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Impact of Agricultural Diversification and Commercialization on Child Nutrition in Zambia: A Dose Response Analysis

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Abstract

Zambia, and in particular Eastern Province, has one of the highest levels of malnutrition in the world with 40% of the children having stunted growth. Agricultural diversification and commercialization remain critical for improving the nutrition status of children. However, the impact may vary according to the level of the two agricultural interventions. Results from the dose response function using generalised propensity score method showed that for commercialization, there is highest risk of stunting at medium commercialization levels at 50%. A farm at this point can improve nutrition status by moving either towards high or towards zero levels. Commercialization has a negative effect on short-term nutrition outcomes leading to underweight and wasting. This could indicate that in areas with less everyday access to a range of food items, capital accumulation may not help to avoid deficiencies in child nutrition. In combination with our findings on diversification, two policy options can be recommended. Either the households specialize in cash crops to increase income, or they go into subsistence farming with high levels of diversification. Other off-farm income sources are suggested for resilience in case of yield shocks.

Keywords: agriculture, commercialization, diversification, generalized propensity score, nutrition, Zambia

1. Introduction

Malnutrition and nutrition related problems, especially among children, remain high in Africa. Small children in particular remain vulnerable to malnutrition and nutrient-related health problems. Studies indicate that children that suffer from chronic malnutrition during the first two years of life tend to suffer from irreversible negative effects on brain and cognitive development (United Nations International Children's Fund [UNICEF], 1990). This leads to reduced learning capacity in school and wage earning potential as adults.

Zambia has one of the highest rates of child malnutrition in the world. Most vulnerable are rural households, which highly depend on seasonal food production and survive on diets that are deficient in a variety of micronutrients. About 60.5% of the country's population lives in the rural areas (Central Statistical Office [CSO], 2010). According to the 2014 preliminary Demographic Health Survey (DHS) 40 % of the children in the country have stunted growth (z-score less than -2), 6% suffer from wasting and 15% are underweight (CSO, 2014). Although the prevalence of underweight children has declined from 25.1% in 1992 to 15% in 2014, it remains a major concern as to whether Zambia will achieve the target made in the Malabo declaration of reducing underweight to 5% and stunting from the current 40% to 10% by 2025. Wasting cases, which are relatively moderate, also remain worrisome, as the rates have increased from 3.1% in 1996 to 6% 2014 (Table 1).

Considering that 70% (includes urban agriculture) of Zambia's population is dependent on agriculture for their livelihood and 90% of farmers are smallholders, understanding the impact of agriculture on nutrition becomes imperative. Rais, Pazderka, and Vanloon (2009) found that in India, most of the subsistence farms cannot provide for the entire household's food needs from production alone, often due to small landholdings and low productivity. Therefore, they have to generate income to purchase additional food. Intrinsically, agricultural diversification and commercialization provide alternative strategies for the rural households to improve diets (Hendrick & Msaki, 2009; Khandker & Mahmud, 2012), the former by yielding diverse food items for own consumption and the latter by increasing income and the household's ability to purchase a diverse range of food items. The growing of different groups of food crops contribute directly to a more diversified nutritional intake. At the same time, agricultural commercialization provides means of earning income that enables households to purchase goods and services like health-care, which are essential for sustaining their nutrition.

Table 1. Nutrition status and Malabo declaration targets

Indicator	1990	2001/2	2007	**2014**	2025 Target
Percentage of underweight children (under 5 years of age)	25	23	15	**15**	5
Percentage of stunted children (under 5 years of age)	40	53	45	**40**	10
Percentage of wasted children (under 5 years of age)	5.1	6	5	**6**	-

Source: CSO several years.

There is evidence in recent literature showing the effects of agricultural diversification and commercialization on child nutrition (e.g., Mazunda, Kankwamba, & Pauw, 2015; Zere & McIntyre, 2003; Monteiro et al., 2010; Alderman et al., 2006). However, there is tendency to treat diversification and commercialization as a binary variables. We find this an oversimplification, given that households produce at different intensity levels of diversification and commercialization which may have different effects on the nutritional status. In the current study, we change this econometric setup, and measure the impact of different levels of diversification and commercialization. This way, the paper adds a new dimensions to the discussion of nutritional impacts of agricultural diversification and commercialization by analyzing the varying levels of the two interventions.

To help evaluate agricultural diversification and commercialization as critical rural strategies for increasing access to nutritious foods in the Eastern Province of Zambia, the paper addresses the following questions:

1) Does a diversified farm production system significantly affect the nutritional status of children?

2) Does participation in agricultural markets improve the nutritional status of the rural smallholder households?

2. Agriculture and Nutrition in Eastern Province

The Eastern Province is one of Zambia's most productive regions in terms of agriculture. It ranks third in terms of maize production (the national staple food) and first in terms of groundnuts, the main source of protein in rural Zambia. In 2010/2011, the province produced 23% of the country's maize and 30% of the groundnuts (IAPRI/CSO/MAL, 2012). As shown in Table 2, the Eastern Province is also well known for high crop diversification. The Simpson index for crop diversification of 0.47 is third highest out of ten provinces and above the national average of 0.42 (IAPRI/CSO/MAL, 2012) (Note 1).

While malnutrition levels are very high in the province, the Eastern Province has the second largest population of livestock produced by smallholders in the country. Similarly, the population of village chickens is highest in Eastern and Southern Provinces which produces 16.1% and 15.8% of the total smallholder village chickens in the country respectively (Lubungu & Mofya-Mukuka, 2013). However, the number of livestock owned per household is much lower compared to other provinces. While, for instance, households in Southern and Luapula Provinces own an average of 10 and 16 cattle respectively, households in Eastern Province own an average of only five cattle per household (Lubungu & Mofya-Mukuka, 2013). The smaller number of cattle owned per household could have implications on the level of protein source diversification and livestock commercialization which may negatively affect child nutrition.

Despite the high and diversified crop production, diversified production of protein and calorie is relatively low (less than 0.3 Simpson Index of diversification) for Eastern Province. This could explain the shocking high levels of child malnutrition recorded in the province.

Table 2. Simpson index of crop diversification per province

		Specialized		Diversified
	Mean	Percentile 25th	Median	Percentile 75th
Central	0.41	0.2	0.48	0.61
Copperbelt	0.3	0	0.32	0.5
Eastern	0.47	0.38	0.5	0.63
Luapula	0.43	0.29	0.5	0.62
Lusaka	0.21	0	0.09	0.44
Muchinga	0.54	0.44	0.62	0.7
Northern	0.54	0.46	0.62	0.7
North Western	0.4	0.23	0.46	0.58
Southern	0.31	0.09	0.33	0.5
Western	0.42	0.32	0.49	0.59
Zambia	**0.42**	**0.24**	**0.49**	**0.63**

Note. At 25th percentile, the households are moving to specialization while at 75th percentile the household moves to more specialization.

Source: Authors own computation based on the IAPRI/CSO/MAL RALS 2014 Survey.

With 43.3%, Eastern ptovince's stunting rates in 2013-14 were among the highest three provinces in the country, higher than the national average of 40%. As shown in Figure 1, prevalence of underweight and wasting among children is much higher than in all other provinces. These high rates of malnutrition amidst high and diversified and commercialized agricultural production in the province are a paradox that requires evidence-based research drawing effective and sustainable solutions.

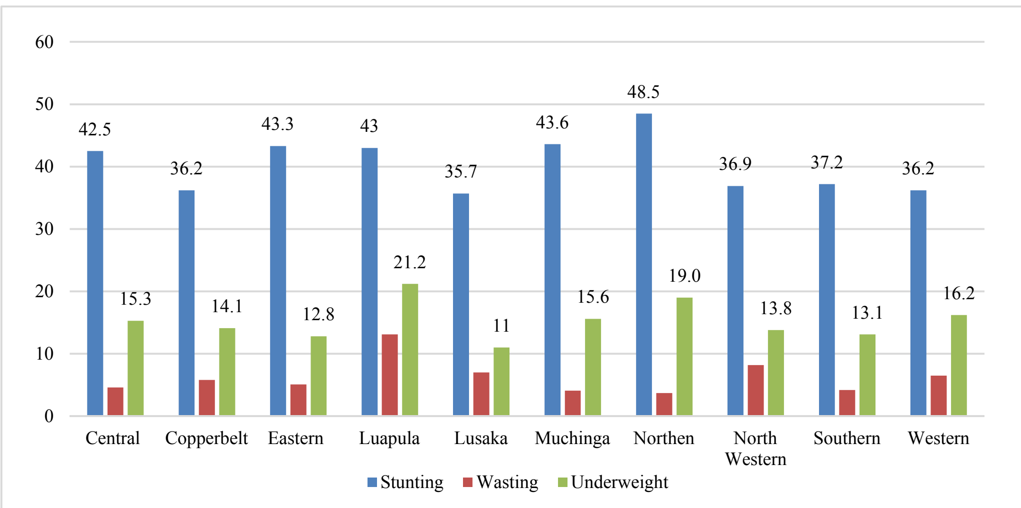


Figure 1. Incidence of stunting, underweight, and wasting of children (3-59 months) by province

Source: CSO, 2014.

3. Conceptual Framework

The conceptual framework developed by the United Nations International Children's Fund (UNICEF, 1990) provides a fundamental basis for designing the analytical framework on the link between agriculture and nutrition. The interactions between agricultural and health conditions have implications on the utilization of food by the body. A lack of health services, among other non-food factors, can lead to failure by the body to utilize the available food. At household level, the economic status of a household is an indicator of access to adequate food supplies, use of health services, availability of improved water sources, and sanitation facilities, which are prime determinants of child nutritional status (UNICEF, 1990).

Based on the UNICEF (1990) framework, Gillespie, Harris, and Kadiyala (2012) developed a framework that reaffirms agricultural initiatives alone cannot solve the nutrition crisis but can make a much bigger contribution than those currently in place. The Gillespie, Harris, and Kadiyala (2012) framework highlights seven key pathways between agriculture and nutrition:

- Agriculture as a *source of food*, the most direct pathway in which the household translates agricultural production into consumption (via crops cultivated by the household);
- Agriculture as a *source of income*, either through wages earned by agricultural workers or through the marketed farm-products;
- The link between agricultural policy and *food prices*, involving a range of supply-and-demand factors that affect the prices of various marketed food and nonfood crops, which, in turn, affect the incomes of net sellers and the ability to ensure household food security (including diet quality) of net buyers;
- Income derived from agriculture and *how it is actually spent*, especially the degree to which nonfood expenditures are allocated to nutrition-relevant activities (for example, expenditures for health, education, and social welfare);
- Women's *socioeconomic status* and their ability to influence household decision making and intra-household allocations of food, health, and care;
- Women's *ability to manage* the care, feeding, and health of young children; and
- Women's *own nutritional status*, if their work-related energy expenditure exceeds their intakes, their dietary diversity is compromised, or their agricultural practices are hazardous to their health (which, in turn, may affect their nutritional status).

Yet, empirical evidence of the impacts of agricultural interventions on nutrition remains scanty. A review of ten studies by Webb and Kennedy (2014) shows that although there are differences in the methods and focus of the studies, empirical evidence for plausible and significant impacts of agricultural interventions on specific nutrition outcomes remain scarce. However, the absence of evidence should not be mistaken for evidence of no impact. Weakness in methods and general study design may explain the weak results of some studies. They suggest that future investigations on the impact of agriculture on nutrition must be set rationally, based on well-defined mechanisms and pathways.

Gillespie, Harris, and Kadiyala (2012) review 26 studies on the links between agriculture-derived income and household food expenditure or individual nutrition status. The analysis finds that in some studies (e.g., Headey, Chiu, and Kadiyala, 2011) agricultural growth rates are significantly associated with improvements in women's BMI but weakly associated with child stunting at the national level. However, Gillespie, Harris and Kadiyala (2012) conclude that if one looks at heterogeneity across communities, it seems clear that in some areas agricultural growth is associated with improvements in stunting, while in other cases there is a total disconnection.

4. Data and Methods

4.1 Data

We use a uniquely rich dataset that comprises socioeconomic, agricultural, and anthropometric data. The study covers 1,120 children from the Eastern Province of Zambia with data collected in two rounds. The first dataset is based on the 2012 Rural Agricultural Livelihood Survey (RALS), a nationally representative dataset covering 8,839 households. The RALS, which was conducted by the Indaba Agricultural Policy Research Institute (IAPRI) in partnership with the Central Statistical Office (CSO) and the Ministry of Agriculture and Livestock (MAL), provides information for calculating crop diversification and agricultural commercialization.

The second dataset is anthropometric data collected from the same households and is used to calculate stunting (measured by height for age z-score (haz)), wasting (measured by height for weight z-score (whz)), and underweight (measured by weight for age z-score (waz)) in children. This dataset also provides variables related to the health environment. The data was collected in December 2012 under the Feed the Future Project of the United States Agency for International Development (USAID, 2012) which gives almost two years from January 2011 when the household begin to consume the produce from the 2010/11 farming season, to the time of collection of Anthropometric data. This period was very important to examine height-for-age cumulative effects of past nutrition deprivations. The Anthropometric data included only children (0-59 months) from the 1,120 households in five districts in Eastern Province.

We calculate diversification using the Simpson Index for production of major food groups: starchy foods, legumes-nuts-seeds, starchy vegetables, non-starchy vegetables, starchy fruits, non-starchy fruits, dairy, and eggs. Table 3 shows the food groups and the produce that fall in the groups.

Table 3. Food groups and agricultural produce

Food Group	**Agricultural Produce**
Starchy Foods	Maize, Sorghum, Rice, Millet
Legumes-nuts and Seeds	Sunflower, Groundnuts, Soybeans, Mixed beans, Bambara nuts, Cowpeas
Starchy Vegetables	Green maize, Sweet potatoes, Irish potatoes, Cassava
Non-Starchy Vegetables	Cabbage, Carrots, Rape, Spinach, Tomato, Onion, Okra, Eggplant, Chilies, Pumpkin, Chomolia, Lettuce, Green beans, Impwa, Pumpkin leaves, Sweet potato leaves, Cassava leaves, Beans/Cowpea leaves, Chinese Cabbage, Bondwe
Starchy Fruit	Bananas, Avocado
Non-Starchy Fruit	Oranges, Pineapples, Guavas, Pawpaw, Watermelon, Mangos, Tangerine, Lemons, Grapefruit, Sugarcane, Sweet Sorghum
Dairy	Milk
Eggs	Eggs

Source: Authors.

Meat and meat products could not be added to the list because these were consumed very rarely. We measure production in two ways; firstly in terms of protein production (PDIV) and secondly in terms of calorie production (CDIV).

$$PDIV = 1 - \sum_{t=1}^{s} p_i^2 \quad (1)$$

$$CDIV = 1 - \sum_{i=1}^{s} c_i^2 \quad (2)$$

Where, S is the number of food groups and p and c are protein and calorie content for food group i respectively. Commercialization was measured as an index derived from the share of agricultural sales in household's total value of agricultural production. Descriptive statistics for these variables, as well as other household characteristics variable that were controlled are presented in Table 4.

Table 4. Descriptive statistics of balancing variables

Variable	Description	Mean	Std. Dev.
Nutritional outcome variables			
Stunting (haz)	Length/height-for-age z-score	-1.86	1.69
Underweight (waz)	Weight-for-age z-score	-0.86	1.18
Wasting (whz)	Weight-for-length/height z-score	0.26	1.51
Treatment variables			
Calorie Simpson Index	Index "=1-sum of squared calorie shares of the produce.	0.26	0.19
Protein Simpson Index	Index "=1-sum of squared crop protein shares of the produce.	0.28	0.18
Commercialization	Household commercialization index	0.50	0.27
Farm characteristics			
Fhhdefacto	=1 if de facto female-headed HH	0.12	0.33
Noformaled	=1 if HH head has no formal education	0.18	0.39
Grade1_4	=1 if HH head completed lower primary (grades 1 to 4)	0.18	0.39
Grade5_7	=1 if HH head completed upper primary (grades 5 to 7)	0.34	0.47
Agehead	Age of the HH head	40.48	12.51
Ftesum	Full-time equivalent HH members	6.19	2.57
Shareageun~5	Share of household members aged below 5	0.20	0.14
Shareage5_14	Share of household members aged 5 to 14	0.30	0.19
Shareabove60	Share of household members aged 60	0.04	0.12
Deathinfam~y	=1 if the household experienced death of a member within the reference perion	0.05	0.23
Landholdsz12	Total land holding size less rented in and borrowed in	3.58	3.09
Landother	Sum of land borrowed in and rented in	0.16	0.81
Landtitled	Land with title deeds	0.28	1.56
Deflstock	Value of livestock (real ZMK, 2007/08=100) (Note 2)	2,781,176.00	4,534,321.00
Defvalequip	Value of farm equipment (ZMK/10,000; 2007/08=100)	43.07	88.94
Fisphh	=1 if HH acquired FISP fertilizer	0.47	0.50
Remit_c	Cash remittances received	139,725.90	808,848.70
Remit_m	Value of maize received	7,527.23	32,657.21
Remit_o	Value of other commodities received	15,975.00	110,869.80
Bomai	Km from the homestead to the nearest boma	31.20	20.74
Feedroadi	Km from the homestead to the nearest feeder road	1.81	5.07
Agrodealeri	Km from the homestead to the nearest agro-dealer	24.99	20.84
Clinic_max	Distance to the nearest clinic	6.49	5.97
District2	Dist==Katete	0.22	0.42
District3	Dist==Lundazi	0.25	0.43
District4	Dist==Nyimba	0.10	0.30
District5	Dist==Petauke	0.19	0.39

Source: Authors.

Figure 2 and 3 show the distribution of households for calorie and protein diversification intensity respectively. In terms of calorie diversification, majority of the households have diversification levels of 0 to 0.4 indicating low diversification levels by the majority of the households. Protein diversification, on the other hand is highest between 0.4 and 0.5 Simpson Index of diversification. Further, the data shows that more households are more specialized in terms of Calories while there is more diverse in the production of protein foods.

On the other hand, agriculture commercialization is high with majority of the households selling 60% to 80% of their agricultural produce. Figure 4 shows the distribution of Commercialization index.

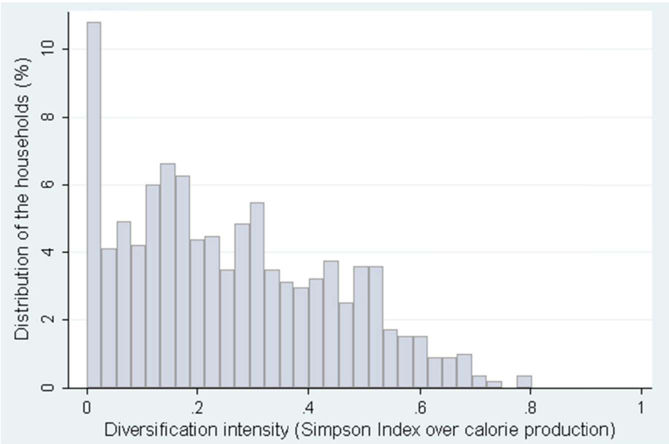


Figure 2. Calorie diversification of households

Source: Authors.

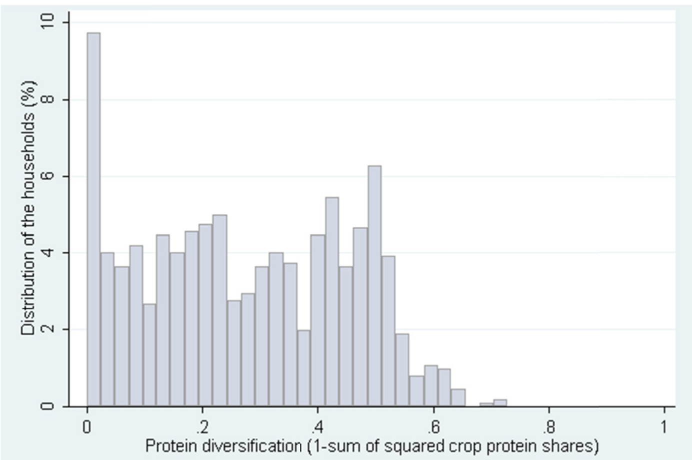


Figure 3. Protein diversification of households

Source: Authors.

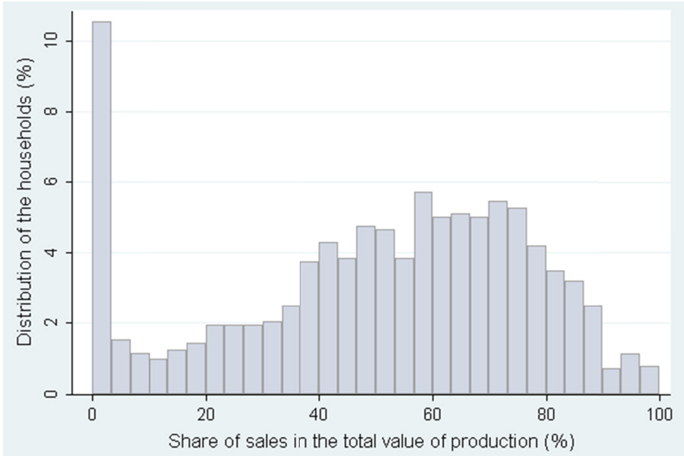


Figure 4. Agricultural Commercialization of Households

Source: Authors.

4.2 Method

To quantify the effect of diversification as well as commercialization, it is possible to employ the typical impact evaluation framework, in which diversification (commercialization) is seen as a treatment, and the nutritional status is the observed outcome. In the following section, we explain the econometric method by focusing on diversification as the treatment, but all the explanations also hold for commercialization.

In a first step, we use a simplified model in which treatment A is a binary variable, i.e., the farmer chooses to diversify (A = 1) or not (A = 0). This is the conventional impact assessment scenario, and we will later on consider a more flexible approach. The expected treatment effect for the treated population is of primary significance. This effect is given as

$$\tau|_{A=1} = E(\tau \mid A=1) = E(O_1 \mid A=1) - E(O_0 \mid A=1) \tag{3}$$

Where, τ is the average treatment effect for the treated (ATT), A is a dummy for diversification decision, O_1 denotes the value of the outcome when the household diversified its production, and O_0 indicates the value of outcome in case the household did not diversify its production.

The measurement of the ATT is not trivial. The estimation problem arises due to the fact that it cannot be observed how a diversified household would have performed if it had not diversified its production, i.e., $E(O_0 \mid A=1)$ cannot be observed. Although the difference $[\tau^e = E(O_1 \mid A=1) - E(O_0 \mid A=0)]$ could be estimated, it would potentially be a biased estimator of the ATT, because the groups compared are likely to be different in their characteristics. This is because of self-selection of households, which is likely to occur when farm characteristics affect the utility that a farm derives from diversification or commercialization. To formalize the effect of farm characteristics on the treatment variable, we assume the following relationship between utility U and farm and household characteristics Z of farm household i:

$$U = \alpha' Z_i + \eta_i \tag{4}$$

Where, η_i indicates the residual. Given that the farmer maximizes utility by choosing whether to diversify or not to diversify, the probability of employing the diversification strategy is shown by the following equation:

$$\Pr(A_i = 1) = \Pr(U_{A,i} > U_{NA,i}) = \Pr(\eta_i > -\alpha' Z_i) = 1 - \Phi(-\alpha' Z_i) \tag{5}$$

Where, $U_{A,i}$ is the maximum utility gained from choosing the treatment while $U_{NA,i}$ is the maximum utility derived from being in the control group. Φ indicates the distribution of the residual, which is logistic in the case of the Logit model we apply in our later analysis. Results of outcome comparisons between groups are biased even if farm characteristics are controlled for in simple regression analyses. To show this, consider a reduced-form relationship between the technology choice and the outcome variable such as,

$$O_i = \alpha_0 + \alpha_1 A_i + \alpha_2 Z_i + \mu_i \tag{6}$$

Where, O_i represents a vector of outcome variables for household i such as demand for inputs, A_i denotes a binary choice variable of diversification as defined above, Z_i represents farm level and household characteristics, and μ_i is an error term with $\mu_i \sim N(0, \sigma)$. The issue of selection bias arises if the error term of the technology choice η_i in Equation (4) and the error term of the outcome specification μ_i in Equation (6) are influenced by similar variables in Z_i. This results in a non-zero correlation between the two error terms, which would in turn lead to biased regression estimates if Equation (6) is estimated with conventional OLS techniques. In particular, α_1 would not be a valid estimator of the ATT.

Several econometric techniques exist to re-establish a randomized setting in the case of self-selection. The difference-in-differences method is not applicable, as it requires panel data from several time periods, which are not provided by RALS data. The instrumental variables technique relies on parametric assumptions regarding the functional form of the relationship between the outcomes and predictors of the outcome, as well as on the exogeneity of the instruments used. Since this approach is quite sensitive to violations of these strict assumptions, we follow the matching approach, in which households of the group of diversified farmers are matched to households in the control group which are similar in their observable characteristics.

4.3 Generalized Propensity Score

It is common to treat diversification and commercialization as a binary decision variable. The most common method applied is the propensity Score Matching (PSM) which we explain in detail in the appendix. The PSM is, however, an oversimplification, since households produce at different intensity levels of diversification and commercialization. These various levels may have different effects on the nutritional status. In this paper, we change this econometric setup, and measure the impact of different levels of diversification and commercialization. For this, we use the method proposed by Hirano and Imbens (2004) and employ the Generalized Propensity Score (GPS) to balance the differences among farms of different intensity levels. The unbiased heterogeneous impact of different intensities of diversification and commercialization on health outcomes can then be illustrated with dose response functions.

For each household$i$, we observe the vector of pre-treatment variables X_i, the actual level of treatment received, T_i, and the outcome variable associated with this treatment level $O_i = O_i(T_i)$. Of interest is the dose response function (DRF), which relates to each possible production intensity level t_i, the potential welfare outcome $O(t)$ of farm household i:

$$\theta(t) = E[O_i(t)] \quad \forall t \in T \quad \text{where}, T = (0,...,1) \tag{7}$$

Where, θ represents the DRF, and t is the treatment level, which is measured as a diversification index (the Simpson index) or as the share of crops sold in total crop revenues (commercialization index). Similar to the conditional independence assumption (CIA) in the PSM setting for dichotomous treatment variables, we presume weak confoundedness (Note 3). In order to adjust for a large number of observable characteristics, Hirano and Imbens (2004) suggest estimating the generalized propensity score (GPS), which is defined as the conditional density of the actual treatment given the observed covariates. Formally, let $r(t,x) = f_{T|X}(t|x)$ be the conditional density of potential treatment levels given specific covariates. Then the GPS of a household i is given as $R_i = r(T_i,X)$. The GPS is a balancing score, i.e., within strata with the same value of $r(t_i,X)$, the probability that $T = t$ does not depend on the covariates X_i,. Due to its balancing property, the GPS can be used to derive unbiased estimates of the DRF (Hirano & Imbens, 2004). For this, the conditional expectation of the outcome first needs to be calculated as $\gamma(t,r) = E[O_i|T_i = t, R_i = r]$. The average DRF of Equation (7) can then be estimated at particular levels of treatment as follows:

$$\theta(t) = E[\gamma(t,r(t,X_i))] \tag{8}$$

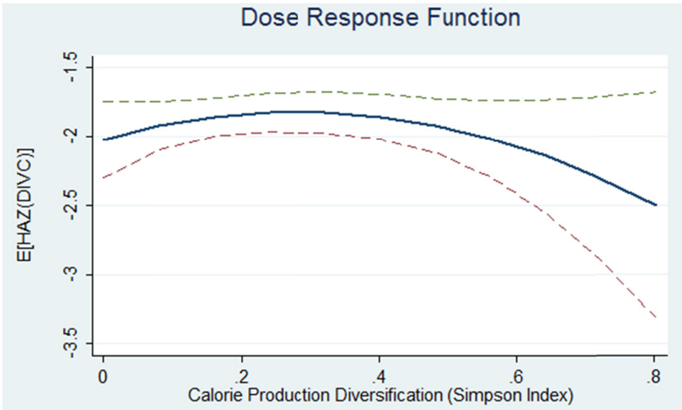
The GPS is estimated with a generalized linear model (GLM) with covariates X_i and a fractional logit (Flogit) specification, which takes into account that both of the analyzed treatment variables (diversification and commercialization) range between 0 and 1 (Note 4).

The common support condition is imposed by applying the method suggested by Flores and Flores-Lagunes (2009) (Note 5). We test the balancing property of the estimated GPS by employing the method proposed by Kluve et al. (2012) (Note 6). The conditional expectation of the outcome for each farm is estimated using a flexible polynomial function, with quadratic approximations of the treatment variable and the GPS, and interaction terms (Hirano & Imbens, 2004). The specification is estimated using OLS regression for continuous welfare outcomes. Then the DRF of Equation (8) is evaluated at 10 evenly distributed levels of agricultural diversification or commercialization. Confidence bounds at 95% level are estimated using the bootstrapping procedure with 1,000 replications.

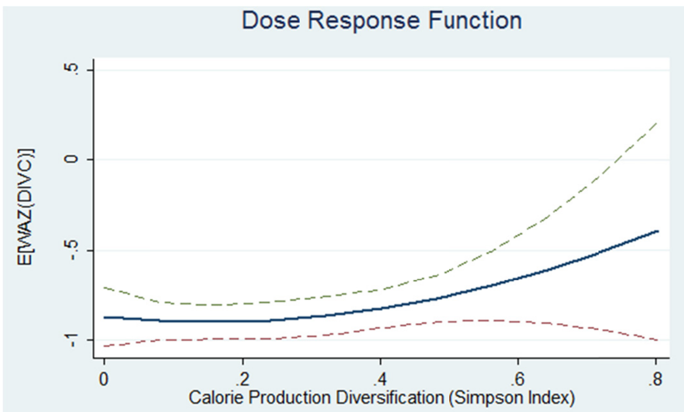
5. Results

5.1 Results of Treatment with Diversification of Calorie Production

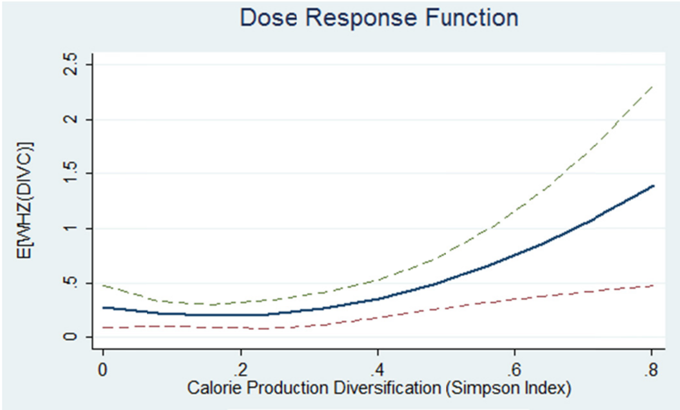
Figure 5 depicts the effects of different intensities of calorie diversification on the nutritional status of children. In each of the three diagrams a), b) and c), the x-axis indicates the intensity of calorie diversification measured in terms of the Simpson index (CDIV), and the y-axis measures the expected effects on a) stunting b) underweight and c) wasting at the a given level of diversification. The histogram on calorie diversification shows how farmers are distributed over the intensity levels of calorie diversification. Once the continuous nature of diversification is taken into account, trends can be observed in terms of how calorie diversification affects the nutritional status of children.



a) Height-for-age (z-score)



b) Weight-for-age (z-score)



c) Weight-for-height (z-score)

Figure 5. Nutritional status and calorie production diversification (Simpson index)

Note. The solid line is the dose response function and dashed lines indicate 95% confidence interval.

Source: Authors.

5.1.1 Stunting Effects of Diversification of Calorie Production

The stunting indicator shows that the long term nutritional effect of calorie diversification tends to be positive at low diversification levels (i.e., high specialization), however at a relatively marginal rate. As shown in Figure 5, the dose response function (DRF) depicted in diagram a) has a maximum at roughly 0.3, and becomes negative at high levels of diversification.

An explanation for this non-linear relationship might be that on the one hand, specialization in very few crops results in a permanently less diverse diet with quickly arising long-term consequences for nutritional status of the child. On the other hand, extremely high diversification levels could reduce food security of children due to a less efficient production structure that delivers fewer amounts of nutrients than less diversified farms could produce. The histogram and a median of calorie diversification at 0.23 indicate that for most farmers a moderately increased diversification of food production would be beneficial with respect to long-term nutritional outcomes.

5.1.2 Underweight and Wasting Effects of Diversification of Calorie Production

The DRFs for the effect of calorie diversification on underweight (graph b of Figure 6) and wasting (graph c of Figure 5) are similar, but show a very different shape than the stunting function. Both graphs show a positive relationship between calorie diversification and the children's nutritional status. High levels of diversifications may prevent households from short term shock situations due to their stable provision of diverse set of nutrients that are correlated with calories from different agricultural products.

It has to be kept in mind however, that very few farms have actually reached diversification levels above 0.5, as the histogram shows. In these very high intensities of calorie diversification, the estimations of all three DRFs are, therefore, based on few treatment units and should therefore be interpreted with caution. This is also seen by the spread of the confidence interval at that point of intensity in all study graphs. Thus, although the average effect has a clear trend, statistical predictions become shakier.

5.2 Treatment with Diversification of Protein Production

Figure 6 presents the heterogeneous effect of protein diversification on the nutritional outcomes. As in Figure 5, graphs a), b), c) indicate the dose response on Stunting, underweight and wasting, respectively, and graph d) shows the distribution of farmers on protein diversification levels. The effects are very similar to the calorie diversification, but have one major difference.

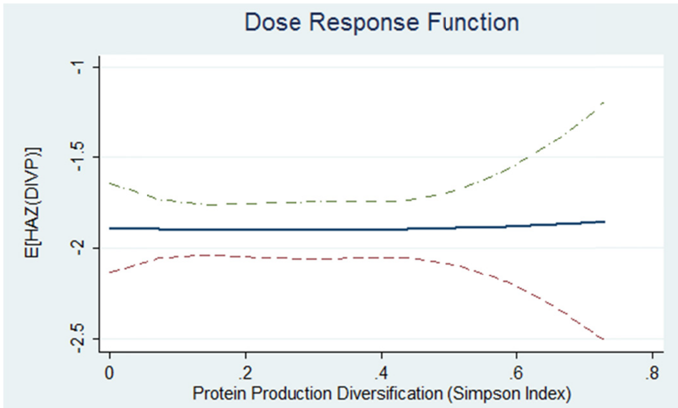
5.2.1 Stunting Effects of Diversification of Protein Production

The stunting dose response function remains flat over the whole range of treatment levels, therefore indicating that for stunting levels there are in fact no significant effects to expect from a diversification in protein sources (Graph a of Figure 6). This is not surprising, given that the data used for calculating the treatment variable did not provide enough timeframe to establish impact on long-term nutritional status.

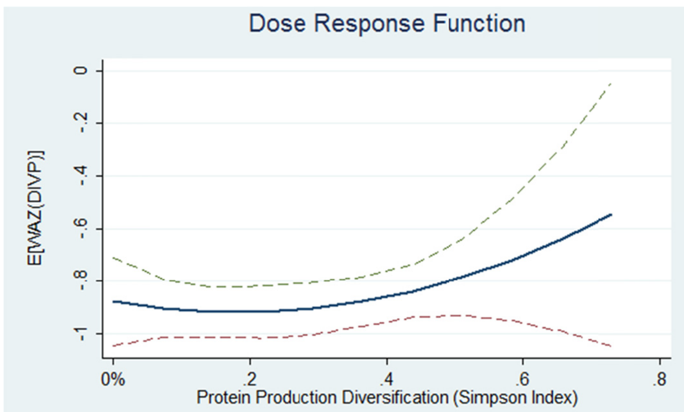
5.2.2 Underweight and Wasting Effects of Diversification of Protein Production

The protein effect on underweight and wasting are clearly positive and significant at quite high levels of diversification (Graph b and c of Figure 6 respectively).

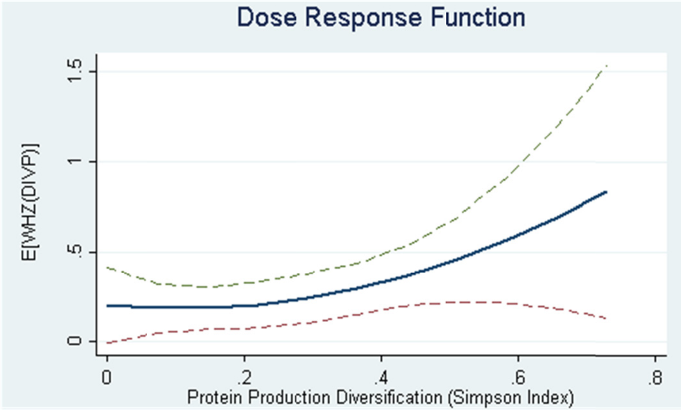
Since animal products contribute quite significantly to protein supply, and that products like milk and eggs deliver protein continuously over the time, it seems that their stabilizing effect contributes to the short- and middle-term nutritional outcomes of children. As with calorie diversification, the histogram d) shows very few farms at protein diversification levels above 0.5. Therefore, results should be interpreted with care, but there is nevertheless a quite clear upward trend at high levels of protein diversification.



a) Height-for-age (z-score)



b) Weight-for-age (z-score)



c) Weight-for-height (z-score)

Figure 6. Nutritional status and protein diversification (Simpson index)

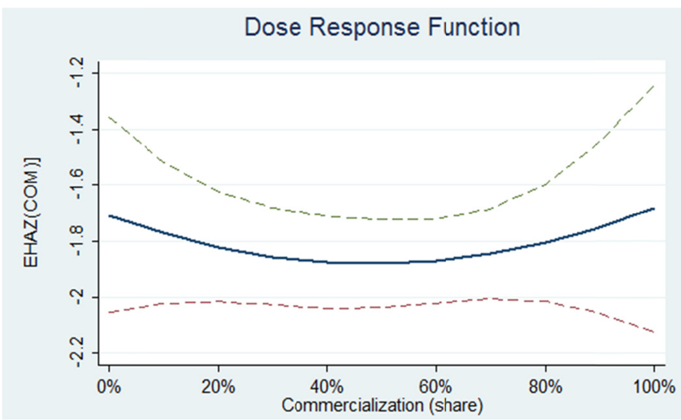
Note. The solid line is the dose response function and dashed lines indicate 95% confidence interval.

Source: Authors.

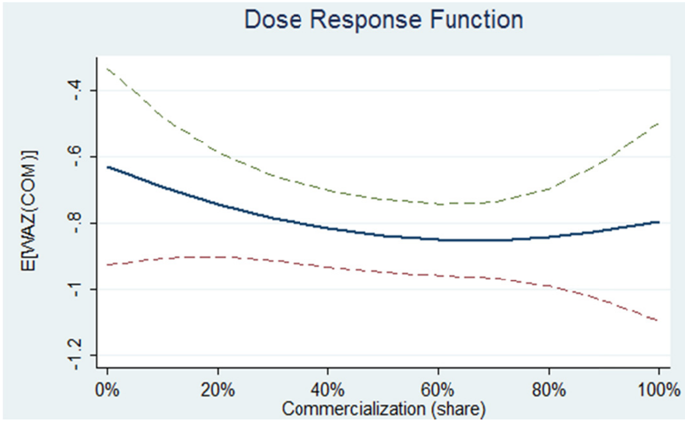
5.3 Treatment with Agricultural Commercialization

Figure 7 presents the effect of commercialization on the nutritional outcomes, and the histogram of commercialization. Unlike the diversification curves, commercialization seems to have a negative slope for underweight and wasting, and also for most intensity levels of stunting. However, at higher intensities of commercialization, commercialization seems to become more beneficial for the nutritional long-term status (reducing stunting), but it only reaches similar levels as those households with no commercialization at all. The commercialization effect on wasting appears more significant compared to the effects on stunting and underweight.

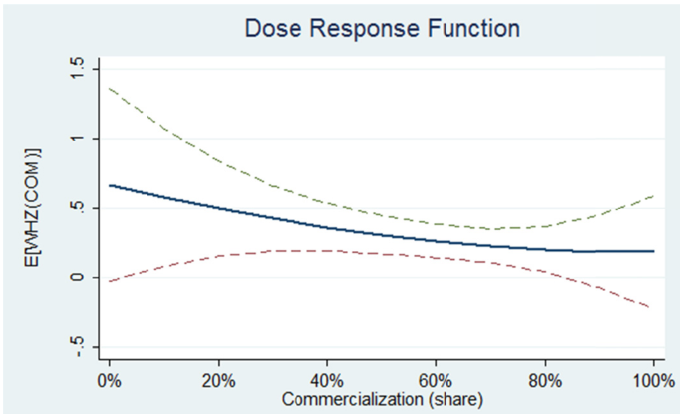
There might be two strategies to tackle the large problem of stunting in Zambia, either specializing in cash crops, or going into a subsistence farm, which maybe has other income sources than agriculture. While farmers might not want to opt fully for either strategy, the graphs indicate that commercialization at medium levels does not, in general, result in more beneficial stunting outcomes. The histogram seems to confirm the finding of two commercialization strategies, as it is clearly bimodal with a considerable numbers of households producing near subsistence levels, but the largest fraction of households at intensities beyond 40%.



a) Height-for-age (z-score)



b) Weight-for-age (z-score)



c) Weight-for-height (z-score)

Figure 7. Nutritional status and agricultural commercialization index

Note. The solid line is the dose response function and dashed lines indicate 95% confidence interval.

Source: Authors.

6. Conclusion and Policy Recommendations

Agricultural diversification and commercialization remain critical for improving the nutrition status of children. However, there are important aspects of improving nutritional status of children with the two agricultural strategies that need to be taken into account. First, the results in this paper have shown that intensity of treatment (crop diversification and commercialization) at household level matters in the nutrition status of the children. Very high levels of diversification can improve nutritional status while smaller levels do not have significant impacts.

Second, it is important to promote agricultural production diversification according to the food groups because different food groups have varying impact on different forms of malnutrition. The impact of protein production diversification has a positive and significant effect at high levels of diversification for short and medium term malnutrition effects. However, the impact on long term malnutrition is not significant even with increasing intensity of diversification. Also, the impact of calorie diversification is non-linear, an indication that specialization in very few crops results in a permanently less diverse diet with quickly arising long-term consequences for nutritional status of the child. This is consistent with food production and consumption patterns in rural Zambia which is mainly based on calorie consumption. These results explain why stunting is high despite a diversified calorie production.

Third, commercialization has a significant but negative effect on improving the short-term malnutrition status of children. Referring to the high commercialization index of 0.5 (50 percent of production is sold), the results imply that most households sell most of their agricultural produce, regardless of the quantities produced, leaving very little for home consumption. It can further be concluded that the revenue realized from these sales, is not being spent on purchasing nutritious food.

Policies need to consider the current diversification intensity of households and the different consequences on wasting and stunting when implementing diversification strategies. High levels of diversification could improve the wasting and underweight status of children by delivering a high amount of nutrients, but may come at the cost of reducing the production efficiency of the households and thus increasing the possibility of longer term stunting. Interventions, such as out grower schemes, focused on improving agricultural diversification and high degrees of commercialization may enhance adequate and diverse protein and calorie sources, while at the same time providing households with the opportunity to sell their agricultural products on the market to meet their other income demands.

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Notes

Note 1. The Simpson Diversity Index measures the extent of diversity and is calculated as follows:

$$DI = \sum_{i=1}^{n} Pi^2$$

Where, P_i = Proportionate area of the ith crop in the Gross Cropped Area; If $\sum Pi^2 = 1$ there will be complete specialization.

Note 2. At the time of the RALS, the Kwacha-dollar rate was $1 = ZMK5,012.

Note 3. This assumption essentially postulates that once all observable characteristics are controlled for, there is no systematic selection into specific levels of diversification/commercialization intensity left that is based on unobservable characteristics (Flores & Flores-Lagunes, 2009).

Note 4. The fractional logit model is implemented as a GLM with Bernoulli distribution and a logit link-function.

Note 5. We thank Helmut Fryges and Joachim Wagner for granting us access to a modified Stata program that allows the imposition of common support.

Note 6. For the calorie index, six variables are significant at the 1% level before the GPS is included. After the GPS was introduced into all regressions, there is no variable with significant effect on the treatment intensity anymore. In case of the protein index and before the incorporation of the GPS into the regression, seven variables were significant at 1% level, two were significant at 5% level and one was significant at 10% level. After the inclusion of the GPS in the PDIV equations, one variable remains significant, however at a low 10% significance level. For commercialization, the test shows that before the inclusion of GPS, six variables are significant at 1% level and four are significant at 10% level, while none is significant when the GPS is included. We therefore conclude that the variables used for balancing fairly well balance the differences in farm characteristics and go on with the analysis of the treatment effect.

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