production diversity scores in farm households

Against this background it is unrealistic to assume that own production diversity could be the core element of dietary diversity in smallholder farm households. Uganda, where own production diversity accounts for 60% of household dietary diversity (Figure 1), almost looks like an exception. However, even in Uganda fostering market access and commercialization may be a better strategy to improve nutrition than promoting the cultivation of additional food groups. As we also showed, a high production diversity score can be associated with lower cash incomes, which would rather be counterproductive for household dietary quality.

4. Conclusion

We have analyzed the relationship between farm production diversity and household dietary quality using micro-level data from Indonesia, Kenya, and Uganda. We have contributed to the existing literature by using different indicators and comparing results, thus shedding light on the robustness of previous findings and also helping to better understand some of the underlying linkages. When measuring farm diversity in terms of a simple count of crop and livestock species produced, we found a positive relationship with household dietary diversity. This is consistent with previous findings (Sibhatu et al., 2015; Jones et al., 2014; Pellegrini and Tasciotti, 2014; Keding et al., 2012). However, as was also reported by Sibhatu et al. (2015), this effect of production diversity on consumption diversity is relatively small.

The small positive effect also remains when using other indicators of dietary quality, such as household consumption levels of calories and micronutrients. We conclude that the results are not driven by the way dietary quality is measured. While dietary diversity scores are not a perfect predictor of specific nutritional deficiencies, they seem to work well in terms of capturing broader aspects of dietary quality in farm households. This is a welcome finding, because the calculation of dietary diversity scores requires less data than the calculation of nutrient consumption levels.

We also tested the sensitivity of results with respect to changes in the production diversity indicator. When using production diversity scores instead of a simple species count, the effect on dietary quality gets smaller, in many cases it turns insignificant. This is an interesting finding. The production diversity score measures the number of different food groups produced on a farm, so one could have expected the effect on the number of food groups consumed in the farm household to be stronger. The fact that this is not the case reveals that the subsistence pathway is not the main mechanism underlying the production-consumption relationship. Cash income generated from agricultural sales seems to be a more important pathway contributing to improved dietary quality. Additional model estimates confirmed a significant positive association between agricultural cash revenues and dietary quality, measured either in terms of dietary diversity scores or nutrient consumption levels.

These results suggest that market access is more important for farm household nutrition than production diversity per se. Our data show that own production typically accounts for less than 30% of the different food groups consumed in farm households; the rest is purchased from the market. Diversifying the farm production portfolio such that more food groups were produced would foster subsistence, reduce cash incomes, and thus rather worsen dietary quality. Indeed, we showed that a larger number of food groups produced on a farm is often negatively associated with agricultural cash revenues. This does not mean that farm diversity is bad. But the type of diversification should follow market incentives, building on farmer's comparative advantage, rather than trying to maximize the number of food groups produced. Our results clearly suggest that diversifying into cash crops can help improve diets through the income pathway.

It needs to be stressed that the data used in this study mainly refer to situations where farmers have relatively good access to markets. Results for Uganda suggest that in less commercialized settings the subsistence pathway still plays a more important role. However, even in situations where farmers primarily produce for subsistence, a large share of the food consumed is purchased from the market (Luckett et al., 2015; Sibhatu et al., 2015). Hence, also in such situations policy initiatives should not foster subsistence but improve farmers' access to markets through strengthening infrastructure and institutions. Farmers' subsistence orientation is primarily a response to risk and various other market failures. Reducing these failures and supporting a higher level of market integration can contribute to higher incomes and better nutrition in smallholder households.

We conclude that farm diversification should not be considered a goal in itself. If diversification helps to increase household income, it will contribute to better nutrition. Otherwise, diversification can also be counterproductive from a dietary quality perspective. It should be stressed that diversity may also have environmental benefits, which we did not analyze here. Furthermore, it should be stressed that our results refer to the individual farm level. At higher scales (villages, districts, provinces, countries etc.) sufficient diversity is important, because affordable access to diverse foods from the market certainly requires that somebody produces these foods. This means that policy biases towards only a small number of staple foods – as often observed in the past – need to be rectified. If markets and technologies for a wide range of products exist, food systems will become more diverse, even without every farmer having to maximize diversity on her own farm.

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Appendix

Table A1. Effect of farm species count on dietary quality (pooled sample)

Explanatory variables	(1) HDDS	(2) Calories (kcal/AE)	(3) Iron (mg/AE)	(4) Zinc (mg/AE)	(5) Vitamin A (μg/AE)
Species count (crop + livestock)	0.010***	67.499***	0.506***	0.251**	30.965
	(0.002)	(19.095)	(0.142)	(0.101)	(19.517)
Distance to market (km)	-0.001*	-9.265*	-0.033	-0.013	0.154
	(0.001)	(5.625)	(0.047)	(0.024)	(6.735)
Cultivated land area (acres)	0.001***	10.192	0.095*	0.045	9.231*
	(1.9E-04)	(7.315)	(0.049)	(0.030)	(5.159)
Share of land under food crops (%)	-2.5E-04*	0.618	0.018	0.005	2.650**
	(1.4E-04)	(1.514)	(0.012)	(0.008)	(1.201)
Male household head (dummy)	0.041***	-43.835	0.173	-0.992	-150.992
	(0.011)	(115.275)	(0.894)	(0.605)	(101.040)
Age of household head (years)	-0.001**	7.894***	0.051**	0.009	3.266
	(2.9E-04)	(2.962)	(0.023)	(0.014)	(3.052)
Education of household head (years)	0.005***	7.487	0.124	0.032	27.024**
	(0.001)	(11.005)	(0.091)	(0.054)	(12.731)
Household size (number)	0.005***	-159.393***	-1.043***	-0.614***	-25.300*
	(0.002)	(17.282)	(0.131)	(0.082)	(14.689)
Indonesia (dummy)	0.119***	152.026	-1.702	-0.361	96.974
	(0.018)	(169.145)	(1.322)	(0.791)	(153.196)
Uganda (dummy)	0.197***	-87.904	-8.228***	8.247***	-5.457
	(0.011)	(112.243)	(0.857)	(0.621)	(96.595)
Constant	2.095***	3085.113***	20.397***	13.382***	752.306***
	(0.028)	(258.310)	(1.998)	(1.276)	(290.853)
Number of observations	1484	1484	1484	1484	1484
Pseudo R^2 / R^2	0.017	0.088	0.095	0.351	0.024

Notes: Column (1) was estimated with a Poisson estimator. Columns (2)-(5) were estimated with OLS. Coefficient estimates are shown with robust standard errors in parentheses. *, **, *** denote significance at the 10%, 5%, and 1% level, respectively. HDDS stands for household dietary diversity score. AE stands for adult equivalent.

Table A2. Effect of farm species count on dietary quality (Indonesian sample)

Explanatory variables	(1) HDDS	(2) Calories (kcal/AE)	(3) Iron (mg/AE)	(4) Zinc (mg/AE)	(5) Vitamin A (μg/AE)
Species count (crop + livestock)	0.015***	300.402***	2.499***	1.006***	204.475**
	(0.005)	(66.202)	(0.546)	(0.249)	(84.544)
Distance to market (km)	-0.001	-13.188*	-0.033	-0.024	3.759
	(0.001)	(6.747)	(0.057)	(0.028)	(8.514)
Cultivated land area (acres)	4.3E-04**	8.915	0.084*	0.039	7.573
	(1.9E-04)	(7.194)	(0.047)	(0.029)	(4.969)
Share of land under food crops	-0.001***	-1.593	-0.011	-0.007	-3.272
(%)	(2.7E-04)	(3.336)	(0.028)	(0.015)	(2.510)
Male household head (dummy)	0.028	178.446	1.670	0.833	138.395
	(0.020)	(231.696)	(1.900)	(0.809)	(185.315)
Age of household head (years)	3.4E-04	8.535*	0.074*	0.011	7.890
	(4.3E-04)	(5.142)	(0.044)	(0.019)	(6.165)
Education of household head	0.007***	24.072	0.322**	0.066	62.071**
(years)	(0.001)	(17.153)	(0.152)	(0.068)	(25.285)
Household size (number)	0.008**	-196.305***	-1.565***	-0.641***	-60.989
	(0.004)	(33.081)	(0.295)	(0.114)	(38.134)
Constant	2.154***	2651.500***	13.534***	9.885***	-39.350
	(0.035)	(390.809)	(2.982)	(1.466)	(457.519)
Number of observations	672	672	672	672	672
Pseudo R^2 / R^2	0.004	0.110	0.113	0.090	0.050

Notes: Column (1) was estimated with a Poisson estimator. Columns (2)-(5) were estimated with OLS. Coefficient estimates are shown with robust standard errors in parentheses. *, **, *** denote significance at the 10%, 5%, and 1% level, respectively. HDDS stands for household dietary diversity score. AE stands for adult equivalent.

Table A3. Effect of farm species count on dietary quality (Kenyan sample)

Explanatory variables	(1) HDDS	(2) Calories (kcal/AE)	(3) Iron (mg/AE)	(4) Zinc (mg/AE)	(5) Vitamin A (µg/AE)
Species count (crop + livestock)	0.004**	-2.972	0.028	0.046	-31.527
	(0.002)	(25.358)	(0.165)	(0.173)	(21.179)
Distance to market (km)	-0.002*	16.987	0.029	0.105	-7.074
	(0.001)	(10.328)	(0.071)	(0.076)	(9.347)
Cultivated land area (acres)	0.003***	-2.364	1.5E-04	0.044	38.648**
	(0.001)	(16.436)	(0.135)	(0.113)	(17.845)
Share of land under food crops	-7.1E-05	-0.894	-0.003	-0.003	1.048
(%)	(1.6E-04)	(2.139)	(0.013)	(0.015)	(1.700)
Male household head (dummy)	0.026*	136.589	4.144***	-2.311	-122.358
	(0.014)	(182.447)	(0.957)	(1.470)	(169.735)
Age of household head (years)	-0.001	4.530	-0.015	-0.045	-0.171
	(4.3E-04)	(5.659)	(0.036)	(0.036)	(4.398)
Education of household head	0.004***	13.361	0.207*	0.119	29.339**
(years)	(0.001)	(17.916)	(0.114)	(0.127)	(12.649)
Household size (number)	0.001	-248.816***	-1.326***	-1.292***	-104.862***
	(0.003)	(39.987)	(0.239)	(0.256)	(24.007)
Constant	2.366***	3964.714***	17.800***	29.632***	1800.099***
	(0.039)	(448.199)	(3.182)	(3.270)	(380.319)
Number of observations	395	395	395	395	395
Pseudo R^2 / R^2	0.002	0.131	0.119	0.100	0.073

Notes: Column (1) was estimated with a Poisson estimator. Columns (2)-(5) were estimated with OLS. Coefficient estimates are shown with robust standard errors in parentheses. *, **, *** denote significance at the 10%, 5%, and 1% level, respectively. HDDS stands for household dietary diversity score. AE stands for adult equivalent.

Table A4. Effect of farm species count on dietary quality (Ugandan sample)

Explanatory variables	(1) HDDS	(2) Calories (kcal/AE)	(3) Iron (mg/AE)	(4) Zinc (mg/AE)	(5) Vitamin A (μg/AE)
Species count (crop + livestock)	0.021***	83.035**	0.470*	0.301**	35.618
	(0.004)	(33.648)	(0.255)	(0.152)	(30.738)
Distance to market (km)	-0.001	-14.381	-0.109	-0.057	-7.171
	(0.002)	(13.643)	(0.104)	(0.052)	(11.823)
Cultivated land area (acres)	-0.001	26.701	0.123	0.162	-11.130
	(0.003)	(20.905)	(0.164)	(0.111)	(17.030)
Share of land under food crops	-3.6E-04	-1.522	0.017	0.007	6.271**
(%)	(3.5E-04)	(2.797)	(0.022)	(0.013)	(2.454)
Male household head (dummy)	0.052**	-176.676	-1.872	-0.387	-169.442
	(0.021)	(176.997)	(1.405)	(0.788)	(154.543)
Age of household head (years)	-0.002**	11.271**	0.091**	0.054**	3.926
	(0.001)	(4.620)	(0.037)	(0.022)	(4.419)
Education of household head	0.006**	-32.411	-0.312*	-0.201*	-27.582*
(years)	(0.002)	(20.458)	(0.180)	(0.107)	(15.528)
Household size (number)	0.003	-130.325***	-0.780***	-0.476***	11.989
	(0.003)	(22.348)	(0.169)	(0.104)	(17.015)
Constant	2.063***	3007.942***	21.492***	10.339***	751.280*
	(0.056)	(403.447)	(3.132)	(1.762)	(421.745)
No. of observations	417	417	417	417	417
Pseudo R^2 / R^2	0.010	0.119	0.093	0.094	0.044

Notes: Column (1) was estimated with a Poisson estimator. Columns (2)-(5) were estimated with OLS. Coefficient estimates are shown with robust standard errors in parentheses. *, **, *** denote significance at the 10%, 5%, and 1% level, respectively. HDDS stands for household dietary diversity score. AE stands for adult equivalent.

Table A5. Effect of production diversity score on dietary quality (pooled sample)

Explanatory variables	(1) HDDS	(2) Calories (kcal/AE)	(3) Iron (mg/AE)	(4) Zinc (mg/AE)	(5) Vitamin A (µg/AE)
Production diversity score (food	0.008***	30.382	0.140	0.157	-31.662
groups)	(0.003)	(28.238)	(0.212)	(0.145)	(23.545)
Distance to market (km)	-0.001**	-9.443	-0.032	-0.015	1.433
	(0.001)	(5.790)	(0.049)	(0.025)	(6.837)
Cultivated land area (acres)	0.001***	10.538	0.097**	0.046	9.316*
	(2.0E-04)	(7.418)	(0.049)	(0.030)	(5.203)
Share of land under food crops	-3.4E-04**	0.018	0.013	0.003	2.316**
(%)	(1.4E-04)	(1.487)	(0.012)	(0.008)	(1.173)
Male household head (dummy)	0.043***	-33.726	0.237	-0.948	-152.233
	(0.012)	(114.936)	(0.890)	(0.606)	(100.502)
Age of household head (years)	-4.5E-04	9.183***	0.062***	0.013	4.572
	(2.9E-04)	(2.963)	(0.023)	(0.014)	(3.079)
Education of household head	0.006***	9.938	0.146	0.039	30.109**
(years)	(0.001)	(11.015)	(0.091)	(0.054)	(12.876)
Household size (number)	0.006***	-150.898***	-0.971***	-0.586***	-17.368
	(0.002)	(16.916)	(0.129)	(0.080)	(14.230)
Indonesia (dummy)	0.094***	-110.792	-4.100***	-1.125	-246.359*
	(0.019)	(184.301)	(1.435)	(0.847)	(144.422)
Uganda (dummy)	0.208***	-36.673	-7.935***	8.483***	-28.744
	(0.012)	(116.819)	(0.874)	(0.648)	(94.013)
Constant	2.121***	3336.638***	22.622***	14.148***	1044.834***
	(0.028)	(262.419)	(2.030)	(1.293)	(275.266)
Number of observations	1484	1484	1484	1484	1484
Pseudo R^2 / R^2	0.017	0.081	0.089	0.348	0.024

Notes: Column (1) was estimated with a Poisson estimator. Columns (2)-(5) were estimated with OLS. Coefficient estimates are shown with robust standard errors in parentheses. *, **, *** denote significance at the 10%, 5%, and 1% level, respectively. HDDS stands for household dietary diversity score. AE stands for adult equivalent.

Table A6. Effect of production diversity score on dietary quality (Indonesian sample)

Explanatory variables	(1) HDDS	(2) Calories (kcal/AE)	(3) Iron (mg/AE)	(4) Zinc (mg/AE)	(5) Vitamin A (µg/AE)
Production diversity score (food groups)	0.002	12.793	0.088	-0.019	-33.383
	(0.005)	(48.037)	(0.410)	(0.179)	(40.762)
Distance to market (km)	-0.001	-10.461	-0.009	-0.014	6.707
	(0.001)	(7.001)	(0.061)	(0.029)	(8.804)
Cultivated land area (acres)	4.8E-04**	9.879	0.092*	0.042	8.155
	(2.1E-04)	(7.668)	(0.051)	(0.031)	(5.253)
Share of land under food crops (%)	-0.001***	0.151	0.004	1.9E-04	-1.468
	(2.7E-04)	(3.254)	(0.028)	(0.015)	(2.176)
Male household head (dummy)	0.034*	280.023	2.511	1.160	198.291
	(0.019)	(237.396)	(1.896)	(0.808)	(187.363)
Age of household head (years)	0.001	12.169**	0.104**	0.024	10.963*
	(4.2E-04)	(5.270)	(0.045)	(0.020)	(6.390)
Education of household head (years)	0.007***	31.050*	0.381**	0.090	67.837**
	(0.001)	(17.317)	(0.153)	(0.069)	(26.406)
Household size (number)	0.008**	-186.797***	-1.485***	-0.604***	-51.405
	(0.004)	(33.447)	(0.298)	(0.115)	(38.322)
Constant	2.163***	2805.095***	14.799***	10.356***	35.092
	(0.035)	(405.753)	(3.036)	(1.520)	(450.734)
Number of observations	672	672	672	672	672
Pseudo R^2 / R^2	0.003	0.068	0.071	0.056	0.035

Notes: Column (1) was estimated with a Poisson estimator. Columns (2)-(5) were estimated with OLS. Coefficient estimates are shown with robust standard errors in parentheses. *, **, *** denote significance at the 10%, 5%, and 1% level, respectively. HDDS stands for household dietary diversity score. AE stands for adult equivalent.

Table A7. Effect of production diversity score on dietary quality (Kenyan sample)

Explanatory variables	(1) HDDS	(2) Calories (kcal/AE)	(3) Iron (mg/AE)	(4) Zinc (mg/AE)	(5) Vitamin A (µg/AE)
Production diversity score (food groups)	0.004	37.246	0.088	0.308	-69.592**
	(0.003)	(46.244)	(0.297)	(0.294)	(33.458)
Distance to market (km)	-0.003*	15.736	0.025	0.092	-3.619
	(0.001)	(10.426)	(0.070)	(0.078)	(9.524)
Cultivated land area (acres)	0.003***	-7.083	-0.006	0.015	41.990**
	(0.001)	(16.912)	(0.134)	(0.115)	(17.787)
Share of land under food crops (%)	-1.1E-04	-0.300	-0.002	0.001	0.885
	(1.6E-04)	(2.105)	(0.013)	(0.015)	(1.641)
Male household head (dummy)	0.025*	136.790	4.140***	-2.319	-117.946
	(0.014)	(182.834)	(0.960)	(1.472)	(169.746)
Age of household head (years)	-4.2E-04	3.384	-0.016	-0.051	0.133
	(4.3E-04)	(5.600)	(0.036)	(0.035)	(4.310)
Education of household (years)	0.004***	10.905	0.204*	0.104	30.946**
	(0.002)	(17.876)	(0.114)	(0.126)	(12.650)
Household size (number)	0.001	-251.965***	-1.328***	-1.308***	-104.471***
	(0.003)	(39.855)	(0.238)	(0.254)	(23.600)
Constant	2.375***	3846.098***	17.717***	29.047***	1814.003***
	(0.037)	(449.830)	(3.176)	(3.289)	(372.653)
Number of observations	395	395	395	395	395
Pseudo R^2 / R^2	0.002	0.133	0.119	0.102	0.078

Notes: Column (1) was estimated with a Poisson estimator. Columns (2)-(5) were estimated with OLS. Coefficient estimates are shown with robust standard errors in parentheses. *, **, *** denote significance at the 10%, 5%, and 1% level, respectively. HDDS stands for household dietary diversity score. AE stands for adult equivalent.

Table A8. Effect of production diversity score on dietary quality (Ugandan sample)

Explanatory variables	(1) HDDS	(2) Calories (kcal/AE)	(3) Iron (mg/AE)	(4) Zinc (mg/AE)	(5) Vitamin A (μg/AE)
Production diversity score (food groups)	0.033***	108.229	0.835	0.599*	49.277
	(0.009)	(70.622)	(0.547)	(0.321)	(55.715)
Distance to market (km)	-0.001	-15.457	-0.118	-0.063	-7.661
	(0.002)	(13.966)	(0.105)	(0.053)	(11.896)
Cultivated land area (acres)	-4.5E-04	27.355	0.124	0.162	-10.883
	(0.003)	(21.307)	(0.167)	(0.112)	(16.796)
Share of land under food crops (%)	-4.0E-04	-1.616	0.015	0.006	6.220**
	(3.6E-04)	(2.792)	(0.022)	(0.013)	(2.475)
Male household head (dummy)	0.058***	-154.607	-1.719	-0.281	-159.617
	(0.022)	(175.568)	(1.400)	(0.786)	(155.215)
Age of household head (years)	-0.001*	12.419***	0.098***	0.060***	4.435
	(0.001)	(4.681)	(0.038)	(0.022)	(4.342)
Education of household head (years)	0.006**	-31.594	-0.313*	-0.203*	-27.297*
	(0.002)	(20.885)	(0.183)	(0.108)	(15.897)
Household size (number)	0.005*	-122.336***	-0.757***	-0.467***	15.135
	(0.003)	(21.459)	(0.166)	(0.102)	(17.106)
Constant	2.023***	2944.099***	20.046***	9.105***	709.994
	(0.067)	(492.010)	(3.820)	(2.219)	(433.212)
Number of observations	417	417	417	417	417
Pseudo R^2 / R^2	0.009	0.112	0.092	0.094	0.043

Notes: Column (1) was estimated with a Poisson estimator. Columns (2)-(5) were estimated with OLS. Coefficient estimates are shown with robust standard errors in parentheses. *, **, *** denote significance at the 10%, 5%, and 1% level, respectively. HDDS stands for household dietary diversity score. AE stands for adult equivalent.

Table A9. Association between agricultural cash revenues and dietary quality

Explanatory variables by country	(1) HDDS	(2) Calories (kcal/AE)	(3) Iron (mg/AE)	(4) Zinc (mg/AE)	(5) Vitamin A (μg/AE)
Pooled					
Agricultural cash revenues	3.8E-06***	0.093***	0.001***	3.4E-04***	0.070***
(US$/AE)	(5.5E-07)	(0.021)	(1.5E-04)	(8.7E-05)	(0.016)
Indonesia (dummy)	0.061***	-142.310	-4.368***	-1.426***	-274.297***
	(0.010)	(92.970)	(0.745)	(0.400)	(83.738)
Uganda (dummy)	0.196***	172.288*	-6.053***	9.229***	93.876
	(0.010)	(90.668)	(0.672)	(0.515)	(75.884)
Constant	2.233***	3031.343***	22.207***	11.632***	1224.370***
	(0.009)	(66.997)	(0.545)	(0.308)	(56.928)
Number of observations	1484	1484	1484	1484	1484
Pseudo R^2 / R^2	0.014+	0.066	0.087	0.338	0.042
Indonesia					
Agricultural cash revenues	3.7E-06***	0.095***	0.001***	3.4E-04***	0.074***
(US$/AE)	(5.8E-07)	(0.022)	(1.6E-04)	(9.4E-05)	(0.017)
Constant	2.294***	2882.418***	17.744***	10.205***	941.235***
	(0.005)	(69.511)	(0.542)	(0.276)	(63.563)
Number of observations	672	672	672	672	672
Pseudo R^2 / R^2	0.001+	0.113	0.096	0.103	0.055
Kenya					
Agricultural cash revenues	3.6E-06**	0.052***	2.6E-04**	2.7E-04	0.035
(US$/AE)	(1.4E-06)	(0.016)	(1.2E-04)	(1.6E-04)	(0.024)
Constant	2.429***	3245.445***	16.593***	20.933***	1354.308***
	(0.005)	(61.180)	(0.405)	(0.439)	(54.779)
Number of observations	395	395	395	395	395
Pseudo R^2 / R^2	0.0002+	0.009	0.006	0.005	0.006
Uganda					
Agricultural cash revenues	3.5E-05	1.072***	0.005***	0.004***	0.144
(US$/AE)	(2.5E-05)	(0.240)	(0.002)	(0.001)	(0.194)
Constant	2.227***	2862.870***	21.467***	10.936***	1211.644***
	(0.010)	(77.754)	(0.648)	(0.378)	(72.216)
Number of observations	417	417	417	417	417
Pseudo R^2 / R^2	0.0002+	0.043	0.014	0.034	0.001

Notes: The models in column (1) were estimated with a Poisson estimator. The models in columns (2)-(5) were estimated with OLS. Coefficient estimates are shown with robust standard errors in parentheses. *, **, *** denote significance at the 10%, 5%, and 1% level, respectively. HDDS stands for household dietary diversity score. AE stands for adult equivalent.