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Child health and crop diversification: Empirical evidence from Tanzania

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Abstract. Malnutrition is recognized as a major issue among low-income households in developing countries with long-term implications for economic development. Recently, crop diversification has been recognized as a strategy to improve nutrition and health, and as a risk coping strategy used by farmers in the face of climate change. However, there is no systematic empirical evidence on the role played by crop diversification in improving human health. We use the Tanzania National Panel Survey to investigate whether crop diversification could be considered as a promising agricultural strategy to improve child health in Tanzania controlling for unobservable heterogeneity. We find a positive and significant effect of crop diversification on long-term child nutritional status, in particular for very young children and children living in households with limited market access.

Keywords: child health; crop diversification; health policy; nutrition; agriculture; Tanzania

JEL Classification: I12, I15, O12; Q12; Q18, Q56

1. Introduction

Improving children nutrition has become an important goal for most developing countries' governments given its long-term implications for health, human capital formation, productivity and income during adulthood, and economic development (Alderman et al., 2006a; World Bank, 2006). Malnutrition is recognized as a major issue among low-income households in developing countries (UNICEF-WHO-World Bank Group, 2015). In Tanzania, despite the improvements of the last two decades, child malnutrition is still prevalent, in particular in rural areas where subsistence farming is the main source of food (Ecker et al., 2011). About 42 percent of children under age five are stunted making Tanzania one of the ten worst affected country in the world (World Health Organization, 2012). In this study, we investigate whether crop diversification could be considered as a promising agricultural strategy to improve child health in Tanzania.

Different strategies have been proposed to improve children nutritional status such as nutrition educational activities, school feeding programs, encouraging breastfeeding, or price subsidies (e.g., Barrera, 1990; Christiaensen and Alderman, 2004; Bhutta et al., 2008, 2013; Jensen and Miller, 2011; Kazianga et al., 2014). In Tanzania, for example, NGOs have been introducing community driven supplementary feeding for young children and feeding posts (Alderman et al., 2006b). More recently, agricultural interventions have also been recognized as a way to improve nutrition and health (e.g., Frison et al., 2006; Ecker et al., 2011; Hirvonen and Hodinott, 2014; Dillon et al., 2014).

In the context of developing countries, agriculture plays a dual role in affecting adults and children nutrition. As shown in Ruel and Alderman (2013), households can benefit from agricultural activities as a source of income for the purchase of food products and through the direct provision of healthy and diverse foods for own consumption. In areas of prevalent subsistence farming and limited access to the food markets, such as in rural Tanzania (Ecker et al., 2011), the latter contribution gains greater relevance (Arimond and Ruel, 2004). This suggests that nutritional gains can be achieved through a variety of interventions: interventions that boost agricultural income (e. g. improved seeds variety), interventions that improve access to food markets (e.g. roads) or interventions that improve the quality and variety of the products for own consumption (e.g. crop diversification). Given the pervasive presence of heterogeneous market failures in developing countries, what policy works best is a complex matter.

In this paper we investigate the direct impact of existing crop diversification practices on child nutrition through improved dietary diversity. To the best of our knowledge, there is no systematic empirical evidence on the role played by crop diversification in improving human health status. Most of the empirical evidence focuses on either the relationship between agricultural diversification and dietary diversity (e.g., Remans et al., 2011; Hirvonen and Hodinott, 2014; Dillon et al., 2014), or the relationship between dietary diversity and anthropometric outcomes (e.g., Arimond and Ruel, 2004; Kennedy et al., 2007; Moursi et al., 2008; Steyn et al., 2006). This paper bridges the gap between these two strands of literature by investigating the effect of crop diversification on child health via dietary diversity.

Monoculture production has proven to endanger food security in particular in view of the increasing climate variability (Di Falco and Chavas, 2008; Di Falco et al., 2011).[1] In particular, crop diversification is widely recognized as a risk coping strategy used by farmers in the face of climate change (e.g., Seo and Mendelshon, 2008; Wang et al., 2010; Di Falco and Veronesi, 2013). Despite being advocated by many international organizations as an easy-to-implement response to climate variability (UNFCCC, 2009), crop diversification still remains scarcely adopted in many parts of sub-Saharan Africa (Mugendi Njeru, 2013). By analysing the potential co-benefits of climate adaptation strategies, through their effects on children health in rural areas, this paper provides evidence in support of the adoption of such resilience strategy in most impoverished areas. The literature on the co-benefits

[1] A historic example of the negative effects of monoculture is the potatoes famine experienced in Ireland during the period 1845-52.

of mitigation and adaptation strategies in developing countries is very limited but it is much needed by international and national organizations seeking interventions that can help achieve the double outcome of environment preservation and poverty alleviation (Lovo et al., 2015).

We use the Tanzania National Panel Survey (TZNPS), an integrated survey on agriculture covering about 4,000 children over the period 2008-2013, to investigate the relationship between crop diversification and child health. The use of panel data allows us to account for potential omitted variable bias related to time invariant unobservable factors such as parents' childbearing abilities. In addition, we perform several robustness checks, and placebo tests to address remaining endogeneity concerns. We control for a rich set of covariates that includes child and household characteristics, as well as services accessibility such as water and electricity, and weather conditions. We use different measures of crop diversification to support our findings, including a GPS-based measure that addresses potential concerns related to self-reported measurements. In addition, we investigate the mechanism underlying the relationship between crop diversification and child health by providing some evidence on the link between dietary diversity and crop diversification. We find that crop diversification has a positive and significant effect on long-term child nutritional status via higher dietary diversity, in particular for very young children and children living in households with limited market access.

The paper is organised as follows. In Section 2 we describe the data and in Section 3 we present the empirical strategy. In Section 4 we describe the results, perform several robustness checks, and explore potential heterogeneous effects. In Section 5 we provide some evidence on the underlying mechanism between crop diversification and child health. We provide concluding remarks and discuss policy implications in Section 6.

2. Data description

The empirical analysis uses child-level data provided by the Tanzania National Panel Survey (waves 1-3) conducted in years 2008/2009, 2010/2011, and 2012/2013 by the Tanzania National Bureau of Statistics (NBS) as part of the World Bank Living Standards Measurement Study - Integrated Surveys on Agriculture.[2] The survey is representative at the national level and is characterised by very low sample attrition: about 97 percent of the households were re-interviewed in the following waves (NBS, 2014). The survey assembles a wide range of information on agricultural production, non-farm income generating activities, consumption expenditures, and other socio-economic characteristics.

In particular, the Tanzania National Panel Survey collects information on anthropometrics for all adults and children. We use this information to compute a set of standard anthropometric measures: height-for-age z-score (HAZ), weight-for-age z-score (WAZ), and BMI[3]-for-age z-score (BAZ).[4] These measures indicate the number of standard deviations above or below the reference mean value provided by the World Health Organization (WHO) according to the age and gender of the child. WHO provides reference values for children age 0 to 19 (WHO, 2006; de Onis et al., 2007). The height-for-age z-score is considered as a measure of long-term nutritional status, while the weight-for-age z-score is an indicator of short-term health conditions, and the BMI-for-age z-score is considered to provide a combination of both (Delgado et al., 1986; Caulfield et al., 2006).

In addition, the Tanzania National Panel Survey collects information on fifty different types of seasonal crops, and more than thirty permanent crops. The classification is consistent across years. This allows us to compute the Margalef index of crop diversification (Benin et al., 2004; Di Falco et al., 2010). The Margalef index is calculated as $M_{jt} = \frac{C_{jt}-1}{ln\,(A_{jt})}$, where C_{jt} represents the number of crops

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[2] The data set can be found at http://go.worldbank.org/EJMAC1YDY0 (accessed on April 29, 2016).
[3] BMI stands for Body Mass Index.
[4] Our anthropometric measures were calculated using the World Health Organization Anthro macro for STATA for children up to five years of age, and the World Health Organization AnthroPlus macro for STATA for older children. The macro allows for the computation of the weight-for-age z-score only for children up to 10 years old. The macro can be found at http://www.who.int/childgrowth/software/en/ (accessed on April 29, 2016).

grown by household j at time t and A_{jt} is the total area cultivated. We compute the Margalef index considering the total number of seasonal and permanent crops grown in both short and long rainy seasons, and excluding crops with little or none nutritional properties such as cash crops (e.g., cotton and wood) and spices. The complete list of crops by food category is reported in Table A1 of the appendix.

As a robustness check we also construct alternative indicators of crop diversification. First, we consider the Shannon-Wiener index, which accounts for species richness and evenness. This index is given by $(-\sum_k p_k \, ln \, p_k)$ where p_k is the share of land planted with each crop k. While this index might provide a more detailed account of spatial diversification, it also relies more heavily on the accuracy of land measurement data, which are proved to be particularly noisy when households adopt intercropping (64 percent of plots in 2010). As second indicator of crop diversification, we use the number of crops grown by the household that allows an easier economic interpretation of the results. In addition, we compute the Margalef index using GPS-based plot size to address concerns regarding the use of self-reported measurements.[5]

We consider only children in households engaged in agriculture in at least two years and that did not split off between waves (about 1,500 households). In addition, we exclude children for whom anthropometric measures were not collected. Table 1 reports the descriptive statistics for the main variables used in the empirical analysis. The statistics refer to 4,036 children (10,496 observations). As robustness check, we also restrict the analysis to subsistence households, that are households that did not sell crops in any waves. This sub-sample accounts for about 15 percent of total households (622 children; 1,601 observations).

[5] Unfortunately, GPS measures are available only for the last two waves of the panel survey, and so we cannot use this index as our main measure of crop diversification throughout our study for all three waves. However, we can show that the strong and positive association between the Margalef index and child health remains even when we use a GPS-based Margalef index.

[TABLE 1 ABOUT HERE]

The final sample is equally split between boys and girls. The average child is about eight years old, 120 centimetres tall, and weighs about 25 kilos. About 82 percent of children are severely underweight (BMI < 17.6), about eight percent are underweight (17.5 < BMI < 18.6), and about 11 percent have an optimal weight (18.5 < BMI < 25.1). We observe a significant improvement overtime in the height-for-age z-score, in the BMI-for-age z-score, and in the Margalef index or number of crops (*p*-value = 0.000, based on ANOVA tests). These simple comparisons seem to indicate that greater crop diversification is associated to better child health. In addition, the percentage of children working on farm has significantly increased from 14 percent in the first wave to 27 percent in the last wave (*p*-value = 0.000). A similar pattern is observed for children attending school, from 48 percent to 63 percent (*p*-value = 0.000).

Average land size is of about eight hectares per household. The most common seasonal crop is maize followed by beans and paddy. The number of crops grown is on average between three and four with a minimum of one (about 10 percent of the sample) and a maximum of 17 (0.02 percent). About 89 percent grow between one and seven crops while about 11 percent grow more than seven crops. Other variables of interest include household consumption (in thousands of USD), whether the household owned livestock in the last year, the presence of elderly people in the household, the average annual total rainfall (mm), access to treated water and electricity (including solar energy), and sibling's and parents' health. Sibling's health is measured by averaging the height-for-age z-score of a child's brothers and sisters while parents' health is measured by the number of days parents were hospitalized or spend an overnight in a medical facility during the last twelve months.

3. Empirical strategy

We estimate the effect of crop diversification on children health using the following specification:

$$H_{ijt} = \beta M_{jt} + \mathbf{X_{ijt}}\boldsymbol{\gamma} + \mathbf{Z_{jt}}\boldsymbol{\theta} + \boldsymbol{\mu_i} + \varepsilon_{ijt}, \quad (1)$$

where H_{ijt} is a measure of the health status of child i living in household j at time t; M is a measure of crop diversification (e.g., Margalef index); $\boldsymbol{\mu_i}$ represents child specific effects, and ε is an idiosyncratic error term. We control for a set of time-variant child characteristics, **X**, which include binary indicators of whether the child worked on farm and/or attended school in the last twelve months. We also include the age of the child (in months) at the time of each survey since surveys were undertaken at different point in time. Moreover, we control for the month of interview since large variations in monthly consumption were identified by Kaminski et al. (2014) using the same survey indicating that food insecurity might be more pronounced in particular times of the year.

In addition, our baseline specification controls for a vector **Z** of household level characteristics, including whether the household owns livestock, the number of children in age groups 0-5, 6-12, and 13-17, and the presence of elderly people in the household. Household size, being the main source of farm labor, could be correlated with a household's ability to diversify agricultural production. On the other hand, while an increase in household members could imply that fewer resources are allocated to a child, it is also possible that larger families can provide better quality childcare. We also include total annual household consumption, a proxy for income, since crop choices could be related to income levels, which in turn could affect the quality of food and healthcare for children (Bengtsson, 2010; Reis, 2011). This will allow us to test the effect of crop diversification controlling for possible income effects.

Because crop choices are endogenous household decisions, an important issue to address is the presence of potential omitted variable bias. While we are concerned with the possibility that crop diversification is also capturing household unobservable characteristics, such as parents' health status, or local effects, such as variations in local agro-ecology, we are less concerned with the possibility that the Margalef index is correlated with the diversity of locally available crops. A positive correlation is likely to emerge in areas that are less connected with national or sub-national food markets. This, however, represents an indirect effect of household-level crop diversification that we aim to capture in our analysis. Crop diversification, therefore, is expected to influence children's health not only directly but also by influencing the local availability of crop varieties in relatively marginalized areas. This is a secondary effect that we do not want to rule out from our estimations since it is part of the overall effect of crop diversification on health outcomes (Ecker et al., 2011).

We adopt a three-step approach to alleviate the scope of omitted variables bias. First, we exploit the aforementioned panel structure of our dataset and include the vector $\boldsymbol{\mu}$ of child fixed effects in equation (1). The inclusion of child fixed effects allows us to control for unobservable time-invariant heterogeneity such as parental and local characteristics that did not change over time, for instance, parents' skills or pre-natal child factors. However, we are still concern with the presence of potential time-variant unobservable effects that could bias our results. Then, in a second step, we perform several robustness checks by using a rich set of control variables, such as the health status of parents and child's siblings, participation in the off-farm market, services accessibility (water and electricity), and average rainfall to capture potential sources of time-variant unobservable effects. The robustness of the point estimates to the inclusion of relevant covariates mitigates the concerns that our results might be driven by omitted variables. Finally, in the third step we perform a set of placebo tests by considering the degree of participation in the food market and the role of diversification across crops that are expected to have no immediate nutritional impact, and so no effect on child health, such as cash crops and spices.

4. Results and robustness analysis

In this section, we first present the main results on the relationship between crop diversification and child health by estimating equation (1). Then, we perform several robustness checks to assess the sensitivity of our findings by (i) including additional control variables; (ii) using alternative measures of crop diversification; and (iii) performing placebo tests to mitigate endogeneity concerns. Finally, we explore potential heterogenous effects, and investigate whether the effect of crop diversification on child health differs by the age and gender of the child as well as by the distance to the market.

4.1 Baseline results

We document the relationship between crop diversification and child health by estimating equation (1). Table 2 presents child fixed effects estimates of the Margalef index of crop diversification on three health measures: height-for-age z-score (HAZ) (columns 1, 2), weight-for-age z-score (WAZ) (columns 3, 4), and BMI-for-age z-score (BAZ) (columns 5, 6). We first present results controlling for child characteristics such as education, working on farm, and age (columns 1, 3, 5), and then including household characteristics such as family structure and total consumption (columns 2, 4, 6). We report robust standard errors clustered at the household level.

[TABLE 2 ABOUT HERE]

We find that crop diversification measured by the Margalef index positively and strongly affects children's height-for-age z-score while it does not affect children's weight-for-age z-score and BMI-for-age z-score. These results are robust to the inclusion of child- and household-level control variables. The differences across health outcomes can be explained by the fact that BAZ and WAZ tend to be more sensitive to short-term shocks and less likely to capture longer-term nutritional status, which instead is captured by HAZ (Delgado et al., 1986; Zhang, 2012). The remaining of the paper, therefore, will focus on the positive and strongly significant effect of crop diversification on the height-for-age z-score.[6] The effect on HAZ is relevant; a one standard deviation increase in the Margalef index (0.22 units) produces an impact on HAZ comparable to about a 0.8 percent increase in total consumption.

By including child fixed effects, we consider the impact of changes in crop diversification over time on children health accounting for time-invariant unobservable characteristics such as parents' skills or innate and pre-natal child attributes. For instance, Jensen and Richter (2001) find that pre-natal nutrition can explain different growth trajectories between children from rich and poor households. The inclusion of total consumption in the specification shows that there is a direct impact of crop diversification on children health even after controlling for any possible income effect. This is also crucial to rule out any other potential confounding effects that operate through changes in income. The remaining of the paper will present several robustness checks to test the sensitivity of the findings and mitigate remaining endogeneity concerns.

4.2 Baseline regressions with additional control variables

The inclusion of child fixed effects in equation (1) allows us to control for unobservable time-invariant heterogeneity, however, a concern is that changes in crop diversification could be related to changes in land size and, therefore, could reflect an increase in agricultural output. In Table 3, column 1 we explicitly control for changes in land size over the period, although this issue should already be partially accounted for by using the Margalef index, which considers the amount of land cultivated, and by controlling for total consumption. The coefficient on the Margalef index remains strongly significant and almost unchanged to the inclusion of land size.

[6] The remaining analysis on the relationship between crop diversification and WAZ or BAZ is available upon request, and confirms a non-significant effect of crop diversification on the short-term nutritional status.

[TABLE 3 ABOUT HERE]

In column 2 of Table 3 we control for whether there is at least one household member working off-farm. Participation in the off-farm labor market could be correlated with both crop diversification and child health. Households engaged in non-farming activities may produce fewer crop varieties given the lower availability of family labor for farming. This is in line with the findings by Kasem and Thapa, (2011), where farmers report the apprehension that they might have to forgo their off-farm income opportunities if they opt to grow a greater variety of crops. On the other hand, they might be relatively less disadvantaged and more exposed to information and alternative food sources with consequent effects on the health status of their household members. We find that the coefficient of the off-farm labor variable is not significant while the coefficient of the Margalef index remains positive and strongly significant at the 1 percent level.

Other potential concerns are related to the accessibility of services such as water and electricity, and the effect of weather conditions on crop choices and human health. For instance, Mangyo (2008) shows that access to in-yard water sources improves child health if mothers are educated. In addition, several studies document a significant correlation between weather and child health (e.g., Maccini and Yang, 2009; Graff Zivin and Neidell, 2013; Dell et al., 2014; Rocha and Soares, 2015), and between weather and crop choices (e.g., Seo and Mendelshon, 2008; Wang et al., 2010; Di Falco et al., 2011; Di Falco and Veronesi, 2013). In column 3 of Table 3 we control for household's access to treated water and electricity while in column 4 we deal with the possibility that variations in rainfall could be correlated with farming choices but also with child health. We find that rainfall is positively and significantly correlated to the height-for-age z-score, and we confirm the strong and significant association between crop diversification and child health.

Because crop decisions might be driven by parents' health conditions, which in turn might have an impact on their child health, in column 5 we also control for the health status of the parents. Finally, in column 6 we include the average height-for-age z-score (average HAZ) of a child's siblings as a measure of siblings' health. This will allow for shocks that are correlated with both crop diversification and a child health to be captured by their effects on his/her brothers and sisters. Our results remain unchanged.

The robustness of the point estimates to the inclusion of important additional covariates suggests that these results are most likely not due to omitted variables. However, since we cannot exclude this possibility completely, we further test the sensitivity of our main finding below.

4.3 Subsistence households and placebo tests

We now propose a set of tests, shown in Table 4, to provide additional support to our main result that crop diversification has a positive and significant effect on the height-for-age z-score. All specifications refer to our most comprehensive model that include child fixed effects, child characteristics, household characteristics, and additional covariates (as in column 5 of Table 3). To facilitate comparisons, the coefficient estimates from column 5 of Table 3 are repeated in the first column of Table 4. We first consider only subsistence households (column 2), which are households that did not sell crops in any of the three waves, and so they consume most of what they produce. The effect of crop diversification on child health is positive and highly significant. In addition, the impact is significantly much larger than in the full sample since these households are likely to rely more heavily on own-produce for food consumption. This supports the hypothesis that crop diversification is associated to better child health, in particular for households less engaged in the food market.

In addition, in columns 3 and 4 of Table 4 we propose two placebo tests. In column 3, we construct a Margalef index that includes only crops that were completely sold. While a greater variety of crops sold might have an impact on consumption through higher income, it should not have any direct nutritional impact on children health. As expected, we find that the effect is not significant. In column 4, we offer a second placebo test and construct a Margalef index that includes only crops that are expected to have no direct impact on health because have little or none nutritional content, such as cash crops (e.g., cotton, tobacco), or spices.[7] We find that the coefficient is highly insignificant. These results support our hypothesis that crop diversification leads to better child health through higher nutritional diversity.

[TABLE 4 ABOUT HERE]

4.4 Alternative measures of crop diversification

The aforementioned robustness checks have substantially reduced the scope for potential confounding effects, however, some concerns still remain. Different measures are used in the literature to measure crop diversification as we described in Section 2. In Table 5 we show that our findings do not depend on the type of indicator employed. Columns 1-5 present child fixed effects estimates; again all specifications refer to our most comprehensive model (as in column 5, Table 3). In column 1, we use a GPS-based measure of the Margalef index to address possible concerns on the use of self-reported measurements of plot size while column 2 presents results using the Shannon-Wiener index, which accounts for crop richness and evenness. All indices lead to the same conclusion that crop diversification has a positive and strongly significant effect on a child height-for-age z-score. Moreover, the inclusion of the number of crops in column 3 provides us with a simpler economic

[7] The full list of crops included in the placebo test with little or none nutritional properties is provided in Table A1, panel B of the appendix.

interpretation of the results. One additional crop induces an improvement in the height-for-age z-score equivalent to almost a 0.29 percent increase in total household consumption.[8]

[TABLE 5 ABOUT HERE]

Different agricultural products are likely to contribute to dietary diversity and, ultimately, to child nutrition to different extents. For example, adding an additional cereal to a cereal-rich diet is likely to have a different impact on child nutrition than introducing a vegetable or fruit item. Therefore, it might be argued that what matters for child nutrition is the variety across food categories rather than agricultural products in general. To test this hypothesis we measure crop diversification based on the Food Agricultural Organization (FAO) food groups, which are meant to better capture dietary diversity (FAO, 2011). In particular, we create a new Margalef index based on nine food groups that are described in detailed in Table A1 of the appendix.[9] Results are reported in columns 4 and 5 of Table 5. We find a strong positive effect of the new Margalef index on the height-for-age z-score (column 4). Similarly, the number of food groups has a positive impact on the height-for-age z-score (column 5). These results confirm our previous finding that crop diversification is positively related to long-term child nutritional status.

4.5 Heterogeneous effects

In this section, we explore whether the effect of crop diversification varies according to the characteristics of the child (age and gender), and access to the market. The first three columns of Table

[8] The coefficient of total consumption is 0.070 (s.e. 0.026).
[9] It is worth noting, however, that while we have followed FAO guidelines on food groups, there is no universal consensus on crop aggregation into food categories, and the relevant level of food diversity for dietary purposes.

6 present the estimates for different age groups (0-5, 6-10, and above 10 years old).[10] The results suggest that the impact is larger for younger children aged between zero and five. This is not surprising as young children are more likely to be affected by nutritional improvements. During early childhood children experience very high growth rates, therefore when subject to faltering growth, for example due to a poor quality diet, they quickly fall behind their peers (Victora et al., 2010).

[TABLE 6 ABOUT HERE]

In columns 4 and 5 we explore differences by child gender, and while we confirm the strong significant effect of crop diversification on height-for-age z-score for both genders, we find no significant differences between boys and girls. In the last three columns of Table 6 we explore whether access to food markets affects the relationship between crop diversification and child health. We measure accessibility by considering a household's distance to the nearest market. In particular, we divide households into three equally sized groups: "close" (0-5 Km to the market), "medium" (6-11 Km), and "far" (12-82 Km). We find that the relationship between crop diversification and child health is particularly strong for households far from the market and so with limited access to purchased food varieties. Children in households close to the market do not benefit from greater crop diversification to the same extent of children with limited market access, most likely because their diet can rely more heavily on market products (Hirvonen and Hodinott, 2014), and also because they can sell their agricultural products more easily (Key et al., 2000). If for example we consider the 2011/2012 wave, our data show that while households close to the market obtain on average 38 percent of their food

[10] All columns of Table 6 include child fixed effects, child characteristics, household characteristics, and additional covariates as specified in column 5 of Table 3. Robust standard errors clustered at the household level are reported in parenthesis.

consumption from own produce, the share increases to 53 percent for households with limited access to the market.

5. Underlying mechanism: dietary diversity and crop diversification

The results reported so far have shown that greater crop diversification is beneficial for children health in particular for younger children or children living in households with limited access to the food market. In addition, the robustness tests described in the previous section help us exclude the possibility that the effect is due to higher income or other confounding effects while support the hypothesis that crop diversification leads to greater availability of food varieties, and so nutritional diversity. To further corroborate this argument we provide some suggestive evidence on the underlying mechanism by formally testing the relationship between crop diversification and dietary diversity. Dietary diversity is obtained computing a Margalef index of food consumption at the household level using information on the week prior to the survey. Given the limited time coverage and the focus on the household rather than on the child, this indicator might not fully capture the extent of children dietary diversity for the entire between-waves period. Nevertheless, it still provides some evidence on the relationship between our measure of crop diversification and dietary diversity.

Table 7 shows that crop diversification is positively related to dietary diversity. Households with a higher Margalef index (column 1) or producing more crops (column 3) display greater dietary diversity, i.e. consumption of a greater variety of food products (columns 2, 4).

[TABLE 7 ABOUT HERE]

In Table 8 we present household fixed effects estimates of household dietary diversity on the Margalef index of crop diversification (column 1) and number of crops (column 2) using our most comprehensive specification.[11] We report robust standard errors clustered at the household level. A one standard deviation increase in crop diversification (0.30) significantly increases average dietary diversity by 3 percent. Because our measure of dietary diversity might not capture the consumption of seasonal perishable agricultural products, it is likely to provide a lower bound estimate of the actual effect of crop diversification on dietary diversity. The association between crop diversification and dietary diversity is reassuring and support our main hypothesis that greater crop diversification is related to greater dietary diversity and, ultimately, to an improvement in child health.

[TABLE 8 ABOUT HERE]

6. Conclusions

Although poverty and children malnutrition are predominant in developing countries, little empirical evidence is available on the links between health, nutrition, and agriculture. We use a three-waves panel dataset from the Tanzania National Panel Survey to investigate the association between child health and crop diversification controlling for unobservable heterogeneity. We document a strong positive effect of crop diversification on child height-for-age z-score, in particular for very young children, children living in households with limited access to the food market, and subsistence households who rely more heavily on own-produced food. We show that the effect operates through greater nutritional diversity using a set of robustness checks and auxiliary specifications.

These results have important policy implications. Poor health quality is a well-recognized cause of poverty, and early-life malnutrition has been found to persist into adulthood affecting education and productivity outcomes (Maccini and Young, 2009). The positive effect of crop diversification on long-term nutritional status suggests that crop diversification, a relatively low cost strategy to respond to

[11] All columns of Table 8 include household fixed effects, household characteristics, and additional covariates as specified in column 5 of Table 3.

greater climate variability, can also produce important co-benefits in terms of improved health quality. Promoting crop diversification, therefore, can help achieve the double outcome of climate resilience, and improved child nutrition and health. Finally, the results also highlight the importance of encouraging informed crop choices among farmers, in particular in remote areas, as they have a direct impact on human health besides any indirect income effect. This certainly does not preclude the adoption of improved varieties, which have greater yield potential and can as well contribute to poverty alleviation (Evenson and Gollin, 2003), alongside more traditional but nutritionally diversified crops.

References

Alderman, H., J. Hoddinott, and B. Kinsey. 2006a. “Long term consequences of early childhood malnutrition.” Oxford Economic Papers 58(3):450-474.

Alderman, H., H. Hoogeveen, and M. Rossi. 2006b. “Reducing child malnutrition in Tanzania: combined effects of income growth and program interventions.” Economics & Human Biology 4(1):1-23.

Arimond, M., and M. T. Ruel. 2004. “Dietary diversity is associated with child nutritional status: evidence from 11 Demographic and Health Surveys.” Journal of Nutrition 134 (10):2579-2585.

Barrera, A. 1990. “The interactive effects of mother's scholling and unsupplemented breastfeeding on child health.” Journal of Development Economics 34(1–2):81-98.

Bengtsson, N. 2010. “How responsive is body weight to transitory income changes? Evidence from rural Tanzania.” Journal of Development Economics 92(1):53-61.

Benin, S., M. Smale, J. Pender, B. Gebremedhin, and S. Ehui. 2004. “The economic determinants of cereal crop diversity on farms in the Ethiopian highlands.” Agricultural Economics 31(2-3):197-208.

Bhutta, Z. A, J. K. Das, A. Rizvi, M. Gaffey, N. Walker, S. Horton, P. Webb, A. Lartey, and R. E. Black. 2013. “Evidence-based interventions for improvement of maternal and child nutrition: what can be done and at what cost?” The Lancet 382(9890):452–477.

Bhutta, Z. A, T. Ahmed, R. E. Black, S. Cousens, K. Dewey, E. Giugliani, B. A. Haider, B. Kirkwood, S. S. Morris, H. P. S. Sachdev, and M. Shekar. 2008. “What works? Interventions for maternal and child undernutrition and survival.” The Lancet 371(9610):417–440.

Caulfield, L. E., S. A. Richard, J. Rivera, P. Musgrove, and R. E. Black. 2006. “Stunting, wasting, and micronutrient deficiency disorders.” In Disease control priorities in developing countries. 2nd edition., edited by D. T. Jamison, J. G. Breman, A. R. Measham, G. Alleyne, M. Claeson, D. B.

Evans, P. Jha, A. Mills and P. Musgrove, 551-567. Washington DC: The International Bank for Reconstruction and Development / The World Bank.

Christiaensen, L., and H. Alderman. 2004. "Child malnutrition in Ethiopia: can maternal knowledge augment the role of income?" Economic Development and Cultural Change 52(2):287-312.

de Onis, M., A. W. Onyango, E. Borghi, A. Siyam, C. Nishida, and J. Siekmann. 2007. "Development of a WHO growth reference for school-aged children and adolescents." Bulletin of the World Health Organization 85 (9):660-667.

Delgado, H., L. F. Fajardo, R. Klein, J. O. Mora, M. M. Rahaman, D. Nabarro, M. Z. Nichaman, N. P. Rao, and J. C. Waterlow. 1986. "Use and interpretation of anthropometric indicators of nutritional status." Bulletin of the World Health Organization 64(6):929-942.

Dell, M., B. F. Jones, and B. A. Olken. 2014. "What do we learn from the weather? The new climate-economy Literature." Journal of Economic Literature 52(3):740-98.

Di Falco, S., and J-P.Chavas. 2008. "Rainfall shocks, resilience, and the effects of crop biodiversity on agroecosystem productivity." Land Economics 84(1):83–96.

Di Falco, S., A. A. Penov, and T. M. van Rensburg. 2010. "Agrobiodiversity, farm profits and land fragmentation: evidence from Bulgaria." Land Use Policy 27(3):763-771.

Di Falco, S., and M. Veronesi. 2013. "How African agriculture can adapt to climate change? A counterfactual analysis from Ethiopia." Land Economics 89(4):743-766.

Di Falco, S., M. Veronesi, and M. Yesuf. 2011. "Does adaptation to climate change provide food security? A micro-perspective from Ethiopia." American Journal of Agricultural Economics 93(3):829-846.

Dillon, A., K. McGee, and G. Oseni. 2014. "Agricultural production, dietary diversity, and climate variability." Policy Research working paper no. WPS 7022. Washington, DC: World Bank Group.

Ecker, O., A. Mabiso, A. Kennedy, and X. Diao. 2011. "Making agriculture pro-nutrition: opportunities in Tanzania." International Food Policy Research Institute (IFPRI) discussion paper 1124.

Evenson, R. E., and D. Gollin. "Assessing the impact of the Green Revolution, 1960 to 2000." Science 300.5620 (2003):758-762.

Food and Agriculture Organization. 2011. Guidelines for measuring household and individual dietary diversity. Rome: Food and Agriculture Organization. Available at http://www.fao.org/docrep/014/i1983e/i1983e00.htm (accessed on April 29, 2016).

Frison, E. A., I. F. Smith, T. Johns, J. Cherfas, and P. B. Eyzaguirre. 2006. "Agricultural biodiversity, nutrition, and health: making a difference to hunger and nutrition in the developing world." Food and Nutrition Bulletin 27 (2):167-179.

Graff Zivin, J., and M. Neidell. 2013. "Environment, health, and human capital." Journal of Economic Literature 51(3):689-730.

Hirvonen, K., and J. Hoddinott. 2014. "Agricultural production and children's diets: evidence from rural Ethiopia." International Food Policy Research Institute (IFPRI) No. 69.

Jensen, R., and N. Miller. 2011. "Do consumer price subsidies really improve nutrition?" Review of Economics and Statistics 93(4):1205-1223.

Jensen, R., and K. Richter. 2001. "Understanding the relationship between poverty and children's health." European Economic Review 45(4–6):1031-1039.

Kaminski, J., L. Christiaensen, and C. L. Gilbert. 2014. "The end of seasonality? New insights from sub-Saharan Africa." World Bank Policy Research Working Paper No. 6907.

Kasem, S., and G. B. Thapa. 2011. "Crop diversification in Thailand: status, determinants, and effects on income and use of inputs." Land Use Policy 28(3):618-628.

Kazianga, H., D. de Walque, and H. Alderman. 2014. "School feeding programs, intrahousehold allocation and the nutrition of siblings: evidence from a randomized trial in rural Burkina Faso." Journal of Development Economics 106:15-34.

Kennedy, G. L., M. R. Pedro, C. Seghieri, G. Nantel, and I. Brouwer. 2007. "Dietary diversity score is a useful indicator of micronutrient intake in non-breast-feeding Filipino children." Journal of Nutrition 137(2):472-477.

Key, N., E. Sadoulet, and A. De Janvry. 2000. "Transactions costs and agricultural household supply response." American Journal of Agricultural Economics 82.2 (2000):245-259.

Lovo, S., M. Bezabih, and G. Singer. 2015. "Green agricultural policies and poverty alleviation." Grantham Research Institute on Climate Change and the Environment policy brief series.

Maccini, S., and D. Yang. 2009. "Under the weather: health, schooling, and economic consequences of early-life rainfall." American Economic Review 99(3):1006-1026.

Mangyo, E. 2008. "The effect of water accessibility on child health in China." Journal of Health Economics 27(5):1343-1356.

Moursi, M. M., M. Arimond, K. G. Dewey, S. Treche, M. T. Ruel, and F. Delpeuch. 2008. "Dietary diversity is a good predictor of the micronutrient density of the diet of 6-to 23-month-old children in Madagascar." Journal of Nutrition 138 (12):2448-2453.

Mugendi Njeru, E. 2013. "Crop diversification: a potential strategy to mitigate food insecurity by smallholders in sub-Saharan Africa." Journal of Agriculture, Food Systems, and Community Development 3(4):63–69.

NBS (Tanzania National Bureau of Statistics). 2014. Basic information document. National Panel Survey. Available at http://siteresources.worldbank.org/INTLSMS/Resources/3358986-1233781970982/5800988-1286190918867/TZNPS_2012-2013_BID_DEC_2014.pdf (accessed on April 29, 2016).

Reis, M. 2011. "Food insecurity and the relationship between household income and children's health and nutrition in Brazil." Health Economics 21(4):405-427.

Remans, R., D. F. B. Flynn, F. DeClerck, W. Diru, J. Fanzo, K. Gaynor, I. Lambrecht, J. Mudiope, P. K. Mutuo, P. Nkhoma, D. Siriri, C. Sullivan, and C. A. Palm. 2011. "Assessing nutritional diversity of cropping systems in African villages." PLoS ONE 6 (6):e21235.

Rocha, R., and R. R. Soares 2015. "Water scarcity and birth outcomes in the Brazilian semiarid." Journal of Development Economics 112:72-91.

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

Seo, N., and R. Mendelsohn. 2008. "An analysis of crop choice: adapting to climate change in Latin American farms." Ecological Economics 67:109-116.

Steyn, N. P., J. H. Nel, G. Nantel, G. Kennedy, and D. Labadarios. 2006. "Food variety and dietary diversity scores in children: are they good indicators of dietary adequacy?" Public Health Nutrition 9 (5):644-650.

UNFCCC. 2009. Report on the technical workshop on increasing economic resilience to climate change and reducing reliance on vulnerable economic sectors, including through economic diversification, FCCC/SBSTA/2009/7. Available at http://unfccc.int/documentation/documents/advanced_search/items/6911.php?priref=600005427 (accessed on April 29, 2016).

UNICEF-WHO-World Bank Group. 2015. Joint child malnutrition estimates. Key findings of the 2015 edition. Available at http://www.who.int/nutrition/publications/jointchildmalnutrition_2015_estimates/en/ (accessed on April 29, 2016).

Victora, C. G., M. de Onis, P. C. Hallal, M. Bloessner, and R. Shrimpton. 2010. "Worldwide timing of growth faltering: revisiting implications for interventions." Pediatrics 125 (3):E473-E480.

Wang, J., R. Mendelsohn, A. Dinar, and J. Huang. 2010. "How Chinese farmers change crop choice to adapt to climate change." Climate Change Economics 1:167-186.

World Bank. 2006. Repositioning nutrition as central to development: a strategy for large-scale action. Washington DC: The International Bank for Reconstruction and Development / The World Bank. Available at http://www.unhcr.org/45f6c4432.pdf (accessed on April 29, 2016).

World Health Organization. 2006. WHO child growth standards: length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age: methods and development. Geneva: World Health Organization. Available at http://www.who.int/childgrowth/standards/technical_report/en/ (accessed on April 29, 2016).

World Health Organization. 2012. Landscape analysis on countries' readiness to accelerate action in nutrition. Tanzania assessment for scaling up nutrition. Geneva: World Health Organization. Available at http://www.who.int/nutrition/landscape_analysis/TanzaniaLandscapeAnalysisFinalReport.pdf (accessed on April 29, 2016).

Zhang, J. 2012. "The impact of water quality on health: Evidence from the drinking water infratructure program in rural China." Journal of Health Economics 31:122-134.

Table 1. Descriptive statistics.

Variables	Pooled sample		Wave 1		Wave 2		Wave 3	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Dependent variables								
Height-for-age z-score (HAZ)	-1.679	1.205	-1.788	1.354	-1.675	1.131	-1.556	1.090
Weight-for-age z-score (WAZ)	-1.166	1.035	-1.148	1.107	-1.184	1.006	-1.171	0.949
BMI-for-age z-score (BAZ)	-0.496	1.057	-0.344	1.128	-0.525	1.045	-0.636	0.961
Explanatory variables								
Crop diversification measures								
Margalef	0.296	0.219	0.251	0.190	0.315	0.228	0.327	0.231
Margalef GPS	0.321	0.230	-	-	0.316	0.229	0.328	0.233
Shannon-Wiener index	1.139	0.604	0.996	0.562	1.201	0.612	1.231	0.611
Number of crops	4.208	2.512	3.715	2.157	4.397	2.615	4.554	2.675
Margalef food groups index	0.240	0.157	0.227	0.146	0.246	0.162	0.249	0.163
Number of food groups	3.575	1.743	3.413	1.603	3.639	1.795	3.687	1.819
Child characteristics								
Age (in months)	106.281	51.733	87.912	50.340	109.268	51.288	124.063	46.680
Male	0.491	0.500	0.492	0.500	0.495	0.500	0.485	0.500
Dummy: worked on farm	0.213	0.409	0.141	0.348	0.237	0.425	0.267	0.443
Dummy: attending school	0.557	0.497	0.480	0.500	0.573	0.495	0.629	0.483
Household characteristics								
Number of children 0-5	1.629	1.579	1.678	1.348	1.631	1.562	1.570	1.827
Number of children 6-12	2.012	1.327	1.941	1.366	2.021	1.291	2.085	1.321
Number of children 13-17	1.129	1.055	1.011	1.021	1.130	1.027	1.265	1.111
Dummy: elderly	0.218	0.413	0.196	0.397	0.224	0.417	0.238	0.426
Household consumption (US$)	3,233.23	2,937.00	2,528.42	2,467.21	3,076.35	2,252.95	4,242.77	3,773.47
Dummy: livestock	0.751	0.433	0.762	0.426	0.764	0.424	0.720	0.449
Additional controls								
Land size (hectares)	8.153	26.768	9.428	39.104	6.979	15.699	8.083	18.282
Dummy: off-farm job	0.520	0.500	0.489	0.500	0.561	0.496	0.507	0.500
Dummy: water accessibility	0.258	0.438	0.245	0.430	0.288	0.453	0.237	0.425
Dummy: electricity accessibility	0.081	0.273	0.051	0.220	0.075	0.264	0.124	0.329
Average rainfall (mm) /100	8.822	2.918	7.955	2.215	7.949	2.258	10.885	3.286
Parents' hospitalizations	0.123	0.357	0.098	0.315	0.152	0.407	0.116	0.335
Siblings' average HAZ	-1.715	1.225	-1.804	1.425	-1.697	1.077	-1.631	1.133
Observations	10,496		3,626		3,755		3,115	

Notes: Data are from the Tanzania National Panel Survey for years 2008/2009 (wave 1), 2010/2011 (wave 2), and 2012/2013 (wave 3). Weight-for-age z-score is only available for children under 10. Margalef GPS index is available only for the last two waves because of missing GPS information for hectares of land in the first wave.

Table 2. Crop diversification and child health. Baseline regressions.

Dependent variable	Height-for-age z-score (HAZ)		Weight-for-age z-score (WAZ)		BMI-for-age z-score (BAZ)	
	(1)	(2)	(3)	(4)	(5)	(6)
Crop diversification						
Margalef index	0.222***	0.211***	0.101	0.111	-0.072	-0.072
	(0.066)	(0.067)	(0.072)	(0.074)	(0.063)	(0.063)
Child characteristics						
Dummy: attending school	-0.021	-0.027	0.037	0.039	-0.097***	-0.099***
	(0.027)	(0.027)	(0.028)	(0.028)	(0.024)	(0.024)
Dummy: worked on farm	-0.049*	-0.046*	-0.109**	-0.106**	0.022	0.022
	(0.027)	(0.026)	(0.043)	(0.043)	(0.022)	(0.022)
Age (in months)	0.009***	0.007***	-0.010***	-0.010***	-0.021***	-0.021***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)
Age squared	-0.030***	-0.027***	0.054***	0.056***	0.067***	0.067***
	(0.006)	(0.006)	(0.013)	(0.013)	(0.005)	(0.005)
Household characteristics						
Number of children 0-5		0.005		0.021		-0.015
		(0.018)		(0.017)		(0.013)
Number of children 6-12		0.028*		-0.011		-0.008
		(0.016)		(0.016)		(0.015)
Number of children 13-17		-0.002		-0.029*		-0.019
		(0.016)		(0.018)		(0.016)
Dummy: elderly		0.070		0.004		0.036
		(0.061)		(0.065)		(0.052)
Household consumption (log)		0.061**		0.006		0.009
		(0.029)		(0.029)		(0.021)
Dummy: livestock		-0.060*		-0.066**		-0.037
		(0.032)		(0.031)		(0.027)
Month of interview		-0.007		0.001		-0.003
		(0.006)		(0.007)		(0.005)
Constant	-2.233***	-3.015***	-0.788***	-0.844**	0.881***	0.859***
	(0.087)	(0.375)	(0.065)	(0.396)	(0.066)	(0.296)
Child fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	10,496	10,496	6,318	6,318	10,493	10,493
Number of children	4,036	4,036	2,825	2,825	4,036	4,036

Notes: All specifications include child fixed effects. Data are from the Tanzania National Panel Survey for years 2008/2009, 2010/2011, and 2012/2013. Robust standard errors clustered at the household level in parenthesis. ***, **, * indicate significance at the 1%, 5%, and 10% level, respectively.

Table 3. Baseline regressions with additional control variables.

Dependent variable: Height-for-age z-score	(1)	(2)	(3)	(4)	(5)	(6)
Margalef index	0.231***	0.228***	0.228***	0.238***	0.235***	0.267***
	(0.066)	(0.066)	(0.066)	(0.066)	(0.066)	(0.069)
Land size	-0.004***	-0.004***	-0.004***	-0.004***	-0.004***	-0.004***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Dummy: off-farm job		0.023	0.023	0.025	0.025	0.027
		(0.021)	(0.021)	(0.021)	(0.021)	(0.022)
Dummy: water accessibility			-0.023	-0.016	-0.018	-0.009
			(0.024)	(0.024)	(0.024)	(0.025)
Dummy: electricity accessibility			-0.018	-0.032	-0.030	-0.006
			(0.048)	(0.048)	(0.048)	(0.048)
Average rainfall				0.014***	0.015***	0.016***
				(0.005)	(0.005)	(0.005)
Parents' hospitalizations					0.061**	0.070**
					(0.028)	(0.028)
Siblings' average height-for-age z-score						0.028*
						(0.016)
Child characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Household characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Child fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	10,496	10,496	10,496	10,496	10,496	9,670
Number of children	4,036	4,036	4,036	4,036	4,036	3,823

Notes: All specifications include child fixed effects, and the control variables considered in Table 2, column 2. Column 6 refers to the sub-sample of households with a child's siblings. Data are from the Tanzania National Panel Survey for years 2008/2009, 2010/2011, and 2012/2013. Robust standard errors clustered at the household level in parenthesis. ***, **, * indicate significance at the 1%, 5%, and 10% level, respectively.

Table 4. Subsistence households and placebo tests.

Dependent variable: Height-for-age z-score	Full sample	Subsistence households	Placebo tests: Crops 100% sold	Placebo tests: Cash crops or spices
	(1)	(2)	(3)	(4)
Margalef index	0.235***	0.535***	-0.075	-0.031
	(0.066)	(0.203)	(0.304)	(0.522)
Child characteristics	Yes	Yes	Yes	Yes
Household characteristics	Yes	Yes	Yes	Yes
Additional controls	Yes	Yes	Yes	Yes
Child fixed effects	Yes	Yes	Yes	Yes
Observations	10,496	1,601	8,895	2,072
Number of children	4,036	622	3,414	1,121

Notes: All specifications include child fixed effects, child characteristics, household characteristics, and additional covariates as specified in column 5 of Table 3. Data are from the Tanzania National Panel Survey for years 2008/2009, 2010/2011, and 2012/2013. Column 1 is equivalent to column 5 of Table 3. Column 2 refers to subsistence households, that is to the sub-sample of households that that did not sell crops in any of the three ways. Column 3 refers to a Margalef index that includes only crops that were completely sold, and so excludes subsistence households. Column 4 refers to a Margalef index that includes only cash crops or spices. Robust standard errors clustered at the household level in parenthesis. *** indicates significance at the 1% level.

Table 5. Alternative measures of crop diversification.

Dependent variable: Height-for-age z-score	Margalef GPS index (1)	Shannon-Windex index (2)	Number of crops (3)	Margalef food groups index (4)	Number of food groups (5)
Crop diversification index	0.186***	0.078***	0.020***	0.267***	0.023***
	(0.069)	(0.022)	(0.006)	(0.086)	(0.008)
Child characteristics	Yes	Yes	Yes	Yes	Yes
Household characteristics	Yes	Yes	Yes	Yes	Yes
Additional controls	Yes	Yes	Yes	Yes	Yes
Child fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	6,868	10,496	10,496	10,496	10,496
Number of children	4,012	4,036	4,036	4,036	4,036

Notes: All columns include child fixed effects, child characteristics, household characteristics, and additional covariates as specified in column 5 of Table 3. The indexes are described in Section 2. Data are from the Tanzania National Panel Survey for years 2008/2009, 2010/2011, and 2012/2013, except for column 1 that refers to the last two waves because of missing GPS information for hectares of land in the first wave. Robust standard errors clustered at the household level in parenthesis. *** indicates significance at the 1% level.

Table 6. Heterogeneous effects.

Dependent variable:	Child age			Child gender		Market distance		
Height-for-age z-score	0-5	5-10	>10	Boy	Girl	Close	Medium	Far
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Margalef index	0.731**	0.222**	0.158**	0.236***	0.223**	0.165	0.208*	0.340***
	(0.342)	(0.104)	(0.076)	(0.083)	(0.094)	(0.114)	(0.115)	(0.113)
Child characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Additional controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Child fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	718	3,957	5,821	5,153	5,343	3,482	3,543	3,471
Number of children	280	1,451	2,305	1,998	2,038	1,348	1,348	1,340

Notes: All specifications include child fixed effects, child characteristics, household characteristics, and additional covariates as specified in column 5 of Table 3. Data are from the Tanzania National Panel Survey for years 2008/2009, 2010/2011, and 2012/2013. “Close” refers to market distance 0-5 Km, “Medium” 6-11 Km, and “Far” 12-82 Km. Robust standard errors clustered at the household level in parenthesis. ***, **, * indicate significance at the 1%, 5%, and 10% level, respectively.

Table 7. Crop diversification and dietary diversity.

Quintile of the Margalef index distribution	Average dietary diversity (Margalef index of food consumption)	Number of crops	Average dietary diversity (Margalef index of food consumption)
(1)	(2)	(3)	(4)
1	0.551	1-3	0.559
2	0.549	4-6	0.605
3	0.590	7-9	0.679
4	0.622	10-12	0.711
5	0.680	> 12	0.808

Notes: Data are from the Tanzania National Panel Survey for years 2008/2009, 2010/2011, and 2012/2013.

Table 8. Crop diversification and dietary diversity.

Dependent variable: Average household dietary diversity	(1)	(2)
Margalef index	0.100**	
	(0.047)	
Number of crops		0.010**
		(0.004)
Household characteristics	Yes	Yes
Household fixed effects	Yes	Yes
Observations	4,369	4,369
Number of households	1,519	1,519

Notes: The dependent variable is the Margalef index of household food consumption in logarithm, which measures the average household dietary diversity. All specifications include household fixed effects, household characteristics, and additional covariates as specified in column 5 of Table 3. Data are from the Tanzania National Panel Survey for years 2008/2009, 2010/2011, and 2012/2013. Robust standard errors clustered at the household level in parenthesis. ** indicates significance at the 5% level.

Appendix

Table A1. List of crops and food categories.

Crop name	Food category	Crop name	Food category
Panel A: Crops with nutritional properties			
Amaranths	Cereals	Lemon	Other fruits
Bulrush millet	Cereals	Lime	Other fruits
Finger millet	Cereals	Malay apple	Other fruits
Maize	Cereals	Mandarin	Other fruits
Paddy	Cereals	Mitobo	Other fruits
Sorghum	Cereals	Monkey bread	Other fruits
Wheat	Cereals	Orange	Other fruits
Seaweed	Dark green leafy vegetables	Pears	Other fruits
Spinach	Dark green leafy vegetables	Pineapple	Other fruits
Mango	Fruits rich in vitamin A	Plums	Other fruits
Papaw	Fruits rich in vitamin A	Pomegranate	Other fruits
Passion fruit	Fruits rich in vitamin A	Rambutan	Other fruits
Peaches	Fruits rich in vitamin A	Star Fruit	Other fruits
Bambara nuts	Legumes, nuts and seeds	Tamarind	Other fruits
Beans	Legumes, nuts and seeds	Water Mellon	Other fruits
Cashew nut	Legumes, nuts and seeds	Bamboo	Other vegetables
Chick peas	Legumes, nuts and seeds	Cabbage	Other vegetables
Cowpeas	Legumes, nuts and seeds	Cauliflower	Other vegetables
Field peas	Legumes, nuts and seeds	Cucumber	Other vegetables
Green gram	Legumes, nuts and seeds	Eggplant	Other vegetables
Groundnut	Legumes, nuts and seeds	Fiwi	Other vegetables
Pigeon pea	Legumes, nuts and seeds	Medicinal Plant	Other vegetables
Sesame	Legumes, nuts and seeds	Okra	Other vegetables
Soybeans	Legumes, nuts and seeds	Onions	Other vegetables
Sunflower	Legumes, nuts and seeds	Sisal	Other vegetables
Palm oil	Oils and fats	Tomatoes	Other vegetables
Apples	Other fruits	Carrot	Vegetables and tubers
Avocado	Other fruits	Pumpkins	Vegetables and tubers
Banana	Other fruits	Sweet potatoes	Vegetables and tubers
Bilimbi	Other fruits	Bread fruit	White roots and tubers
Coconut	Other fruits	Cassava	White roots and tubers
Custard apple	Other fruits	Cocoyams	White roots and tubers
Guava	Other fruits	Irish potatoes	White roots and tubers
Jack fruit	Other fruits	Yams	White roots and tubers
Panel B: Crops with little or none nutritional properties			
Cotton	Cash crops	Black pepper	Spices, condiments and beverages
Rubber	Cash crops	Cardamom	Spices, condiments and beverages
Tobacco	Cash crops	Chillies	Spices, condiments and beverages
Wattle	Cash crops	Cinnamon	Spices, condiments and beverages
Sugar cane	Sweets	Clove	Spices, condiments and beverages
Fence tree	Wood and timber	Cocoa	Spices, condiments and beverages
Firewood/fodder	Wood and timber	Coffee	Spices, condiments and beverages
Timber	Wood and timber	Tea	Spices, condiments and beverages

Notes: Categories are based on FAO guidelines (FAO, 2011). Panel A refers to the crops with nutritional properties used for the crop diversification measures described in Section 2. Panel B refers to crops with little or none nutritional properties used for the palcebo test described in Section 4.