To Market, to Market: Does smallholder vegetable production lead to increased children's dietary diversity and improved diet quality? Empirical evidence from Northwest Vietnam

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Abstract

In this paper, we examine the relationship between smallholder vegetable production and children's dietary diversity and diet quality using three pathways that link agriculture and nutrition outcomes at the household level. The data is from a survey conducted in July/August 2016 in four districts in northwest Vietnam. Household diet information is collected in two non-consecutive 24-hour food recall periods (one weekday and one weekend) to minimize within-person random error due to day-to-day variability in food consumption. We develop two diet indicators: child dietary diversity score, and the multidimensional Healthy Food Diversity index. Results show positive and significant marginal effects of smallholder/subsistence vegetable production and market participation – either through modern channels or traditional outlets – on the dietary diversity of children under five years old in these remote rural areas as measured by the child dietary diversity score. Further study is required to examine the link between Healthy Food Diversity Index and nutritional outcomes.

Key words: dietary diversity, diet quality, undernutrition, vegetable production, Vietnam

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1 Introduction

Child undernutrition, or stunting, is highly prevalent in South Asia and Africa, and in other developing countries dependent on agriculture (Ali *et al.* 2013; International Food Policy Research Institute 2016; Smith and Haddad 2015). This is particularly the case in rural areas rather as opposed to urban locations (Paciorek *et al.* 2013). Recent interventions to address these concerns have tended to be health or nutrition-specific, focussing on targeting the most immediate cause of child undernutrition, which include poor sanitation, individual health and inadequate dietary intake (Black *et al*. 2013, Smith and Haddad 2015). These interventions are effective, but also limited in scope as they tend to focus on one issue, e.g. supplementation of micronutrients, for instance, iron or vitamin A, to address priority diseases like anaemia or night blindness. One line of thinking is harnessing agriculture and other multi-sectoral programs and policies like those that relate with women empowerment, education, and social safety nets, to complement these nutrition-specific interventions (Ruel *et al*. 2013a). Agriculture, in particular, is seen as pivotal in improving nutritional outcomes as many of the poor rural farming households in this cohort depend on it as their main source of livelihood and diverse diets (Ravallion *et al.* 2007).

A number of pathways have been identified which link agriculture and improved nutritional outcomes (Alderman *et al*. 2013, Carletto *et al.* 2015, Dangour *et al.* 2012, Gillespie *et al.* 2012, Herforth and Harris 2014, Kadiyala *et al.* 2014, Kanter *et al.* 2015, Pinstrup-Andersen 2014, Turner *et al.* 2013, Webb 2013). At the household level, the link could be a result of one or a combinations of three main factors: (1) consumption of healthy and diverse diets from consumption of own food production, (2) consumption of more nutritious and diverse food from higher agricultural income from selling produce to food markets, and (3) gender-related factors which could be related with women's social status and empowerment in agriculture, women's time, education, health and nutritional status (Carletto *et al.* 2015).

Several recent studies have found positive associations between agricultural production and children's diets in Asia and Africa (Hirovinen and Hoddinott 2016, Koppmair *et al*. 2016, Kumar *et al*. 2015, Malapit *et al*. 2015, Shively and Sununtnasuk 2015). However, the literature exploring whether a specific causal linkage exists between smallholder vegetable production and consumption is very limited, especially with respect to remote rural farming households in Asia. Most studies that evaluated the impact of vegetables on nutritional outcomes were part of horticultural intervention programs (Taren and Alaofe 2013), with weak and mixed results due largely to poor study design and methodological rigor (Carletto *et al.* 2015, Girard *et al.* 2012; Leroy and Frongillo, 2007; Masset *et al.* 2012, Ruel *et al.* 2013a, Webb 2013). Several previous studies have suggested a need to incorporate rural households' market engagement when examining the link between smallholder and subsistence agricultural households and nutrition (e.g. Hirvonen and Hoddinott 2016, Hoddinott *et al.* 2015, Koppmair *et al*. 2017, Stifel and Minten 2017).

This paper helps bridge the gap in literature by considering all three of the aforementioned main pathways, both direct and indirect, which may connect vegetable production to improved household nutrition. We use a unique cross-sectional data set collected in 2016 in Lao Cai province, which is in the northwest mountainous region of Vietnam. Lao Cai province is a temperate vegetable producing region in the Northern Midlands and Mountainous region of Vietnam. It is an ideal research location for several reasons. First, the province is among the poorest provinces in Vietnam with 33 percent of its population living below the poverty line (GSO 2012). Second, while many rural households are dependent on farming as the main source of livelihoods, with many growing vegetables for their own consumption due to the small land area (IFPRI, 2002), their vegetable consumption per capita remains low[2] (GSO 2012). Third, the province suffers from high prevalence of stunting (35.2 percent) and underweight (20.0 percent) among children under five due to insufficient household food security (caused by poverty), and inadequate maternal and childcare (NIN 2014). Fourth, the region is home to many ethnic minority groups that are considered one of the most vulnerable groups in the country (Kozel 2014). And lastly, many households are poor due to a "spatial trap" – i.e. their remoteness limits their access to various resources like health, education, infrastructure and credit, and they may be isolated from both input and output markets (Dang 2012, Epprecht *et al.* 2009, Kozel 2014). Further, Bonnin and Turner (2012) suggest that a major factor contributing poverty may be strong adherence to cultural traditions versus acceptance of new technological agronomic innovations that offer opportunities to improve productivity and efficiency.

While government programs have already been implemented in the province with efforts to overcome nutrition issues, which mainly aim at iron, vitamin A and iodine deficiencies (Chaparro *et al.* 2014), they have not met the target to date. For us to contribute to tackling the child undernutrition problem, we attempt to understand the link between vegetable production and diet quality.

The aim of this article is to find empirical evidence linking vegetable production with children's dietary diversity and diet quality working on three hypotheses:

1. when there is limited access to product markets, smallholder households consume the vegetables they produce, and therefore have improved and healthy diets;

[2] Vegetable intake of 24 kg/cap/year (67g/capita/day) from GSO (2012, p. 283). These should be taken with caution as the national average values differ by source – FAOSTAT has 141 kg/capita/year for 2012 (Food and Agriculture Organization of the United Nations 2015) while NIN has 72 kg/capita/year for 2009 (or about 195g/capita/day) (NIN and UNICEF 2011, p.28) which are both higher than VHLSS's estimates.

2. when smallholder households engage in semi-commercial vegetable production, it results in increased household income/cash through marketing, which in turn leads to changes in food purchasing behaviour and more diverse diets; and
3. when women are empowered, they have a strong positive influence on children's diets.

The article is organised as follows: the next section presents detailed information about the data collection process, including the dietary assessment tool which incorporated 24-hour food recall methodology, determination of the intrahousehold food allocation, and the indicators of dietary diversity and diet quality; then, the econometric model specification, followed by the results and discussion, and conclusions.

2 Materials and methods

2.1 Data

The data comes from the survey conducted in July/August 2016 in four districts: Bac Ha, Sa Pa, Muong Khuong and Si Ma Cai. These districts were selected based on their mean elevation of 600 meters above sea level (masl) as vegetable cultivation in the region, especially counter-season vegetables, often occurs in higher altitude areas because of the local climate and good soil conditions.

Smallholder farming households were selected using a stratified multistage sampling strategy. Households had to be engaged in farming over the past three years to qualify for the study. Communes in the four selected districts were grouped using the median elevation and the median vegetable per capita density. From the elevation data and vegetable per capita density collated by the Vietnam Women's Union (VWU), each commune was coded as either low elevation (<=1,335m) or high elevation (>1,335m), and low vegetable per capita density (<=97.6) or high vegetable per capita density (>97.6). Then, communes were categorised into four strata low vegetable per capita density-low elevation (LV-LA); low vegetable per capita density-high elevation (LV-HA); high vegetable per capita density-low evaluation (HV-LA); high vegetable per capita density-high elevation (HV-HA). Finally, three communes in each stratum, and four villages per commune were randomly selected (one project commune site was included in Sa Pa district, and three project villages). In each village, 10 households were randomly selected from a list of households provided by the rural commune (*xã*)/commune-level town (*thị trấn*) administrative offices for a total of 510 households from 51 villages in 13 communes.

The survey instrument contained detailed information on household and individual food consumption patterns, farm production and crop disposals, market access, and socio-demographics. Data for each member of the household was collected to measure intrahousehold differences in consumption behaviour.

In each household, the main food preparer was interviewed along with the household head (or the spouse if the main food preparer is the household head). The sample included in the analysis was limited to children aged 6 to 59 months totalling to 256 observations. Our focus is on children six months and above as this is when they start to consume more than one food group, and the 24-59 months are the critical time to detect impacts on stunting (Smith and Haddad 2015). There were 212 out of 216 total households with complete information available for all of the variables considered in the econometric analysis.

2.2 Dietary assessment using the 24-hour food recall

The food variety and the patterns of consumption were collected using the 24-hour food recall methodology. It is one of the most common methods of acquiring consumption data together with the food frequency questionnaire, and the food diary or diet records (Baranowski 2012, Himmelgreen and Crooks 2005, Headey and Ecker 2013, Thompson and Subar 2013), and is commonly used in nutritional anthropological research (Himmelgreen and Crooks 2005). The 24-hour food recall is based on the quantities of food consumed by an individual in the previous day (Baranowski 2012, Gibson and Ferguson 2008, Wolper *et al*. 1995). It minimizes potential recall bias due to the shorter recall period, but also suffers from within-person random error since it is only a snapshot of the consumption patterns which could vary day-to-day. One solution is to conduct repeat administrations of the 24-hour recall, with the number of repeat days depending on the observed day-to-day variability of the food (Baranowski 2012, Gibson and Ferguson 2008). From an intensive ethnographic study conducted with households in the study area during July-August 2015, we observed a homogenous diet among the rural farming households in our target areas. Hence, we determined that within-person variation is not likely to pose a serious problem. Thus, the consumption data was collected in two non-consecutive days (one weekday and one weekend), since consecutive days are not independent of each other (Baranowski 2012) as leftover food is quite common.

The food consumption module was composed of three sections. First, the respondent (main food preparer in the household) was asked to list and provide the quantity of dishes and individual food items prepared and consumed by all household members, including those eaten away from home. If the other household members were present in the household during the time of the interview, they were also asked to participate to confirm and verify their actual consumption. All quantities recorded were either in grams or millilitres. The second part contained the list of ingredients used for all home-cooked dishes, which were quantified in the first part, including the source where the household obtained the specific food item, the person-in-charge of purchase, the raw quantity used in the food preparation, the unit of measure (either in grams or millilitres), and the average price per unit. The third section included the list of dishes prepared by the household during special occasions in the last 12 months (e.g. family affairs like birthdays, offering prayers to the Gods; festivals celebrated as part of their ethnic tradition or culture like the *Mông* Spring festival; and festivals celebrated countrywide like the *Tet*, Holiday of the Dead or *Thanh Minh*, etc.).

Food models (using shredded paper and clay) and standard measuring instruments were used by trained enumerators/interviewers to improve the accuracy of the portion size estimates either in grams or millilitres (Gibson and Ferguson, 2008). Portion sizes in millilitres were converted to grams using the density conversion rates from the FAO/INFOODS Density Database Version 2.0 and the USDA National Nutrient Database Release 28.

2.3 Determination of intra-household food allocation

The food ingredients used in home-cooked meals only (those listed in the second part of the consumption module) were used to calculate diet quality. The intrahousehold food consumption in each recall period was calculated as follows. First, we derived the share of food consumed by each household member for a home-cooked recipe per occasion by dividing the quantity consumed by each individual by home-cooked recipe by occasion with the total quantity of each home-cooked recipe by occasion. Then, we multiplied the share with the quantity of food ingredient used in each recipe by occasion with the total quantity of the food ingredient per day to weight the share of each food ingredient by home-cooked recipe by occasion for each household member. Next, we calculated the total weighted share of each food ingredient consumed in each recall period by getting the sum of the weighted shares of each food ingredient consumed by each household member by recipe by occasion. Finally, we derived the total quantity of each food ingredient consumed by each individual for each recall period by multiplying the total weighted share of each household member for food ingredient per day with the total quantity of food ingredient per day.

2.4 Indicators of diet quality: Development of the Child Dietary Diversity Score (CDDS) and the Vietnam Healthy Food Diversity index (HFDI)

The Child Dietary Diversity Score is a simple unweighted count of the number of unique food groups consumed by the child in the 24-hr recall period. Previous research suggests that it is a good proxy for diet quality in developing countries (Ruel *et al*. 2013b), especially for micronutrient intake of children in developing countries (Kennedy 2009, Kennedy *et al.* 2007, Moursi *et al.* 2008, Rah *et al.* 2010, Steyn *et al.* 2006). It is also associated with the nutritional status in children as measured by anthropometry (Arimond and Ruel 2004).

The child dietary diversity score range from 1 to 14, and are based on the food groupings in the Vietnamese Food Composition Table 2007 edition[3]: cereals and products; starchy roots and tubers; combined leafy vegetables, fruit-types, wild vegetables, including fresh and dried; fruits and berries; oils and fats and butters; meat, poultry game and its products; fish, shellfish and products; nuts and beans; eggs and products; milk and milk products; canned products; sugars, preserves and confectionery; soft drinks, beverages, alcoholic beverages; and spices and

[3] The food groups in the 1994 and the 2007 versions of the Vietnamese Food Composition Tables are similar, except that the ordering of food group “softdrink, beverages, alcoholic beverages (13)” and “condiments and traditional sauces (14)” are interchanged.

sauces. Several food items that were initially categorised under "others" were reclassified. For instance, *mincin* or Ajinomoto was reclassified under "condiments and traditional sauces" from "others (specify)".

An additional measure that reflects both diet diversity and diet quality is the Healthy Food Diversity Index (HFDI) that was developed by Drescher *et al.* (2007). It is a validated measure of nutritional adequacy (Leschewski *et al* 2017). The HFDI (Eq 1 and Eq 2) has been previously implemented in Germany (Drescher *et al.* 2009), Canada (Drescher and Goddard, 2008), and the United States (Vadiveloo *et al.* 2014). The HFDI takes a value between 0 and almost 1, with higher values reflecting more healthy foods consumed in the household. Unlike other count measures of dietary diversity such as the Dietary Diversity Score, the HFDI is multidimensional and measures dietary variety, dietary quality, and proportionality (consuming larger and fewer amounts of certain food groups based on the dietary guidelines) (Drescher *et al.* 2007).

(1) $$HFDI_i = (1-\sum s_i^2) \times hv$$

(2) $$hv = \sum hf \times s_i$$

where:

s_i is the share of food ingredient to total quantity of food consumed by each child i;

hf is the health factor based on the National Institute of Nutrition's dietary guidelines;

hv is the health value. The HFDIndex was calibrated by dividing it by the maximum hf to achieve an index that is bounded between 0 and almost 1 (Drescher *et al.* 2007).

To measure diversity or the number and proportion of food, HFDI uses the Berry Index [BI=(1-$\sum s_i^2$)], which looks at the volume shares as opposed to expenditure shares. It uses a group-based food classification scheme that is also based on the Vietnamese Food Composition

Table 2007 food classifications. A health factor (*hf*) for each group was created based on the recommended proportion in the diet in accordance with Vietnam's 2010-2020 dietary guidelines for adults to measure dietary quality (Table 1). It is hypothesised that this can be applied for children since their nutritional requirements, especially from age two years onwards, are similar with adults when it comes to the health factor. We averaged the two non-consecutive visits for each diet quality indicator to get the mean CDDS and HFDI of each child.

3 Econometric model specification

The econometric analysis focuses on examining the determinants of diet quality with vegetable production diversity (number of vegetables grown), market access, market participation, and women empowerment as the main explanatory variables of interest.

For the model that uses child dietary diversity score as the dependent variable, we use a Poisson model because of the count nature of the dependent variable (Cameron and Trivedi 1998). The Poisson estimator assumes equidispersion, that is, the (conditional) mean of the dependent variable should equal the (conditional) variance, and this is commonly violated due to the presence of unobserved heterogeneity leading to overdispersion (or underdispersion) (Cameron and Trivedi, 2010). We used robust standard errors clustered at the household level to avoid bias due to unobservable household characteristics, and correct the problem of overdispersion based on the auxiliary regression test (Cameron and Trivedi, 2010). The marginal effects are reported for all explanatory variables for the Poisson estimator (Model 2) for ease in interpretation. In our models, the marginal effects describe how the child dietary diversity score changes when the regressors change by a unit.

We model two diet quality indicators (DQ_{ijh}), (a) child dietary diversity score (CDDS) or the number of food groups of child *i* taken care by food preparer *j* in household *h*, and (b) Healthy Food Diversity Index (HFDI), separately. The main equation estimated is given in Eq 3:

$$DQ_{ijh} = constant + \beta VD_h + \lambda MA_h + \psi G_h + \varphi'\boldsymbol{HH}_h + \delta'\boldsymbol{CH}_i + \gamma'\boldsymbol{FP}_j + \varepsilon_{ijh} \quad (3)$$

Our explanatory variables of interest are:

VD_h is the number of vegetables grown by household *h* where the child belongs to. Vegetable production was assessed by asking the household the types of vegetables cultivated and harvested (crop output and disposal) in their own field in the last production cycle. Almost all rural farming households produced vegetables. To date, only the study of Keding *et al*. (2012) measured vegetable production diversity in the literature, which is a simple count of the number of vegetable types cultivated and collected. We expect the marginal effect of vegetable production diversity to be positive and significant. The premise is that when households increase nutrient-dense vegetable production, they will have relatively easy access to nutritious food which will ultimately lead to improved diets.

MA_h is a vector of market engagement that includes market access and market participation. Market engagement is an essential factor in the study of food security and nutritional outcomes as the impact of agriculture on nutrition can either be direct (production-own-consumption), indirect (income effect from semi-commercial production and market engagement), or both (Aberman *et al*. 2015, Darrouzet *et al*. 2015, Kennedy 1994, Minot *et al*. 2006, von Braun 1994). We define market access as a household's proximity to the nearest food market. It benefits the household in two ways: (a) households have access to a wide variety of food, and (b) households can sell their agricultural produce, and use the additional income to purchase a wide variety of food. Market participation, on the other hand, is when a household sells its agricultural produce to any market outlet, e.g. modern or traditional (Aberman *et al.* 2015). In total, we used four market indicators: average travel time (one-way) from residence to the nearest market for market access; and three dummy variables for market participation, i.e. farming households who sold vegetables to modern retailers in the last production cycle, farming households who sold vegetables to traditional outlets in the last production cycle, and farming households who did not sell and only consumed vegetables that they produced in the last production cycle. Traditional markets are either local markets in the village, commune, or district, depending on what exists in the locality; selling to fellow farmers in the village/commune; selling to collectors in the village/commune; or selling directly to consumers in the nearby market. Modern retail outlets are cooperatives, wholesale markets, supermarkets and other retailers in Hanoi. Market access[4] is often measured using distance to market, travel time, and cost of transportation (Meerman *et al*. 2015). We used travel time to the nearest market since it takes into account road quality, terrain, transport network, and the best available means of transportation (in most cases, the use of motorbikes either through ownership or rental) (Epprecht *et al.* 2009) instead of using distance, which was also difficult to estimate by our sampled households perhaps due to the serpentine nature of the roads in these mountainous areas. For households that could not estimate the average travel time to the nearest market, we imputed the missing values with the estimated mean one-way travel time by village or commune or district. We expect the coefficients to be significant. Longer travel time to the nearest food

[4] We also tried other commercialisation indicators like percentage of total quantity of vegetable sold to total quantity of vegetable produced, percentage of total value of vegetable sold to total agricultural sales, but eventually removed them since the marginal effects were lower as compared to the three dummy variables.

market is expected to have a negative correlation with children's dietary diversity since certain food groups can only be purchased at the market. Likewise, households that engage in semi-commercial vegetable production, while it reduces vegetable production diversity to only cash crops or high value crops, is augmented by the income gains from semi-commercialisation, which gives them the ability to purchase other nutritious food from the market.

G_h are dummy variables measuring women empowerment based on the Abbreviated-Women's Empowerment in Agriculture Index (A-WEAI). It is multidimensional capturing six indicators from five dimensions: input in productive decisions, ownership of assets, access to and decisions on credit, control over income, group membership, and workload. Each of the six indicators are assigned a value of 1 if the woman's (secondary decision-maker in the household) achievement is adequate, and 0 if otherwise (Malapit *et al.* 2015a). In our sample, we only included four indicators: input in productive decisions, access to and decisions on credit, group membership, and workload[5]. We expect the marginal effects to be positive and significant since women tend to be more concerned with the health and well-being of children and men (Quisumbing *et al.* 1995). Hence, their ability to control the resources at home, spend and select diverse and nutritious food for the family will have a strong positive effect on child dietary diversity.

We also control for other confounding variables that can be grouped into three: household characteristics ($\boldsymbol{HH_h}$), child characteristics ($\boldsymbol{CH_i}$), and food preparer characteristics ($\boldsymbol{FP_j}$).

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[5]Initially, we included the total weighted women adequacy/empowerment scores, as well as the individual weighted scores of the six indicators in the A-WEAI. However, we eventually dropped the total weighted women adequacy/empowerment scores since they were not significant in any kind of regression models we tested. We also used the dummies (=1 if adequate, and =0 if otherwise) instead of using the individual weighted scores for the six indicators. In the final model, we dropped two of the indicators (i.e. woman owning assets, and woman having control over use of household income) in the analysis since there was no variation in the sample – all our women respondents own assets, and have control over the use of household income.

$\boldsymbol{HH_h}$ is a vector of household characteristics including the stratum to which the village belongs to according to elevation and vegetable per capita density, monthly per capita food expenditure, monthly non-food expenditure, total cultivated area, number of years the farming household is engaged in vegetable cultivation, and the total number of household members. Both per capita food expenditure and non-food expenditure are included to control for household-level behaviours associated with the use of productive resources. Food-related expenditures may directly influence the quantity and quality of household diets, while non-food expenditures, through substitution effects, may indirectly influence the amount of resources available for diversifying diets. The latter is also used as proxy for household income. $\boldsymbol{CH_i}$ are child-related controls that include age and a dummy for male child. We did not control for education as our target group are children aged 6-59 months. In addition, we also controlled for the food preparer's characteristics. ***FPj*** are controls for food preparer characteristics that include age, dummy for women as food preparer, education, and dummy for *Mong* as the ethnic minority group of the food preparer. ε_{ijh} is an error term.

The same causal and control variables were used for the Healthy Food Diversity index (HFDI). We used the Tobit estimator due the censored nature of the HFDI which ranges between 0 and almost 1 (Cameron and Trivedi, 2010). For comparison, we also included the OLS results to verify the marginal effects of the Poisson estimator. For the OLS, several regression diagnostic tests were done: variance inflation factor for multicollinearity, White test for heteroscedasticity, Ramsey RESET test (Regression Equation Specification Error test), and goodness-of-fit if applicable. All statistical analyses were carried out using Stata version 14.2 (StataCorp., Texas, USA).

4 Results and discussion

Table 2 provides descriptive statistics for the characteristics of the household, child and main food preparer, and other variables of interest. A typical rural farming household, on average, is composed of six members, with an average monthly per capita food expenditure and monthly non-food expenditure of 2.1 million VND and 4.2 million VND, respectively. In terms of its production practices, it has on average 15 years of experience in vegetable cultivation, on a 1.1 hectares (ha) of cultivated land. Our sample also shows that majority of the main food preparer are women (65 percent) from the *Mông* ethnic minority group (72 percent), with an average age of 35 years. Many have not attended school (46 percent); and for those who did, majority only attended primary and/or lower secondary education. We have a nearly balanced number of male and female children (53 percent male) aged 6 to 59 months, with an average age of 35 months. Their mean CDDS is 4.55 (±1.189), and the mean HFDI is 0.44 (±0.135).

4.1 Child Dietary Diversity Score (CDDS)

Results of the regression analysis (Table 3, column 2) show that, on average, the child dietary diversity score (CDDS) is increasing with the number of vegetables cultivated. Market participation is also positively associated with CDDS. The predicted increase in child dietary diversity scores for households selling at modern channels and traditional market are 0.835 and 0.740, respectively. For those that are only engaged in subsistence vegetable production (do not sell to any market and only consume the vegetables that they grow), the marginal effect to child dietary diversity score is larger at 0.923. This means that households who only produce for home consumption, aside from vegetable cultivation, may also be producing other crops and fruit trees, and rearing animals and other livestock to augment their dietary requirement, and hence the positive and significant marginal effect with child dietary diversity scores at the 5 percent level.

In terms of women empowerment/adequacy, women whose agricultural workload is less than the poverty line of 10.5 hours (dummy) have positive marginal effect on child dietary diversity score, increasing the predicted count by 0.392 as compared to those who work longer hours. Intuitively, women who work less than 10.5 hours can spend more time at home to plan and prepare diverse food for the household members. However, how balanced and healthy these diverse food is another matter, when we look at the individual Healthy Food Diversity index (HFDI). Likewise, women who participates more in the agricultural production decisions has a negative effect on the predicted child dietary diversity score (-0.678). The more they are engaged in agricultural production activities, regardless of whether it is actual farm work or participation in the decision-making process only, veers them away from household chores including food preparation. When pressed for time, women simply prepare food that are easy and practical, for instance, cooking boiled fermented bamboo shoot with balm-mint leaves (*mang xao tia to*) for dinner, and reheating it the next day for the whole family's consumption as both parents prepare for field work. In these rural areas, women normally participate in agricultural activities (the share of women with input in agricultural production decisions is 98 percent, see Table 2).

Four important covariates are significant in the Poisson model (column 2). The monthly non-food expenditure and education of food preparer are positively associated with CDDS, while ethnicity and household size are negatively associated with CDDS. These results are consistent with a priori expectations. Wealthier and more educated households have been shown to have a positive effect on the dietary diversity score (Jones *et al.* 2014, McDonald *et al.* 2015). Higher income (proxied by monthly non-food expenditure) increases a household's ability to purchase more food, and higher education of the food preparer is predicted to have a positive effect on diet quality by increasing the allocative efficiency of health production.

On the other hand, larger household size negatively affects the proportion of food distributed within the household. Given that about 33 percent of the households in these areas are below the poverty threshold (GSO 2012), it limits the number of food items from different food groups that the household can purchase. It also affects the amount of resources that the household can allocate on food production, and in the purchase of inputs for their vegetable production. In terms of ethnicity, diets of the *Mong* children are less diverse vis-à-vis the decline in the predicted child dietary diversity score of 0.666 if the food preparer is a *Mong* versus other ethnicities (e.g. *Kinh, Tày, Mường, Nùng, Dao, Khơ Mú, Giáy, Phù Lá (Xa Pho),* and *Bố Y*).

4.2 Healthy Food Diversity Index (HFDI)

In terms of the HFDI, we did not find any significant associations with our main variables of interest (Table 3, column 4). There are certain limitations in the use of the HFDI. The relationship of HFDI with the variable of interest is non-linear, which means that an increase in any quantity of food consumed does not result in a proportional increase of the HFDI. The index also fails to take into account the absolute value of the quantities consumed. For instance, if two individuals consumed the same set of food items in one reference period, and person A consumed twice the amount of food consumed by person B, then both individuals will still yield the same index. The multidimensional nature of the index captures dietary diversity, proportionality and dietary quality, but it fails to take into account this difference in quantity consumed between individuals.

The positive and significant covariates are the following: village stratum, monthly non-food expenditure, total cultivated area, household size, and age of the child. Those in the upper stratum have better diets than those in the low-lying and low vegetable per capita areas (reference group). This difference with the reference group is more pronounced for those in the high vegetable per capita density areas (strata 3 and 4). Although the effect is minimal, the higher the monthly non-food expenditure, total cultivated area, household size, and the age of the child is, the better the predicted child's HFDI. Both monthly non-food expenditure and total cultivated area could indicate wealth, and wealthier households have been found to have better diets than poor households. While household size has a negative effect on CDDS, it has a positive effect on the child's HFDI. This could be because as a household becomes larger, it limits the purchase of other food groups, and focus on the consumption of food items that are readily available in their environment which are staples, vegetables, as well as meat from their backyard (cattle, horse, pig, chicken, duck). These food groups have higher weights placed on them in the food pyramid especially for staples (0.34) and vegetables (0.28). Similarly, the older a child is, the better his/her HFDI becomes which makes sense because the more they eat a diverse range of food items. The multidimensional nature of the HFDI did not yield any significant relationship with any of the variables-of-interest.

5 Conclusions

In this article, we find strong evidence supporting our three hypotheses that shows smallholder vegetable production is significantly associated with the dietary diversity outcomes of children aged 6 to 59 months of age. This suggests the importance of vegetable production in the diets of children in these remote rural farming areas: for subsistence families who have to produce their own food to meet their dietary requirements due to missing markets; and for farming households who have access to traditional and modern food retail markets to sell their agricultural produce and buy other nutritious and diverse food. Our results also show the delicate balance women in rural farming areas must contend with, wherein active involvement in the agricultural production decision-making negatively affects their child dietary diversity outcomes on the one side, and, a lesser workload on the field to tend to their children at home positively affects their child dietary diversity outcomes. The latter, however, implies working less hours and transferring workload from one productive and experienced individual to other household members or hired laborers that require financial resources, and may not operate in similar efficient capacity as the mother. There are several limitations of this work. First, our data only covers one season (July-August 2016), and therefore cannot be extrapolated for the entire year. We are also aware of potential issues with endogeneity with respect to household. To our knowledge, our study is the first to assess the role of smallholder vegetable production on children's dietary diversity in Northwest Vietnam.

References

Aberman, N.L., Meerman, J. and Benson, T. (eds.) (2015). *Mapping the Linkages between Agriculture, Food Security and Nutrition in Malawi*. IFPRI, Lilongwe, Malawi, and Washington, D.C. Available from http://www.ifpri.org/publication/mapping-linkages-between-agriculture-food-security-and-nutrition-malawi.

Alderman, H., Elder, L., Goyal, A., Herforth, A., Hoberg, Y.T., Marini, A., Ruel-Bergeron, J., Saavedra Chanduvi, J., Shekar, M., Tiwari, S. and Zaman, H. (2013). *Improving nutrition through multisectoral approaches*. World Bank, Washington, D.C. Available from http://documents.worldbank.org/curated/en/625661468329649726/Improving-nutrition-through-multisectoral-approaches.

Ali, D., Saha, K.K., Nguyen, P.H., Diressie, M.T., Ruel, M.T., Menon, P. and Rawat, R. (2013). Household food insecurity is associated with higher child undernutrition in Bangladesh, Ethiopia, and Vietnam, but the effect is not mediated by child dietary diversity, *Journal of Nutrition* 143, 2015-2021. Available from http://jn.nutrition.org/content/early/2013/10/02/jn.113.175182

Arimond, M. and Ruel, M.T. (2004). Dietary diversity is associated with child nutritional status: Evidence from 11 Demographic and Health Surveys, *Journal of Nutrition* 134, 2579-2585. Available from http://jn.nutrition.org/content/134/10/2579.full.pdf+html

Baranowski, T. (2012). 24-Hour Recall and Diet Record Methods, in Willett, W. (ed.), *Nutritional Epidemiology Third Edition.* Oxford University Press, New York, pp 49-69.

Berti, P.R., Krasevec, J. and FitzGerald, S. (2004). A review of the effectiveness of agriculture interventions in improving nutrition outcomes, *Public Health Nutrition* 7, 599-609. Available from https://doi.org/10.1079/PHN2003595.

Black, R.E., Victora, C.G., Walker, S.P., Bhutta, Z.A., Christian, P., de Onis, M., Ezzati, M., Grantham-McGregor, S., Katz, J., Martorell, R., Uauy, R., Maternal and Child Nutrition Study Group (2013). Maternal and child undernutrition and overweight in low-income and middle-income countries, *Lancet* 382, 427-451. Available from http://dx.doi.org/10.1016/S0140-6736(13)60937-X.

Bonnin, C. and Turner, S. (2012). Livelihood Vulnerability and Food Security among Upland Ethnic Minorities in Northern Vietnam, *Kasarinlan: Philippine Journal of Third World Studies* 26, 324-340. Available from http://journals.upd.edu.ph/index.php/kasarinlan/article/view/3503.

Cameron, A.C. and Trivedi, P.K. (2010). *Microeconometrics using Stata (Revised Edition)*. Stata Press, Texas.

Cameron, A.C. and Trivedi, P.K. (1998). *Regression Analysis of Count Data*. Cambridge University Press, Cambridge, UK, and New York, USA.

Carletto, G., Ruel, M., Winters, P. and Zezza, A. (2015). Farm-Level pathways to improved nutritional status: introduction to the special issue, *Journal of Development Studies* 51, 945-957. Available from http://dx.doi.org/10.1080/00220388.2015.1018908.

Chaparro, C., Oot, L. and Sethuraman, K. (2014). *Vietnam Nutrition Profile*. FHI 360/FANTA, Washington, D.C. Available from https://www.fantaproject.org/sites/default/files/download/Vietnam-Nutrition-Profile-Apr2014.pdf.

Dang, H.-A. (2012). Vietnam: A Widening Poverty Gap for Ethnic Minorities, in Hall, G. and Patrinos, H.A. (eds.), *Indigenous Peoples, Poverty, and Development*. Cambridge

University Press, New York, pp 304-343. Available from http://siteresources.worldbank.org/EXTINDPEOPLE/Resources/407801-1271860301656/Chapter_8_Vietnam.pdf.

Dangour, A.D., Green, R., Hasler, B., Rushton, J., Shankar, B. and Waage, J. (2012). Linking agriculture and health in low- and middle-income countries: an interdisciplinary research agenda, *Proc Nutr Soc* 71, 222-228. Available from https://doi.org/10.1017/S0029665112000213.

Darrouzet-Nardi, A.F. and Masters, W.A. (2015). Urbanization, market development and malnutrition in farm households: evidence from the Demographic and Health Surveys, 1986–2011, *Food Security* 7, 521-533. Available from http://link.springer.com/article/10.1007/s12571-015-0470-9.

Drescher, L., Thiele, S., Roosen, J. and Mensink, G.B. (2009). Consumer demand for healthy eating considering diversity - an economic approach for German individuals, *International Journal of Consumer Studies* 33, 684-696. Available from http://onlinelibrary.wiley.com/doi/10.1111/j.1470-6431.2009.00812.x/full.

Drescher, L.S. (2007). Healthy Food Diversity as a Concept of Dietary Quality: Measurement, Determinants of Consumer Demand, and Willingness to Pay, Cuvillier Verlag, Göttingen. Available from https://cuvillier.de/uploads/preview/public_file/3692/9783867273008.pdf.

Drescher, L.S. and Goddard, E.W. (2008). *Comparing predictors of diet quality in Canada over time under consideration of altering food guides*. Staff Paper #08-01, University of Alberta, Department of Resource Economics and Environmental Sociology. Available from https://era.library.ualberta.ca/files/df65v8929#.WNj6HnqRY-k.

Drescher, L.S., Thiele, S. and Mensink, G.B. (2007). A new index to measure healthy food diversity better reflects a healthy diet than traditional measures, *The Journal of Nutrition* 137, 647-651. Available from http://jn.nutrition.org/content/137/3/647.full.

Epprecht, M., Müller, D. and Minot, N. (2009). How remote are Vietnam's ethnic minorities? An analysis of spatial patterns of poverty and inequality, *The Annals of Regional Science* 46, 349-368. Available from http://link.springer.com/article/10.1007/s00168-009-0330-7.

FAO/INFOODS (2012). FAO/INFOODS Density Database Version 2.0. FAO, Rome. Available from http://www.fao.org/docrep/017/ap815e/ap815e.pdf.

Food and Agriculture Organization of the United Nations. (2015). FAOSTAT statistics database. FAO, Rome.

Gibson, R.S. and Ferguson, E.L. (2008). *An interactive 24-hour recall for assessing the adequacy of iron and zinc intakes in developing counties*. International Food Policy Research Institute (IFPRI) and International Center for Tropical Agriculture (CIAT), HarvestPlus Technical Monograph Series 8, Washington, D.C., and Cali, Colombia. Available from http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/128218.

Gillespie, S., Harris, J. and Kadiyala, S. (2012). *The agriculture-nutrition disconnect in India: what do we know*. International Food Policy Research Institute, IFPRI Discussion Paper 01187, Washington, D.C. Available from http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/126958.

Girard, A.W., Self, J.L., McAuliffe, C. and Olude, O. (2012). The effects of household food production strategies on the health and nutrition outcomes of women and young children: a systematic review, *Paediatric and Perinatal Epidemiology* 26 Suppl 1, 205-222.

Available from http://onlinelibrary.wiley.com/doi/10.1111/j.1365-3016.2012.01282.x/abstract.

GSO (2012). *Result of the Viet Nam Household Living Standards Survey 2012*. Statistical Publishing House, Hanoi. Available from http://www.gso.gov.vn/default_en.aspx?tabid=483&idmid=4&ItemID=13888.

Headey, D. and Ecker, O. (2013). Rethinking the measurement of food security: from first principles to best practice, *Food Security* 5, 327-343. Available from http://link.springer.com/article/10.1007/s12571-013-0253-0.

Herforth, A. and Harris, J. (2014). *Understanding and applying primary pathways and principles*. *Brief #1*. USAID/Strengthening Partnerships, Results, and Innovations in Nutrition Globally (SPRING) Project, Improving Nutrition through Agriculture Technical Brief Series, Arlington, VA. Available from https://www.spring-nutrition.org/publications/briefs/understanding-and-applying-primary-pathways-and-principles.

Himmelgreen, D.A and Crooks, D.L. (2005). Nutritional Anthropology and Its Application to Nutritional Issues and Problems, in Kedia, S. and van Willigen, J. (eds.), *Applied Anthropology: Domains of Application*. Praeger Publishers, Westport, CT, pp 149-188.

Hirvonen, K. and Hoddinott, J. (2016). Agricultural production and children's diets: evidence from rural Ethiopia, *Agricultural Economics* 00, 1-12. Available from http://onlinelibrary.wiley.com/doi/10.1111/agec.12348/abstract.

IFPRI (2002). *Fruits and vegetables in Vietnam: adding value from farmer to consumer*. International Food Policy Research Institute, Washington, D.C. Available from http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/126309.

International Food Policy Research Institute (2016). *Global Nutrition Report 2016: From promise to impact: ending malnutrition by 2030*. International Food Policy Research Institute, Washington, D.C. Available from http://www.ifpri.org/publication/global-nutrition-report-2016-promise-impact-ending-malnutrition-2030.

Jones, A.D., Shrinivas, A. and Bezner-Kerr, R. (2014). Farm production diversity is associated with greater household dietary diversity in Malawi: Findings from nationally representative data, *Food Policy* 46, 1-12. Available from https://doi.org/10.1016/j.foodpol.2014.02.001

Kadiyala, S., Harris, J., Headey, D., Yosef, S. and Gillespie, S. (2014). Agriculture and nutrition in India: mapping evidence to pathways, *Ann N Y Acad Sci* 1331, 43-56. Available from http://onlinelibrary.wiley.com/doi/10.1111/nyas.12477/abstract.

Kanter, R., Walls, H.L., Tak, M., Roberts, F. and Waage, J. (2015). A conceptual framework for understanding the impacts of agriculture and food system policies on nutrition and health, *Food Security* 7, 767-777. Available from http://link.springer.com/article/10.1007/s12571-015-0473-6.

Kawarazuka, N. and Bene, C. (2010). Linking small-scale fisheries and aquaculture to household nutritional security: an overview, *Food Security* 2, 343-357. Available from http://link.springer.com/article/10.1007/s12571-010-0079-y.

Keding, G., Msuya, J., Maass, B. and Krawinkel, M. (2012). Relating dietary diversity and food variety scores to vegetable production and socio-economic status of women in rural Tanzania, *Food Security* 4, 129-140. Available from https://dx.doi.org/10.1007/s12571-011-0163-y

Kennedy, E. (1994). Health and Nutrition Effects of Commercialization of Agriculture, in von Braun, J. and Kennedy, E. (eds.) *Agricultural Commercialization, Economic Development, and Nutrition*, pp. 79-102. Johns Hopkins University Press, Baltimore. Available from http://www.ifpri.org/publication/health-and-nutrition-effects-commercialization-agriculture

Kennedy, G.L. (2009). Evaluation of dietary diversity scores for assessment of micronutrient intake and food security in developing countries, PhD Thesis, Wageningen University, Wageningen, The Netherlands. Available from http://library.wur.nl/WebQuery/wurpubs/385125.

Kennedy, G.L., Pedro, M.R., Seghieri, C., Nantel, G. and Brouwer, I. (2007). Dietary diversity score is a useful indicator of micronutrient intake in non-breast-feeding Filipino children, *The Journal of Nutrition* 137, 472-477. Available from http://jn.nutrition.org/content/137/2/472.

Koppmair, S., Kassie, M. and Qaim, M. (2017). Farm production, market access and dietary diversity in Malawi, *Public Health Nutrition* 20, 325-335. Available from https://doi.org/10.1017/S1368980016002135

Kozel, V. (2014). Reducing Poverty among Ethnic Minorities, in Kozel, V. (ed.), *Well Begun but Not Yet Done: Progress and Emerging Challenges for Poverty Reduction in Vietnam*. World Bank, Washington, D.C., pp 163-193. Available from http://dx.doi.org/10.1596/978-1-4648-0006-1_ch5.

Kumar, N., Harris, J. and Rawat, R. (2015). If they grow it, will they eat and grow? Evidence from Zambia on agricultural diversity and child undernutrition, *The Journal of Development Studies* 51, 1060-1077. Available from http://dx.doi.org/10.1080/00220388.2015.1018901.

Leschewski, A.M., Weatherspoon, D.D. and Kuhns, A. (2017). Rethinking household demand for food diversity, *British Food Journal* 119, 1176-1188. Available from http://dx.doi.org/10.1108/BFJ-09-2016-0429

Leroy, J.L. and Frongillo, E.A. (2007). Can interventions to promote animal production ameliorate undernutrition?, *The Journal of Nutrition* 137, 2311-2316. Available from http://jn.nutrition.org/content/137/10/2311.abstract.

Malapit, H.J.L., Kadiyala, S., Quisumbing, A.R., Cunningham, K. and Tyagi, P. (2015). Women's empowerment mitigates the negative effects of low production diversity on maternal and child nutrition in Nepal, *Journal of Development Studies* 51, 1097-1123. Available from http://dx.doi.org/10.1080/00220388.2015.1018904.

Malapit, H.J., Kovarik, C., Sproule, K., Meinzen-Dick, R.S. and Quisumbing, A.R. (2015a). *Instructional guide on the abbreviated Women's Empowerment in Agriculture Index (A-WEAI).* International Food Policy Research Institute (IFPRI), Washington, D.C. Available from http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/129719.

Masset, E., Haddad, L., Cornelius, A. and Isaza-Castro, J. (2012). Effectiveness of agricultural interventions that aim to improve nutritional status of children: systematic review, *BMJ* 344, d8222. Available from https://doi.org/10.1136/bmj.d8222

McDonald, C.M., McLean, J., Kroeun, H., Talukder, A., Lynd, L.D. and Green, T.J. (2015). Correlates of household food insecurity and low dietary diversity in rural Cambodia, *Asia Pacific Journal of Clinical Nutrition* 24, 720-730. Available from https://www.ncbi.nlm.nih.gov/pubmed/26693758

Meerman, J., Aberman, N.L., Harris, J. and Pauw, K. (2015). Chapter 2: Indicators for Examining Links between Agriculture, Food Security, and Nutrition, in Aberman, N.L., Meerman, J. and Benson, T. (eds.), *Mapping the Linkages between Agriculture, Food Security and Nutrition in Malawi*. IFPRI, Lilongwe, Malawi, and Washington, D.C., pp. 8-22. Available from http://www.ifpri.org/publication/mapping-linkages-between-agriculture-food-security-and-nutrition-malawi.

Minot, N., Epprecht, M., Anh, T.T.T. and Trung, L.Q. (2006). Income diversification and poverty in the Northern Uplands of Vietnam, *Research Report of the International Food Policy Research Institute* 1-137.

Moursi, M.M., Arimond, M., Dewey, K.G., Treche, S., Ruel, M.T. and Delpeuch, F. (2008). Dietary diversity is a good predictor of the micronutrient density of the diet of 6-to 23-month-old children in Madagascar, *The Journal of Nutrition* 138, 2448-2453. Available from https://www.ncbi.nlm.nih.gov/pubmed/19022971.

NIN (1995). *Thành Phân Dinh Du'õ'ng Thú'c An Viêtnam, Food Products in Vietnam, Composition and Nutritive Value.* National Institute of Nutrition, Ministry of Health, Medicine Publisher, Hanoi.

NIN (2007). *Vietnamese Food Composition Table*. Medical Publishing House, Hanoi. Available from http://www.fao.org/infoods/infoods/tables-and-databases/asia/en/.

NIN (2013). *The Vietnamese Food Pyramid - Vietnam's food-based dietary guidelines for an adult for 2010-2020*. National Institute of Nutrition. Available from http://www.fao.org/nutrition/education/food-based-dietary-guidelines/regions/countries/vietnam/en/.

NIN (2014). Prevalence of undernutrition by severity - 2014 - by 6 ecological region. Available from URL: http://viendinhduong.vn/news/vi/106/61/0/a/so-lieu-thong-ke-ve-tinh-trang-dinh-duong-tre-em-qua-cac-nam.aspx [accessed 16 March 2015].

NIN and UNICEF (2011). *Nutritional Institute of Nutrition: A Review of the Nutrition Situation in Vietnam 2009-2010*. Medical Publishing House, Hanoi. Available from http://www.wpro.who.int/vietnam/publications/nutritionreview/en/.

Paciorek, C.J., Stevens, G.A., Finucane, M.M., Ezzati, M. and Nutrition Impact Model Study Group (2013). Children's height and weight in rural and urban populations in low-income and middle-income countries: a systematic analysis of population-representative data, *Lancet Glob Health* 1, e300-309. Available from https://doi.org/10.1016/S2214-109X(13)70109-8

Pinstrup-Andersen, P. (2014). Food Systems and Human Nutrition: Relationships and Policy Interventions, in Thompson, B. and Amoroso, L. (eds.), *Improving Diets and Nutrition: Food-Based Approaches.* CABI and FAO, Rome, Italy. Available from http://www.cabi.org/cabebooks/ebook/20143140788.

Quisumbing, A.R., Brown, L.R., Feldstein, H.S., Haddad, L. and Peña, C. (1995). *Women: the key to food security.* International Food Policy Research Institute, Food Policy Report, Washington, D.C. Available from http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/125877.

Rah, J.H., Akhter, N., Semba, R.D., de Pee, S., Bloem, M.W., Campbell, A.A., Moench-Pfanner, R., Sun, K., Badham, J. and Kraemer, K. (2010). Low dietary diversity is a predictor of child stunting in rural Bangladesh, *European Journal of Clinical Nutrition* 64, 1393-1398. Available from http://www.nature.com/ejcn/journal/v64/n12/full/ejcn2010171a.html.

Ravallion, M., Chen, S. and Sangraula, P. (2007). New evidence on the urbanization of global poverty, *Population and Development Review* 33, 667-701. Available from http://onlinelibrary.wiley.com/doi/10.1111/j.1728-4457.2007.00193.x/abstract.

Ruel, M.T., Alderman, H. and Maternal and Child Nutrition Study Group (2013a). Nutrition-sensitive interventions and programmes: how can they help to accelerate progress in improving maternal and child nutrition?, *Lancet* 382, 536-551. Available from http://dx.doi.org/10.1016/S0140-6736(13)60843-0.

Ruel, M., Harris, J. and Cunningham, K. (2013b). Diet Quality in Developing Countries. in Preedy, V.R., Hunter, L.-A. and Patel, V.B. (eds.), *Diet Quality: An Evidence-Based Approach Volume 2*. Springer New London, pp 239-264. Available from http://link.springer.com/chapter/10.1007%2F978-1-4614-7315-2_18.

Shively, G. and Sununtnasuk, C. (2015). Agricultural diversity and child stunting in Nepal, *Journal of Development Studies* 51, 1078-1096. Available from http://dx.doi.org/10.1080/00220388.2015.1018900.

Smith, L.C. and Haddad, L. (2015). Reducing child undernutrition: past drivers and priorities for the post-MDG era, *World Development* 68, 180-204. Available from http://dx.doi.org/10.1016/j.worlddev.2014.11.014.

Smith, L. and Haddad, L. (2000). *Explaining child malnutrition in developing countries: A cross-country analysis*, International Food Policy Research Institute (IFPRI), Washington, D.C. Available from http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/48054.

Steyn, N., Nel, J., Nantel, G., Kennedy, G. and Labadarios, D. (2006). Food variety and dietary diversity scores in children: are they good indicators of dietary adequacy?, *Public Health Nutrition* 9, 644-650. Available from https://www.ncbi.nlm.nih.gov/pubmed/16923296.

Stifel, D. and Minten, B. (2017). Market access, well-being, and nutrition: Evidence from Ethiopia, *World Development* 90, 229-241. Available from http://dx.doi.org/10.1016/j.worlddev.2016.09.009

Taren, D. and Alaofe, H. (2013). *Feed The Future learning agenda literature review: improved nutrition and diet quality*. USAID, Feed the Future FEEDBACK Project, Rockville, MD. Available from http://pdf.usaid.gov/pdf_docs/PA00JW41.pdf.

Thompson, F.E. and Subar, A.F. (2013). Chapter 1 - Dietary Assessment Methodology, in Ferruzzi, A.M., Coulston, C.J. and Boushey, M.G. (eds.), *Nutrition in the Prevention and Treatment of Disease (Third Edition)*. Academic Press, pp 5-46. Available from http://dx.doi.org/10.1016/B978-012193155-1/50003-9.

Turner, R., Hawkes, C., Jeff, W., Ferguson, E., Haseen, F., Homans, H., Hussein, J., Johnston, D., Marais, D., McNeill, G. and Shankar, B. (2013). Agriculture for improved nutrition: the current research landscape, *Food Nutr Bull* 34, 369-377. Available from https://doi.org/10.1177/156482651303400401.

US Department of Agriculture, Agricultural Research Service, Nutrient Data Laboratory. USDA National Nutrient Database for Standard Reference, Release 28. Version Current: September 2015, slightly revised May 2016. Internet: /nea/bhnrc/ndl.

Vadiveloo, M., Dixon, L.B., Mijanovich, T., Elbel, B. and Parekh, N. (2014). Development and evaluation of the US Healthy Food Diversity index, *Br J Nutr* 112, 1562-1574. Available from https://doi.org/10.1017/S0007114514002049.

Van Duyn, M.A. and Pivonka, E. (2000). Overview of the health benefits of fruit and vegetable consumption for the dietetics professional: selected literature, *Journal of the American*

Dietetic Association 100, 1511-1521. Available from http://dx.doi.org/10.1016/S0002-8223(00)00420-X.
von Braun, J. (1994). Production, Employment, and Income Effects of Commercialization of Agriculture, in von Braun, J. and Kennedy, E. (eds.) *Agricultural Commercialization, Economic Development, and Nutrition*, pp. 37-64. Johns Hopkins University Press, Baltimore. Available from http://www.ifpri.org/publication/production-employment-and-income-effects-commercialization-agriculture-0
Webb, P. (2013). *Impact pathways from agricultural research to improved nutrition and health: Literature analysis and research priorities*. FAO and WHO, Rome. Available from http://hdl.handle.net/10427/009839.
WHO and FAO (2004). *Fruit and vegetables for health: Report of a Joint FAO/WHO Workshop, 1-3 September, 2004, Kobe, Japan*. WHO, Geneva. Available from http://apps.who.int/iris/handle/10665/43143.
WHO, UNICEF, IFPRI, UC Davis, USAID, FANTA, Macro International. (2008). *Indicators for assessing infant and young child feeding practices*. World Health Organization, Geneva. Available from http://www.who.int/maternal_child_adolescent/documents/9789241596664/en/
Wolper, C., Heshka, S. and Heymsfield, S.B. (1995). Measuring Food Intake: An Overview, in Allison, D.B. (ed.), *Handbook of Assessment Methods for Eating Behaviors and Weight-related Problems: Measures, Theory, and Research.* Sage Publications, Thousand Oaks, California, pp. 215-240.

Table 1. Development of the health factors based on Vietnam's food-based dietary guidelines for an adult for 2010-2020

Food group	Monthly recommendation (kg) A	Calculated daily recommendation (kg) B†	Health factor (*hf*) C
1. Cereals and products 2. Starchy roots and tubers	12.00	0.40	0.34
4. Combined leafy vegetables, fruit-types, wild vegetables, including fresh and dried	10.00	0.33	0.28
5. Fruits and berries‡	6.00	0.20	0.17
6. Oils and fats and butters	0.60	0.02	0.02
7. Meat, poultry game and its products	1.50	0.05	0.04
8. Fish, shellfish and products	2.50	0.08	0.07
3. Nuts and beans 9. Eggs and products 10. Milk and milk products	2.00	0.07	0.06
11. Canned products§			refer to Note
12. Sugars, preserves and confectionery	0.50	0.02	0.01
13. Soft drinks, beverages, alcoholic beverages	N/A	N/A	N/A
14. Spices and sauces	0.18	0.01	0.01
Total	**35.28**	**1.18**	**1.00**

Source: Monthly recommendation from NIN (2013).
Notes: †[B] = [A] / 30 days. "N/A" is not applicable since no recommendation for softdrink and alcoholic beverages.
‡For fruits and berries, no specified value in the dietary guidelines. The recommended amount was calculated based on the WHO minimum recommendation of 400g (WHO and FAO, 2004) of fruit and vegetables per day (50 percent fruit, 50% vegetable, 200g/1000g X 30days = 6kg/month).
§For canned products, the health value depends on its contents, e.g. canned mackerel, or canned pineapple, or canned corned beef, etc. See appendix for detailed itemisation of canned products and its associated health factors.

Table 2. Descriptive statistics of key variables for smallholder households in Lao Cai province, Vietnam, 2016

Variable	Description	Mean	SD	Min	Max
Dependent variables					
Child DDS	Dietary Diversity Scores of young children aged 6-59 months	4.547	1.189	2.000	8.500
Child HFDI	Healthy Food Diversity index of young children aged 6-59 months	0.440	0.135	0.000	0.693
Vegetable production					
Vegetable diversity	Number of vegetables produced at the farm in the last cropping cycle	2.920	1.829	0.000	13.000
Market access and market participation					
Time to market	Average travel time from residence to nearest market (hour)	0.417	0.329	0.017	1.650
Sell to modern markets	Farming household sold vegetables to modern markets (cooperatives, wholesale markets, supermarkets and other retailers in Hanoi) (dummy)	0.217	0.413	0.000	1.000
Sell to traditional market	Farming household sold vegetables to traditional outlets (other farmers, collectors, directly to consumers in nearby market, other buyers) (dummy)	0.392	0.489	0.000	1.000
Does not sell	Farming household only consumed vegetables that they produced in last production cycle (dummy)	0.439	0.497	0.000	1.000
Women empowerment					
Input in productive decisions	Woman has input in agricultural production decisions (dummy)	0.981	0.136	0.000	1.000
Access to and decisions on credit	Woman has access to and can make decisions on credit (dummy)	0.491	0.501	0.000	1.000
Group membership	Woman is an active member of a group (dummy)	0.901	0.299	0.000	1.000
Workload	Woman's workload is less than the time poverty line of 10.5 hours (dummy)	0.660	0.475	0.000	1.000
Household characteristics					
Stratum	Stratification of the target locations based on vegetable per capita density and elevation (categorical)	2.646	1.111	1.000	4.000
Per capita food expenditure	Monthly per capita food expenditure in million VND	2.106	19.145	0.000	197.802
Non-food expenditure	Monthly non-food expenditure in million VND	4.150	8.590	0.274	83.282
Farm area	Total cultivated area in hectares	1.103	2.105	0.000	19.600
Vegetable cultivation experience	Number of years the farming household is engaged in vegetable cultivation	14.585	13.033	0.000	53.000
Household size	Total number of household members	5.745	1.873	2.000	13.000

Variable	Description	Mean	SD	Min	Max
Child characteristics					
Age of child	Age of the young child in months	36.146	14.242	6.000	59.000
Gender of child	Young child is male (dummy)	0.528	0.500	0.000	1.000
Food preparer characteristics					
Age of food preparer	Age of the food preparer in years	34.934	12.492	19.000	69.000
Women as food preparer	The food preparer is a woman in the farming household (dummy)	0.651	0.478	0.000	1.000
Education of food preparer	Highest educational attainment of food preparer (categorical)	2.151	2.076	0.000	8.000
Ethnicity of food preparer	The food preparer belongs to the *Mông* ethnic minority group (dummy)	0.722	0.449	0.000	1.000
Observations		212			

Source: Survey conducted by GFAR (UofA) in Jul/Aug 2016. The total number of young children aged 6-59 months in the 202 households is 212.
Note: "SD" is standard deviation, "Min" is Minimum, and "Max" is Maximum. "VND" is Vietnamese Dong.

Table 3. Impact of vegetable production, market access and market participation on child's dietary diversity and diet quality

Dependent variable:	**CDDS**		**HFDI**	
Variables	**(1) OLS**	**(2) Poisson**	**(3) OLS**	**(4) Tobit**
Vegetable production				
Number of vegetables produced at the farm in the last cropping cycle	0.068	0.072*	0.002	0.003
	(0.045)	(0.042)	(0.005)	(0.005)
Market access and market participation				
Ave travel time from residence to nearest market (hour)	-0.003	-0.009	0.009	0.009
	(0.288)	(0.264)	(0.035)	(0.033)
Dummy, Farming household sold vegetables to modern markets[†] (1=yes 0=no)	0.870**	0.835**	0.009	0.009
	(0.400)	(0.333)	(0.038)	(0.037)
Dummy, Farming household sold vegetables to traditional outlets[‡] (1=yes 0=no)	0.764*	0.740**	0.051	0.051
	(0.416)	(0.356)	(0.040)	(0.038)
Dummy, Farming household only consumed vegetables that they produced in last production cycle (1=yes 0=no)	0.936**	0.923**	0.037	0.037
	(0.425)	(0.374)	(0.042)	(0.040)
Women adequacy/empowerment scores				
Dummy, Woman has input in productive decisions (1=adequate 0=otherwise)	-0.720	-0.678*	-0.016	-0.018
	(0.561)	(0.405)	(0.063)	(0.059)
Dummy, Woman has access to and can make decisions on credit (1=adequate 0=otherwise)	0.037	0.026	0.014	0.015
	(0.170)	(0.161)	(0.020)	(0.019)
Dummy, Woman is an active member of a group (1=adequate 0=otherwise)	0.250	0.267	-0.020	-0.022
	(0.247)	(0.250)	(0.031)	(0.030)
Dummy, Woman's workload is less than the time poverty line of 10.5 hours (1=adequate 0=otherwise)	0.403**	0.392**	-0.014	-0.013
	(0.188)	(0.181)	(0.021)	(0.020)
Household characteristics				
Village stratification: LV-HA[∀] (=2, reference is LV-LA=1)	0.110	0.103	0.065**	0.065**
	(0.288)	(0.272)	(0.030)	(0.028)
Village stratification: HV-LA (=3)	-0.121	-0.127	0.097***	0.098***
	(0.256)	(0.241)	(0.029)	(0.028)
Village stratification: HV-HA (=4)	0.209	0.161	0.083***	0.083***
	(0.269)	(0.250)	(0.026)	(0.025)
Monthly per capita food expenditure (million VND)	-0.001	-0.001	0.000	0.000
	(0.002)	(0.002)	(0.000)	(0.000)
Monthly non-food expenditure (million VND)	0.024***	0.019***	0.001**	0.001**
	(0.008)	(0.005)	(0.001)	(0.001)
Total cultivated area (ha)	-0.076	-0.071	0.008**	0.008**
	(0.053)	(0.051)	(0.003)	(0.003)
Number of years the farming household is engaged in vegetable cultivation	0.010	0.009	-0.001	-0.001
	(0.010)	(0.009)	(0.001)	(0.001)
Household size	-0.090*	-0.089**	0.013**	0.013**

Dependent variable:	CDDS		HFDI	
Variables	**(1) OLS**	**(2) Poisson**	**(3) OLS**	**(4) Tobit**
	(0.046)	(0.044)	(0.007)	(0.006)
Child characteristics				
Age of the young child in months	0.002	0.002	0.003***	0.003***
	(0.005)	(0.005)	(0.001)	(0.001)
Dummy, Young child is male (1=male 0=female)	0.227	0.211	0.025	0.026
	(0.155)	(0.145)	(0.020)	(0.019)
Food preparer characteristics				
Age food preparer in years	0.013	0.013	-0.000	-0.000
	(0.011)	(0.010)	(0.001)	(0.001)
Dummy, Food preparer is female (1=female 0=male)	0.211	0.209	0.028	0.028
	(0.196)	(0.181)	(0.024)	(0.023)
Education of food preparer (categorical)	0.091	0.084*	0.002	0.002
	(0.058)	(0.049)	(0.005)	(0.005)
Dummy, Ethnicity of food preparer (1=Mong 0=other ethnic groups)	-0.683***	-0.666***	-0.003	-0.003
	(0.220)	(0.209)	(0.023)	(0.022)
Constant	3.441***	1.266***	0.159	0.156
	(0.788)	(0.144)	(0.104)	(0.098)
Observations	212	212	212	212
R-squared	0.332		0.234	
Adjusted R-sq	0.251		0.141	
Pseudo R-sq				-0.254
Log likelihood	-294.3	-377.5	151.9	138.7
F-statistic	15.32		3.997	4.352
Degrees of freedom	23	23	23	23
Chi-sq		326.3		
Number of iterations		2		
Pearson goodness-of-fit		42.41867		
p-value		1.0000		

Notes: Robust standard errors, clustered at the household level, are indicated in parentheses. Model 2 for Poisson estimator shows the marginal effects (for factor levels, it is the discrete change from the base level). Model 4 has 4 left-censored observations at HFDI <= 0, 208 uncensored observations, and 0 right-censored observations, and with standard errors adjusted for 171 clusters (household). *** p<0.01, ** p<0.05, * p<0.1.

[†]Types of modern channels are cooperatives, wholesale markets, supermarkets and other retailers in Hanoi.

[‡]Types of traditional outlets are fellow farmers in the village/commune, collectors, selling directly to consumers in the nearby market, other types of buyers.

[∀]Villages were stratified according to low vegetable per capita density-low elevation (LV-LA, this is the reference category); low vegetable per capita density-high elevation (LV-HA); high vegetable per capita density-low evaluation (HV-LA); high vegetable per capita density-high elevation (HV-HA). Refer to the Methods section for details.