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Linking farm diversification to household diet diversification: Evidence from a sample of Kenyan ultra-poor farmers

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Abstract

This paper provides new empirical evidence on the nexus between farm production diversification and household diet diversity in East Africa. Starting with a conceptual framework for the pathways from agriculture to nutrition, we use data collected from a sample of ultra-poor, labor constrained families living in five rural districts of Kenya. We find production diversification to be positively and significantly associated with household diet diversification, with poultry ownership most strongly correlated. These findings suggest that supporting investments in diversified livelihood systems in general and in small livestock assets such as poultry in particular are viable intervention classes to improve household food security and nutrition for very poor, marginalized smallholders.

Keywords: Agriculture, diet diversity, farm-household, Kenya

JEL Codes: O12, D12, Q10, Q12, Q18

1 Introduction

The concept of “nutrition sensitive agriculture” assumes that agricultural production practices have the potential to positively affect the underlying determinants of nutrition (Ruel *et al.*, 2013a). Although this assumption is intuitively a sensible one, especially if the focus is narrowed to food crop production, empirically, it has proven difficult to support, not least because the causal pathways hypothesized to run between agriculture and nutrition are long and winding. Moreover, although agricultural advances have been impressive in past decades, progress in improving the nutrition and health of poor rural households in developing countries has not followed suite. As such, understanding the capacity of farming systems to contribute to improved nutrition outcomes is gaining ground as an objective among economists and other development professionals (Carletto *et al.*, 2015).

However, surveys which capture the range of information required to test the association between farm level production practices, individual level dietary intake, and nutrition outcomes are few and far between. A more common, albeit imperfect, option, are household surveys which capture information on both crop/livestock production and household food consumption (Carletto *et al.*, 2013). The latter can be used to construct indicators of household level diet diversity, including the widely used Household Diet Diversity Score (HDDS), which measures the number of food groups (out of 12 total) consumed by one or more household members over a given reference period; typically 24 hours or 7 days (Swindale and Bilinsky, 2006; Kennedy *et al.*, 2013).

Diet diversity measured at the individual level has been repeatedly validated as predictive of diet quality and is associated with nutritional status across a range of countries and contexts, including a positive association between higher diet diversity and reduced prevalence of stunting and underweight among children under five, and a positive association between diet diversity and mean micronutrient adequacy for women and children. Simply put, nutritional needs are more likely to be met where diverse diets are the norm, as a diverse diet is more likely to include the variety of nutrient dense foods required for good health than a monotonous one. Two reviews, Ruel, 2003 and Ruel *et al.*, 2013, have summarized these findings and Individual Diet Diversity Scores are now widely considered important indicators of diet quality and nutritional status in developing countries.

Unlike individual level measures of diet diversity, household level food diversity should not be used to predict nutrient adequacy of individual level dietary intake (Kennedy *et al.*, 2013). However they *are* well-established indicators of what foods households can afford to eat, not only in terms of diversity but also in terms of quality of food groups consumed (Hoddinnot and Yohannes, 2002). As such, in contexts where individual level diet diversity data are unavailable but where household surveys are, HDDS may serve as a next-best option for assessing diet quality, reflecting what households are eating as a unit and thus providing important clues about the nutrient adequacy of options available at individual level[1].

Following this logic, we used household survey data to investigate associations between farm level production diversity and household level diet diversity in seven counties of Kenya. Our sample consisted of ultra-poor and labour constrained families surveyed during an economic evaluation of Kenya’s flagship social protection programme: *Cash Transfer for Orphans and Vulnerable Children (CTOVC).*

[1] Albeit without unpacking how those options may be exercised, as intra-household food allocation practices are not addressed during data collection.

The geographical context of these data is relevant given (i) the widespread food insecurity and pervasive undernutrition present in East Africa, (ii) the kinds of agricultural policies currently promoted sub-continent-wide (i.e. market-based commercial agriculture), and (iii) the fact that agriculture is the primary livelihood base for most Africans. The fact that the sample is ultra-poor and labour constrained is also important, given the need to focus especially on the most vulnerable populations when applying a "nutrition lens" to empirical analysis. Around the world, the burden of undernutrition tends to fall disproportionately on the lowest-income groups. This is certainly the case in Kenya; where many more children are stunted and/or wasted in Kenya's lowest wealth quintile relative to its highest[2].

[2] Stunting in children aged 0 to 5 years is currently estimated to be 35.9 percent in Kenya's lowest income quintile, relative to 13.8 percent in its highest. Wasting prevalence is estimated to be 7.3 percent in the lowest income quintile, relative to 2.5 percent in the highest (KDHS, 2014).

2 Conceptual framework

Multiple pathways have been proposed for the various ways through which agriculture may plausibly improve nutrition outcomes, and there is now general consensus on a conceptual framework which includes agriculture as a source of food via 1) production for own-consumption, and 2) income effect (Gillespie *et al.* 2012; Meeker and Haddad, 2013; Ruel et. al., 2013; Herforth and Harris, 2014; Webb, 2013; World Bank, 2013; Jones *et al.*, 2014; Kadiyala *et al.*, 2014):

- The own-consumption pathway applies to scenarios where a household is growing food for own consumption and assumes that production practices have the potential to improve the diversity, nutrient quality, and quantity of foods available to the household year-round.
- The income pathway assumes that agricultural earnings– via wages or sale of crops/ crop products - are used to purchase not only more food, but more high quality, nutrient-dense food. It also assumes that the additional income may be spent on healthcare as needed, thus increasing the likelihood of positive synergies between improved dietary intake and improved health status.

Production diversification - specifically increased production of nutrient-dense crops and small-scale animal husbandry - is key to both these pathways, first in terms of immediate and fundamental increases in diet quality and diversity, i.e. pathway 1, and second in terms of increased resilience to climate and price shocks, reduction of seasonal food and income fluctuations, and increased income generation, i.e. pathway 2 (FAO, 2015).

These models also include a third pathway on women, often referred to as the "empowerment pathway". In many countries, women work as much or more than men in agriculture, and they almost always make the majority of nutrition-related decisions for the household. Agricultural activities that increase women's income and decision-making power can thus have positive impacts on nutrition due to increased household expenditures on nutrition-relevant goods and services[3].

Most of these conceptual frameworks also acknowledge external factors which may affect the trajectories of all three causal pathways. For example: Pre-farm gate, the availability of natural resources such as water and soil are fundamental. Post-production, potential bottlenecks include whether food markets are present and functioning, the presence/absence of contaminants and other factors affecting the health environment, and the nutrition knowledge and norms of the population in question.

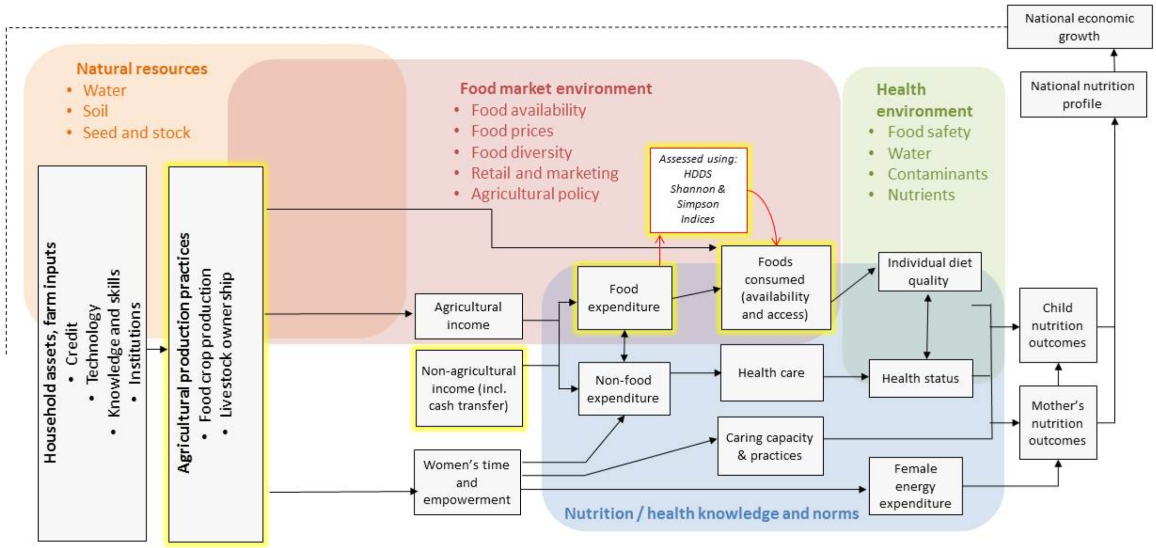
We re-purposed one of these recent conceptual frameworks (Herforth and Harris, 2013), to better reflect our focus on the links between production diversification and household level dietary diversity, as shown in Figure 1. Boxes highlighted in yellow reflect inputs and outputs included in our analysis.

We used data on agricultural production practices (food crops produced and livestock ownership) to estimate production diversity, and food expenditure data and data on non-agricultural income to estimate what foods were consumed by surveyed households. The

[3] Assuming that there is a positive *net effect* on i) the amount of time a woman is occupied in agricultural activities, with consequences for the time she can focus on the food, health, and care of her family; and ii) the amount of energy a woman expends, with consequences for her own nutrition and health outcomes, as well as those of her children (and for fetal health if she is pregnant).

diversity and nutritional quality of those foods was then assessed using HDDS as well as via Simpson and Shannon indices, the latter to estimate the relative “depth” of the HDDs (see Section 4.2).

Figure 1. Conceptual Framework for Agriculture to Nutrition Pathways, adapted to CT-OVC data analysis



Source: Herforth and Harris 2013
(Adapted from Herforth and Harris 2014, Gillespie *et al.* 2012 and Headey *et al.* 2012)

3 Hypotheses and modelling strategy

3.1 Hypotheses

Hypotheses were constructed based on the own-consumption and income pathways described above:

1) On-farm production diversification correlates positively with household diet diversification in poor and rural settings.
2) Individual production activities are associated with diet diversification through income pathways or through production for own-consumption pathways.

To explore whether agriculture might provide entry-points for enhancing women's control over household food resources, we interacted diversity of agricultural production practices with gender of household head. In addition, we analysed the relationship between diversity of agricultural production practices and level of education of household head. While not explicitly included in our conceptual framework, education levels are well-known driver of nutrition outcomes (Clausen *et al.*, 2005; Thorne-Lyman *et al.*, 2010; Jones *et al.*, 2014). Research hypotheses corresponding to these pathways were:

3) Female household headship correlates positively with diet diversity at household level.
4) Education level of household head correlates positively with diet diversity at household level.

Finally, we tested the association between non-agricultural income sources and diet diversification, as follows:

5) Participation in the CT-OVC programme is associated with household diet diversity.
6) Off-farm income sources are associated with household diet diversity.

3.2 Measurement of household diet diversity

Food consumption was estimated using expenditure data collected during a 7 day recall period, rather than a 24 or 48 hour time frame. While a longer recall period might capture a wider variety of foods consumed by a household, it also adds some level of "noise" to the estimates by reducing their accuracy.

HDDSs were calculated by first aggregating foods that survey respondents reported consuming in the seven days prior to the interview into 12 equally weighted groups: (i) cereals, (ii) tubers, (iii) beans and pulses, (iv) fruits, (v) vegetables, (vi) meat, (vii) fish, (viii) eggs, (ix) milk, (x) fats, (xi) sugar and (xii) non-sugar condiments (e.g. salt). The number of groups reported was then summed to obtain an HDDS (0 to 12) for the household as a whole (Swindale and Bilinsky, 2006; Kennedy *et al.*, 2013).

Foods included in HDDSs were from different sources, namely: (i) foods purchased outside the home and consumed in the home, (ii) home-produced foods (i.e. production for own consumption), (iii) foods received as gifts, and (iv) foods purchased and eaten outside the home[4].

[4] Food was predominantly purchased or obtained from home production while the proportion of food received as gifts or eaten out was negligible standing below 5 percent.

While an HDDS assesses the presence of various food groups in a household's meals, it does not capture differences in the distribution of consumption, as all groups are equally weighted regardless of quantity consumed. For example, two HDDSs of 12 might in reality reflect two very different dietary diversity situations across the recall period, with one reflecting consumption of relatively large quantities of foods from 2 or 3 food groups and very small quantities from all others, the other reflecting an even distribution of consumption across all twelve groups. In sum, higher dietary diversity scores can be more or less meaningful depending on the relative share of each food consumed (Arimond and Ruel, 2004).

To mitigate this issue, we used two additional diversity measures – the Simpson index (Simpson, 1949) and the Shannon index (Shannon, 1948) - to estimate the relative concentration or "distribution" of food group consumption, and to corroborate HDDS scores for number of food groups consumed.

Both indices were calculated based on food consumption – assessed using expenditure shares - from (i) purchases, (ii) home production, and (iii) food received as gifts or eaten out[5]:

$$\text{Simpson index } = 1 - \sum_{i} \mathrm{w_i^2} \qquad (1)$$

Where $\mathrm{w_i}$ is the expenditure share of food group i. The Simpson index ranges between zero and one; a value of zero implies only one food group is consumed while a value closer to one reflects a more even distribution of food expenditure by food type[6].

$$\text{Shannon index} = -\sum_{i} \mathrm{w_i} \log(\mathrm{w_i}) \qquad (2)$$

Where $\mathrm{w_i}$ is again the expenditure share of food group i. Values for the Shannon index can range from zero to the value of the log of the highest number of food groups consumed. A value of "0" flags consumption of only one food group to a maximum of log n (when all shares equal 1/n).

Taken together, the Simpson and Shannon indices clarify the distribution or "evenness of consumption" of foods consumed. In so doing, they add granularity to the HDDS, which captures only the "crude" diversity of diets. To our knowledge, this is a unique use of these metrics, which are more typically used in agricultural analyses.

[5] Constructing food expenditure shares using different sources is a well-grounded technique in economic analysis for estimating consumption aggregates and evaluating, for example, poverty incidence at country level (see among others Deaton and Zaidi, 2002). All food expenditure estimates reported below are in per capita terms, constructed based on number of adults and children residing in the household. For this analysis, a regional price deflator was also constructed to allow for comparison in consumption expenditure across different districts (Deaton and Zaidi, 2002). We took this precaution as food prices in Kenya are markedly different across regions due to variation in market development and distance to port or surplus producing areas.

[6] To give a simple numeric example: Household "A" and household "B" display a consumption expenditure distribution comprised only of meat and cereals. If household A consumes 20 per cent meat and 80 per cent cereals while household B consumes 40 per cent meat and 60 per cent cereals, the Simpson score will be greater for B relative to A, since the expenditure shares are more equally distributed. The Shannon index works in a similar manner, however while Simpson squares the food shares, thus reducing the weight of foods with smaller expenditure shares relative to foods with greater shares, the Shannon index logs expenditure shares, thus reducing the weight of foods with greater shares relative to foods with smaller.

3.3 Measurement of farm diversification and off-farm activities

A wide variety of indicators for production diversity have been used in recent years to research the association between crop diversity and nutrition, with many studies using some iteration of a crop count of specific species cultivated and livestock species raised (Powell *et al.*, 2015).

We were not able to use a crop count in this study because of the following two data circumstances: First, in some cases, the agriculture module of the CT-OVC questionnaire (see Section 4) collected information on crop groups as opposed to specific species (e.g. "fruits" as opposed to "mangos"); and second, because only a very small percentage of surveyed households reported certain practices (e.g. cultivating vegetables). As such, we constructed a unique production diversity metric using broad taxonomic rankings (e.g. grains, tubers, small ruminants, poultry) as opposed to specific species in order to ensure explanatory power. We named this metric the "agriculture enterprise score" (AES). For each household in the data set, the AES was calculated by summing the following crop and livestock categories[7]:

(i) Cereals, (ii) potatoes, (iii) beans and pulses, (iv) vegetables and fruits, (v) cattle, (vi) poultry, (vii)goats and sheep, and (viii) pigs.

While using an unweighted score of crop and livestock categories permitted identification of which of those categories contributed the most to diet diversification, it is important to note that the AES has no capacity to identify how specific crop or livestock species within each taxonomic group affect household diet diversification. Rather, this indicator is a summary measure which reflects basic diversity of food group production. We attempted to address this issue later in our analysis by disaggregating the AES into individual crop practices for which data were available (see Section 4.4).

Theoretically, the use of unweighted categories in the AES also runs the risk of "masking" the nutritional implications of production practices. For example farms raising a single cereal variety and cultivating a single fruit tree would receive a higher AES than farms growing a wide variety of vegetables. However as mentioned above, one rationale for our need to use the AES - as opposed to a more conventional unique crop count - was the very fact that few CT-OVC farmers were producing vegetables in the first place.

As rural off-farm activities represent an income stream which might affect household diet diversity, we also constructed an "off-farm activities" variable, comprised of the following: (i) wage employment, (ii) annual private transfer income (remittances) and (iii) non-agricultural business. Households which received income from all three sources were scored "3"; households which received income from none of these sources were scored "0"[8].

3.4 Analytical methodology

As discussed in the conceptual framework above, it is reasonable to expect a positive association between diversified farming practices and diet diversity. However, smallholders generally practice some mix of subsistence and market-oriented production. High value products, including meat animals, eggs and milk, are likely to be sold in the market while

[7] To avoid losing explanatory power in the multivariate regression analysis, we included only those crops harvested and livestock species reared which comprised 5 per cent or more of total farm output.

[8] While counting the number of income sources can capture income diversification; it does not automatically imply that households with more off-farm income sources have higher income levels relative to families engaged in fewer off-farm activities.

basic staples are likely to be produced for own consumption. These nuances make the relationship between farm production diversity and dietary diversity complicated difficult to disentangle (Jones, *et al.*, 2014).

Multiple linear regression models using three measures of diet diversity as dependent variables (HDDS count as well as the Simpson and Shannon Indices, each in separate regressions) and one independent variable (AES) were used for the analysis. Previous peer-reviewed literature has used multiple regressions to assess the determinants of diet diversity (Jones, *et al.*, 2012; Thorne-Lyman *et al.*, 2010; Clausen *et al.*, 2005). The relationship was adjusted for confounding factors such as livelihood features, household head characteristics, demographic characteristics, household expenditure and community characteristics. It is well known that, under several assumptions (i.e. the errors are uncorrelated and homoscedastic), OLS is the best linear unbiased estimator (according to the Gauss–Markov theorem). The reason motivating the adoption of such assumptions in our framework is threefold: First, the cross-sectional nature of the data did not allow us to control for time-invariant unobserved heterogeneity within the household. Second, despite a thorough exploration of the data, we were unable to identify an instrumental variable, which would have been a good candidate on theoretical grounds to eliminate endogeneity concerns. Third, it was not possible to model the adoption of different farming practices using propensity score matching, as farm diversification practices are the result of many different components which are quantitively and qualitatively different in their nature. Given these limitations, causal attribution was not possible with our model. However, since the model includes multiple control variables at household and community level, as well as geographical dummies, concerns related to unobserved heterogeneity were low, making the OLS estimator the best candidate for our analysis.

The OLS regression model used to estimate the link between farming activities and household diet diversity is given as follows:

$$\mathrm{Y} = \alpha + \beta_1 \mathrm{AES} + \sum_{j=2}^{n} \beta_j \mathrm{X} + \upsilon \qquad (3)$$

Here, *Y* is a diet diversification measure constructed using the HDDS count, the Simpson or the Shannon index and AES is the agriculture enterprise count reflecting basic diversity in food group production as explained above. In theory, the more a household diversifies its production practices, the stronger and more significant the positive association with household level food diversification should be. As such, the coefficient β_1 should provide empirical evidence on our first hypothesis.

X consists of a vector of household and community characteristics (e.g. gender of household head and household size) which might plausibly have impacted diet diversification in the sample. Selection criteria for these characteristics were based on empirical research on the drivers of household level dietary diversity (Torheim *et al.*, 2004; Clausen *et al.*, 2005; Thorne-Lyman *et al.*, 2010; Jones *et al.*, 2014). As transfer programmes can increase food expenditure on more nutritious foods, *X* also includes participation in the CT-OVC programme, so as to purge the association between farming diversification and diet diversification from this potential confounder.

As we wished to test which production activities were most strongly associated with diet diversity, we also disaggregated the *AES* to investigate how single practices correlated with diet diversity:

$$\mathrm{Y} = \alpha + \sum_{k=1}^{n} \beta_k AG \; + \sum_{o=n+1}^{m} \beta_o X \; + \mathrm{u} \qquad (4)$$

Here, *AG* is a set of dummy variables flagging whether or not a household engaged in each of the production practices captured in the AES, where k is the production practice in question. The coefficient β_k tells us if and to what extent *k* farm practice correlates with dietary diversification. *X* is the same set of control variables as explained above.

For both regression models, we clustered standard errors at community level to count for intra-correlation in our estimation strategy.

We tested whether the three measures of diet diversity were correlated by using Pearson product-moment, and we used ANOVA analysis to assess whether statistically significant differences in household characteristics and outcome indicators existed across districts.

A common concern when using multivariate regression analysis to analyze correlation is multicollinearity between the independent variables used to generate the model. That is, magnitude of some coefficient estimates might be increased because of associations between predictor variables, resulting in misleading measurements of the strength of the association in question. To test if this was an issue in our model, we observed variance inflation factors that ranged between 2.1 to 2.5, well below the suggested cut-off value of 10 provided by Kutner *et al.* (2004). As such we concluded that multicollinearity was not an issue in our model.

To examine the robustness of our findings we re-ran the model with a stepwise exclusion of the control variables.

While we controlled for confounding variables – gender and education of household head, participation in the CT-OVC transfer programme, wealth quintile, land ownership, and district fixed effects – it should be noted that unobserved characteristics might still be of concern with respect to estimated strength of association between farming diversity and diet diversity.

4 Data

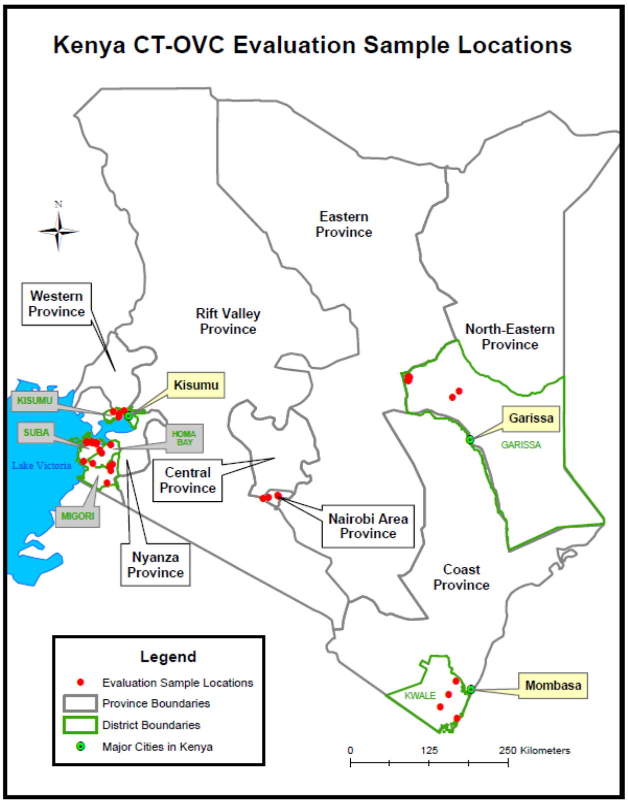
We used data collected during the final wave of an evaluation of the welfare and economic impacts of Kenya's Cash Transfer for Orphans and Vulnerable Children (CT-OVC). This programme targets families representing the poorest 20 per cent of the population of Kenya and as such these survey data cannot be considered nationally representative. Rather they represent a sample of ultra-poor[9] and labour constrained families highly affected by the HIV/AIDS pandemic, mostly relying on semi-subsistence farming practices to meet daily basic needs.

The impact evaluation used a cluster randomized longitudinal design, with a baseline household survey conducted in 2007 and subsequent follow-ups to the same households in 2009 and 2011. Per Figure 2, the impact evaluation was carried out in seven districts (now counties): Homabay, Kisumu, Migori, Suba (all Western Province), Kwale (Coastal Province), Garissa (North-East Province), and Nairobi.

Each survey consisted of a basic questionnaire on household and individual standard of living, consumption expenditure on food and non-food items, and demographic information. The 2011 survey also included an additional, detailed module which collected information on crop production and livestock ownership. Data from this final follow-up survey provided the base for our analysis.

The initial household sample, surveyed in 2007, consisted of 2,294 households split between 1,540 beneficiaries and 754 delayed beneficiaries (control). However, four years after the programme rolled out, the number of households participating in the evaluation had decreased, leading to a final attrition of 22.32 per cent with respect to the full sample. While attrition can undermine statistical inference, in the case of the CT-OVC data, mean differences in relevant household characteristics between beneficiaries and the counterfactual remained stable over time, suggesting that representativeness of the sample remained intact[10].

We excluded from the analysis sample households living in urban areas (Nairobi Area), as they showed levels of crop production and livestock ownership very close to "0". We also excluded from the



Source: Asfaw, *et al.*, 2014

[9] In this paper we refer to ultra-poor households as those which i) were in the bottom 20 percent of the consumption expenditure distribution, and ii) which fit CT-OVC targeting criteria, namely: presence of orphans and vulnerable children, low education level, poor dwelling quality, limited access to safe water, limited sources of income, and low asset ownership. The resulting demographic profile of beneficiaries proxies for families affected by HIV/AIDS. For more details on the CT-OVC programme's targeting criteria and definition of "ultra-poor households", see Handa *et al.*, (2012).

[10] For more details on CT-OVC sample attrition see Handa *et al.* (2014) and Handa *et al.* (2015).

analysis survey data from households located in Garissa. Livelihoods in Garissa are primarily pastoral and crop production is not the main activity. After removing urban households and families residing in Garissa, the remaining sample was 1,353 household units.

5 Results

5.1 Household characteristics

Table 1 presents descriptive characteristics of sample households disaggregated by district. Approximately 67 per cent of households received cash transfers through the CT-OVC programme, mean land holdings were 3.1 acres, 64 per cent of households were headed by women over 60, mean years of education for household head was under 4 years, and average household size was approximately 5.

Table 1 CT-OVC household sample characteristics by district

	Western province				**Coast province**		
	Homabay	Kisumu	Migori	Suba	Kwale	Total	F-test
Household livelihood							
CT-OVC beneficiaries (share)	0.68	0.67	0.72	0.69	0.47	0.67	16.01***
Agricultural land (acres)	2.00	3.27	2.80	3.83	3.92	3.11	82.18***
Household head characteristics							
Female	0.63	0.63	0.65	0.66	0.57	0.64	2.14
Age	60.61	62.40	60.04	60.06	53.94	60.24	43.13***
Years of education	3.55	3.62	3.38	3.39	1.87	3.35	22.89***
Demographic characteristics							
Household size	4.60	5.24	5.59	5.39	8.04	5.50	78.08***
Household expenditure							
Food expenditure	1975.14	2329.15	1874.99	2464.14	1721.65	2124.46	98.46***
Non-food expenditure	473.40	540.19	481.10	632.79	313.09	515.15	78.27***
Number of off-farm activities	1.39	1.19	1.36	1.63	0.94	1.35	57.05***
Community characteristics							
Local market (1=in the village)	0.38	0.23	0.22	0.23	0.68	0.29	66.25***
Road to the village (1 = yes)	0.52	0.90	0.79	0.95	0.74	0.81	81.10***
Drinkable water (1= within 60 minutes' walk)	0.71	0.91	0.93	0.73	0.85	0.84	34.20***
Number of observations	214	342	388	301	108	1353	

Note: Authors' analysis of 2011 CT-OVC data. We excluded from the sample urban areas and households residing in Garissa district. Mean differences are significant at ***=1% level, ** 5% level, * 10% level. The F-tests are obtained making use of ANOVA analysis and shown mean tests for differences across regions. Standard deviations are available upon request.

Households spent more money on food than anything else, an average of approximately 2,124 Ksh (US$21) per capita, per month. For contrast, monthly non-food expenditures averaged around 515 Ksh (US$5). The mean for off-farm activities was 1.14, indicating that, on average, sample households were benefitting from at least one off-farm income source other than agricultural production[11]. Although 81 percent of surveyed households reported road access and 84 percent reported access to potable water, only 29 percent of households reported living in a village with a local market.

[11] This variable did not include participation in CT-OVC as this was controlled for separately.

Taken together, these results imply a semi-autarkic food environment among surveyed households, comprised of some combination of production-for-own consumption and purchased foods.

5.2 *Agricultural diversification and household level dietary diversity*

Per Table 2, surveyed households reported harvesting approximately 2 crops per production cycle. The most frequently grown crops were cereals (96 percent), followed by beans and pulses. Eighty-eight percent of surveyed households reported owning at least one animal. Seventy-four percent of households reported raising poultry, 57 percent reported owning cattle, and 46 percent reported owning goats or sheep. A very small number - 2 percent – of households reported raising pigs. Again, data from Kwale indicate that families living in that district were relatively worse-off, most notably with respect to cattle and poultry holdings.

Table 2 Household agriculture practices

	Western province				Coast province		
	Homabay	Kisumu	Migori	Suba	Kwale	Total	F- test
Crops harvested (prevalence)							
Household harvested at least one crop (1=yes)	0.97	0.98	0.97	0.94	0.96	0.97	0.59
Number of crops harvested	2.07	2.29	1.91	1.94	1.62	2.02	56.88***
Cereals	0.97	0.97	0.97	0.94	0.94	0.96	0.59
Roots and Tubers	0.21	0.26	0.42	0.02	0.26	0.25	55.97***
Beans and pulses	0.54	0.65	0.42	0.32	0.45	0.48	57.92***
Vegetables and fruits	0.11	0.07	0.15	0.03	0.03	0.09	9.29**
Number of observations	214	342	388	301	108	1353	
Livestock owned (prevalence)							
Household owns at least one animal	0.88	0.92	0.89	0.87	0.74	0.88	8.01**
Cattle	0.57	0.65	0.63	0.55	0.12	0.57	75.24***
Poultry	0.79	0.81	0.79	0.65	0.54	0.74	29.38***
Goats and sheep	0.39	0.45	0.36	0.63	0.55	0.46	42.19***
Pigs	0.08	0	0.02	0	0	0.02	3.54
Number of observations	214	342	388	301	108	1353	

Note: Authors' analysis of 2011 CT-OVC data. We excluded from the sample urban areas and households residing in Garissa district. Mean differences are significant at ***=1% level, ** 5% level, * 10% level. The F-tests are obtained making use of ANOVA analysis and shown mean tests for differences across regions. Standard deviations are available upon request.

Per Table 3, all households reported consuming cereals during the 7 day recall period. In terms of micronutrient rich foods, almost all households reported consuming vegetables, 91 percent reported consuming fish, and 78 percent reported consuming pulses. Sixty-two percent of households reported consuming fruit and 65 percent reported consuming milk. Forty-one percent reported consuming meat and 32 percent reported consuming eggs.

However, in terms of expenditure shares, households spent a whopping 44 percent of their food budgets on cereals, with far less allocated to micronutrient rich foods. As such, given that the latter are more expensive than cereals, it is reasonable to assume that only minimal amounts of micronutrient rich foods were actually being eaten. In line with this assumption, although mean HDDS was 9.15, indicating a relatively high level of intake (i.e. approximately 9 out of 12 food groups per week), mean Simpson index level was 0.73 and mean Shannon index level was 1.61, indicating that a less than “even” distribution of food groups were being eaten, (1 and 2.48 indicate perfect “evenness” of distribution for the Simpson and Shannon indices, respectively).

There was strong and significant correlation between the three indicators ($p<0.00$): The Pearson cross-product correlation coefficient was equal to 0.62 between the HDDS and the Simpson index and 0.79 between the HDDS and the Shannon index. The correlation between the Simpson and the Shannon index was 0.90 (data not shown).

Table 3 Food consumption (valued in KSh., includes own production and purchased) and diet diversity indicators by district

Consumption by food group

	Homabay	Kisumu	Migori	Suba	Kwale	Total	F-test
Cereal	1	0.994	0.997	1	1	0.998	3.441
Tuber	0.664	0.673	0.735	0.575	0.407	0.646	48.168***
Beans and pulses	0.869	0.795	0.773	0.721	0.722	0.778	18.556***
Fruits	0.407	0.81	0.649	0.551	0.546	0.622	103.75***
Vegetables	0.986	0.991	0.997	0.997	0.815	0.979	157.71***
Meat	0.304	0.453	0.459	0.402	0.333	0.41	19.13***
Fish	0.939	0.909	0.907	0.993	0.648	0.911	119.68***
Eggs	0.308	0.389	0.358	0.286	0.0741	0.319	41.86***
Milk	0.617	0.751	0.696	0.558	0.574	0.657	34.01***
Fat	0.963	0.988	0.987	0.99	0.843	0.973	79.054***
Sugar	0.813	0.971	0.802	0.914	0.935	0.882	65.44***
Condiments (e.g. salt)	0.967	0.962	0.972	1	0.954	0.973	11.91**
Number of observations	214	342	388	301	108	1353	

Percent shares of food expenditure by food group

	Homabay	Kisumu	Migori	Suba	Kwale	Total	F-test
Cereal	0.48	0.37	0.44	0.44	0.55	0.44	133.71***
Tuber	0.04	0.04	0.05	0.03	0.02	0.04	67.32***
Beans and pulses	0.07	0.08	0.06	0.05	0.05	0.06	45.77***
Fruits	0.01	0.04	0.03	0.01	0.04	0.03	132.98***
Vegetables	0.08	0.08	0.09	0.08	0.06	0.08	61.07***
Meat	0.03	0.05	0.06	0.04	0.04	0.05	21.22**
Fish	0.09	0.09	0.08	0.14	0.04	0.09	215.82***
Eggs	0.01	0.01	0.01	0.01	0.00	0.01	27.30***
Milk	0.04	0.05	0.04	0.03	0.04	0.04	49.13***
Fat	0.05	0.06	0.06	0.06	0.05	0.06	23.16***
Sugar	0.05	0.08	0.05	0.07	0.08	0.06	159.50***
Condiments (e.g. salt)	0.01	0.01	0.01	0.01	0.01	0.01	22.03**
Number of observations	214	342	388	301	108	1353	

Food diversity indicators by district

	Homabay	Kisumu	Migori	Suba	Kwale	Total	F-test
Household diet diversity score	8.84	9.69	9.33	8.99	7.85	9.15	75.07***
Simpson index	0.70	0.78	0.73	0.73	0.60	0.73	156.91***
Shannon index	1.55	1.75	1.63	1.60	1.27	1.61	156.47***
Agriculture enterprise score	3.52	3.73	3.5	3.13	2.68	3.42	67.25***
Number of observations	214	342	388	301	108	1353	

Note: Authors' analysis of 2011 CT-OVC data. Note that reported levels of food expenditure and related food shares comprise monetary value of food from purchases, home production and food received as gifts or eaten out. Table 3.B does not report food shares classified as "other" foods as we could not identify their actual content; the share of expenditure devoted to "other " foods was minimal being on average equal to 0.03 and ranging between 0.04 in Homabay to 0.02 in Kwale. We excluded from the sample urban areas and household residing in Garissa district. Mean differences are significant at ***=1% level, ** 5% level, * 10% level. The F-tests are obtained making use of ANOVA analysis and shown mean tests for differences across regions.

5.3 Determinants of household diet diversity

Per Table 4, the AES was strongly and positively correlated with all three household diet diversity indices ($p<0.01$). All else equal, this result is important given that the sample in question was of ultra-poor families who were likely relying heavily on starchy staples to meet their caloric needs. The positive and significant association across all three diversity indices implies not only that diversified farming practices were associated with higher levels of diet diversity but also that farm diversification positively correlates with a more even distribution of consumption expenditure across all food groups, including more nutrient dense foods.

Participation in the CT-OVC programme also had a positive and significant association with diet diversity, confirming previous studies (Asfaw *et al.*, 2014; Kenya CT-OVC Evaluation Team, 2012) that receipt of the transfer increased consumption of nutrient-dense foods. To determine whether a production-for-own consumption effect was occurring in addition to the obvious income effect, we tested the association between participation in CT-OVC and the AES (through simple regression with AES as a dependent variable). The results (not shown) were negligible, indicating that the transfer's impact on diet diversification was channeled primarily through foods purchased, rather than via increased production diversification. These results are in line with findings from Asfaw *et al.* (2014).

Gender of household head was not associated with diet diversity. Age of household head had a negative and significant association with the HDDS though no significant relationship was detected with respect to the Simpson and Shannon indices.

Not surprisingly, wealth was a key determinant of diet diversification. Households in the bottom quintile[12] of the consumption expenditure distribution consumed on average 1.8 food groups ($p<0.01$) less compared to families in the wealthiest quintile. They also displayed significantly ($p<0.01$) lower values of the Simpson and Shannon indices.

Off-farm income was also positively associated with household diet diversity. These results are in line with theories which frame income diversification as an ex-ante risk management strategy for food insecure poor families (Barrett *et al.*).

[12] Note that quintiles of consumption expenditure were calculated based on the consumption data we extracted from the CT-OVC sample rather than ranking households based on quintiles of consumption expenditure obtained from a nationally representative household survey.

Table 4 Regression analysis of determinants of household dietary diversity

	Household diet diversity score	Simpson index	Shannon index
	(1)	(2)	(3)
Agriculture enterprise score	0.19***	0.01***	0.03***
	(0.037)	(0.002)	(0.007)
CT-OVC selection criteria			
CT-OVC beneficiary household (1=yes)	0.59***	0.02***	0.07***
	(0.090)	(0.006)	(0.016)
Agricultural land	-7.298e-04	-4.297e-04	-1.290e-03
	(7.210e-03)	(3.718e-04)	(1.098e-03)
Household head characteristics			
Female	0.14	0.01	0.03
	(0.106)	(0.008)	(0.021)
Age	-6.229e-03**	4.76e-04*	6.70e-04
	(2.898e-03)	(2.667e-04)	(6.128e-04)
Years of education	0.01	0.00**	0.01**
	(0.013)	(0.001)	(0.003)
Demographic household characteristics			
Household size	0.17***	-1.39e-03	3.44e-03
	(0.023)	(0.001)	(0.004)
Household expenditure and livelihood			
Food expenditure	4.18e-04***	4.84e-06	3.6e-05***
	(7.07e-05)	(4.69e-06)	(1.27e-05)
Non-food expenditure	-4.25e-04***	6.15e-06	3.88e-07
	(1.067e-04)	(7.96e-06)	(1.94e-05)
Expenditure quintile 1: Poorest	-1.87***	-0.07***	-0.19***
	(0.260)	(0.016)	(0.046)
Expenditure quintile 2	-1.07***	-0.04***	-0.10***
	(0.212)	(0.013)	(0.038)
Expenditure quintile 3	-0.36*	-0.02**	-0.04
	(0.184)	(0.011)	(0.031)
Expenditure quintile 4	-0.10	0.00	0.02
	(0.161)	(0.008)	(0.023)
Expenditure quintile 5: Wealthiest	pivot	pivot	pivot
	-	-	-
Off-farm activities	0.21***	0.01	0.02*
	(0.050)	(0.003)	(0.009)
Community characteristics			
Local market (1= in the village)	0.07	-4.07e-03	1.75e-03
	(0.112)	(0.008)	(0.020)
Road to the village (1=yes)	0.16	3.25e-03	0.03
	(0.119)	(0.009)	(0.024)
Drinkable water (1 = within 60 minutes' walk)	0.23*	0.01	0.04
	(0.137)	(0.010)	(0.025)
Geographical location			
Homabay	0.85***	0.06***	0.19***
	(0.195)	(0.018)	(0.043)
Kisumu	1.26***	0.13***	0.35***
	(0.170)	(0.016)	(0.038)
Kwale	pivot	pivot	pivot
	-	-	-
Migori	1.21***	0.08***	0.27***
	(0.180)	(0.017)	(0.040)
Suba	0.42**	0.07***	0.19***
	(0.181)	(0.016)	(0.039)
Obs.	1,353	1,353	1,353
R-squared	0.372	0.240	0.284

Note: OLS estimates are statistically significant at *** 1% level, ** 5% level, * 10% level and standard errors in parentheses are clustered at community level.

5.4 *Association between individual agricultural practices and household diet diversity*

In an attempt to assess which practices might play a greater role in shaping household dietary patterns in the sample population, we decomposed the AES to explore the association between individual farming practices and the three household diet diversity indicators (Table 5).

Table 5 Regression analysis of individual crop and livestock production practices on household diet diversity

	Household diet diversity score	Simpson index	Shannon index
	(1)	(2)	(3)
Crop Incidence			
Roots and tubers	0.015	0.003	0.014
	(0.095)	(0.006)	(0.017)
Beans and other pulses	0.382***	0.001	0.028
	(0.092)	(0.007)	(0.018)
Vegetables and fruits	0.004	-0.005	-0.012
	(0.152)	(0.009)	(0.026)
Livestock ownership			
Cattle	0.123	0.009	0.024
	(0.101)	(0.007)	(0.018)
Poultry	0.433***	0.014*	0.060***
	(0.113)	(0.008)	(0.021)
Goats and sheep	0.144*	0.009	0.022
	(0.085)	(0.006)	(0.016)
Obs.	1,353	1,353	1,353
R-squared	0.379	0.242	0.287

Note: OLS estimates are statistically significant at *** 1% level, ** 5% level, * 10% level and standard errors in parentheses are clustered at community level. Models are adjusted for the same covariates as those shown in Table 4.

Anticipating that disaggregation of the AES would likely result in confounding effects or intra-correlation, we also ran a series of robustness checks (data not shown). Results indicated the following clean correlations:

- Cultivation of pulses was associated with a significant ($p<0.01$) increase in the number of food groups consumed (i.e. HDDS). However, no significant relationship was detected with respect to diet distribution (i.e. Simpson and Shannon indices).
- Poultry ownership was significantly ($p<0.01$) and positively correlated with all three diet diversification outcome variables.

Should these associations be attributed to increased availability of foods due to production-for-own-consumption, or to income effects resulting from the sale of agricultural products? As described in Section 2, both are principle pathways through which agricultural production is hypothesized to impact household dietary diversity and, eventually, nutrition outcomes.

To assess the extent to which bean production and poultry ownership as well as other production practices were associated with household diet diversity through income effects versus production-for-own-consumption effects, we tested whether individual crop and livestock practices correlated with incidence of HDDS food groups (Annex 1).

If cultivation of a certain crop or ownership of a certain livestock type significantly increased the likelihood of consuming a variety of food groups, the conclusion was that the activity might plausibly increase diet diversity primarily via income effects. Conversely, if a particular production practice was significantly associated with only those few foods which could be the result of that specific activity (e.g. cow ownership and milk) the own-consumption pathway was assumed to be more likely.

Pulses were strongly associated with their own consumption and milk's ($p<0.01$), as well as more weakly with tubers, fish, fat ($p<0.05$), and meat ($p<0.1$). Poultry displayed a strong and significant association ($p<0.01$) with pulses, fruit, and meat, as well as a weaker but still significant association with eggs ($p <0.05$) and milk ($p<0.1$).

These results are intuitive, suggesting that as well as being eaten on-farm, beans were being used to purchase, *inter alia*, other foods. Similarly, poultry require few inputs, mature quickly, and are affordable relative to larger livestock. Previous studies have found that poultry is frequently sold in order to purchase other types of foods as well as non-food items (Azzarri *et al.*, 2014; Robinson *et al.*, 2007). As such, poultry can be considered "liquid assets" which are attractive and accessible to extremely poor households facing chronic, severe income constraints.

Goats and sheep, which may also be considered "liquid" relative to cattle, were significantly associated with increased consumption of fish ($p<0.01$) as well as pulses and meat ($p<0.05$). Cereals were associated with increased consumption of meat and milk ($p<0.05$) and more weakly with beans ($p<0.1$).

Conversely, tubers were strongly associated with their own consumption ($p<0.01$) and nothing else, and cattle holdings were markedly associated with milk ($p<0.01$). These results imply a production-for-own consumption effect.

Cattle are less "liquid" than poultry and smaller livestock. They require more inputs, mature less quickly and are less affordable. As such, within the CT-OVC sample, cattle ownership might have contributed substantially to milk consumption via production-for-own consumption, but not to overall diet diversity via income effect. This conclusion is in line with the data's reflection of thin markets, implying high perishability risk and consequent reduced incentive to sell.

5.5 Interaction terms and robustness checks

We interacted the AES with a number of control variables - gender of household head, level of education of household head, proximity to a local market, and participation in the CT-OVC programme - to further test associations between farming diversification, household characteristics and diet diversification (data not shown except for gender, Table 6).

While the interaction terms were always positive, we found a significant result (at 10%) only when interacting the AES with female headed households in the HDDS model, implying a stronger association between farm diversification and diet diversity for female than male headed households.

Finally, as a robustness check, we reran the model with a stepwise exclusion of control variables deemed to be relevant in the model specification (Annex 2). With these covariates removed from the model, we found that the association between the AES and household diet diversity increased consistently and remained significant, thus providing evidence of the overall robustness of our model.

Table 6 Interaction between gender of the head and agriculture enterprise score

	Household diet diversity score	Simpson index	Shannon index
	(1)	(2)	(3)
Female head	-0.080	4.27e-04	0.003
	(0.166)	(0.013)	(0.032)
Agriculture enterprise score	0.195***	0.006***	0.025***
	(0.037)	(0.002)	(0.007)
Female headed * Agriculture enterprise score	0.334*	0.011	0.043
	(0.198)	(0.015)	(0.038)

Note: OLS estimates are statistically significant at *** 1% level, ** 5% level, * 10% level and standard errors in parentheses are clustered at community level. Models are adjusted for the same covariates as those shown in Table 4.

6 Conclusions and policy message

While historically, limited attention has been given to linking agriculture to nutrition, especially in the context of semi-subsistence producers, growing interest in the feedback loops between agriculture, food systems, and nutrition is now building the evidence base for this type of information, with a growing number of studies looking explicitly at the links between household diet diversity and various measures of production diversification (Powell *et al.*, 2015; Carletto *et al.*, 2015).

This study attempts to contribute by showing that production diversification was significantly and positively correlated with household diet diversification in a sample of ultra-poor, labor-constrained, subsistence-oriented farmers.

Of all the on-farm activities included in the analysis, poultry had the most compelling correlation with household diet diversification, followed by pulses. In both cases, the association was most plausibly attributed to an income effect. There was also a significant association between cattle holdings and milk consumption, likely attributable to a production-for-own-consumption effect, and significant findings linking small livestock to a variety of food groups.

From a "nutrition-sensitive" policy perspective, our findings are thus indicative of the potential value of four broad intervention areas: (i) Support to diversified farming systems and diversified income sources; (ii) promotion and support of poultry and small livestock holdings; (iii) promotion and support of cow ownership; and (iv) "pro poor" attention to districts with limited agricultural potential and labor constraints.

In a semi-autarkic smallholder context, a diversification strategy which integrates crop and livestock production adds value directly via increasing diet diversity and quality, and indirectly via income effects. In addition to improving diets, diversifying into the production of pulses, vegetables and fruits (currently not widely practiced) and livestock serves as a risk management instrument, protecting against weather and market shocks. Pulse production in particular is a sound investment strategy given their nutrient value, low water footprint, and low carbon-to-nitrogen ratio, the latter especially important given current soil depletion challenges facing many smallholders.

That said, given that our findings are not nationally representative and as such must be applied exclusively to extremely poor, rural populations, it may be that sub-district or even community-based promotion of and support to poultry enterprises is an especially important intervention to emphasize. Scavenging family poultry provide much-needed protein and income at very low investment and operating costs. Chicken meat and eggs are sources of not only high-quality protein, but also important vitamins and minerals. And while increased milk consumption is a valuable consideration when the ultimate objective is improved nutrition outcomes in small children, the start-up and maintenance costs of cow ownership may put this type of intervention out of reach for very low income farmers. In contrast, poultry require few inputs, mature quickly, and are affordable even for extremely poor households facing chronic and severe income constraints.

An additional, related consideration concerns the fact that many districts in Kenya suffer from water stresses and over-pumping of boreholes. The chances of poultry production efforts attaining success is thus increased if complimentary measures to establish adequate and sustainable water supplies are in place. Such measures are of course also incentives for diversification into small livestock holdings and horticulture.

In conclusion, it is important to note the shrinking size of African smallholder farms (Jayne *et al.*, 2014). Farm families are having to do more with less, as in many cases area expansion is not an option. And while increasing yield per hectare of one or two heavily promoted and often subsidized cereal crops has been the de facto response for decades, climate change concerns, land degradation, loss of biodiversity and other sustainability issues- not to mention stubborn and deadly rates of undernutrition - point to an increasingly pressing need to do things differently (FAO, 2013; Pingali, 2015; World Bank, 2016, Global Panel on Agriculture and Food Systems, 2013). Government policies in agriculture, especially those directed towards small and marginal farms, need to support diversified farming systems, giving greater attention to poultry, pulses, fruits and vegetables than hitherto.

7 References

Arimond, M. & Ruel, M.T. 2004. Dietary diversity is associated with child nutritional status: evidence from 11 demographic and health surveys. *Journal of Nutrition,*134(10), 2579-2585.

Arimond, M., Wiesmann, D., Becquey, Carriquiry, E., Melissa, A. Daniels, A., Deitchler, M., Fanou-Fogny, N., Joseph, M. L., Kennedy, G., Martin-Prevel, G., Y. & Torheim, L.E. 2010. Simple Food Group Diversity Indicators Predict Micronutrient Adequacy of Women's Diets in 5 Diverse, Resource-Poor Settings. *Journal of Nutrition,* 140(11), 20595-20695.

Asfaw, S., Davis, B., Dewbre, J., Handa, S. & Winters, P. 2014. Cash Transfer Programme, Producitive Activities and Labour Supply: Evidence from a Randomised Experiment in Kenya. *Journal of Development Studies*, 50(8), 1172-1196.

Azzarri, C., Cross, E., Haile, B. & Zezza, A. 2014. Does livestock ownership affect animal source foods consumption and child nutritional status? Evidence from rural Uganda. In: Presentation at the Farm Production and Nutrition Workshop, World Bank, June 7.

Barrett, C., Reardon, T. & Webb, P. 2001a. Nonfarm Income Diversification and Household Livelihood Strategies in Rural Africa: Concepts, Dynamics and Policy Implications. *Food Policy,* 26(4), 315-331.

Black, R. E., Allen, L.H., Bhutta, Z. A., Caulfield, L.E., de Onis, M., Ezzati, M. & Rivera, J. and Child Undernutrition Study Group. 2008. Maternal and child undernutrition: global and regional exposures and health consequences. *The Lancet*, 371(9608), 43-260.

Bouis, H. E., Eozenou, P. & Rahman, A. 2011. Food prices, household income, and resource allocation: Socioeconomic perspectives on their effects on dietary quality and nutritional status. *Food and Nutrition Bulletin*, 32(1), 14-23.

Carletto, C., Zezza, A. & Banerjee, R. 2013. Towards better measurement of household food security: Harmonizing indicators and the role of household surveys. *Global Food Security*, *2*(1), 30-40.

Carletto, C., Ruel, M., Winters, P. & Zezza, A. 2015. Farm-Level Pathways to Improved Nutritional Status: Introduction to the Special Issue, *The Journal of Development Studies, 51:8, 945-957.*

Clausen, T., Charleton, K.E., Gobotswang, K. & Holmboe-Ottesen, G. 2005. Predictors of food variety and dietary diversity among older persons in Botswana. *Nutrition*, 21(1), 86–95.

Davis, B., Winters, P., Carletto, G., Katia, Covarrubias, Quinones, E., Zezza, A., Stamoulis, K.G. & Di Giuseppe, S. 2010. A Cross-Country Comparison of Rural Income Generating Activities. World Development, 38(1), 48-63.

Deaton, A. & Zaidi, S. 2002. Guidelines for Constructing Consumption Aggregates for Welfare Analysis, World Bank Publications, The World Bank, number 14101.

FAO. 2013. State of Food and Agriculture 2013: Food Systems for Better Nutrition (available at www.fao.org/publications/sofa/2013/en).

FAO. 2015. Key Recommendations for Improving Nutrition through Agriculture and Food Systems. Rome.

Fiedler, J., Carletto, C. & Dupriez, O. 2012. Still waiting for Godot? Improving household consumption and expenditure surveys to enable more evidence-based nutrition policies. *Food and Nutrition Bulletin*, 33(3), 242-251.

Fiszbein, A. & Schady, N. 2009. Conditional cash transfers: reducing present and future poverty. Washington, DC, The World Bank**:** 361.

Gillespie, S., Harris, J. & Kadiyala, S. 2012. The agriculture nutrition disconnect in India: what do we know? IFPRI Discussion Paper 01187. Washington, DC: International Food Policy Research Institute.

Global Panel on Agriculture and Food Systems for Nutrition. 2014. *How can Agriculture and Food System Policies improve Nutrition?* Technical Brief, London, UK: Global Panel on Agriculture and Food Systems for Nutrition.

Handa, S. Huang, C., Hypher, N., Teixeira, C., Soares, F.V. & Davis, B. 2012. Targeting effectiveness of social cash transfer programmes in three African countries. *Journal of Development Effectiveness,* 4(1), 78-108.

Handa, S., Halpern, C., Pettifor, A. & Thirumurthy, H. 2014. The Government of Kenya's Cash Transfer Program Reduces the Risk of Sexual Debut Among Young People Age 15-25. *PLOS ONE*, 9(1), 1-9.

Handa, S., Peterman, A., Huang, C., Halpern, C., Pettifor, A. & Thirumurthy, H. 2015. Impact of the Kenya Cash Transfer for Orphans and Vulnerable Children on early pregnancy and marriage of adolescent girls. *Social Science & Medicine*, (141) 36-45.

Hawksworth, D.L. 1995. In D.L. Hawksworth (ed.), Biodiversity Measurement and Estimation. The Royal Society and Chapman and Hall, London.

Headey, D., Taffesse, A. S. & Liangzhi, Y. 2014. Diversification and Development in Pastoralist Ethiopia. *World Development,* 56(C), 200-213.

Headey, D., Chiu, A. & Kadiyala, K. 2012. Agriculture's role in the Indian enigma: help or hindrance to the crisis of undernutrition? *Food Security,* 4(1), 87-102.

Herforth, A. 2010. Promotion of Traditional African Vegetables in Kenya and Tanzania: A Case Study of an Intervention Representing Emerging Imperatives in Global Nutrition. Cornell University, Ithaca, NY.

Herforth, A. & Harris, J. 2013. Conceptual Framework Linking Agriculture to Nutrition (draft). In: Agriculture for Nutrition and Health (A4NH) Gender-Nutrition Methods Workshop: Nairobi: International Food Policy Research Institute.

Herforth, A. & Harris, J. 2014. Understanding and Applying Primary Pathways and Principles. Brief #1. Improving Nutrition through Agriculture Technical Brief Series. Arlington, VA: USAID/Strengthening Partnerships, Results, and Innovations in Nutrition Globally (SPRING) Project.

Hoddinot, J. & Yohannes, Y. 2002. Dietary diversity as a food security indicator. Washington DC: International Food Policy Research Institute.

Hoddinott, J., Headey, D. & Dereje, M. 2014. Cows, missing milk markets and nutrition in rural Ethiopia. In: Presentation at the Farm Production and Nutrition Workshop, World Bank, June 7.

Improving Nutrition Through Multisectoral Approaches. 2013. Washington DC: The World Bank, Washington DC (available at http://documents.worldbank.org/curated/en/2013/01/17211210/improving-nutrition-through-multisectoral-approachess).

Jayne, T., Chamberlin, J. & Headey, D. 2014. Land pressures, the evolution of farming systems, and development strategies in Africa: A synthesis. *Food Policy* 48: 1-17.

Jin, M. & Iannotti, L. 2014. Livestock production, animal source food intake, and young child growth: The role of gender for ensuring nutrition impacts. *Social Science and Medicine*, (105), 16-21.

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

Kadiyala, S., Harris, J., Headey, D., Yosef, S. & Gillespie, S. 2014. Agriculture and nutrition in India: mapping evidence to pathways. *Annals of the New York Academy of Sciences*, 1331(1), 43-56.

Kanter, R., Walls, H.L., Tak, M., Roberts, F. & Waage, J. 2015. Conceptual framework of the links between agriculture, the food system and public health nutrition. *Food security*, 7(4), 767-777.

Kennedy, G., Ballard, T. & Dop, M.C. 2013. Guidelines for measuring household and individual diet diversity, 2013. The Food and Agriculture Organization of the United Nations. http://www.fao.org/docrep/014/i1983e/i1983e00.pdf

Kenya Demographic and Health Survey: Key Indicators. 2014. Nairobi: National Bureau of Statistics (available at http://dhsprogram.com/pubs/pdf/PR55/PR55.pdf).

Kutner, M. H., Nachtsheim, C. J. & Neter, J. 2004. Applied Linear Regression Models, fourth ed. McGraw-Hill Irwin.

Meeker, J. & Haddad, L. 2013. A State of the Art Review of Agriculture-Nutrition Linkages. Institute of development studies report

Meng, E. C. H., Smale, M., Bellon, M. & Grimanelli, D. 2010. Farmer gene banks and crop breeding: economic analyses of diversity in wheat, maize and rice. In: Smale, M. (ed.), Definition and Measurement of Crop Diversity for Economic Analysis. Kluwer Academic Publishers, The Netherlands, 19-32.

Nicholson, C.F., Mwangi, L., Staal, S.J. & Thornton, P.K. 2003. Dairy Cow Ownership and Child Nutritional Status in Kenya. *American Agricultural Economics Association (New Name 2008: Agricultural and Applied Economics Association).*

Pingali, P.L. 1997. From Subsistence to Commercial Production Systems: The Transformation of Asian Agriculture. *American Journal of Agricultural Economics.* 79(2), 628-634.

Pingali, P. 2015. Agricultural policy and nutrition outcomes – getting beyond the preoccupation with staple grains. *Food Sec,* 7:585-591.

Pinstrup-Andersen, P. 2010. The African food system and human health and nutrition: a conceptual and empirical overview. In P. Pinstrup-Andersen (Ed.), *The African Food System and Its Interaction with Human Health and Nutrition* (pp. 1–13). Cornell University Press.

Powell, B., Haraksingh Thilstead, S., Ickowitz, A., Termote, C., Sunderland, T. & Herforth, A. 2015. Improving diets with wild and cultivated bioversity from across the landscape. *Food Sec.* 7:535-554.

Rawlins, R., Pimkina, S., Barrett, C. B., Pedersen, S. & Wydick, B. 2014. Got milk? The impact of Heifer International's livestock donation programs in Rwanda on nutritional outcomes. *Food Policy*, 44(C), 202-13.

Ruel, M.T. 2003. Operationalizing dietary diversity: a review of measurement issues and research priorities. *Journal of Nutrition*, 133: 3911S-26S.

Ruel, M.T., Alderman, H. & Maternal and Child Nutrition Study Group. 2013a. Nutrition-sensitive interventions and programmes: how can they help to accelerate progress in improving maternal and child nutrition? *The Lancet*, 382(9891), 536–551.

Ruel, M.T., Harris, J. & Cunningham, K. 2013b. Diet quality in developing countries. Preedy, Victor R., Hunter, Lan-Anh; Patel, Vinood B. (ed.), In *Diet Quality: An Evidence-Based Approach* (239-261). New York: Springer.

Shannon, C.E. & Weaver, W. 1948. A mathematical theory of communication*. The Bell System Technical Journal*, (27), 379-423 and 623-56.

Simpson, E.H. 1949. Measurement of diversity. *Nature,* (163), 688.

Smale, M., Hartell, J., Heisey, P.W. & Senauer, B. 1998. The contribution of genetic resources and diversity to wheat production in the Punjab of Pakistan. *American Journal of Agriculture Economics,* 80(3), 482-493.

Swindale, A. & Bilinsky, P. 2006. Household dietary diversity score (HDDS) measurement of household food access: indicator guide, Version 2. Food and Nutrition Technical Assistance Project, Academy for Educational Development, Washington, D.C.

The Kenya CT-OVC Evaluation Team. 2012. The impact of the Kenya Cash Transfer Program for Orphans and Vulnerable Children on household spending. *Journal of Development Effectiveness*, 4(1), 9-37.

FAO, IFAD & WFP. 20125. *The State of Food Insecurity in the World 2012. Economic growth is necessary but not sufcientto accelerate reduction of hunger and malnutrition*. Rome, FAO (available at www.fao.org/docrep/016/i3027e/i3027e.pdf).

Thorne-Lyman, A.L., Valpiani, N., Sun, K., Semba, R.D., Klotz, C.L., Kraemer, K., Akhter, N., de Pee, S., Moench-Pfanner, R., Sari, M. & Bloem, M. W. 2010. Household dietary diversity and food expenditures are closely linked in rural Bangladesh, increasing the risk of malnutrition due to the financial crisis. *Journal of Nutrition,* 140(1), 182-188.

Torheim, L.E., Ouattara, F., Diarra, M.M., Thiam, F. D., Barikmo, I., Hatløy, A. & Oshaug, A. 2004. Nutrient adequacy and dietary diversity in rural Mali: association and determinants. *European Journal of Clinical Nutrition*, 58(4), 594-604.

Webb, P. 2013. Impact Pathways from Agricultural Research to Improved Nutrition and Health: Literature Analysis and Research Priorities*. Background Paper prepared for the ICN2*. Rome: FAO.

World Bank. 2016. Future of Food: Shaping the Global Food System to Deleiver improved Nutrition and Health. Washington DC: World Bank.

Annex 1: Individual crop and livestock practices by incidence of HDDS food groups

Variable	Cereals	Tubers	Beans	Fruits	Vegetables	Meat	Fish	Eggs	Milk	Fat	Sugar	Condiments
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Roots and tubers	-0.000	0.071**	0.006	0.009	0.001	-0.037	-0.015	0.020	-0.003	0.001	-0.003	0.002
	(0.002)	(0.029)	(0.023)	(0.027)	(0.001)	(0.027)	(0.010)	(0.028)	(0.027)	(0.008)	(0.011)	(0.004)
Number of observations	1,353	1,353	1,353	1,353	1,353	1,353	1,353	1,353	1,353	813	1,353	1,353
Variable	Cereals	Tubers	Beans	Fruits	Vegetables	Meat	Fish	Eggs	Milk	Fat	Sugar	Condiments
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Beans and pulses	0.002	0.071**	0.101***	0.046	-0.000	0.051*	0.031**	0.039	0.092***	-0.014**	0.023	0.003
	(0.003)	(0.031)	(0.023)	(0.033)	(0.001)	(0.029)	(0.012)	(0.026)	(0.030)	(0.007)	(0.014)	(0.005)
Number of observations	1,353	1,353	1,353	1,353	1,353	1,353	1,353	1,353	1,353	813	1,353	1,353
Variable	Cereals	Tubers	Beans	Fruits	Vegetables	Meat	Fish	Eggs	Milk	Fat	Sugar	Condiments
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Cattle	-0.005*	0.031	0.060**	-0.008	-0.001	0.048	-0.010	-0.010	0.140***	-0.015**	0.019*	0.002
	(0.003)	(0.029)	(0.027)	(0.032)	(0.001)	(0.031)	(0.011)	(0.028)	(0.030)	(0.007)	(0.011)	(0.006)
Number of observations	1,353	1,353	1,353	1,353	1,353	1,353	1,353	1,353	1,353	813	1,353	1,353
Variable	Cereals	Tubers	Beans	Fruits	Vegetables	Meat	Fish	Eggs	Milk	Fat	Sugar	Condiments
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Poultry	0.000	0.032	0.096***	0.085***	0.002	0.131***	0.006	0.072**	0.048*	0.001	0.026	0.011
	(0.000)	(0.033)	(0.026)	(0.031)	(0.002)	(0.032)	(0.014)	(0.033)	(0.028)	(0.006)	(0.016)	(0.007)
Number of observations	1,353	1,353	1,353	1,353	1,353	1,353	1,353	1,353	1,353	813	1,353	1,353
Variable	Cereals	Tubers	Beans	Fruits	Vegetables	Meat	Fish	Eggs	Milk	Fat	Sugar	Condiments
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Goats and sheep	0.000	0.030	0.054**	0.008	-0.000	0.065**	0.033***	-0.009	0.036	0.010	0.015	0.006
	(0.000)	(0.028)	(0.021)	(0.028)	(0.001)	(0.028)	(0.012)	(0.026)	(0.027)	(0.008)	(0.015)	(0.006)
Number of observations	1,353	1,353	1,353	1,353	1,353	1,353	1,353	1,353	1,353	813	1,353	1,353

Note: Probit marginal effects are significant at 1 % level, ** 5% level, * 10% level and standard errors are clustered at community level. Dependent variables are consumption of food groups obtained from the consumption module. Each cell is the result of one probit model in which the dependent variable is regressed one farm activity (e.g. cereals) and estimates are adjusted for the same covariates as those shown in Table 4. Cereals, Vegetables and Fruit and Pigs are leaved out from the placebo test due to the low variability of the variables from either the production or the consumption side.

Annex 2: Agriculture enterprise count on food diversity, robustness checks

	Panel A: Excluding CT-OVC controls			**Panel B:** Excluding household head characteristics			**Panel C:** Excluding wealth and income sources variables			**Panel D:** Excluding geographical controls		
-	Household diet diversity score	Simpson index	Shannon index	Household diet diversity score	Simpson index	Shannon index	Household diet diversity score	Simpson index	Shannon index	Household diet diversity score	Simpson index	Shannon index
-	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Agricultural. enterp. score	0.195***	0.006***	0.025***	0.247***	0.006***	0.027***	0.317***	0.010***	0.039***	0.270***	0.010***	0.039***
	(0.037)	(0.002)	(0.007)	(0.036)	(0.002)	(0.006)	(0.037)	(0.002)	(0.006)	(0.038)	(0.002)	(0.007)

Note: OLS estimates are statistically significant at *** 1% level, ** 5% level, * 10% level and standard errors in parentheses are clustered at community level. We excluded from the model presented in Table 4 set of variables to test the robustness of our finding.

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