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Crop Diversification and Child Health: 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 considered as a strategy to improve nutrition and health. However, there is no systematic empirical evidence on the role played by crop diversification in improving human health. We use three waves of the Tanzania National Panel Survey to test the effect of crop diversification on child health. We implement two instrumental variable approaches, and perform several robustness checks to address potential endogeneity concerns. We find a positive but small effect of an increase in crop diversification on child height-for-age z-score, through greater dietary diversity. The effect is larger for subsistence households and children living in households with limited market access.

Keywords: child health; crop diversification; dietary diversity; nutrition; food security; Tanzania

JEL Classification: I12, I15, O12, Q12, Q18, Q54, Q56

1. Introduction

Improving children's 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., 2006; 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 performing countries in the world (World Health Organization, 2012). In this study, we test whether crop diversification can improve child health in Tanzania.

In the context of developing countries, agriculture plays a dual role in affecting adults' and children's nutrition. As shown in Ruel and Alderman (2013), households can benefit from agricultural activities indirectly as a source of income for the purchase of food products, and directly through the provision of healthy and diverse foods for their own consumption. In areas of prevalent subsistence farming and limited access to food markets, such as in rural Tanzania (Ecker et al., 2011), the latter contribution is likely to gain 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 seed 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).

The contribution of this paper is threefold. First, while empirical studies have shown that specific agricultural interventions can improve child nutrition and health (e.g., Larsen and Lilleør, 2016), and that animal products are particularly important for child growth and the reduction of stunting (e.g., Rawlins et al., 2014; Tang et al., 2014; Hoddinott et al., 2015; Iannotti et al., 2017;

Headey et al., 2018) there is no systematic empirical evidence on the role played by crop diversification in improving human health status. Sibhatu and Qaim (2018) provides a comprehensive meta-analysis of studies that investigate the relationship between production diversity, diets, and nutrition in smallholder farm households. While most of the studies covered by this systematic review focus on the effect of crop diversification on nutrient intake or dietary quality, only few have tested empirically the effect of crop diversification on child health and the results are mixed. On one hand, for example, Kumar et al. (2015) find a positive effect of agricultural production diversification on the height-for-age z-score of children in Zambia. On the other hand, Shively and Sununtnasuk (2015) find no significant effect of crop count on height-for-age z-score in children in Nepal. Both studies, however, use cross-sectional data and so do not account for important confounding effects that might bias their results.[1] This is also the case for all other studies analyzed by Sibhatu and Qaim (2018). Our paper is the first one to test the impact of crop diversification on child health by using panel data and performing several robustness checks to address endogeneity concerns. The use of panel data allows us to exploit within-child variations over a six-year period, and so to account for unobserved child-specific effects that could otherwise confound the effect of crop diversification on child health. In doing so we shift the focus of the analysis from cross-household differences towards within-child comparisons. Hence, we are able to capture the effects of changes in crop choices on health outcomes over time.

Second, while other strands of the literature have focused separately on either the relationship between agricultural diversification and dietary diversity (e.g., Remans et al., 2011; Dillon et al., 2015; Hirvonen and Hodinott, 2016), or the relationship between dietary diversity and anthropometric outcomes (e.g., Arimond and Ruel, 2004; Steyn et al., 2006; Kennedy et al., 2007; Moursi et al., 2008), this paper bridges the gap between these two strands of literature by testing the effect of crop diversification on child health. We show that crop diversification affects child health through greater

[1] Kumar et al. (2015) find an unexpected negative effect on the height of children under age two, which might be related to the use of cross-sectional data that do not allow them to account for unobservable heterogeneity.

dietary diversity above and beyond potential income effects. Third, we contribute to the literature by investigating heterogenous effects of crop diversification on child health by child age, child gender, households' distance from the market, and geographical location.

In this paper, we first provide a conceptual framework to describe the extent of the linkages between crop choices and health outcomes. We then empirically test the relationship between crop diversification and child health, through improved dietary diversity. We use a rich dataset that combines child-level health information with household-level agricultural data. We use the three rounds of the Tanzania National Panel Survey (TZNPS), an integrated survey on agriculture, which covers about 2,500 children over the period 2008-2013.

We perform several robustness checks to address potential endogeneity concerns resulting from unobserved heterogeneity. We control for year-ward fixed effects, village time trends, and a rich set of covariates that includes child and household characteristics, service accessibility, and weather conditions. We also implement two IV approaches and use different sub-samples and measures of crop diversification to support our findings.

Finally, we investigate the mechanism underlying the relationship between crop diversification and child health, and provide some evidence on the link between dietary diversity and crop diversification. Our results indicate that crop diversification has a small positive effect on height-for-age z-score—a measure of long-term child nutritional status—through greater dietary diversity. The effect is larger for children living in subsistence households and households with limited market access.

2. Conceptual framework

In this section, we provide a simple conceptual framework that guides our analysis on the relationship between crop diversification and child health. As shown in Figure 1, there are two main mechanisms that link crop diversification to child health: dietary diversity and income. Considering the first mechanism (link A in Figure 1), empirical evidence provides support for a direct relationship between agricultural diversification and dietary diversity (e.g., Remans et al., 2011; Dillon et al., 2015; Hirvonen and Hodinott, 2016). As subsistence households produce mainly for own consumption—this is the case of Tanzania where more than 50 percent of households sell less than 15 percent of their produce—the choice of agricultural outputs largely determine their diet. We expect, however, this relationship to weaken as households get more connected to the market and the transaction costs of purchasing food items are reduced.

As de Janvry et al. (1991) show, the presence or absence of markets affects household consumption behavior. In particular, the absence of the output market is a condition that determines the non-separability between production and consumption decisions. Indeed, at the household level, market integration can act as a substitute for crop diversification as households gain access to different agricultural products through their purchases at the local market. In this context, diversification of production at the community or regional level becomes a more prominent determinant of dietary diversity. Yet, despite the benefits of market integration, participation among smallholders in many Sub-Saharan countries remains low (Barrett, 2008) and many households are still disconnected from the local marketplace. Indeed, 70 percent of Tanzanian households live at least 10 km away from the nearest market.

[FIGURE 1 ABOUT HERE]

The pathway from crop diversification to child health is complete with the effect of dietary diversity on child health (link D in Figure 1). The association between dietary diversity and anthropometric outcomes has been separately investigated in the empirical literature. Dietary diversity has been found to reflect diet quality and nutritional status in several developing countries (Arimond and Ruel, 2004; Jones et al., 2014). This is partly explained by the positive association between dietary diversity and micronutrient intakes (Kennedy et al., 2007; Moursi et al., 2008; Steyn et al., 2006).

The second mechanism relates farm diversification to child health through income stability or growth (link B, in Figure 1). The relationship is, a priori, ambiguous. On one hand, diversification decreases the overall production risk and can help households cope better with negative weather or price shocks. It can also allow farmers to grow products that can be marketed at different times during the year (Di Falco and Perrings, 2005). In addition, crop rotation can have beneficial effects in term of soil fertility, conservation, and pest control (Chavas, 2008). On the other hand, diversification can have negative effects on income due to the foregone benefits from specialization. There are very few studies that relate crop diversification to household income in developing countries. Pellegrini and Tasciotti (2014) and Michler and Josephson (2017), for example, find a positive relationship between crop diversification and income. It is important to note that the relationship between household income and crop diversification works both ways.

Besides the link described above, since crop choices are endogenous household decisions, they are driven by household preferences and capabilities that are largely determined by their economic status. To complete the pathway (links E and C in Figure 1), income has been found to be positively associated with child nutritional status and child health, although heterogeneous effects are found depending on the gender of the income recipient and of the child (Bengtsson, 2010; Duflo, 2000). These effects can occur both through increased consumption or improved diet quality when households have access to the market. Hatløy et al. (2000), for example, find a positive association between dietary diversity and socioeconomic status, in particular in urban areas.

Ultimately, considering that households are likely to consume part of what is produced, crop choices are therefore driven by both profit considerations and by a taste for variety in food consumption and other consumption-related drivers. Profit considerations are determined by farm-specific conditions, such as land, labor, agro-ecological conditions, and access to the input and output markets. This suggests, that when attempting to establish a causal relationship between crop diversification and child health, challenges are posed by the interaction between production choices, income and consumption, and by the presence of unobservable factors that can drive both farm choices and child health. For example, within the household, conditions that can affect both crop diversification and child health include parents' skills, health, decision making responsibility, and awareness about crop varieties and nutrition. Hirvonen et al. (2017), for example, find that nutrition knowledge leads to considerable improvements in children's diet in areas with good market access. The role of the gender of the decision-maker in terms of crop choices is also likely to matter. As documented in Smale et al. (2015), there is a close relationship between women's diets and the diets of their children and this is likely to affect their crop choices when in charge of agricultural decisions.

Finally, crop choices are likely driven by agro-ecological and local market conditions (links F and H in Figure 1). The availability of seeds, for example, is an important determinant of crop choices. Better access to seeds could be correlated with both greater crop variety and better access to other infrastructures (such as clinics) or information, and therefore better health outcomes (link I in Figure 1). Overall, local conditions determine the availability of crop varieties at the local level and suggest that crop diversification, at the household level, can influence children's health not only directly but also by capturing the local availability of crops if neighbors choices are correlated (link G in Figure 1). A positive correlation is more likely to emerge in markets that are small and less connected with national or sub-national food markets (Ecker et al., 2011). In the empirical analysis that follows, we will attempt to disentangle the effects of crop diversification on child health with a greater focus on the dietary diversity mechanism, above and beyond possible income effects.

3. Empirical strategy

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

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

where H is a measure of the health status of child i living in household j at time t; D is a measure of crop diversification; μ represents child-specific fixed effects, **d** indicates year and month of interview fixed effects, and ε is an idiosyncratic error term. We include year fixed effects to account for time-series variations, i.e. common aggregated shocks, in the dependent variable and our measure of crop diversification, and month of interview fixed effects to account for seasonality. We also control for a set of time-variant child characteristics, **X**, which include the age of the child (in months) at the time of each survey, and binary indicators of whether the child worked on the farm and/or attended school in the last twelve months. In addition, our baseline specification controls for a vector, **Z**, of household characteristics such as the number of children in age groups 0-5, 6-12, and 13-17, the presence of elderly people in the household, land size, annual household consumption, total revenues, whether the household owns livestock, and participation in the off-farm market.

Household size is an important control. The number of family members, being the main source of farm labor, could be correlated with the 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 control for land size to account for a potential correlation between crop choice and changes in agricultural land, and for livestock ownership given the importance of animal products for child growth (e.g., Rawlins et al., 2014; Tang et al., 2014; Hoddinott et al., 2015; Iannotti et al., 2017; Headey et al., 2018).

We also include total annual household consumption and total revenues, our proxies for income, because crop choices could be related to income levels, which in turn could affect the quality of food and healthcare for children as discussed in the conceptual framework. This allows us to test the effect of crop diversification above and beyond possible income effects. In addition, we control for participation in the off-farm labor market, which 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 (Kasem and Thapa, 2011). 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.

As illustrated in the previous section, crop choices are endogenous household decisions; therefore, it is crucial to address the presence of potential omitted variable bias. We adopt a five-step approach to alleviate the scope of omitted variable bias. First, we exploit the aforementioned panel structure of our dataset and include the vector μ of child fixed effects, as shown in equation (1). The inclusion of child fixed effects is very important to control for unobservable time-invariant factors such as local characteristics (e.g., market distance) and household characteristics (e.g., parents' skills, the propensity to seek information and so parents' awareness) that are unlikely to change over time. In addition, it also allows us to control for pre-natal child factors such as the diversity of crops grown while the child was in the womb. Jensen and Richter (2001), for instance, find that pre-natal nutrition can explain different growth trajectories between children from rich and poor households. Exploiting the panel dimension of our data enhances our ability to interpret the findings in a causal fashion and changes the focus of our analysis from cross-household comparisons to within-child changes over time.

A remaining concern is that the presence of potential time-variant unobservable variables could bias our results. Therefore, in the 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, service accessibility (water and electricity), and average change in greenness to capture potential sources of time-variant unobservable factors. In addition, in the third step we include year-ward fixed effects to control for idiosyncratic variation in crop choices,[2] and village time trends to take into account village level unobservable factors including parental awareness if this comes from village-level information diffusion and is accumulated over time. In the fourth step, we consider deviations of crop diversification and child health from village averages to address the concern that household-level crop choices could capture the local availability of food varieties.

Finally, we implement two instrumental variables approaches to bound our estimates. Standard IV methods require that appropriate instruments are available to identify an effect via exclusion restrictions so that the effect of the instruments on the main dependent variable (in our case, child health) is only indirect. The first approach we implement follows Lewbel's (2012) method. This approach allows the estimation of models with endogenous regressors by using heteroscedasticity based instrumental variables. In this method, the exclusion restriction is satisfied by creating instruments that are the product between the mean-centered exogenous variables of the model and the residuals from the first stage regression of the endogenous variable on all the exogenous regressors of the model. The model is identified by having regressors that are uncorrelated with the product of the heteroskedastic errors.

The second IV approach aims at estimating a range of possible estimates rather than a single point estimate by requiring weaker exclusion restrictions. In particular, we follow Nevo and Rosen (2012) and propose two "imperfect instruments" (IIV) that allow us to find a lower and an upper bound for the impact of crop diversification on child health. Nevo and Rosen (2012)'s approach relaxes an important assumption for the identification of instrumental variable estimations. The instruments are allowed to correlate with the error term to a certain extent, i.e. the zero correlation assumption between the instrument and the error term is replaced with an assumption about the sign of the correlation. In particular, the authors suggest that if the instrument is correlated with the error term in the same

[2] A ward is an administrative unit that includes several villages in rural areas and represents one single town or a portion of a bigger town in urban areas up to 21,000 people.

direction as the correlation between the endogenous variable and the error term (Assumption 3, A3, in their framework) and the instrumental variable is less correlated with the error term than the endogenous variable (Assumption 4, A4), then it is possible to derive analytic bounds for the estimated parameters.

We consider the changes in district-level average number of crops and maize price variability as "imperfect" instrumental variables for household-level crop choices. Because both instruments are positively correlated with the endogenous variables, the IIV approach would yield only one-sided bounds. Following Nevo and Rosen (2012) it is, however, possible to combine the available instruments in order to obtain an additional composite instrument, z_C, that is negatively correlated with the endogenous variable. In particular, we subtract the district-level average number of crops (z_1) from the maize price variance (z_2) using the formula $z_c = z_2 \frac{\sigma_{z2}}{(\sigma_{z1}+\sigma_{z2})} - z_1 \frac{\sigma_{z1}}{(\sigma_{z1}+\sigma_{z2})}$, where σ indicates the standard deviation of each instrument (z_1 and z_2). The new combined instrument is negatively correlated with the endogenous crop diversification variable.

Two main mechanisms can explain the relationship between crop diversification and child health: an income effect and a dietary diversity effect. By controlling for total annual household consumption and total revenues we are able to isolate the effects of crop diversification on child health above and beyond any potential income effects, and also partially deal with potential confounding effects that are correlated with both crop choices and child health, through income effects.

In order to test the dietary diversity mechanism underlying the relationship between crop diversification and child health we investigate the association between crop diversification and dietary diversity by estimating the following household-level equation:

(2) $$DD_{jt} = \beta D_{jt} + \boldsymbol{Z}_{jt} + \boldsymbol{\nu}_j + \boldsymbol{d}_t + \varepsilon_{ijt}$$

where *DD* is a measure of the dietary diversity of household *j* at time *t*; *D* is the same measure of crop diversification used in equation (1) and $\mathbf{Z}$ the same vector of household characteristics; $\boldsymbol{\nu}$ represents household-specific fixed effects, **d** indicates year and month of interview fixed effects, and ε is an idiosyncratic error term. We also estimate a two-step model where in the first step dietary diversity is estimated as a function of crop diversification and, in the second step, the estimated dietary diversity is allowed to affect child health. The two equations are estimated jointly, within a conditional mixed-process framework, to take account of possible correlations between the errors and so improve efficiency.

4. Data description

The empirical analysis uses child-level data provided by the Tanzania National Panel Survey (TZNPS) conducted in years 2008/2009, 2010/2011, and 2012/2013 (waves 1-3) by the Tanzania National Bureau of Statistics (NBS) as part of the World Bank Living Standards Measurement Study – Integrated Surveys on Agriculture.[3] The survey is representative at the national level and is characterized by very low sample attrition: about 97 percent of 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, TZNPS collects information on anthropometrics for all adults and children. We use this information to compute a standard anthropometric measure used in the literature to measure long-term nutritional status: the height-for-age z-score (HAZ) (Delgado et al., 1986; Caulfield et al., 2006; Koletzko et al., 2016). This measure indicates the number of standard deviations above or below the reference median value provided by the World Health Organization (WHO) according to the age and gender of the child.[4] WHO provides reference values for children aged zero to 19 (WHO, 2006; de Onis et al., 2007). This is a standard and common measure used to assess the physical growth and nutritional status of children. A child whose HAZ is less than −2 standard deviations is considered

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[3] The survey data are collected every two years over a period of one year, for example from October 2012 to October 2013. Hence, the time gap between any two waves varies from 12 months to 37 months with most of the households interviewed every 23-24 months (78 percent). While the empirical specification relates child health and crop choices from the same wave, the former is measured at the time of the interview, while the latter is recalled information from the two previous seasons: the latest completed short rainy season and the latest long rainy season. Almost all households (99.3 percent) report to have completed the harvest of both seasons. In the absence of annual data, relating lagged values of crop diversification to changes in health measures would imply considering the impact of crop choices occurred more than two years before the anthropometric measures were collected, i.e. for example the impact of a change in crop diversification between 2008 and 2010 on the change in health outcomes between 2010 and 2012. This would imply neglecting agricultural choices that occurred over a two-year period, and also losing one entire period of analysis. Hence, we opted for the analysis of "contemporaneous" effects since the time gap between waves allows, to a certain extent, to capture the effects of past crop choices on health. Data are available at http://microdata.worldbank.org/index.php/catalog/lsms.

[4] Our anthropometric measure was calculated using the WHO Anthro macro for STATA for children up to five years of age, and the WHO AnthroPlus macro for STATA for older children. The macro can be found at http://www.who.int/childgrowth/software/en/.

stunted (Caulfield et al., 2006). Stunting is the result of chronic undernutrition, which delays child growth and increases the likelihood of a child to become sick and die from a disease (Caulfield et al., 2006; Leroy et al., 2015). The percentage of children with a low HAZ reflects the cumulative effects of undernutrition. This measure can therefore be interpreted as an indicator of long-term nutritional status.

In addition, TZNPS collects information on 50 different types of seasonal crops, and more than 30 permanent crops. The classification is consistent across years. Information on crop production is obtained from recalled data about the two latest growing seasons: the latest short and long rainy seasons. We measure crop diversification considering the number of crop groups produced during both seasons. These groups are defined according to the guidelines of the Food and Agriculture Organization (FAO, 2011) and include: cereals, leafy vegetables, fruits rich in vitamin A, legumes nuts and seeds, oils and fats, tubers, white roots, other fruits, and other vegetables. In doing so, we exclude from the count crops with little or no nutritional properties such as cash crops (e.g., cotton and wood) and spices. The complete list of crops in each food groups is provided in Table A1 of Appendix A.[5]

Few considerations have driven the choice of this measure of crop diversification. First, this measure maps directly into measures of dietary diversity that reflect the need for children to consume a variety of crop types that meet both energy and micronutrient needs (Ruel, 2003). For example, Hatløy et al. (1998) show that measures of dietary diversity based on food groups are a stronger determinant of nutrient adequacy than measures based on individual foods. It can, therefore, be argued that what matters for child nutrition is the variety across food categories rather than across individual agricultural products. Second, it does not rely on measures of yields or land size that could be affected by measurement error. The latter has been proven to be particularly noisy when households adopt intercropping (Carletto et al., 2013), which is the case in 64 percent of plots in 2010. Finally, despite the aggregation of crops into groups we still observe sufficient variation in the number of crop groups

[5] 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, or the relevant level of food diversity for dietary purposes.

over time within a household (Table 1) to allow us to capture the effect of changes in crop diversification on health outcomes. As a robustness check, we also test the effects of alternative crop diversification measures that are described in Appendix B.

In the empirical analysis, we consider children aged 0-10 in households engaged in agriculture in at least two consecutive years, and that did not split off between waves (about 1,500 households). We focus on children below age ten based on previous studies (e.g., Victora et al., 2008; Black et al., 2013; Hoddinott et al., 2013) that argue that height-for-age z-score—our anthropometric measure of interest—is a strong biological marker of young children's nutritional status and that the growth potential is highest in young children. In addition, we exclude children for whom anthropometric measures were not collected. Table A2 of Appendix A compares the original sample with our final sample, and shows that differences in average characteristics, although sometime significant, are small. Table 1 reports the descriptive statistics for the main variables used in the empirical analysis for the pooled sample, and Table A3 of Appendix A shows additional descriptive statistics by wave. The statistics refer to 2,471 children (6,361 observations). As a robustness check, we also restrict the analysis to subsistence households, which are households that did not sell crops in any waves. This sub-sample accounts for about 15 percent of total households (352 children; 894 observations).

[TABLE 1 ABOUT HERE]

The final sample is equally split between boys and girls. The average child is about six years old, 107 centimeters tall, and weighs about 18 kilos. The percentage of children working on farms has significantly increased from two percent in the first wave to nine percent in the last wave (*p*-value = 0.000). A similar pattern is observed for children attending school – from 22 percent to 55 percent (*p*-value = 0.000). Average land size is about eight hectares per household. We observe a significant improvement over time in the height-for-age z-score and a significant increase in the number of crop groups (*p*-value = 0.000, based on ANOVA tests). 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 11 percent of the sample) and a maximum of 17 (0.02 percent). This translates into an average of 3.5 crop groups per household with about 85 percent of households growing between one and 5 crop groups.

Other variables of interest include real total annual household consumption (in USD), whether the household owned livestock in the last year, the presence of elderly people in the household, the average greenness of the growing season, access to treated water and electricity (including solar energy), and siblings' and parents' health. Siblings' health is measured by averaging the height-for-age z-score of a child's brothers and sisters while parents' hospitalization is a binary variable indicating whether at least one of the parents had been hospitalized or had been overnight in a medical facility during the last twelve months. The greenness index (or Enhanced Vegetation Index), obtained from satellite images (MODIS Land Cover) and readily available at the household level as part of the TZNPS dataset, measures soil moisture during the growing season. The index has been found to respond to rainfall with a 24-32 day lag in sub-Saharan sites (Jamali et al., 2011).

5. Main 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 (i) by including additional control variables, year-ward fixed effects, and village time trends; (ii) by investigating local effects as deviations from village or ward averages; (iii) by performing instrumental variable estimation; and (iv) by using alternative measures of crop diversification and child health. Finally, we explore potential heterogeneous effects, and test whether the effect of crop diversification on child health differs by the age and gender of the child as well as by geographical regions and distance to the market.

5.1 Baseline results

We document the relationship between crop diversification and child health by estimating equation (1). Table 2 presents child and year fixed effects estimates of crop diversification, measured by the number of crop groups, on height-for-age z-score (HAZ).[6] This specification considers the effect of changes in crop diversification over time on children's health accounting for time-invariant unobservable characteristics such as parents' skills and propensity to seek information or innate and pre-natal child attributes. All standard errors are clustered at the household level. In column 1, we control for child characteristics, such as education, age, and on farm work, and household characteristics, such as family structure and changes in land size over the period.

[TABLE 2 ABOUT HERE]

Fixed effects estimates show that crop diversification has a positive and significant effect on children's health. Cultivating one additional crop group increases the height-for-age z-score by 0.025, which is equivalent to 2 percent of a standard deviation, or 4.6 percent of the within-child standard deviation. The effect is small, but this is not surprising given the nature of the empirical setting. Because of the established persistence in childhood anthropometric measures (Denteh et al., 2018), a change in agricultural choices is unlikely to have a large effect on height-for-age z-score over time.

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[6] Pooled ordinary least squares (OLS) estimates without child fixed effects are presented in Table A4 of Appendix A. The OLS estimates show a negative correlation between crop diversification and child health. Undoubtedly, these estimates suffer from omitted variable bias, hence the inclusion of child fixed effects in all our specifications.

The results are robust to the inclusion of child and household-level control variables, including land size. The sign of the coefficient of land size is negative. Nevertheless, although significant, the coefficient is very small. A one-hectare increase in land reduced HAZ by only 0.004, corresponding to less than 0.2 percent of a standard deviation.[7]

In column 2, we include two important controls, real total household consumption and real total revenues that capture the effect of crop diversification on children's health through an income effect. This is also crucial to rule out any other potential confounding effects that operate through changes in income. In column 3, we account for livestock ownership to capture other potential sources of food consumption. Our results remain robust in magnitude and significant to the inclusion of these additional covariates whose effects are instead insignificant.

In addition, in column 4 we control for whether there is at least one household member working off-farm. We find that the coefficient of the off-farm labor variable is not significant while the coefficient of crop groups remains positive and strongly significant at the 1 percent level.[8] Finally, because the survey was undertaken at various months during the year, we are able to control for seasonality by including the month of interview in column 5. Large variations in monthly consumption are identified by Kaminski et al. (2014) using the same survey, indicating that food insecurity might be more pronounced at particular times of the year. While we confirm the presence of some monthly variations in average health outcomes in the data, we do not observe statistically significant differences in average crop diversification across months (Table A5 of Appendix A). This suggests that potential effects of crop diversification on child health caused by differences in the timing of the interview are

[7] Moreover, the variable land size is likely to be endogenous but it is important to include it to capture unobservable time-varying characteristics. For example, an increase in land size could be due to inheritance and so correlated with a negative household shock such as the death of a relative. On the other hand, a decrease in land size could be related to diversification away from agriculture or to migration (remittances) that could have potential positive effects on child health, although this is partially controlled for by off-farm income.

[8] Most of the control variables considered in this and the next section appear to have insignificant effects on child health. This can be explained by the fact that most variables show limited variation over time, which is the source of variation we exploit in our study. This feature distinguishes our paper from most of the studies in the literature that exploit cross-section variations and hence are able to detect a greater variation in explanatory variables.

unlikely. The coefficient of crop groups remains positive and significant when we include month of interview fixed effects. The remainder of the paper will present several robustness checks to test the sensitivity of the findings and mitigate remaining endogeneity concerns.

5.2 Robustness checks

In this section, we provide a set of robustness checks to exclude potential confounding effects and to further test the stability of our results. Additional concerns, for example, relate to the effect that accessibility of services such as water and electricity, and weather conditions can have on both 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 relationship between weather and human health (e.g., Maccini and Yang, 2009; Graff Zivin and Neidell, 2013; Dell et al., 2014), and between weather or climate and crop choices (e.g., Seo and Mendelsohn, 2008; Wang et al., 2010; Di Falco and Veronesi, 2013). In column 1 of Table A6 of Appendix A, we control for households' access to treated water and electricity while in column 2 we deal with the possibility that variations in rainfall could be correlated with farming choices but also with child health. We confirm the strong and significant association between crop diversification and child health. We find that the average greenness of a growing season is positively correlated to HAZ while water and electricity accessibility do not have a significant effect.

Because parents' health conditions might have an effect on their children's health, which in turn might have an effect on crop decisions, in column 3 we also control for whether at least one parent was hospitalized. In column 4, we include the average height-for-age z-score of a child's siblings as a measure of siblings' health. This allows for shocks that are correlated with both crop diversification and a child's health to be captured by their effects on his/her brothers and sisters. Our results remain unchanged. In column 5, we use a measure of permanent wealth, based on a wealth index constructed following Filmer and Pritchett (2001), instead of consumption per capita. The index combines a set of variables covering assets, dwelling characteristics and access to services by using principal component analysis. The wealth index is pretty stable over time, so its effect on HAZ is not statistically significant.

In column 6, we include a full set of year-by-ward fixed effects and village time trends to control for ward characteristics that might have changed overtime and might have been correlated with crop choices and child health. In doing so we aim at capturing, for example, policy interventions that have been targeted to specific wards. Village-level time trends are instead meant to capture existing time patterns at the village level, and also partially accounts for parental awareness if this comes from the diffusion of information at the village-level. Our results are robust also to the inclusion of year-ward fixed effects and village time trends. The robustness of the point estimates to the inclusion of important additional covariates and fixed effects suggests that these results are most likely not affected by omitted variable bias.

5.3 Local effects

In this section, we are concerned with the possibility that household-level crop choices are correlated with village-level crop diversification and, hence, could indirectly capture the local availability of food varieties that could in turn affect a household diet. Indeed, as discussed in Section 2, agro-ecological and market conditions, such as seeds availability, are common to households living in the same area and are likely to influence their crop choices. The inclusion of year-by-ward fixed effects in column 6 of Table A6 partially captures the effect of local, time-variant conditions yet it might not completely account for within-ward variations. However, the inclusion of village time trends in the same column further attenuates the problem. The stability of the crop diversification coefficient to the inclusion of year-by-ward fixed effects and village time trends is reassuring. Yet, a correlation between household crop choices and neighbor's choices is still possible, although it can only affect our results if the correlation exists over time and not just across locations, as the latter is captured by the inclusion of child fixed effects.

We estimate, therefore, two additional specifications: the first one considers deviations from village averages (Table A7 of Appendix A, column 1) while the second one from ward averages (column 2). In these specifications, relative crop diversification, with respect to the village or ward averages, is related to relative child health.[9] We find a positive and significant effect of crop diversification on child health relatively to the average crop diversification of the other households in a village or in a ward. This confirms that household-level crop diversification has an effect on child health above and beyond possible local effects.

5.4 Instrumental variable approaches

One major concern regarding our previous results is that increased crop diversification could be the result, for example, of unobserved coping strategies or technology diffusion. In particular, government or NGOs' interventions, such as those described in Larsen and Lilleør (2016) and Evans et al. (2017), could have affected both crop choices and health outcomes.[10] Interventions could increase crop diversification and also induce better nutrition directly or through complementary programs, creating an upward bias in our estimates. Alternatively, government and organizations could be targeting poorer households with worst child health conditions, creating instead a downward bias. Therefore, the direction of the bias of the coefficient of crop diversification is, a priory, ambiguous.

[9] All other control variables of our baseline specification (column 5, Table 2), excluding binary variables, are also included as deviations.

[10] Larsen and Lilleør (2016) investigate the impact of agricultural interventions (the "Rural Initiatives for Participatory Agricultural Transformation") in Tanzania on child health. Evans et al. (2017) assess the impact of cash transfers conditioned on health clinic visits on health-related outcomes. While these interventions coincide partly with our period of analysis, they involved a very small number of villages and, therefore, it is very likely that none or very few households in our sample were directly involved in these interventions. Nevertheless, other programs could have been implemented and could have affected the households in our sample.

To address these concerns, we implement the two instrumental variables (IV) approaches as described in Section 3. The results obtained by using the Lewbel's (2012) method are reported in column 1 of Table 3 and show a larger effect of crop diversification on height-for-age z-score compared to our previous results. This suggests that our baseline estimates could be downward biased. This is the case, for example, if increased crop diversification occurs among poorer households as a result of potential policy interventions.

In our second IV approach, we consider the changes in district-level average number of crops and maize price variability as "imperfect" instrumental variables for household-level crop choices. Both proposed imperfect instruments are positively correlated with crop choices and, at the same time, it is reasonable to expect these two variables to be less correlated with the error term than crop diversification at the household level. In particular, while our instruments might violate the stable unit treatment value assumption (SUTVA) required for standard instrumental variable approaches, i.e. the assumption that child health is unrelated to the crop choices of neighboring households, partial identification only requires district-wide measures to be less correlated with child-level unobservable characteristics than household-level crop choices. This is likely to be the case since changes in unobservable child characteristics are more closely related to household-level shocks than district-wide changes as the latter effect is mediated by a household responsiveness to external shocks.

[TABLE 3 ABOUT HERE]

Columns 2 and 3 of Table 3 present the results of the partial identification procedure proposed by Nevo and Rosen (2012) and described in Section 3. In particular, the first row shows the estimated lower and upper bound effects, while the related 95 percent confidence intervals are in square brackets. By relaxing the strict exogeneity assumption (A3), we can bound the coefficient of crop diversification as shown in column 2, where the lower bound is obtained by using z_1 as an instrument in a standard IV approach. This implies that if we were to assume the average number of crops in the district (z_1) to be an exogenous instrument, 0.093 would be the point estimate. The 95 percent confidence interval goes only slightly below zero. In the same column, the upper bound coefficient (0.141) is obtained using the difference between the two imperfect instruments (z_2 - z_1) as instrument in a standard IV approach. The so obtained upper bound is very similar to those obtained with the Lewbel's approach. Finally, when using the additional assumption of a weaker correlation between the instruments and the error term (A4) we obtain a slightly narrower interval (column 3). The lower bound in this case is obtained by using a weighted combination of the two imperfect instruments (z_C) as instrument in a standard IV approach. In all specifications, the excluded variables are highly significant in the first stage, as indicated by the reported F-statistics at the bottom of Table 3. All IV specifications show higher estimates. Our previous fixed effects estimates lie outside the bounds estimated relaxing the exogeneity assumption, although they are within the 95 percent confidence interval. Overall these results confirm a positive relationship between crop diversification and child health and yield to conclude that if our baseline results are biased the bias is most likely downward. The effect of one additional crop group on the height-for-age z-score is estimated to be between 10 and 12 percent of a standard deviation (22 and 26 percent of within-child variation), when considering the narrower interval in column 3.

5.5 Alternative measures of child health and crop diversification

The aforementioned robustness checks have substantially reduced the scope for potential confounding effects, however, some concerns still remain concerning the choice of our health and crop diversification measures. Leroy et al. (2015), for instance, argue that our preferred measure of child health, height-for-age z-score, is inappropriate for measuring changes in linear growth over time because it is constructed using standard deviations from cross-sectional data; they suggest instead the use of height-for-age differences (HAD). We, therefore, test the sensitivity of our results to the use of this alternative measure of child health in Table A8 of Appendix A. Results confirm the positive and significant effect of crop diversification on child health.

In Table A8, we also present the results for weight-for-age z-score (WAZ), and BMI-for-age z-score (BAZ). Although nutrient absorption and its effects on diet can have acute clinical manifestations and could also potentially affect weight, we find that crop diversification does not affect children's WAZ or BAZ.[11] 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). In addition, weight loss or gain can be acute and change rapidly more often due to seasonal variations or infections (Nabarro, 1983). Finally, in Table A9 of Appendix A we show that our findings do not depend on the choice of the crop diversification measure (see Appendix B for the description of the alternative measures). All alternative measures of crop diversification lead to the same conclusion that crop diversification has a positive and strong significant effect on a child HAZ.

We also estimated a model that uses an index of food groups that includes not only crop groups but also animal products given the importance of the latter for child growth (e.g., Headey et al., 2018). This allows us to test how sensitive our results are to the exclusion of animal products. The coefficient on this index is very similar to previous estimates (0.023, s.e. 0.009) obtained from specifications where we control for ownership of livestock.

5.6. Heterogeneous effects

The results above have shown that crop diversification has a positive and robust effect on child health. Yet, the overall estimates are small, partly due to a possible underestimation of the impact as suggested

[11] Kumar et al. (2015) also do not find a significant effect of crop diversification on weight.

by the instrumental variable estimates but also due to the persistence in early childhood anthropometric outcomes.

In this section, we explore potential heterogeneous effects to investigate whether the small average effect masks significant differences among households. We do so by interacting our measure of crop diversification—the number of crop groups—with a child characteristic (age, gender), the geographical location of the household, and the distance to the market.[12] Although several studies indicate that targeted interventions are more likely to improve the height of very young children (e.g., Gertler, 2004; Behrman et al., 2005; Ruel et al., 2008), the WHO and the United Nations Sub-Committee on "Nutrition Through the Life-Cycle Approach" have called attention to the lack of information on nutrition for school age children, and so the need for future research on these groups (United Nations ACC/SNC, 2000; Butte et al., 2007). Our data allow us to test the effect of crop diversification on children in the critical age group (below five years) and compare them with older children until 10 years of age. The first column of Table 4 presents the estimates for these two different age groups. The insignificant coefficient of the interaction term between crop diversification and age group 5-10 suggests that the difference in the effect between younger and older children is not statistically significant. The same apply to the differences between boys and girls (column 2) and between regions (column 3).

[TABLE 4 ABOUT HERE]

In column 4, 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 sized groups: "far" (> 20 km to the

[12] Note that we also include each characteristic separately in our regression, however, when the characteristic is fixed overtime it is absorbed by the child fixed effects and so not reported in Table 4.

market), "medium" (6-20 km), and "close" (0-5 km). The coefficients of the interaction terms between crop diversification and the distance dummy variables suggests that the relationship between crop diversification and child health is substantially weaker for households close to the market than for those far from the market. This is in line with the fact that households close to the market can substitute diversity in own produced food for diversity in purchased food as they can rely more heavily on market products for their diet (Hirvonen and Hodinott, 2016) and can sell their agricultural products more easily (Key et al., 2000). Instead, households far from the market are more likely to have limited access to purchased food varieties and rely more on own produced food varieties for their diet. These results indicate that crop diversification can help improve the health of children in remote areas, yet left alone this agricultural strategy cannot substantially improve health conditions.

6. Underlying mechanism: crop diversification and dietary diversity

The results reported so far have shown that greater crop diversification is beneficial for children's health – in particular, for children living in households with limited access to the food market. As discussed in Section 2, two main mechanisms can explain the relationship between crop diversification and child health: an income effect and a dietary diversity effect. By controlling for household income and total revenues we isolate the effects of crop diversification on child health above and beyond any potential income effects. In this section, we provide suggestive evidence on the second underlying mechanism by formally testing the relationship between crop diversification and dietary diversity.

Dietary diversity is measured by the number of food groups consumed at the household level using information on the week prior to the survey.[13] 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's

[13] This variable is measured according to the guidelines of the Food and Agriculture Organization (FAO, 2011). However, we recognize that there is no international consensus on which food groups to include.

dietary diversity over the entire between-waves period. Nevertheless, it can still provide some evidence on the relationship between our measure of crop diversification and dietary diversity.

In Table 5, we present household, year, and month of interview fixed effects estimates of equation (2), that is of household dietary diversity on crop diversification.[14] We find a significant and positive effect of crop diversification on dietary diversity. Column 1 shows that one additional crop group is associated to an increase in average dietary diversity by 0.05. The effect is small, which is line with the size of the effect of crop diversification on child health estimated above, and the results presented in the meta-analysis by Sibhatu and Qaim (2018).

[TABLE 5 ABOUT HERE]

There are many challenges in comparing our results with other similar studies due to the use of different measures of dietary diversity, different age groups, different country settings, different samples, and different empirical methods. In particular, our specifications exploit within household variation as opposed to cross household variation, as done in most studies, which shifts the focus of the analysis towards changes in crop and dietary choices over time. In an attempt to improve comparability, in Table 5 we have included alternative measures of crop diversification and dietary diversity similar to those explored in the literature. In general, our results are in line with those from the meta-analysis by Sibhatu and Qaim (2018), and lie within those observed in comparable empirical studies. For instance, Hirvonen and Hodinott (2016) find a larger positive effect of crop diversification on dietary diversity. Their empirical specification compares to the one we report in column 1 of Table 5, although their measure of dietary diversity is child-specific and not household-specific, and the estimates are obtained from a cross-section of young children. Dillon et al. (2015) use cross-sectional

[14] All columns of Table 5 include household, year, and month of interview fixed effects, and household characteristics as specified in column 5 of Table 2. Robust standard errors are clustered at the household level.

data from Nigeria and find very similar results to those we report in column 2 of Table 5. Sibhatu et al. (2015) use measures of crop diversification similar to those we report in columns 3 and 4 of Table 5.

The significant association between crop diversification and dietary diversity is reassuring and supports our main hypothesis that greater crop diversification is related to greater dietary diversity and, ultimately, to an improvement in child health. To further corroborate these results, we also estimate a two-step model within a conditional mixed-process framework as described in Section 3. The results, reported in Table A10 of Appendix A, confirm our previous finding and indicate a positive but small effect of crop diversification on child health through greater dietary diversity.

6.1 Subsistence households and placebo tests

In this section, we propose a set of empirical tests, shown in Table 6, to provide additional support to the dietary diversity channel described above.[15] 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 are likely to have consumed most of what was produced. For these households, we expect the dietary diversity effect to be large, while a potential income effect to be small since agriculture output is not a source of revenues but rather only a source of food for own consumption. The effect of crop diversification on child health remains positive and more than doubles in size. These findings largely exclude potential income effects and, instead, support the hypothesis that crop diversification is associated with better child health through its direct effect on food consumption. The effect of crop diversification for subsistence households is comparable to that obtained for remote households (Table 4, column 4).

In addition, we propose two placebo tests aimed at excluding possible non-dietary effects. In column 3 of Table 6, we construct a measure of crop diversification that includes only crops that were

[15] All specifications refer to our baseline model that includes child, year, and month of interview fixed effects, child characteristics, and household characteristics as in column 5 of Table 2. To facilitate comparisons, the coefficient estimates from column 5 of Table 2 are repeated in the first column of Table 6.

completely sold. While a greater variety of crops sold might have an impact on consumption, mainly through income, it should not have any direct nutritional effect on children's health. As expected, we find that the effect is not significant. This shows that, controlling for income and revenues, crop varieties that are sold and not used for own consumption do not have an effect on child health because they do not form part of a child diet.

In column 4, we offer a second placebo test and measure crop diversification considering only the number of crops that are expected to have no direct effect on health because they have little or no nutritional content, such as cash crops (e.g., cotton, tobacco), or spices.[16] We employ our baseline specification that controls for both income and revenues and find that the coefficient is highly insignificant. Overall, our placebo tests show that crop diversification matters only if it involves crops that are relevant for dietary diversity and crops that are consumed by the household. Hence, they support our hypothesis that crop diversification leads to better child health through greater nutritional diversity.

[TABLE 6 ABOUT HERE]

7. Conclusions

We use a three-wave panel dataset from the Tanzania National Panel Survey to test the effect of crop diversification on child health, controlling for unobservable heterogeneity and income effects. We document a positive but small effect of an increase in crop diversification on child height-for-age z-score over time. The effects are larger for children living in households with limited access to the market, and subsistence households who rely more on own-produced food. Although the effects are small in magnitude, our results are important in showing how agricultural choices, in particular in remote areas, can have an effect on human health besides any possible income effect.

[16] The full list of crops included in the placebo test with little or no nutritional properties is provided in Table A1, panel B of Appendix A.

We also show that the effect of crop diversification on child health operates through greater dietary diversity using a set of auxiliary specifications. While our study shows that the effect of crop diversification on child health status transmits, at least in part, through nutritional diversity, we recognize that the pathway from agricultural production to consumption is complex and often indirect. Other complementary or opposing mechanisms could be at play and their investigation is beyond the scope of this paper.

Our findings remain relevant also in light of increased market participation by smallholder farmers. As agricultural households become more integrated into the market, crop decisions will be more likely driven by agro-climatic conditions, specialization, and comparative advantages. The local marketplace, therefore, will become an important source of food variety. Given the importance of food diversification for child health, as shown in this paper, it is important to ensure that local markets are well integrated with regional or national markets to ensure that sufficient crop varieties remain available at the local level. Hence, recommending the adoption of wider crop diversification at the farm level, besides marked-based diversification, is not an intention of this research, as diversification strategies also carry opportunity costs that have not been analyzed in this paper.

In addition, while we show a positive effect of crop diversification on child health, this paper does not offer a comparison with alternative agricultural and food policies, nor with interventions or factors not related to food such as health care, maternal care and knowledge. In addition, our empirical setting and data limitations do not allow us to test and compare the effects of crop diversification on infants or on a child while in the womb, nor the impact of market access on dietary diversification. A comprehensive assessment of alternative policy instruments, therefore, requires further research.

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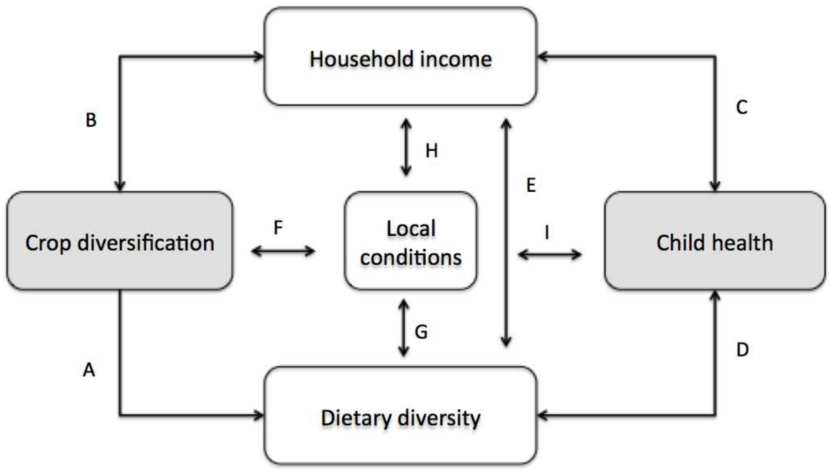

Figure 1. Simplified pathway from crop diversification to child health.

Table 1. Descriptive statistics.

Variables	Mean	Std. dev.	Std. dev. (within)	Std. dev. (between)
Dependent variables				
Height-for-age z-score (HAZ)	-1.564	1.217	0.546	1.092
Weight-for-age z-score (WAZ)	-1.157	1.031	0.416	0.952
BMI-for-age z-score (BAZ)	-0.254	1.036	0.551	0.886
Height-for-age differences (HAD)	-7.608	5.912	2.303	5.519
Explanatory variables				
Crop diversification measures				
Number of crop groups	3.516	1.735	0.908	1.491
Number of crops	4.076	2.428	1.228	2.101
Margalef index	0.285	0.213	0.110	0.183
Margalef GPS index	0.285	0.214	0.110	0.185
Margalef food group index	0.235	0.158	0.084	0.135
Simpson index	0.502	0.254	0.154	0.205
Shannon-Wiener index	1.113	0.600	0.341	0.500
Child characteristics	0.022	0.017	0.011	0.013
Dummy: attending school	0.391	0.488	0.310	0.390
Dummy: worked on farm	0.058	0.234	0.175	0.162
Age (in months)	72.378	31.629	17.756	26.785
Male	0.483	0.500	0.000	0.500
Household characteristics				
Number of children 0-5	1.876	1.565	0.609	1.424
Number of children 6-12	2.021	1.355	0.587	1.219
Number of children 13-17	0.898	1.001	0.463	0.888
Dummy: elderly	0.194	0.395	0.131	0.374
Household consumption (USD)	2,059.584	1,914.961	975.128	1,625.542
Total revenues (USD)	201.607	1217.530	926.017	764.750
Dummy: livestock	0.745	0.436	0.258	0.357
Land size (hectares)	7.731	22.592	11.916	18.542
Dummy: off-farm job	0.528	0.499	0.324	0.385
Dummy: water accessibility	0.253	0.435	0.294	0.327
Dummy: electricity accessibility	0.071	0.257	0.125	0.232
Average greenness (EVI)	0.580	0.134	0.029	0.132
Parents' hospitalization	0.145	0.353	0.267	0.234
Siblings' average HAZ	-1.730	0.981	0.435	0.897
Wealth index	-0.898	1.513	0.453	1.482

Notes: Data are from the pooled sample of the Tanzania National Panel Survey for years 2008/2009 (wave 1), 2010/2011 (wave 2), and 2012/2013 (wave 3). The total number of observations is 6,361.

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

Dependent variable:	Height-for-age z-score (HAZ)				
	(1)	(2)	(3)	(4)	(5)
Crop diversification					
Number of crop groups	0.025***	0.023***	0.024***	0.023***	0.023***
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
Child characteristics					
Dummy: attending school	0.039	0.039	0.039	0.040	0.043
	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)
Dummy: worked on farm	-0.072*	-0.072*	-0.072*	-0.074*	-0.072*
	(0.039)	(0.039)	(0.039)	(0.039)	(0.039)
Age (in months)	-0.070***	-0.070***	-0.070***	-0.070***	-0.070***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Age squared	-0.054***	-0.054***	-0.054***	-0.054***	-0.055***
	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)
Household characteristics					
Number of children 0-5	0.039	0.039	0.039	0.040	0.043
	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)
Number of children 6-12	-0.072*	-0.072*	-0.072*	-0.074*	-0.072*
	(0.039)	(0.039)	(0.039)	(0.039)	(0.039)
Number of children 13-17	-0.070***	-0.070***	-0.070***	-0.070***	-0.070***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Dummy: elderly	-0.054***	-0.054***	-0.054***	-0.054***	-0.055***
	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)
Land size	-0.004***	-0.005***	-0.005***	-0.004***	-0.005***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Household consumption (log)		0.016	0.018	0.015	0.020
		(0.030)	(0.030)	(0.030)	(0.030)
Total revenues (log)		0.003	0.003	0.003	0.003
		(0.003)	(0.003)	(0.003)	(0.003)
Dummy: livestock			-0.031	-0.033	-0.030
			(0.034)	(0.035)	(0.034)
Dummy: off-farm job				0.035	0.034
				(0.025)	(0.025)
Child fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Month fixed effects	No	No	No	No	Yes
Observations	6,361	6,361	6,361	6,361	6,361
Number of children	2,471	2,471	2,471	2,471	2,471

Notes: All specifications include child and year fixed effects. Column 5 also includes month of interview 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% and 10% level, respectively.

Table 3. IV Estimates.

Dependent variable:	Height-for-age z-score (HAZ)		
	Lewbel (2012)	Imperfect IV (Nevo and Rosen, 2012)	
	(1)	(2)	(3)
Number of crop groups	0.146*	(0.093 - 0.141)	(0.120 - 0.141)
	(0.083)	[-0.006 - 0.287]	[0.003 - 0.287]
F-statistics	-	146.5/80.385	122.07/80.385

Notes: All specifications include child, year, and month of interview fixed effects, and child and household characteristics as specified in column 5 of Table 2. Data are from the Tanzania National Panel Survey for years 2008/2009, 2010/2011, and 2012/2013. The first column follows Lewbel's (2012) method, which uses heteroscedasticity based instrumental variables (IV) and where the standard error presented in parenthesis is clustered at the household level. Columns 2-3 present the lower and upper bound estimates in parenthesis, and the corresponding 95% confidence intervals in square brackets. These are obtained employing Nevo and Rosen's (2012) approach as described in Section 3 where bounds are determined using a combination of the weighted difference between two instruments (district-level crop diversification and maize price variability) as imperfect instruments in column 2, and the weighted average between the number of crops and the weighted instrument in column 3. * indicates significance at the 10% level.

Table 4. Heterogeneous effects by household and child characteristics.

Dependent variable:	Height-for-age z-score (HAZ)			
	Age (1)	Gender (2)	Region (3)	Distance (4)
Number of crop groups	0.026**	0.028**	0.033*	0.064***
	(0.013)	(0.013)	(0.018)	(0.023)
Number of crop groups × age (5-10)	-0.007			
	(0.017)			
Number of crop groups × male		-0.011		
		(0.016)		
Number of crop groups × medium distance				-0.043*
				(0.025)
Number of crop groups × close distance				-0.052*
				(0.029)
Number of crop groups × Northern region			-0.012	
			(0.023)	
Number of crop groups × Southern region			-0.015	
			(0.025)	
Child characteristics	Yes	Yes	Yes	Yes
Household characteristics	Yes	Yes	Yes	Yes
Child fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes
Observations	6,361	6,361	6,361	6,361
Number of children	2,471	2,471	2,471	2,471

Notes: All specifications include child, year, and month of interview fixed effects, and child and household characteristics as specified in column 5 of Table 2. In addition, we add dummy variables for child age, gender, geographic location, or market distance individually and interacted with number of crop groups. Note that the coefficients of the individual dummy variables are not shown because time invariant and so they are absorbed by child fixed effects. The coefficient of number of crop groups in the first row refers to the omitted dummy variable, i.e. the baseline. In column 1, the omitted variable is children age 0-5; in column 2, it is girls; in column 4, it refers to households in the Central region; and in column 3, it refers to households that live "far" from the market (> 20 km). "Close" refers to market distance 0-5 km, and "medium" 6-20 km. Robust standard errors clustered at the household level in parenthesis. Data are from the Tanzania National Panel Survey for years 2008/2009, 2010/2011, and 2012/2013. ***, **, * indicate significance at the 1%, 5%, and 10% level, respectively.

Table 5. Crop diversification and dietary diversity. Household fixed effects estimates.

Dependent variable:	Number of food groups consumed	Number of food groups consumed (log)	Number of food groups consumed	Number of food groups consumed
	(1)	(2)	(3)	(4)
Number of crop groups produced	0.049**			
	(0.020)			
Number of crop groups produced (log)		0.040***		
		(0.013)		
Number of crops			0.032**	
			(0.015)	
Margalef index				0.293*
				(0.169)
Household characteristics	Yes	Yes	Yes	Yes
Household fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes
Observations	3,530	3,502	3,502	3,502
Number of households	1,252	1,249	1,249	1,249

Notes: All specifications include household, year, and month of interview fixed effects, and household characteristics as specified in column 5 of Table 2. 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 6. Subsistence households and placebo tests.

Dependent variable: Height-for-age z-score	Full sample	Subsistence households	Placebo tests	
			Crops 100% sold	Cash crops or spices
	(1)	(2)	(3)	(4)
Number of crop groups	0.023***	0.059**	-0.010	-0.076
	(0.009)	(0.025)	(0.019)	(0.049)
Child characteristics	Yes	Yes	Yes	Yes
Household characteristics	Yes	Yes	Yes	Yes
Child fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes
Observations	6,361	894	5,467	1,255
Number of children	2,471	352	2,119	696

Notes: All specifications include child, year, and month of interview fixed effects, and child and household characteristics as specified in column 5 of Table 2. 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 2. Column 2 refers to subsistence households, that is to the sub-sample of households that did not sell crops in any of the three waves. Column 3 refers to crops that were completely sold, and so excludes subsistence households. Column 4 refers to cash crops or spices as described in Table A1 of Appendix A. Robust standard errors clustered at the household level in parenthesis. ***, ** indicate significance at the 1% and 5% level, respectively.

Online Appendix A

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	Tomatoes	Other vegetables
Palm oil	Oils and fats	Carrot	Vegetables and tubers
Apples	Other fruits	Pumpkins	Vegetables and tubers
Avocado	Other fruits	Sweet potatoes	Vegetables and tubers
Banana	Other fruits	Bread fruit	White roots and tubers
Bilimbi	Other fruits	Cassava	White roots and tubers
Coconut	Other fruits	Cocoyams	White roots and tubers
Custard apple	Other fruits	Irish potatoes	White roots and tubers
Guava	Other fruits	Yams	White roots and tubers
Jack fruit	Other fruits		
Panel B: Crops with little or no 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
Sisal	Other vegetables		

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 4. Panel B refers to crops with little or no nutritional properties used for the placebo test described in Section 6.

Table A2. Comparison between original and final samples.

	(1) Original sample		(2) Final sample		Difference (1) vs (2)	
	Mean	Std. Dev.	Mean	Std. Dev.		
Male	0.49	0.50	0.48	0.50	0.01	
Dummy: attending school	0.46	0.50	0.39	0.49	0.07	***
Dummy: worked on farm	0.05	0.22	0.06	0.23	-0.01	
Age (in months)	75.51	33.83	72.39	31.66	3.12	***
Number of children 0-5	1.69	1.43	1.88	1.56	-0.18	***
Number of children 6-12	1.92	1.30	2.02	1.35	-0.10	**
Number of children 13-17	0.87	0.98	0.90	1.00	-0.03	
Number of elderlies	0.19	0.39	0.19	0.40	0.00	
Household consumption (USD)	2,336.68	2,236.35	2,059.58	1,914.96	277.10	***
Total revenues (USD)	185.48	976.34	201.61	1,217.53	-16.13	***
Dummy: livestock	0.61	0.49	0.75	0.44	-0.13	***
Land size (ha)	8.00	25.31	8.06	24.92	-0.06	
Dummy: off-farm job	0.60	0.49	0.53	0.50	0.07	***
Dummy: water accessibility	0.30	0.46	0.25	0.44	0.05	***
Dummy: electricity accessibility	0.18	0.38	0.07	0.26	0.11	***
Average greenness	0.54	0.15	0.58	0.13	-0.04	***
Parents' hospitalizations	0.15	0.35	0.15	0.35	0.00	
Observations	10,285		6,361			

Notes: "Original sample" refers to the full sample including observations with missing values for crop diversification and the height-for-age z-score. "Final sample" refers to the sample we use in the analysis where we dropped the missing observations. The last column indicates the level of significance of estimates from OLS regressions where the dependent variable is the variable of interest and the independent variable is equal to one if "original sample" and zero if "final sample." ***, ** indicate significance at the 1% and 5% level, respectively.

Table A3. Additional descriptive statistics by wave.

Variables	Wave 1		Wave 2		Wave 3	
Dependent variables	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
Height-for-age z-score (HAZ)	-1.711	1.412	-1.551	1.110	-1.398	1.058
Weight-for-age z-score (WAZ)	-1.124	1.108	-1.182	1.006	-1.171	0.949
BMI-for-age z-score (BAZ)	-0.016	1.091	-0.312	1.021	-0.472	0.922
Height-for-age differences (HAD)	-7.309	6.054	-7.787	5.715	-7.745	5.980
Crop diversification measures						
Number of crop groups	3.362	1.581	3.601	1.794	3.592	1.824
Number of crops	3.620	2.075	4.272	2.532	4.384	2.607
Margalef index	0.244	0.183	0.304	0.222	0.312	0.226
Margalef GPS index	0.243	0.184	0.304	0.222	0.313	0.228
Margalef crop group index	0.223	0.144	0.243	0.163	0.241	0.165
Simpson index	0.442	0.243	0.534	0.254	0.532	0.253
Shannon-Wiener index	0.977	0.547	1.177	0.610	1.194	0.608
Child characteristics						
Age (in months)	54.624	29.592	76.402	30.064	89.296	24.306
Male	0.479	0.500	0.484	0.500	0.486	0.500
Dummy: worked on farm	0.023	0.151	0.065	0.247	0.092	0.290
Dummy: attending school	0.218	0.413	0.432	0.495	0.552	0.497
Household characteristics						
Number of children 0-5	1.947	1.320	1.879	1.579	1.782	1.805
Number of children 6-12	1.828	1.433	2.060	1.305	2.212	1.287
Number of children 13-17	0.817	0.966	0.907	0.981	0.986	1.061
Dummy: elderly	0.175	0.380	0.199	0.400	0.209	0.406
Land size (hectares)	9.735	36.753	6.912	14.655	7.499	15.635
Household consumption (USD)	1,623.335	1,696.956	1,980.402	1,504.019	2,711.774	2,420.988
Total revenues (USD)	109.413	273.956	173.434	426.932	354.711	222.440
Dummy: livestock	0.751	0.432	0.763	0.425	0.714	0.452
Dummy: off-farm job	0.496	0.500	0.574	0.495	0.506	0.500
Additional controls						
Dummy: water accessibility	0.240	0.427	0.281	0.450	0.234	0.423
Dummy: electricity accessibility	0.043	0.203	0.068	0.251	0.112	0.315
Wealth index	-0.996	1.373	-0.879	1.540	-0.801	1.634
Average greenness (EVI)	0.586	0.124	0.569	0.140	0.585	0.137
Parents' hospitalization	0.131	0.337	0.166	0.372	0.136	0.343
Siblings' average HAZ	-1.811	1.040	-1.705	0.960	-1.663	0.925
Observations	2,221		2,367		1,773	

Notes: Data are from the Tanzania National Panel Survey for years 2008/2009 (wave 1), 2010/2011 (wave 2), and 2012/2013 (wave 3).

Table A4. OLS results.

Dependent variable:	Height-for-age z-score (HAZ)				
	(1)	(2)	(3)	(4)	(5)
Crop diversification					
Number of crop groups	-0.061***	-0.067***	-0.067***	-0.068***	-0.065***
	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)
Child characteristics					
Dummy: attending school	0.545***	0.468***	0.468***	0.465***	0.457***
	(0.053)	(0.052)	(0.052)	(0.052)	(0.051)
Dummy: worked on farm	0.169***	0.175***	0.175***	0.171***	0.169***
	(0.064)	(0.063)	(0.063)	(0.063)	(0.064)
Age (in months)	0.008***	0.008***	0.008***	0.008***	0.008***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Age squared	-0.080***	-0.077***	-0.077***	-0.078***	-0.078***
	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)
Household characteristics					
Number of children 0-5	0.027	0.005	0.005	0.006	0.004
	(0.018)	(0.017)	(0.017)	(0.017)	(0.017)
Number of children 6-12	-0.023	-0.050**	-0.050**	-0.050**	-0.049**
	(0.021)	(0.021)	(0.021)	(0.021)	(0.020)
Number of children 13-17	0.042*	-0.012	-0.012	-0.011	-0.011
	(0.024)	(0.025)	(0.025)	(0.024)	(0.024)
Dummy: elderly	0.166**	0.145**	0.145**	0.150**	0.141**
	(0.069)	(0.068)	(0.068)	(0.068)	(0.066)
Land size	-0.000	-0.001	-0.001	-0.001	-0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Household consumption (log)		0.330***	0.330***	0.318***	0.323***
		(0.042)	(0.041)	(0.042)	(0.042)
Total revenues (log)		0.001	0.001	0.002	0.002
		(0.004)	(0.004)	(0.004)	(0.004)
Dummy: livestock			0.006	0.009	0.008
			(0.051)	(0.051)	(0.049)
Dummy: off-farm job				0.069	0.080*
				(0.045)	(0.044)
Child fixed effects	No	No	No	No	No
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Month fixed effects	No	No	No	No	Yes
Observations	6,361	6,361	6,361	6,361	6,361

Notes: All specifications include year fixed effects. Column 5 also includes month of interview 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 A5. Month of interview, child health, and crop diversification.

Dependent variable:	Height-for-age z-score (HAZ)	Number of crop groups
	(1)	(2)
January	-0.268**	0.158
	(-2.23)	(0.75)
February	0.089	-0.298
	(0.76)	(-1.45)
March	0.211*	-0.062
	(1.80)	(-0.29)
April	0.199*	0.140
	(1.78)	(0.61)
May	0.016	0.019
	(0.14)	(0.08)
June	-0.046	-0.141
	(-0.40)	(-0.61)
July	0.027	-0.110
	(0.23)	(-0.52)
August	0.200*	-0.040
	(1.77)	(-0.19)
September	-0.224*	0.156
	(-1.94)	(0.68)
October	-0.060	-0.115
	(-0.50)	(-0.48)
November	0.020	-0.281
	(0.18)	(-1.32)
Observations	6,361	6,361

Note: Omitted category is December. 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 5% and 10% level, respectively.

Table A6. Baseline regressions with additional control variables.

Dependent variable:	Height-for-age z-score (HAZ)					
	(1)	(2)	(3)	(4)	(5)	(6)
Number of crop groups	0.023***	0.023***	0.023***	0.021**	0.023***	0.020**
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.010)
Dummy: water accessibility	-0.003	-0.005	-0.005	0.002	-0.004	0.006
	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)	(0.028)
Dummy: electricity accessibility	-0.051	-0.040	-0.039	0.008	-0.053	0.012
	(0.060)	(0.060)	(0.060)	(0.060)	(0.062)	(0.056)
Average greenness		0.784***	0.787***	0.756***	0.773**	0.691**
		(0.301)	(0.301)	(0.282)	(0.302)	(0.305)
Parents' hospitalizations			0.018	0.031	0.018	0.015
			(0.032)	(0.032)	(0.032)	(0.031)
Siblings' average HAZ				0.098***		
				(0.026)		
Wealth index					0.019	
					(0.018)	
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
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year × ward fixed effects	No	No	No	No	No	Yes
Village time trends	No	No	No	No	No	Yes
Observations	6,361	6,361	6,361	5,919	5,919	6,361
Number of children	2,471	2,471	2,471	2,365	2,365	2,471

Notes: All specifications include child, year, and month of interview fixed effects, and child and household characteristics as specified in column 5 of Table 2. Column 4 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% and 5% level, respectively.

Table A7. Local effects.

Dependent variable:	(1) Deviation from village average height-for-age z-score	(2) Deviation from ward average height-for-age z-score
Number of crop groups as deviation from village average	0.016*	
	(0.010)	
Number of crop groups as deviation from ward average		0.020**
		(0.009)
Child characteristics	Yes	Yes
Household characteristics	Yes	Yes
Child fixed effect	Yes	Yes
Year fixed effects	Yes	Yes
Month fixed effects	Yes	Yes
Observations	6,361	6,361
Number of children	2,471	2,471

Notes: All columns include child, year, and month of interview fixed effects. All controls are included as deviations from local averages. 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 5% and 10% level, respectively.

Table A8. Alternative measures of child health.

Dependent variable:	Height-for-age differences (HAD)	Weight-for-age z-score (WAZ)	BMI-for-age z-score (BAZ)
	(1)	(2)	(3)
Number of crop groups	0.118*	-0.005	-0.019
	(0.067)	(0.009)	(0.012)
Child characteristics	Yes	Yes	Yes
Household characteristics	Yes	Yes	Yes
Child fixed effect	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes
Observations	6,403	5,958	6,403
Number of children	2,471	2,470	2,471

Notes: All columns include child, year, and month of interview fixed effects, child and household characteristics as specified in column 5 of Table 2. The dependent variables are height-for-age differences (HAD) in column 1, weight-for-age z-score (HAZ) in column 2, and BMI-for-age z-score (BAZ) in column 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 10% level.

Table A9. Alternative measures of crop diversification.

Dependent variable:	Height-for-age z-score (HAZ)					
Crop diversification measure	Number of crops	Margalef index	Margalef GPS index	Margalef crop group index	Simpson index	Shannon-Wiener index
	(1)	(2)	(3)	(4)	(5)	(6)
Crop diversification index	0.020***	0.219***	0.150*	0.256***	0.160**	0.054**
	(0.007)	(0.081)	(0.078)	(0.098)	(0.063)	(0.027)
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
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6,361	6,361	4,138	6,361	6,361	6,361
Number of children	2,471	2,471	2,467	2,471	2,471	2,471

Notes: All columns include child, year, and month of interview fixed effects, child and household characteristics as specified in column 5 of Table 2. The crop diversification measures are described in Appendix B. Data are from the Tanzania National Panel Survey for years 2008/2009, 2010/2011, and 2012/2013, except for column (3) that refers only 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. ***, **, * indicate significance at the 1%, 5%, and 10% level, respectively.

Table A10. Conditional mixed process estimates.

Dependent variable:	(1) Height-for-age z-score (HAZ)	(2) Number of food groups consumed
Number of food groups consumed	0.500**	
	(0.199)	
Number of crop groups		0.045***
		(0.011)
Dummy: attending school	0.057*	-0.032
	(0.033)	(0.040)
Dummy: worked on farm	-0.093*	0.057
	(0.049)	(0.059)
Age (in months)	-0.073***	0.004
	(0.004)	(0.004)
Age squared	-0.056***	0.001
	(0.009)	(0.011)
Number of children 0-5	0.003	0.003
	(0.014)	(0.017)
Number of children 6-12	0.019	-0.004
	(0.016)	(0.019)
Number of children 13-17	0.011	-0.016
	(0.019)	(0.023)
Dummy: elderly	0.146**	-0.111
	(0.064)	(0.075)
Dummy: livestock	-0.045	0.025
	(0.032)	(0.038)
Land size	-0.003***	-0.003***
	(0.001)	(0.001)
Household consumption (log)	-0.344**	0.716***
	(0.146)	(0.033)
Yields (log of revenues)	0.004*	-0.003
	(0.002)	(0.003)
Dummy: off-farm job	0.001	0.060*
	(0.028)	(0.031)
Child characteristics	Yes	Yes
Child fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Month of interview	Yes	Yes
Observations	6,361	6,361
Number of children	2,471	2,471

Notes: These estimates are obtained by jointly estimating the two regressions presented in columns 1 and 2. The system of equation is estimated jointly in two steps: in the first step, dietary diversity is estimated as a function of crop diversification, and in the second step, the estimated dietary diversity is allowed to affect child health. Both equations include child, year, and month of interview fixed effects, child and household characteristics as specified in column 5 of Table 2. Data are from the Tanzania National Panel Survey for years 2008/2009, 2010/2011, and 2012/2013. ***, **, * indicate significance at the 1%, 5%, and 10% level, respectively.

Online Appendix B
Alternative measures of crop diversification

As a robustness check we also construct alternative indicators of crop diversification. First, we consider a simple count of all individual crops grown by the household. This is a common measure used also in other studies such as Ecker (2018). This measure allows us to capture variations within crop groups that might go unexplored using a group-based measure of crop diversification. Second, we consider a Margalef index of individual crops and a Margalef index of crop groups that account for the amount of cultivated land (for more details see Margurran, 1988; Smale et al., 1998; Benin et al., 2004). The Margalef index is calculated as $\frac{C_{jt}-1}{ln(A_{jt})}$, where C_{jt} represents the number of crops (or crop groups) grown by household j at time t and A_{jt} is the total area cultivated. Third, in order to account for crop varieties and how evenly they are distributed in terms of land shares, we propose two measures. The first measure is the Simpson diversity index (for details see Simpson, 1949), also used in Ecker (2018) and Jones et al. (2014). This index corresponds to the Herfindahl–Hirschman index in economics and takes into account the number of crop groups and their degree of concentration. This index indicates the probability that two crops taken at random from a household are of the same type, and is calculated as $\sum_k {p_k}^2$ where p_k is the share of land planted with each crop group k. The second measure is the Shannon-Wiener index that accounts for species richness and evenness (Margurran, 1988; Weitzman, 2000; Di Falco and Chavas, 2008). This index is given by $(-\sum_k p_k \, ln \, p_k)$ where p_k is the share of land planted with each crop group k. Finally, we also consider a count index that includes animal products as an additional food group to test how sensitive our results are to the inclusion of other nutritious but non-crop related groups.

References - Online Appendix B

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