ZEF-Discussion Papers on Development Policy No. 312

Tigabu Getahun and Gebeyehu Fetene

The Nexus of Production Diversity, Market Participation and Dietary Diversity: Insights from Ethiopia

Bonn, December, 2021

Tigabu Getahun and Gebeyehu Fetene, The Nexus of Production Diversity, Market Participation and Dietary Diversity: Insights from Ethiopia, ZEF – Discussion Papers on Development Policy No. 312, Center for Development Research, Bonn, December 2021, pp. 41.

ISSN: 1436-9931

Published by:
Zentrum für Entwicklungsforschung (ZEF)
Center for Development Research
Genscherallee 3
D – 53113 Bonn
Germany
Phone: +49-228-73-1861
Fax: +49-228-73-1869
E-Mail: zef@uni-bonn.de
www.zef.de

The authors:
Tigabu Getahun, Center for Development Research (ZEF), University of Bonn, and
Policy Studies Institute (PSI), Addis Ababa, Ethiopia.
Contact: tigyget14@gmail.com
Gebeyehu Fetene, Associate researcher at Policy Studies Institute (PSI), Addis Ababa, Ethiopia.
Contact: gebeyehumd@gmail.com

Acknowledgements

We are grateful to Joachim von Braun, Heike Baumüller, Oliver K. Kirui, Till Ludwig and participants at the EDRI seminar series for their numerous comments, guidance and insightful suggestions.

This study is funded by the “Program of Accompanying Research for Agricultural Innovation” (PARI), which is funded by the German Federal Ministry of Economic Cooperation and Development (BMZ).

Abstract

This study examines the nexus among production diversity, market participation, and consumption diversity in smallholder households. It identifies the main factors that influence smallholder farm households' decision to diversify production and evaluates the effect of production diversity and market participation on consumption diversity. To this end, we use a three-wave panel data of 7110 households in rural Ethiopia. The estimation results from the Mundlak Fixed Effects instrumental method suggest that risk-averse households, households with larger cultivated land, households with larger family size and family labor, and households who participate in community meetings are more likely to diversify their production. The results further reveal that production diversity has a statistically significant and positive effect on the consumption diversity of household members, but not dietary diversity of children and women. We find that market integration is more relevant in improving nutrition than production diversity. These results suggest that policies that merely focus on encouraging smallholder farmers to diversify production would not be that effective unless they are coupled with interventions that aim to integrate smallholder farmers to the market.

Keywords: production diversity; consumption (diet) diversity; risk preference, market participation, endogeneity

JEL codes: D40, Q13, Q18, E21

1 Introduction

Almost 690 million of the world population was undernourished in 2019 (FAO et al., 2020). Lack of dietary diversity is the major cause of micronutrient malnutrition as most diets lack essential vitamins and minerals, especially in Africa and Asia (Adeyeye et al., 2021; Akombi et al., 2017; Drammeh et al., 2019; Horton and Ross, 2003; Kennedy and Moursi, 2015; Steyn et al., 2006, 2013). Under nutrition particularly has a significant and lasting effect on children and women. Studies show that under nutrition puts children at a greater risk of catching infectious diseases, increases the severity of infections, contributes to delayed recovery, stunts growth, reduces school and work performance, and attributes to nearly half of all the deaths in children under 5 years (Baird et al., 2016; Black et al., 2013; Fink et al., 2016, 2017). Moreover, studies show that the nutrition of pregnant and lactating women is crucial not only for the women themselves but also for their children's long-term health (King, 2000; Moore et al., 2004; Saaka, 2012). The economic return from investing in nutrition is found to be substantial (Alderman et al., 2016). It is not surprising, therefore, that improving the diet of children, pregnant and lactating women, adult women and all the other household members has attracted the attention of policymakers and researchers.

Micronutrient deficiency is higher in rural areas among smallholder farm households since they mainly rely on few starchy staple food sources and have limited market access (Berhane et al., 2016; Jones et al., 2014; Pinstrup-Andersen, 2007). Thus, in such areas where the market functions poorly, farmers produce mainly for self-consumption, implying that production diversity (hereafter PD) is essential for consumption/dietary diversity (hereafter DD) and that production and consumption decisions are non-separable (Barrett, 2008; Bellon et al., 2016; Chamberlin and Jayne, 2013; Key et al., 2000; Taylor and Adelman, 2003). On one hand, farmers decide to diversify their production to meet their diverse dietary needs, in that DD affects PD (Bellon et al., 2016; Hirvonen and Hoddinott, 2017). On the other hand, PD affects DD directly since farmers' main consumption in rural areas is their own production (Bellon et al., 2016; Di Falco and Chavas, 2009; Kumar et al., 2017; Malapit et al., 2015; Olney et al., 2009). Moreover, PD indirectly affects DD by affecting income negatively because of the forgone benefits from specialization (Sibhatu et al., 2015) or positively by smoothing income when there is a high variability of production (Ellis, 2000) and by increasing production (Di Falco et al., 2007, 2010).

Market access reduces the link between PD and DD as it reduces the need to produce for self-consumption, and gradually changes the farmers' production decision from fulfilling their own diverse dietary needs to maximizing profits (Bellon et al., 2016; Koppmair et al., 2017; Sibhatu et al., 2015). With better market access, farmers can specialize in the production of a few high-value agricultural products which give them a comparative advantage and help them earn high expected income. They could use this income to buy more varieties of food than producing a large variety of products for self-consumption since the market offers more varieties than any household can produce. Thus, increasing market access is theoretically believed to reduce PD and increase DD, and hence, the link between PD and DD disappears when farmers fully commercialize. Therefore, empirically investigating the causal link between PD and DD requires controlling for the degree of market integration and the reverse causality problem between PD and DD decisions.

Numerous studies investigated the association between PD and DD, and the findings about the impact of PD on DD are mixed, varying with country, location and context. In a meta-analysis of 45 studies Sibhatu and Qaim (2018) found consistent positive association between PD and DD in 20% of the studies, 60% of the studies found positive association only for certain subsample or indicators but not on others, and the rest of the papers found no association. Moreover, the marginal effect of PD on DD is positive, but small, in that the households have to produce 16 species to increase DD by one food group. Similarly, Chegere and Stage (2020) found positive but small effect of PD on household members' DD, but not on children DD in Tanzania; nor does market access impact children DD. Hirvonen and Hoddinott (2017) found that PD increases the DD score of children in rural Ethiopia for households having limited market access (for those residing outside a 3 km radius of the market centers), but not for others who had better market access. Islam et al. (2018) found no impact of PD and market access on DD of women, but found that both PD and market access have statistically significant effect on HDDS. On the other hand, Bellon et al. (2016) found that PD has a statistically significant effect on DD score of women (WDDS) in Benin even after controlling for market access. Dillon et al. (2015) found that HDDS increases with PD and with agricultural revenue, estimated separately. Ludwig (2018) found that both PD and market access have a statistically significant effect on DD of women in rural India as do (Zanello et al., 2019) found in Afghanistan. Ecker (2018) found in Ghana that PD directly and indirectly (via income) increases DD, and the impact increased overtime.

The results from the above studies show that there is no consistent association between PD and DD as well as between market access and DD. However, most of the previous studies do not control for the potential endogeneity problem associated with the non-separable decisions of production and consumption in rural areas where the insurance, finance, input, and output markets function poorly. Controlling for this endogeneity problem helps to introduce better strategies to curtail nutrition and food insecurities. For instance, if the main reason for farmers diversifying production is to meet their diverse dietary demand, then increasing accessibility of markets could induce farmers to produce products that they have a comparative advantage over instead of producing varieties for self-consumption disregarding the suitability of the agro-ecology for some crops. On the other hand, studies show that farmers are risk and ambiguity averse (Akay et al., 2012) in that they choose to diversify their production to reduce risk (Bezabih and Sarr, 2012) even though specialization in few crops production could have a higher return. Then, policies that aim at increasing the income of the households may focus on insurance accessible to reduce the risk. If PD and market access do not increase DD, then, governments may need to complement PD with extension service about nutrition.

Only a couple of studies accounted for the endogeneity problem by using various instrumental variables. Hirvonen and Hoddinott (2017) instrumented PD with temperature, terrain and altitude; Bellon et al. (2016) used land size as IV for PD and the index of the social-economic status of households as IV for market integration; Dillon et al. (2015) used the agricultural stock, deviations from means of rainfall and degree days, and interaction term between rainfall and degree days as IVs for PD; Ludwig (2018) used rainfall as IV; and Zanello et al. (2019) used the community-average PD as PD for households.

Moreover, with few exceptions (Chegere and Stage, 2020; Ecker, 2018; Islam et al., 2018), nearly all of the studies used cross-sectional data and, without controlling for unobserved heterogeneities that could be correlated both with the dependent and independent variables, resulting potentially misleading policy-recommendation (Jones, 2017a). To the best of our knowledge, there is no study that controlled for both time-invariant and time-varying unobserved factors. Most of the previous studies also used proxy variables for measuring market integration of households, usually distance to the market centers (Hirvonen and Hoddinott, 2017; Koppmair et al., 2017), the transport costs to the main markets (Hirvonen et al., 2017) or revenue (Islam et al., 2018). However, while these variables are key determinants of market participation, they do not show the actual participation and the degree of market integration of farmers.

This study contributes to the thin literature by addressing the aforementioned shortcomings of the existing literature. To this end, we use a unique, three-wave panel data, collected from 7110 households in rural Ethiopia. Covering the most important agricultural zones in Ethiopia, our dataset has rich information and covers a large geographical and ecological area that is well-suited for this study. Its diverse agro-ecological conditions allow for producing almost every type of crop and rearing different types of livestock. The panel data has detailed information about the production, consumption, and marketing activities of the households and is suitable for analyzing the research problem.

The study first investigates why farmers choose to diversify their production. We are specifically interested in the effect of the risk preference of farmers, their diverse dietary needs, and the market access[1] impacts on PD. We measured PD in three ways: the count of the number of crops produced, the number of food groups produced (DD measures), and the count of all agricultural products produced. We follow the literature (e.g., Bezabih and Sarr, 2012; Binswanger, 1981; Yesuf and Bluffstone, 2009) in measuring risk preference. It was measured by a hypothetical risk preference experiment where farmers were asked to choose between a certain price for their products (250 ETB for a sack of maize) and an uncertain price (ranges between 0 and 800 ETB). We employ the Mundlak Fixed Effects approach to control for unobserved time-invariant household effects and IV to control for the time-varying unobserved factors.

Second, the study investigates the effects of PD, market integration, and market access on the DD of households and on individual household members including children of age between 6 and 24 months, lactating women, pregnant women, and other adult women. We use both the 7-day and 24-hour consumption recall data to measure HDDS and CDDS while only the 24-hour consumption

[1] Measured by the walking distance to the closest market center where the households buy and sell products.

recall data were used to measure WDDS due to data paucity. We use Mundlak Fixed Effects approach, IVs as well as GMM Poisson model to estimate the effect.

Thus, this paper has at least the following contributions. First, the panel nature of this dataset enables us to control for time-invariant unobserved heterogeneities. Second, we use instrumental variable approach to control for the time-varying unobserved factors. Third, the dataset was collected when both the crop stock at farmers' homes is usually high (Feb & March) and when the crop stock is usually the lowest (July & August). Indeed, the period from February to March is when the least share of food-insecure households was observed in Ethiopia while the period from July to September is when the largest share of food-insecure households was observed (Fetene and Getahun, 2018). We control for such seasonal effects. Moreover, we use both the 7-day and the 24-hour consumption recall data in estimating HDDS as the recall periods affect DD (Jones, 2017b); most of the previous studies used only one of them where the comparison across findings is not straight forward.

2 Data and Descriptive Statistics

2.1 Data and Sampling Method

Our analysis is based on a large three-wave panel dataset that was collected in July/August 2011, July/August 2013 and March 2017 from smallholder farmers located in the four major regions of Ethiopia by the Central Statistical Agency (CSA), the Ethiopian Development Research Institute (EDRI) and the International Food Policy Research Institute (IFPRI). Covering the most important agricultural zones in Ethiopia, the dataset has rich information and covers a large geographical and ecological area that is well-suited for this study. It consists of detailed information on production, consumption, market access as well as the socio-economic and demographic characteristics of the households. It includes the types of agricultural products and the harvesting methods, the number of livestock owned, the size of land cultivated and the type and quality of the plots, the existence of and access to the markets, the revenue from the sale of agricultural products, the access to credit and labor markets as well as information about whether the households have had price information and media access, and the types of food the households have consumed.

The two main ways to measure DD are the food variety score and the DD score (Sibhatu et al., 2015). For this study, the DD score which measures the number of food groups consumed over 7 days before the survey period is used to compare the change in DD over the survey rounds. In 2017, we also included one additional measure of DD, which measures the number of food groups consumed over 24 hours before the start of the survey.

In line with the standard WHO (2010a) measures of DD, we measure DD scores of households, children, and women based on ten, eight, and seven food groups respectively. Households' DD refers to the number of food groups consumed by the households over a specific period. It can also serve as a proxy for food security; the more diverse food households consume, the more food secure they tend to be (Hoddinot & Johannes, 2002). Indeed, there has been debate about whether HDDS indicates nutrition status of individuals household member (Chegere and Stage, 2020; Koppmair and Qaim, 2017; Verger et al., 2017a, 2017b). We use ten food groups to measure household dietary diversity score (HDDS)[2] which are: (1) cereals, (2) roots and tubers, (3) pulses, legumes and nuts, (4) vegetables, (5) fruits, (6) meat, poultry and offal, (7) eggs (8) dairy products (9) sweets and sugar, and (10) condiments. To measure dietary diversity score of women (WDDS)[3], we use eight food groups namely, (1) starchy staples, (2) pulses, legumes and nuts, (3) dairy products, (4) eggs, (5) meat and other miscellaneous small animal protein, (6) vitamin A-rich dark green leafy vegetables, (7) other vitamin A-rich vegetables and fruits, and (8) other fruits and vegetables. The

[2] The FAO measure includes seafood and fats but we do not have such data.

[3] The FAO measure includes also organ meat as the ninth food group. However, our data set does not include information on organ meat.

seven food groups that we use to measure children dietary diversity score (CDDS)[4] are the following: (1) grains, roots and tubers, (2) vitamin A-rich fruits and vegetables, (3) other fruits and vegetables, (4) meat, poultry, fish and seafood, (5) eggs, (6) pulses, legumes and nuts, and (7) milk and milk products. In the calculation of CDDS, we consider only children aged between 6 and 24 months.

Likewise, there are different ways of measuring PD. Some scholars use the number of crops and livestock species that households produce on a farm as measure of production (e.g., Bellon et al., 2016; Sibhatu et al., 2015) while others use the number of consumption food groups that the farm household produce (e.g., Hirvonen and Hoddinott, 2017; Ludwig, 2018). We use both measures in this study to check robustness of our findings.

The sample households were selected using a multistage sampling technique. At the first stage, the four major regions were selected. In the second stage, 93 Woredas (the third largest administrative unit next to Zone and Region in Ethiopia) were selected from the four main crop-producing regions, namely, Amhara, Oromia, Tigray and Southern Nations, Nationalities and Peoples (SNNP). At the third stage, three enumeration areas (villages) were randomly selected from each of the selected Woredas of Amhara, SNNP and Oromia regions and five enumeration areas from each of the selected Woredas of Tigray. At the fourth stage, 26 households were randomly selected from each enumeration area. Out of the selected households, about 7110 households were interviewed in all the three survey waves. The cumulative attrition rate over the three-wave periods was less than 10 percent. This study, therefore, makes use of the data collected from these 7110 smallholder farmers in the three survey waves.

2.2 Descriptive Statistics

In this section, we present a brief report of the sample distribution and descriptive statistics on sample households related to production and consumption diversity. Table 1 presents the sample size of pregnant women, lactating women, other adult women aged between 15 and 49 years, and children less than 24 months old. Out of the panel of 7110 households, 206 are pregnant women, 1577 are lactating women and 1743 are adult women excluding pregnant and lactating women in 2017. With regard to children, 1,565 households have had children aged less than 24 months in 2011, 1,433in 2013, and 1,461 in 2017. Note that the same child cannot be observed in any of the two surveys since the minimum time gap between two consecutive survey rounds is 25 months while we are considering in this study children of not older than 24 months.

The table shows that, overall, 62 percent of the children aged between 6 and 24 months were breastfed where this figure was the highest in 2017. Around 28 percent of these children were exclusively breastfed even though supplementary food is required for children of this age group. On the other hand, 96 percent of the children aged less than 6 months were breastfed, of which only 56

[4] Children under six months of age are not recommended to take supplementary food and hence not eligible to be included in the CDDS calculation.

percent were exclusively breastfed even though it is recommended for children of this age group to be exclusively breastfed (WHO, 2010). As expected, infant formula feeding practice was less common in smallholder farm households as infant formula access and awareness is expected to be quite limited in addition to its high cost.

Table 1: Breastfeeding practice

Variables	Survey year			
	2011	2013	2017	Total
Breastfed children aged 6 – 24 months	66	51	70	62
Exclusive breastfed children aged 6 – 24 months	24	34	26	28
Infant formula fed children aged 6 – 24 months	4	4	5	4
Breastfed children below 6 months old	96	85	95	96
Exclusive breastfed children below 6 months old	62	35	63	56
Infant formula fed children below 6 months old	3	5	4	4
Sample size	1,565	1,433	1,461	4,459

Table 2 presents the three survey years average percentage of sample households who consumed each of the specified food groups over 7 days before the data collection dates. It also presents the percentage of households who consumed each of the specified food groups within 24 hours before the 2017 interview period. Hence, the 7-days and 24-hours dietary diversity scores are not comparable since the latest measure presents only for the 2017 survey – we lack data from the first two rounds. It also presents the corresponding percentage of households who consumed the corresponding number of food groups. At the bottom of the table, information on average DD score of households, children and three groups of women together with the percentage of households who consumed at least four food groups, which is the minimum DD score to run a healthy life is presented.

As expected, cereals (starchy staple foods) were the most commonly consumed food groups, followed by vegetables and pulses by the households. On an average, 95 percent of the households consumed starchy staple foods within 7-days preceding the data collection data while the percentage of households who consumed vegetables and pulses are 84 percent and 66 percent respectively. Fruits and meat are the least consumed food groups; they were consumed by 12 percent, 19 percent of the households over 7 days before the interview dates respectively. Egg products are consumed by 33 percent of the households. The 24-hour recall data suggests a slightly different consumption pattern. About 95 percent of all households consumed starchy staple foods while the proportions for other vegetables and pulses are 22 percent and 62 percent respectively. Meat is the least consumed food group followed by eggs; they were consumed by 3 percent and 5 percent of all households respectively. Milk products are consumed by 14 percent of the households and fruits by 9 percent in 24 hours before the 2017 survey interview date. On an average, households consumed 5 food groups over 7 days before the three surveys round dates. About 79 percent of the household consumed the minimum DD that is required to run a health life.

Some consumption pattern variations are observed among children, pregnant, lactating, and other adult women members of the household. Only half of the children aged between 6 and 24 months and quarter of them, consumed starchy staple foods and pulses respectively while less than a tenth of them consumed meat and other fruits and vegetables over 7 days before the three survey dates. During this time, the average DD score for children was 2.14 out of the seven food groups; only about 10 percent of the children consumed the required DD of four food types. The consumption pattern, the mean DD of children, and the percentage of children who consumed the four minimum food groups for the 24-hour recall data are more or less similar to the 7-day recall data. Slightly less than half of the children consumed grains, roots, and tubers. The next two most commonly consumed food types are vitamin A-rich fruits and vegetables (26 percent) and pulses and nuts 19 percent. Meat and other fruits and vegetables are the least consumed food types and are consumed only by 1 and 6 percent of the children respectively. This has to be a big concern since most of the children are not consuming key sources of protein and vitamins. The results show that most children don't eat many food varieties. The proportion of children who got the required minimum DD over 24 hours before the 2017 survey date was also low. The average DD score for the children is 2 out of the seven food types; only about 7 percent of the children consumed the required DD of four food types.

The analysis of the 24-hour recall data suggests that the most consumed food type by pregnant women is starchy staple foods (65 percent) followed by pulses and nuts (64 percent). The meat is the least consumed food group followed by eggs, which is consumed by 2 and 3 percent respectively of the pregnant women. On an average, pregnant women consumed 2.4 types of food groups, and only 14 percent of them consumed at least four food types over the 24 hours before the 2017 survey date. The starchy staple foods were consumed by 69 percent of the lactating woman followed by pulses and nuts, which was consumed by 58 percent of them. The least consumed food by lactating women is meat (3%) followed by eggs (6%), most of the lactating women (and their children) missing key sources of protein. The average number of food types which lactating women consumed is also 2.4, less than almost by half that a lactating women required to consume at minimum of four for healthy life. Only about 15 percent of the lactating woman from all the households consumed the required diet of four or more food types. Similarly, for other non-lactating and non-pregnant adult women members of the household, starchy staple foods and pulses and nuts are the two most commonly consumed food types. Meat and eggs are the least consumed food types, which are consumed by 3 percent of the other women. The average DD score for other women is 2.3; only about 13 percent of all the other women consumed four or more food types.

Table 2: Consumption Diet based the 7-day and 24-hour recall data

Food groups	Children		Lactating women,	Pregnant women,	Other adult women,	Households	
	7-day recall	24-hour recall	24-hour recall	24-hour recall	24-hour recall	7-day recall	24-hour recall
Pulses, legumes, and nuts	26.46	18.65	58.28	64.08	65.98	65.78	62.44
Meat	7.06	1.15	2.54	1.94	3.21	18.47	3.11
Eggs	14.54	9.35	5.64	3.4	2.93	32.58	5.02
Dairy products	21.00	10.39	56.06	57.77	56.57	26.70	14.26
Cereals, roots and tubers	50.97	46.33	68.99	65.05	61.22		
Other fruits and Vegetables	7.74	5.74	7.29	9.71	7.46		
Vitamin A-rich dark Green leafy vegetables			22.19	22.82	21.63		
Other vitamin A-rich Vegetables and fruits			16.93	16.02	14.11		
Vitamin A-rich fruits and vegetables	18.52	25.60					
Cereals						98.85	95.20
Vegetables						83.78	21.9
Fruits						11.96	8.77
Roots and tubers						47.68	72.68
Sugary foods and drinks						31.27	37.04
Condiments						62.59	86.38
No. of food groups consumed							
No food consumption,	33.16	26.87					

only breastfeeding							
One	25.68	30.29	25.3	21.84	24.21	1.62	2.06
Two	20.21	23.41	33.61	33.98	36.26	5.21	10.06
Three	11.42	12.34	25.87	30.1	26.28	14.17	21.36
Four	6.19	4.84	10.91	11.17	10.1	22.11	28.14
Five	2.34	1.48	2.28	1.94	2.07	25.33	24.7
Six	0.79	0.61	1.59	0.49	0.86	18.65	9.68
Seven	0.21	0.15	0.32	0.49	0.17	8.82	2.66
Eight			0.13	0.00	0.06	2.98	0.78
Nine			25.3	21.84	24.21	0.91	0.38
Ten			33.61	33.98	36.26	0.2	0.17
Mean DD	2.14	1.99	2.38	2.41	2.33	4.77	4.10
Consumed at least four food groups	9.54	7.09	15.22	14.08	13.25	79.00	66.52
N	3515	1828	1577	206	1743	21279	7036

Note 1: The shaded cells denote that the food group is not applicable for the specified household group.

The PD structure of households is presented in Table 3. The upper half of Table 3 presents the percentage of sample households who produced each of the specified food groups over the three survey periods while the lower half of the table presents the percentage of households who produced the given number of food groups over the survey period. As shown in the table most of the households produced cereals and reared livestock.[5] Pulses, legumes, and nuts were the third most-produced food group in that around 44 percent, 37 percent, and 33 percent of the households produced them in 2011, 2013, and 2017 respectively. Around 26 percent of households produced dairy over all the survey years where the figure was the highest in 2017 (37 percent) and the lowest in 2011 (15 percent). Similarly, only around 10 percent of the households produced fruits and vegetables over the survey years. This is a bit similar to the consumption pattern of households.

The analysis of our data indicated that close to a third of the households produced three types of food groups while the percentage of households who produced all the ten food groups is negligible.

[5] Livestock rearing serves as a proxy for producing meat after excluding households that have only one livestock worth greater than 3000 Ethiopian currency since it is unlikely that a farmer slaughters their single most livestock and rather use it for ploughing. This may, in any case, bias upward our estimate of the percentage of households who slaughtered animals.

Around 40 percent of the households produced four or more food groups, where the figure was the highest (47 percent) in 2017 and the lowest (32 percent) in 2013. About 1.6 percent were not producing any type of crop or livestock products during the three survey periods. The disaggregation of the analysis by crop and livestock production indicates that the households produced, on average, 5.6 crop varieties (including fruits and vegetables) in 2011 where the figure declined to 4.5 varieties in 2017. Livestock ownership (including chicken) and production of livestock products were very high in that, on average, households had around 21 counts (ranges from 0 to 58) in all the three survey years. But the consumption of livestock and livestock products was very low entailing that PD is not a sufficient condition for consumption diversity.

Table 3: Percentage of households which produced food groups, over the survey years

Production of food groups	2011	2013	2017	Total
Cereals	92.14	91.83	90.90	91.62
Livestock	92.03	88.16	87.83	89.34
Pulses, legumes, and nuts	43.49	37.07	33.11	37.89
Eggs	27.26	19.69	34.91	27.29
Roots and tubers	21.28	8.79	15.81	15.29
condiments	17.64	12.52	15.96	15.37
Dairy products	14.61	27.17	36.84	26.21
Vegetables	13.40	7.02	10.87	10.43
Fruits	10.10	7.69	11.38	9.72
Sugar and sweets	2.73	2.26	2.52	2.50
No. of food groups produced				
Zero	0.25	2.07	2.49	1.60
One	4.54	8.12	6.65	6.44
Two	20.59	25.46	17.83	21.29
Three	32.42	32.31	26.27	30.33
Four	23.28	19.30	24.89	22.49
Five	12.32	8.76	14.32	11.80
Six	4.88	2.93	5.47	4.43

Seven	1.24	0.86	1.58	1.22
Eight	0.39	0.20	0.48	0.36
Nine	0.06	0.01	0.00	0.02
Ten	0.03	0.00	0.01	0.01
Counts of agricultural products diversification				
Mean No. of crops produced including fruits and vegetables	5.55	3.95	4.50	4.66
Mean No. of livestock & livestock products	20.76	20.81	20.99	20.85
Mean No. of total agricultural products produced including crops, fruits, vegetables, livestock and livestock products	26.31	24.75	25.49	25.51
N	7110	7110	7110	21330

Descriptive statistics for the key variables used in the analysis of the study are shown in Table 4. The table specifically presents the summary of the socio-economic and demographic characteristics of the sample households, the average number of agricultural products they produced and consumed, and the status of market participation together with the mean value of production and consumption diversity and their determinants. As shown in the table, our sample households on average produce 3 types of food groups, 25 agricultural products, and 5 crop species/varieties. The average household size is 8.7. About 63 percent, 77 percent and 67 percent of the household heads are illiterate, married, and risk-averse respectively. About 36 percent, 78 percent, and 23 percent the households are exposed to natural shocks, got enough rain at the beginning of the harvest season, and have media access respectively. On average, the sample households own a cultivated land worth of ETB 52191, hold a land size of 1.7 hectares, and sold 13 percent of their agricultural products in the market.

Table 4: Summary Statistics of Key Variables

Variables	Description	Mean/ Ratio	Standard deviation
Dependent variables			
PD (HDDS based)	Number of household dietary diversity food groups produced (Max 10)	3.27	1.39
PD crop varieties	Number of crops, fruit, vegetable varieties produced by the household (max 26)	4.66	2.90
PD all	No. of agricultural products produced	25.51	11.24

CD	Number of crops, fruits, vegetables and animal product counts consumed by household members in 7 days preceding the survey	6.71	2.34
CDDS	Children dietary diversity score (max 7)	1.43	1.37
DDS of lactating women	Lactating women dietary diversity score (max 8)	2.38	1.79
DDS of pregnant women	Pregnant women dietary diversity score (max 8)	2.41	1.10
DDS of other adult women	Other adult women dietary diversity score (max 8)	2.33	1.10
HDDS	Household dietary diversity score (max 10)	4.77	1.57
Household characteristics			
Child male	Ratio of male children of aged below 24 months	0.50	0.50
Child age	Mean age of children, in months	13.07	7.63
Mother education	Years of schooling of the mother	0.89	2.00
Mother age	Age of the mother, in years	39.12	14.25
Sister education	The highest years of schooling of a daughter in the family	3.27	3.19
Family size	Number of family members	8.70	9.39
Mature head	Ratio of households headed by mature (aged above 34 years) persons	0.72	0.45
Head illiterate	Ratio of households headed by illiterate persons	0.63	0.48
Head married	Ratio of married household heads	0.77	0.42
Risk averse	Dummy indicating whether the head of the household is a risk averse individual	0.67	0.47
Market access and integration			
Market distance	Distance in minutes to the nearest market center	82.07	78.99
Household commercialization index	Ratio of sales to value of total agricultural production in 12 months preceding the survey	0.13	0.18
Hired in labor	Number of hired labor days used in production	56	23
Production and the production environment			
Total harvest	Value of total harvest during the last 12 months, ETB	52191	1053683

Cultivation area	Cultivated area in hectare	1.72	1.50
Enough rain at the beginning	Ratio of households who reported that there was enough rain at the beginning of the harvest season	0.78	0.42
Family labor	Number of family labor days used in production	77	129
Natural shock	Ratio of households experienced natural shock during the last 12 months	0.36	0.48
Media access	Have had media access	0.23	0.42

3 Model Specification and Estimation Strategy

In this section, we model the decision of a smallholder farm household to diversify its production and consumption using a limited dependent variable framework. In the literature, it is widely suggested that market access, risk preference, households' preference to diversify consumption and the socio-economic and demographic characteristics of households as the main factors that influence the decision of farm-households to diversify production (Bezabih and Sarr, 2012; Dorsey, 1999; Yesuf and Bluffstone, 2009). Equation (1) describes the relationship between the level of PD (count diversity) and the various internal and external factors that affect the decision of farm household to diversify their production.

$$PD_{ht} = \alpha + \beta_1 CD_{ht} + \beta_2 M_{ht} + \beta_3 R_{ht} + X_{ht}\theta + c_h + u_{ht} \quad (1)$$

where PD_{ht} is the level of PD (group or count diversity) of household h at time t. It is measured in two ways (i) the number of food groups produced (group diversity), (ii) the number of crop species/varieties produced (count diversity) by household h in year t. CD is the consumption diversity (group or count diversity) of household h at time t, as measured in accordance with the measure of PD. That is, when PD denotes the number of food groups produced (group diversity), CD refers to the number of food groups the household consumed and when PD refers to the number of agricultural products the farm-household produced (count diversity), CD denotes the number of food species the household consumed. M is the market access indicator as measured by the number of minutes it takes to arrive at the nearest market center. R is the risk preference indicator of the farmer as measured by a hypothetical risk preference experiment where farmers were asked to choose between a certain price for their products (250 ETB for a sack of maize) and an uncertain price (ranges between 0 and 800 ETB). We employed risk-averse empirical definition used in the literature previously (Bezabih and Sarr, 2012; Binswanger, 1981; Yesuf and Bluffstone, 2009). Risk-averse farmers are expected to choose a certain outcome with low payoff than an uncertain outcome with higher payoff. X is a vector of other control variables such as cultivated land area, characteristics of households, input market access, and so on.[6] The term 'c' denotes time-invariant unobserved household-specific factors that affect PD. The parameters α, β1, β2, β3, and θ are population parameters to be estimated. The last term, u, is an error term assumed to be white noise.

Due to reverse causality from PD to CD, estimating equation (1) by standard regression or panel data method will suffer from endogeneity bias. For instance, farmers may decide the number of

[6] We follow previous related literature and consider the context of Ethiopian smallholder characteristics into account to choose control variables that would be included in X control variables (Benin et al, 2004; Bezabih and Sarr, 2012; Di Falco & Perrings, 2003). For instance, the larger the cultivated land area, the more likely that the soil quality and topology of the plots become heterogeneous, in that farmers have to harvest a variety of crops to optimize production (Bellon et al., 2016). Household characteristics could also affect PD. For instance, larger family sizes are expected to increase PD through preference heterogeneity and labor hour capacity (Benin et al, 2004). Other covariates include the absolute and relative income of the household, weather conditions, access to price information, and the household's active participation in trainings and meetings.

crops to produce based on their food-diversification preferences, and, similarly, availability of diverse produces may induce to consume diverse foods. To deal with such an endogeneity bias problem, we use the 2017 CD as an instrument to the CD in 2011 and CD in 2013 (for both the group and count diversity). The 2017 CD is a relevant instrumental variable for 2011 and 2013 CD because of the persistency of consumption habit (the z-values of the 2017 CD from the first stage regressions are 15.85 and 18.38 for group (HDDS) and count crop varieties consumed respectively). It is also less likely that the 2017 CD violates the exclusion restriction of instrumental variables since it is less likely that the farmers took the CD in 2017 into account while choosing the PD in 2011 and 2013. Using future (lead) values as an instrumental variable is common in production economics (Hayashi and Inoue, 1990; Wooldridge, 2009). Indeed, the PD in 2011 and 2013 may have effect on the income of households, which in turn may have a trend effect on the 2017 CD. To control for this potential problem, we include income as a covariate. In addition to this, we also used the peasant association level mean value of consumption diversity as instrument to household level consumption diversity, a method which has been used also by previous studies (Zanello et al., 2019)

Similarly, there could be reverse-causality problem between risk-preference and production diversity. On the one hand, the more risk-averse a household is, the more likely that the household diversifies production. On the other hand, the more production is diversified in rainfall shortage countries, the higher is income (Di Falco et al., 2007, 2010), which, in turn, may reduce risk-aversion behavior as evidence in Ethiopia show that poverty and risk-aversion behavior are highly correlated (Yesuf and Bluffstone, 2009). We assume that PD affects risk-behavior through income only, in that controlling for income controls for the impact of PD on risk behavior. Figure 1 below presents cumulative distribution of production and consumption diversity, disaggregated by risk-aversion behavior. The graph shows that risk averse farmers produced slightly more diversified food groups than others. Similarly, there seems positive correlation (unconditional) between risk—aversion behavior and consumption diversity of household members and children.

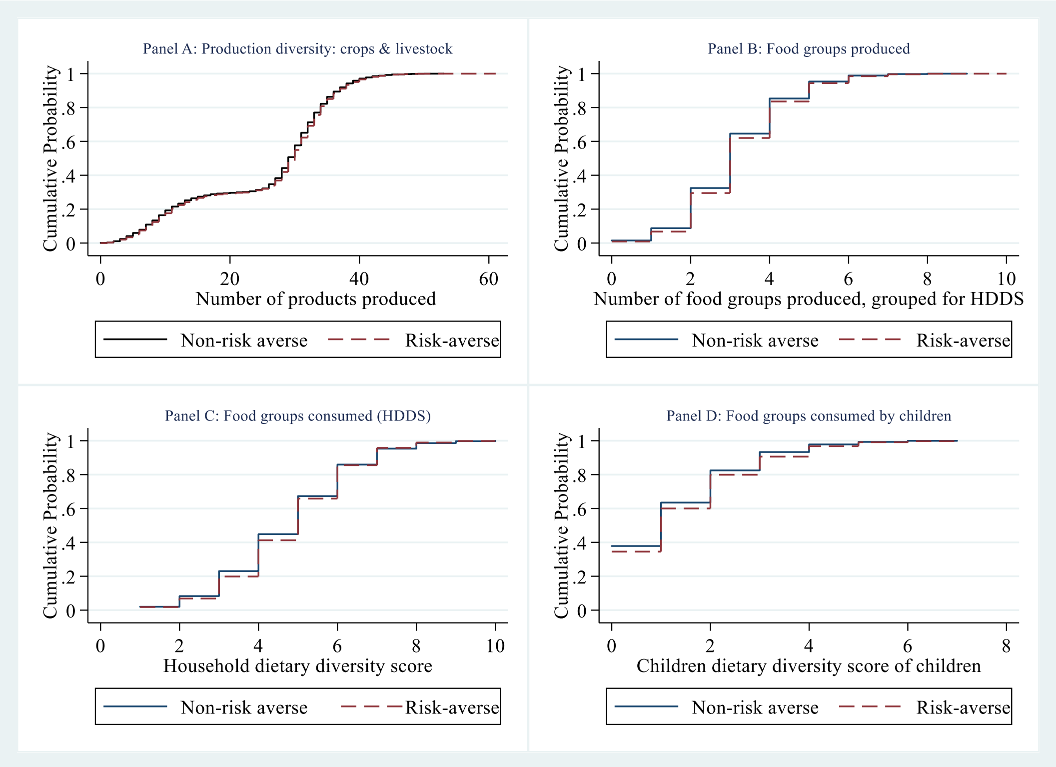

Figure 1. Cumulative distribution of production and consumption diversity, disaggregated by risk behavior

The second concern is that the household-specific unobserved factors, c, are more likely to correlate with covariates such as consumption diversity in that we cannot separate the effects of c from the effects of covariates correlated with c. Suggested solutions for this problem include using Fixed Effects model in which we remove c by time-demeaning each variable in equation (1). However, demeaning each variable causes two problems in our analysis. First, the demeaning removes all the time-invariant key variables of interest that affect PD such as distance to the nearest market, gender of the head of the household, education level of the head of the household, land area, and which all did not significantly change over time. Second, the within-household overtime variation of PD is small in our data in that the variance of the demeaned PD is small and, thus, poorly explained by the included covariates. To tackle this problem, we use the Mundlak (1978) and Chamberlain (1982) approach of augmenting equation (1) by the overtime mean of the time-varying covariates as follows:

$$PD_{ht} = \alpha + \beta_1 CD_{IV} + \beta_2 M_{ht} + \beta_3 R_{ht} + X_{ht}\theta + \bar{z}_h \lambda + u_{ht} \quad (2)$$

where $\bar{z}_h$ is the overtime mean of the time-varying covariates including off-farm household income, hired labor, and family labor used in the production, CD_{IV} is the proxy variable for CD and the rest of the terms are as defined before. The specification in equation (2) in which we control for the sources of unobserved heterogeneity by adding the means of time-varying observed covariates is commonly known as the Pseudo-Fixed Effects or the Mundlak-Chamberlain's Random Effects Model.

Since the dependent variable, PD (group or count diversity), is a count variable, the use of Poisson regression instead of the linear regression approach is preferable. Because a linear regression estimate may not provide the best fit over the values of the PD determinants since it is a count variable (Wooldridge 2009). Hence, we also estimated the Mundlak-Chamberlin Random Effects IV Poisson model:

$$PD_{ht} = \exp(\beta_1 CD_{IV} + \beta_2 M_{ht} + \beta_3 R_{ht} + X_{ht}\theta + \bar{z}_h \lambda + u_{ht}) \quad (3)$$

We also use the Mundlak-Chamberlin Random Effects IV Poisson model to evaluate the effect of PD and market participation on dietary (consumption) diversity of households and children based on the 7-day recall data:

$$DD_{ht} = exp(\beta_1 PD_{ht} + \beta_2 MI_{ht} + \beta_3 M_{ht} + X_{ht}\gamma + \theta S + \bar{y}_h \lambda + \varepsilon_{ht}) \quad (4)$$

where DD_{ht} is the DD score (group diversity) of a household h at time t and PD_{ht} is the corresponding PD (group diversity) of household h at time t. MI denotes the market participation as measured by the household commercialization index which is the ratio of total sales to total value of production of the household. M refers to the market access which is measured in terms of distance to the nearest market center. X is a vector of exogenous variables affecting DD such as household size, education level of the mother and the daughter, sex and marital status of the household head, relative and absolute income levels of the household, off-farm income, media and price information access, participation in trainings and meetings and desertedness of the living area of the household, age, sex and whether the child was breastfed in estimating the CDDS (e.g., Bellon et al., 2016; Hirvonena & Hoddinott, 2017; Islam et al., 2018; Sibhatu et al., 2015). $\bar{y}$ is the overtime mean of time-varying covariates used to control for time-invariant unobserved effects following Mundlak (1978). *S* is a seasonal shift dummy variable used to control for the differences in data collection season-while the 2017 DD data were collected at a time when households have relatively high stock of crops (in March when most farmers in Ethiopia just finish trashing and collecting crops), the 2011 and 2013 data were collected in August when the stock of crops is low and when proportionally larger number of households experienced food shortage problem (Fetene and Tigabu, 2018). The last term is an error term assumed to have zero mean and constant variance and the parameters β1, β2, β3, θ, and the vectors γ and λ are population parameters to be estimated.

To minimize recall bias, we also construct DD scores of households, children, lactating, and other adult women using the 24-hour consumption data. Unfortunately, we neither collected the 24-hour consumption data in the 2011 and 2013 survey rounds nor the 7-day recall data for the eight food groups that would help us calculate the women DD score. Thus, to estimate the effect of DD on lactating and other women DD, we use the cross-sectional data of the 2017 consumption. We also use the 2017 cross-sectional 24-hour consumption data to check the robustness of our estimation result regarding the effect of PD on households and CDDS. Accordingly, we estimate the following cross-sectional Poisson model based on the 24-hour consumption recalls of women, households, and children.

$$DD_h = exp(\beta_1 PD_{IV_h} + \beta_2 MI_h + \beta_3 M_h + X_h\gamma + \theta S + \varepsilon_h) \quad (5)$$

where PD_{IV} is the instrumental variable for PD, and the rest of the variables are the same as defined before. PD is an endogenous explanatory variable as CD affects PD and hence, we need to use an instrumental variable that could create an exogenous link between PD and CD. Previous studies used a number of instruments for PD. For instance, Bellon et al. (2016) used size of landholding and index of socio-economics status, Hirvonena and Hoddinott (2017) used temperate, altitude, the interaction term between the two, and slope of the plots, Dillon et al. (2014) used variation in rainfall and agricultural capital stocks while Ludwig (2018) used average yearly rainfall as instruments for PD. We checked for the relevance of attitude, soil quality, and slope of the plots as instruments for PD in our data and we found that they are weak instruments. On the other hand, we found that cultivated land area and rainfall are relevant instruments. Indeed, cultivated land area affects DD both directly by increasing income of the household, which can be used to buy various food groups, and indirectly by allowing the farmer to produce diverse products since the heterogeneity of the soil quality and other characteristics of the plots may increase with cultivated land area (Bellon et al., 2016; Hirvonen & Hoddinott, 2017). Thus, cultivated land area may violate the exclusion restriction of an instrument. To remedy this, we control for the agricultural income of household so that its effect on DD through income is controlled for (Bellon et al., 2016). The second instrument, sufficiency of the rain at the beginning of the harvest season could affect the type of crops the farmers choose to harvest (Dillon et al., 2014). For instance, a high amount of rain at the beginning of the season may induce the farmers to choose high-water demanding crops and vice-versa, while the average level of rain could be suitable for producing varieties of crops, implying that it affects PD. Indeed, sufficiency of the rain may also affect DD via income, violating the exclusion restriction of an instrument. To address this concern, we control for the income of the household and whether the household experienced natural shocks such as drought, flooding, and hurricane. Moreover, we also (separately) used the peasant association level mean production diversity as IV to the household level PD (Zanello et al., 2019). A potential concern is that the community level PD may affects DD of households by increasing the food varieties available in the market for the household. To curtail this problem, in addition to distance to the markets and ratio of sales of own production, we include a dummy variable indicating whether the households depend mainly on purchased foods for consumption.

4 Estimation Results and Discussion

In this section, we present the estimation results of the determinants of PD and its effect on consumption/dietary diversity of the households, lactating and non-lactating women and their children.

4.1 Determinants of Production Diversity

As indicated before we use Mundlak Fixed Effects IV model (both linear and Poisson regression) to identify the main determinants of PD, where PD is measured in terms of food groups and as count diversity scores. Table 5 presents four regression results from Mundlak Fixed Effects linear model estimates (Mundlak Fixed Effects Poisson regression estimates are presented in the appendix). The second and third columns present regression results when forward value of consumption diversity is used as instrument for lagged years HDDS while the last two columns present regression results when the mean PD of peasant associations is used as IV for consumption diversity. The covariates are jointly statistically significant in all models. This entails that the model fits the data reasonably well. The joint significance of the mean of time-varying explanatory variables is also significantly different from zero, suggesting that there is a correlation between observed and unobserved heterogeneities, which justifies the use of the Mundlak (1978) approach.

The estimation results from the two instruments imply different conclusions about the impact of consumption diversity on production diversity. The results in the second and third columns show that the desire of the farmers to diversify consumption induces them to harvest diverse productions. However, these results are not supported when we use community level mean value of consumption diversity as instrument for the individual level consumption diversity. Moreover, the magnitude of the impacts of consumption diversity on PD are economically less meaningful; for instance, HDDS needs to increase by about 10 food groups to increase PD by one food group. Hence, consumption diversity plays little role in affecting production diversity, ceteris paribus.

On the other hand, all the four models present similar results for most of the covariates. For instance, the results from all the four models show that risk-averse farmers produce more variates than others. This could be because risk-averse individuals would like to reduce risk by diversifying the number of crops they produce. Specifically, the results indicate that risk-averse farmers produced about 0.11 more food groups and around 0.32 more crop varieties than risk-seeking or risk-neutral farmers. This is not unexpected as smallholder farmers' production involves uncertainty because of natural factors (such as drought, flooding, etc.) and market factors (e.g., input and output prices and access to market). The uncertainty is higher in countries such as Ethiopia where farmers mainly depend on rain-fed agriculture and where insurance markets are almost non-existent. As a result, farmers have incentive to diversify production to reduce risk. Our finding is comparable to the findings of Bezabih and Sarr (2012) and Chavas and Di Falco (2012).

The estimation results also suggest that married households, smallholder farm households with larger cultivated land, with larger family size and family labor and households who participate in community meetings are more likely to diversify their production than their counterpart households. On the other hand, households who feel poorer than other households in their village, households living in desert area and households who had enough rain at the beginning of the harvest season produce less varieties. These findings are consistent with the literature (Bellon et al., 2016; Benin et al., 2004; Bezabih and Sarr, 2012; Di Falco et al., 2010)Benin et al., (2004); Di Falco et al., (2010)., Bezabih & Sarr, (2012); and Bellon et al., (2016).

Table 5: Determinants of Production Diversity: The Mundlak Fixed Effects IV linear model

Covariates	Instrument: forward values of consumption diversity		Instrument: Peasant Association level mean values of consumption diversity	
	Number of food groups (PD)	No. of crop species (count diversity)	Number of food groups (PD)	No. of crop species (count diversity)
Consumption diversity (instrumented)	0.111*	0.154*	0.080	-0.096
	(0.051)	(0.068)	(0.052)	(0.083)
Risk averse dummy (1 = risk averse)	0.122***	0.317***	0.107***	0.328***
	(0.023)	(0.049)	(0.024)	(0.051)
Education level of the mother	-0.012	-0.014	-0.012	0.006
	(0.007)	(0.015)	(0.008)	(0.016)
Number of HH members	0.025***	0.085***	0.029***	0.089***
	(0.005)	(0.012)	(0.006)	(0.012)
Illiterate household head	-0.026	-0.088	-0.036	-0.172*
	(0.031)	(0.064)	(0.030)	(0.066)
Male household head	0.019	0.438***	-0.025	0.364***
	(0.044)	(0.082)	(0.045)	(0.083)
Married	0.185***	0.012	0.217***	0.052
	(0.046)	(0.087)	(0.047)	(0.088)
Dummy indicating if the HH faced food shortage last summer	0.063*	0.119*	0.040	-0.007
	(0.030)	(0.060)	(0.031)	(0.066)
The Household is poor relative to the dwellers	-0.117**	-0.218**	-0.135***	-0.388***
	(0.032)	(0.064)	(0.033)	(0.073)
Earned off-farm income (1/0)	0.198***	0.879***	0.160***	0.882***
	(0.038)	(0.080)	(0.039)	(0.082)
Land area size, Ha	0.331***	1.414***	0.385***	1.551***
	(0.028)	(0.061)	(0.030)	(0.064)
Total family labor used	0.000	-0.001*	0.000	-0.001*
	(0.000)	(0.000)	(0.000)	(0.000)
Total labor hired in (days)	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Distance (in minutes) to the nearest mkt	0.001***	0.000	0.001**	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Has media access	0.040	0.100	0.025	0.187
	(0.056)	(0.119)	(0.058)	(0.126)
Follow price information	0.133*	0.114	0.163*	0.234+
	(0.057)	(0.126)	(0.061)	(0.137)
Participate in community	0.264***	0.655***	0.279***	0.773***

meetings	(0.028)	(0.058)	(0.029)	(0.061)
Had enough rain at the	-0.089**	-0.308***	-0.089**	-0.318***
beginning of the seasons	(0.026)	(0.054)	(0.026)	(0.055)
Desert or kola agroecology	-0.290***	-1.100***	-0.292***	-1.208***
	(0.028)	(0.063)	(0.028)	(0.066)
Fixed Effects	Yes	Yes	Yes	Yes
Constant	1.806***	0.969*	1.925***	2.651***
	(0.245)	(0.466)	(0.246)	(0.567)
Observations	12190	12263	12266	12287
chi2	1620.356	3196.325	1667.655	3159.217

Note 2: t statistics from robust standard errors in parentheses. + p<0.10, * p<0.05, ** p<0.001, *** p<0.0001

4.2 Effect of Production Diversity and Market Integration on Dietary Diversity

As mentioned in Section 3, to estimate the effect of PD and market participation on households and children DD index (score) using the three-wave survey 7-day consumption recall data, we employed the Mundlak Fixed Effects IV Poisson model. Whereas to estimate the effect of PD and market participation on household and women DD using the cross-sectional 24-hour recall data we use GMM Poisson model. The estimation results from both the models are reported in Table 6. The Durbin-Wu-Hausman test of endogeneity shows that PD is indeed endogenous (p-value = 0.0000). The first-stage regression result is presented in Annex B. We used land area and sufficiency of the rainfall at the beginning of the seeding season as instruments for PD of food groups. The instrumental variables are jointly significant, but sufficiency of rain dummy is not statistically significant individually. The Hansen-Sargan test result indicates that we cannot reject the null hypothesis of zero correlation between the instruments and the error term (p-value = 0.4253). Moreover, the null hypothesis of weak instruments is also rejected-the effective F-statistics of Montiel-Pflueger robust weak instrument test (162.47) is much higher than the critical value (5.271) at 5 percent level of significance. (The regression results obtained by using peasant association level mean value of PD as household level PD are presented in the appendix D.)

As shown at the bottom of Table 6, the hypothesis of the Wald test that all the regression coefficients are jointly zero is rejected (p-value = 0.0000). This suggests that the regressors are jointly statistically significant in all of the five models reported in Table 6.

The estimation results from the Mundlak Pseudo Fixed Effects IV linear model (the poison model could not converge) indicate that the PD significantly and positively affects HDDS. Specifically, producing two more food groups increases HDDS by about one food group. That is, household members consume at least one out of two food groups produced. However, we do not find a statistically significant impact of PD on any of the individual level measures of consumption diversity, adding the speculation about the use of HDDS as a measure of nutrition (Koppmair and Qaim, 2017;

Verger et al., 2017a, 2017b). This result is consistent with previous studies in that PD affects household members' DD, but not individual level DD (see, e.g., Chegere and Stage, 2020).

The estimation results show also that the more the households integrated with the market, as measure by the ratio of sales to total produce (i.e., commercialization index), the higher are both HDDS and individual level measures of dietary diversity. This shows that policies that target increasing market integration of smallholder farmers could be more effective in improving DD than policies that aim at increasing PD. Because the former increases not only the income of the farm household from specializing in the production of a few high-value agricultural products but also offers the availability of more variants of food items in the market. On the other hand, households who responded that their main source of food is purchased food do not diversify their consumption, unexpectedly. Looking further at the data, we found that these households are relatively poor (33% versus 20% experiencing food shortage in summer) and have less (by about 0.3 hectare) land than other households.

Other explanatory variables have also more or less the expected signs. We found that the education level of the daughter, who are usually the second responsible household members to prepare meal, has a statistically significant effect on the DD of households and lactating women. Similarly, the education level of the mother and the household head have a statistically significant effect on the HDDS while the age of the mother has a negative and statistically significant effect on the DD of lactating women. Expectedly, DD of the households increases with family size - the larger the family size, the more likely that some of the household members may eat varieties of food. On the other hand, DD of the lactating women decreases with family size. Off-farm income, food security (as measured by whether the household experienced food shortage problem last summer), relative income (self-reported income level of the household relative to the village dwellers), media access, and desertedness of the living area significantly affect the DD of households.

We also estimate the determinants of the minimum DD score of households, women and children using Correlated Random Effects Probit model controlling for household specific unobservable heterogeneity and endogeneity problems (Papke & Wooldridge, 2008) for HDDS and CDDS based on the three-wave survey 7-day recall data, and endogenous Probit model for WDDS using the cross-sectional 24-hour consumption cross-sectional data. The required minimum DD scores of households, children and women is four. The results confirm that PD and market participation have a positive and statistically significant effect on the DD of smallholder farm households (see Appendix C).

Table 6: Determinants of Consumption Diversity scores, marginal effects at means

Covariates	Mundlak Fixed Effects IV linear model (7-day recall)		IV GMM Poisson model (24-hour recall), marginal values		
	HDDS	CDDS	HDDS	Lactating women DDS	Other-adult women DDS
Production diversity	0.549*** (5.83)	0.876 (1.04)	0.600*** (5.21)	0.269 (1.56)	0. 4580* (2.38)
Market integration & access					
Household commercialization index	0.435*** (4.46)	-0.0401 (-0.12)	0.621* (3.04)	0.593* (2.08)	0.569+ (1.78)
Purchased food was the main source of consumption for the household	0.149* (3.01)	0.0186 (0.26)	-0.177 (-1.45)	-0.278 (-1.30)	0.050 (0.26)
Distance in minutes to the market center	-0.0012*** (-4.59)	0.00006 (0.14)	-0.001* (-2.46)	-0.0006 (-0.99)	-0.0001 (-0.29)
Household characteristics					
Years of schooling of the most educated daughter	0.0154* (2.68)	-0.00659 (-0.37)	0.0331* (3.12)	0.03461+ (1.81)	0. 0108 (0.63)
Years of schooling of the mother	0.0508*** (4.60)	0.00784 (0.30)	0.041* (2.42)	-0.0335 (-1.49)	0.039 (1.51)
Age of the mother	-0.00193 (-1.06)	-0.00555 (-1.13)	-0.0011 (-0.31)	-0.0182* (-2.40)	-0.0098 (-1.53)
Household size	0.00516* (3.05)	-0.00201 (-0.91)	-0.0265 (-1.34)	0.0056 (0.16)	0.0086 (0.32)
If the head of the household was illiterate	-0.187*** (-4.95)	-0.0861 (-0.67)	-0.1142+ (-1.66)	-0.1276 (-1.26)	-0.124 (-1.22)
Male household head	-0.0747 (-1.35)	-0.0428 (-0.38)	-0.0870 (-0.95)	0.0102 (0.07)	0.072 (0.47)
Married household head	-0.0527 (-0.86)	-0.0173 (-0.12)	0.0655 (0.66)	0.1791 (1.09)	-0.169 (-0.98)
Male child		0.0130 (0.20)			
Age in months of the child		0.000198 (0.07)			
The child was breastfed		0.117 (0.30)			

The household had food shortage problem last summer	-0.266*** (-6.32)	-0.0711 (-0.54)	-0.1121 (-1.13)	-0.175 (-1.32)	-0.071 (-0.49)
The household reported that it is poor relative to the village dwellers	-0.291*** (-7.27)	0.0212 (0.11)	-0.1806* (-2.16)	-0.0388 (-0.29)	0.121 (0.95)
Off-farm income of the household obtained in the last 12 months	0.00000288 (0.90)	- 0.000001 (-0.17)	0.00007* (2.24)	-0.0000096 (-1.57)	-0.0000366 (-0.10)
Media access & training participation					
The household has media access	0.204* (2.49)	0.212 (1.20)	0.359* (2.61)	0.133 (0.67)	0.237 (1.22)
The household follows price of crops information	0.144+ (1.67)	-0.331 (-1.09)	-0.207 (-1.44)	0.3431+ (1.74)	-0.146 (-0.66)
The household participated in community meeting and training	0.168*** (4.01)	-0.00126 (-0.02)	0.105 (1.49)	0.163 (1.51)	-0.0360 (-0.34)
The household lives in desert and semi-desert areas	0.190*** (4.08)	-0.0575 (-0.63)	0.276** (3.73)	-0.149 (-1.18)	-0.0384 (-0.35)
Seasonal break, the data was collected in March to Feb. 2017	-0.281*** (-4.75)	0.206 (0.51)			
Household Fixed Effects	Yes	Yes	-	-	-
Constant	3.209*** (11.10)	0.151 (0.21)	0.851*** (7.27)	0.603* (2.23)	0.191 (0.57)
Joint test of the significant of Mundlak FE variables: chi^2 (3) (P-value)	20.80 (0.0001)	5.28 (0.1523)	-	-	-
N	8853	1295	2167	628	612

t statistics in parentheses. + p<0.10, * p<0.05, ** p<0.001, *** p<0.0001

5 Conclusion

Undernourishment is a particular problem in developing countries where a large share of the population lives in rural areas with limited market access. Accordingly, many countries in Africa have used improving DD as a strategy to reduce undernourishment. In an attempt to improve DD, developing countries usually encourage farmers to diversify their production. However, diversification of production indirectly affects DD by affecting income negatively because of forgone benefits from specialization (Sibhatu, 2015) while other studies show that PD may result in higher return than specialization does in situations where there is high risk of crop failure (Di Falco and Chavas, 2009). Recent studies also disclosed that market access reduces the link between PD and DD (Bellon et al., 2016; Koppmair et al., 2016; Sibhatu et al., 2015) as it reduces the need for producing for self-consumption (Fafchamp, 1992), and gradually changes the farmers' production decisions from fulfilling their diverse dietary needs to maximizing profit (Bellon et al., 2016).

The analysis of the data indicates that starchy staple foods were the most commonly consumed food groups followed by vegetables and pulses. On an average, 95 percent of all the households consumed starchy staple foods 7 days before the three round survey dates while the percentage of households who consumed vegetables and pulses are 84 percent and 66 percent respectively. Fruits and meat are the least consumed food groups; they were consumed by 12 percent, 18 percent of all households over 7 days before the interview dates respectively. Egg products are consumed by 33 percent of the households. On an average, households consumed five out of the ten food groups. About 79 percent of the households consumed the minimum DD that is required to run a health life.

The intra-household analysis of DD discloses some degree of variation among children, lactating women and non-lactating women. The analysis of the 24-recall data suggests that slightly less than half of the children consumed grains, roots and tubers. The next two most commonly consumed food types for children are vitamin A-rich fruits and vegetables (26 percent) and pulses and nuts 19 percent). Meat and other fruits and vegetables are the least consumed food types and are consumed only by 1 and 6 percent of the children respectively. The results show that most children do not eat many food varieties. The average DD score for the children is 2 out of the seven food types; only about 7 percent of the children consumed the required DD of four food types. The descriptive analysis of data also suggests that the starchy staple foods were consumed by 69 percent of the lactating woman followed by pulses and nuts, which was consumed by 58 percent of them. The least consumed food types by the lactating women are meat followed by eggs, which was consumed by 3 percent and 6 percent respectively. The average number of food types lactating women consumed is 2.4. Only about 15 percent of the lactating woman from all households consumed the required diet of four or more food types. Similarly, for other non-lactating and non-pregnant adult women of the household, starchy staple foods and pulses and nuts are the two most commonly consumed food types. Meat and eggs are the least consumed food types, which are consumed by 3 percent each. The average DD score for other women is 2; only about 13 percent of all the other women consumed four or more food types.

The data also indicates that most of the households produced cereals and reared livestock. Pulses, legumes, and nuts is the third most produced food group, in that around 44 percent, 37 percent and 33 percent of the households produced them in 2011, 2013 and in 2017 respectively. Around 26 percent of households produced dairy overall the survey years where the figure was the highest in 2017 (37 percent) and the lowest in 2011 (15 percent). Similarly, only around 10 percent of the households produced fruits and vegetables over the survey years. This is a bit similar to the consumption pattern of the households.

The estimation results from the Mundlak Fixed Effects IV model suggests that risk averse households, households who prefers to diversify future consumption, households with limited access to the market, households with larger cultivated land, households with larger family size and family labor, households who participate in community meetings and married households, are more likely to diversify their production than their counterpart households. Specifically, the results indicate that risk-averse farmers produce, on an average, around 0.11 more food groups and around 0.32 more crop varieties than risk-seeking or risk-neutral farmers. Households located far away from the market (households with limited market access,) are more likely to diversify their production than households located closer to the market (households with better market access). On the other hand, households who feels poorer than the other households in their village, households living in desert and semi-desert areas and households who had enough rain at the beginning of the harvest season are more likely to specialize in the production of few food groups and crop species than their counterparts.

The analysis of the determinants of dietary diversity suggests that PD has a statistically significant and positive effect on HDDS . Ceteris paribus, production of one more food group increases HDDS by 0.55 to 0.60 units. However, we do not find a statistically significant impact of PD on any of the individual level measures of consumption diversity, adding the speculation about the use of HDDS as a measure of nutrition. The results show that market integration is more relevant than PD in improving dietary diversity and nutrition. The more the households integrated with the market, as measured by commercialization index, the higher are both HDDS and individual level measures of dietary diversity.

These results suggest that policies that merely focus on encouraging smallholder farmers to diversify production would not be that effective unless they are coupled with interventions that aim to integrate smallholder farmers to the market.

We also noted that the study has some caveats. First, the data used to analyze the DD score of women was cross-sectional in that, even though we control for the endogeneity problem that arises because of reverse causality between PD and DD, the effect of DD on lactating and non-lactating women could still be confounded by unobserved heterogeneity. Second, the insignificant effect of PD on children DD could be attributed to the sample size of households having children between the age of 6 and 24 months. Third, the instruments we used for consumption and PD may not be strong enough to create an exogenous link between PD and CD even though they pass all the statistical tests of relevance and weak instrument.

6 References

Adeyeye, S.A.O., Ashaolu, T.J., Bolaji, O.T., Abegunde, T.A., and Omoyajowo, A.O. (2021). Africa and the Nexus of poverty, malnutrition and diseases. Crit. Rev. Food Sci. Nutr. 1–16.

Akay, A., Martinsson, P., Medhin, H., and Trautmann, S.T. (2012). Attitudes toward uncertainty among the poor: an experiment in rural Ethiopia. Theory Decis. *73*, 453–464.

Akombi, B.J., Agho, K.E., Merom, D., Renzaho, A.M., and Hall, J.J. (2017). Child malnutrition in sub-Saharan Africa: A meta-analysis of demographic and health surveys (2006-2016). PLOS ONE *12*, e0177338.

Alderman, H., Behrman, J.R., and Puett, C. (2016). Big Numbers about Small Children: Estimating the Economic Benefits of Addressing Undernutrition. World Bank Res. Obs. lkw003.

Baird, S., Hicks, J.H., Kremer, M., and Miguel, E. (2016). Worms at Work: Long-run Impacts of a Child Health Investment*. Q. J. Econ. *131*, 1637–1680.

Barrett, C.B. (2008). Smallholder market participation: Concepts and evidence from eastern and southern Africa. Food Policy *33*, 299–317.

Bellon, M.R., Ntandou-Bouzitou, G.D., and Caracciolo, F. (2016). On-Farm Diversity and Market Participation Are Positively Associated with Dietary Diversity of Rural Mothers in Southern Benin, West Africa. PLOS ONE *11*, e0162535.

Benin, S., Smale, M., Pender, J., Gebremedhin, B., and Ehui, S. (2004). The economic determinants of cereal crop diversity on farms in the Ethiopian highlands. Agric. Econ. *31*, 197–208.

Berhane, G., Abay, M.H., and Woldehanna, T. (2016). Rural-urban differences in children’s dietary diversity in Ethiopia. 8.

Bezabih, M., and Sarr, M. (2012). Risk Preferences and Environmental Uncertainty: Implications for Crop Diversification Decisions in Ethiopia. Environ. Resour. Econ. *53*, 483–505.

Binswanger, H.P. (1981). Attitudes Toward Risk: Theoretical Implications of an Experiment in Rural India. Econ. J. *91*, 867.

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., et al. (2013). Maternal and child undernutrition and overweight in low-income and middle-income countries. The Lancet *382*, 427–451.

Chamberlain, G. (1982). Multivariate regression models for panel data. J. Econom. *18*, 5–46.

Chamberlin, J., and Jayne, T.S. (2013). Unpacking the Meaning of ‘Market Access’: Evidence from Rural Kenya. World Dev. *41*, 245–264.

Chavas, J.-P., and Di Falco, S. (2012). On the Role of Risk Versus Economies of Scope in Farm Diversification With an Application to Ethiopian Farms: Role of Risk Versus Economies of Scope. J. Agric. Econ. *63*, 25–55.

Chegere, M.J., and Stage, J. (2020). Agricultural production diversity, dietary diversity and nutritional status: Panel data evidence from Tanzania. World Dev. *129*, 104856.

Di Falco, S., and Chavas, J.-P. (2009). On Crop Biodiversity, Risk Exposure, and Food Security in the Highlands of Ethiopia. Am. J. Agric. Econ. *91*, 599–611.

Di Falco, S., Chavas, J.-P., and Smale, M. (2007). Farmer management of production risk on degraded lands: the role of wheat variety diversity in the Tigray region, Ethiopia. Agric. Econ. *36*, 147–156.

Di Falco, S., Bezabih, M., and Yesuf, M. (2010). Seeds for livelihood: Crop biodiversity and food production in Ethiopia. Ecol. Econ. *69*, 1695–1702.

Dillon, A., McGee, K., and Oseni, G. (2015). Agricultural Production, Dietary Diversity and Climate Variability. J. Dev. Stud. *51*, 976–995.

Dorsey, B. (1999). Agricultural Intensification, Diversification, and Commercial Production among Smallholder Coffee Growers in Central Kenya. Econ. Geogr. *75*, 178–195.

Drammeh, W., Hamid, N.A., and Rohana, A.J. (2019). Determinants of Household Food Insecurity and Its Association with Child Malnutrition in Sub-Saharan Africa: A Review of the Literature. Curr. Res. Nutr. Food Sci. J. *7*, 610–623.

Ecker, O. (2018). Agricultural transformation and food and nutrition security in Ghana: Does farm production diversity (still) matter for household dietary diversity? Food Policy *79*, 271–282.

Ellis, F. (2000). The determinants of rural livelihood diversification in developing countries. J. Agric. Econ. *51*, 289–302.

FAO, IFAD, UNICEF, WFP, and WHO (2020). The State of Food Security and Nutrition in the World 2020 (FAO, IFAD, UNICEF, WFP and WHO).

Fetene, G.M., and Getahun, T.D. (2018). Agricultural Technology Adoption for Food and Nutrition Security: Evidence from Ethiopia. (Vancouver, British Columbia: International Association of Agricultural Economists), p.

Fink, G., Peet, E., Danaei, G., Andrews, K., McCoy, D.C., Sudfeld, C.R., Smith Fawzi, M.C., Ezzati, M., and Fawzi, W.W. (2016). Schooling and wage income losses due to early-childhood growth faltering in developing countries: national, regional, and global estimates. Am. J. Clin. Nutr. *104*, 104–112.

Hayashi, F., and Inoue, T. (1990). The relation between firm growth and Q with multiple capital goods: Theory and evidence from panel data on Japanese firms (Cambridge, National Bureau of Economic Research).

Hirvonen, K., and Hoddinott, J. (2017). Agricultural production and children's diets: evidence from rural Ethiopia. Agric. Econ. *48*, 469–480.

Hirvonen, K., Hoddinott, J., Minten, B., and Stifel, D. (2017). Children's Diets, Nutrition Knowledge, and Access to Markets. World Dev. *95*, 303–315.

Horton, S., and Ross, J. (2003). The economics of iron deficiency. Food Policy *28*, 51–75.

Islam, A.H.Md.S., von Braun, J., Thorne-Lyman, A.L., and Ahmed, A.U. (2018). Farm diversification and food and nutrition security in Bangladesh: empirical evidence from nationally representative household panel data. Food Secur. *10*, 701–720.

Jones, A.D. (2017a). Critical review of the emerging research evidence on agricultural biodiversity, diet diversity, and nutritional status in low- and middle-income countries. Nutr. Rev. *75*, 769–782.

Jones, A.D. (2017b). Critical review of the emerging research evidence on agricultural biodiversity, diet diversity, and nutritional status in low- and middle-income countries. Nutr. Rev. *75*, 769–782.

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.

Kennedy, G., and Moursi, M. (2015). Dietary Diversity and Biofortification: Closer Than You Think.

Key, N., Sadoulet, E., and Janvry, A. de (2000). Transactions Costs and Agricultural Household Supply Response. Am. J. Agric. Econ. *82*, 245–259.

King, J.C. (2000). Physiology of pregnancy and nutrient metabolism. Am. J. Clin. Nutr. *71*, 1218S-1225S.

Koppmair, S., and Qaim, M. (2017). Response to: 'On the appropriate use and interpretation of dietary diversity scores' by Verger *et al* . Public Health Nutr. *20*, 2075–2075.

Koppmair, S., Kassie, M., and Qaim, M. (2017). Farm production, market access and dietary diversity in Malawi. Public Health Nutr. *20*, 325–335.

Kumar, R., Jain, S., Kumar, S., Sethi, K., Kumar, S., and Tripathi, B.N. (2017). Impact estimation of animal trypanosomosis (surra) on livestock productivity in India using simulation model: Current and future perspective. Vet. Parasitol. Reg. Stud. Rep. *10*, 1–12.

Ludwig, T. (2018). ZEF-Discussion Papers on Development Policy No. 247. 35.

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. J. Dev. Stud. *51*, 1097–1123.

Moore, V.M., Davies, M.J., Willson, K.J., Worsley, A., and Robinson, J.S. (2004). Dietary Composition of Pregnant Women Is Related to Size of the Baby at Birth. J. Nutr. *134*, 1820–1826.

Mundlak, Y. (1978). On the Pooling of Time Series and Cross Section Data. Econometrica *46*, 69.

Olney, D.K., Talukder, A., Iannotti, L.L., Ruel, M.T., and Quinn, V. (2009). Assessing Impact and Impact Pathways of a Homestead Food Production Program on Household and Child Nutrition in Cambodia. Food Nutr. Bull. *30*, 355–369.

Pinstrup-Andersen, P. (2007). Agricultural research and policy for better health and nutrition in developing countries: a food systems approach: Agricultural research and policy for better health and nutrition in developing countries. Agric. Econ. *37*, 187–198.

Saaka (2012). Maternal Dietary Diversity and Infant Outcome of Pregnant Women in Northern Ghana. Int. J. Child Health Nutr.

Sibhatu, K.T., and Qaim, M. (2018). Review: Meta-analysis of the association between production diversity, diets, and nutrition in smallholder farm households. Food Policy *77*, 1–18.

Sibhatu, K.T., Krishna, V.V., and Qaim, M. (2015). Production diversity and dietary diversity in smallholder farm households. Proc. Natl. Acad. Sci. *112*, 10657–10662.

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 Nutr. *9*, 644–650.

Taylor, J.E., and Adelman, I. (2003). Agricultural Household Models: Genesis, Evolution, and Extensions. Rev. Econ. Househ. *1*, 33–58.

Verger, E.O., Dop, M.-C., and Martin-Prével, Y. (2017a). Not all dietary diversity scores can legitimately be interpreted as proxies of diet quality. Public Health Nutr. *20*, 2067–2068.

Verger, E.O., Jones, A.D., Dop, M.-C., and Martin-Prével, Y. (2017b). On the appropriate use and interpretation of dietary diversity scores. Response to: ‘Farm production diversity and individual-level dietary diversity’ by Koppmair and Qaim. Public Health Nutr. *20*, 2073–2074.

WHO (2010). Indicators for assessing infant and young child feeding practices part 3: country profiles.

Wooldridge, J.M. (2009). On estimating firm-level production functions using proxy variables to control for unobservables. Econ. Lett. *104*, 112–114.

Yesuf, M., and Bluffstone, R.A. (2009). Poverty, risk aversion, and path dependence in low-income countries: Experimental evidence from Ethiopia. Am. J. Agric. Econ. *91*, 1022–1037.

Zanello, G., Shankar, B., and Poole, N. (2019). Buy or make? Agricultural production diversity, markets and dietary diversity in Afghanistan. Food Policy *87*, 101731.

(2013). The state of food insecurity in the world 2013: the multiple dimensions of food security (Rome: FAO).

(2017). Disease Control Priorities, Third Edition (Volume 8): Child and Adolescent Health and Development (The World Bank).

Annex

A. Production diversity: Mundlak Fixed Effects and IV Poisson model estimates

Covariates	Number of food groups produced		No. of livestock products & crop varieties produced	
	Marginal value	Std. Err. (Delta-method)	Marginal value	Std. Err. (Delta-method)
Consumption diversity	0.112293	929.3935	0.165	0.068
Risk averse dummy (1 = risk averse)	0.10519	712.0559	0.332	0.050
Years of schooling of the mother	-0.0136	59.16816	-0.018	0.015
Household size	0.02838	1452.186	0.082	0.011
Illiterate household head	-0.03049	152.2148	-0.051	0.061
Male household head	-0.01328	448.8215	0.563	0.094
Married household head	0.251226	1907.368	0.131	0.105
Experienced food shortage problem in summer	0.046381	8.28E+19	0.128	0.065
The household is poor relative to dwellers in the village	-0.13221	1321.817	-0.245	0.068
Off-farm income, ETB	0.14597	286478.4	0.844	0.071
Cultivated area, ha	0.38285	3129.835	1.360	0.060
Family labor days used in production	0.000044	0.016132	0.000	0.000
Hired labor days	5.66E-05	0.176389	0.000	0.000
Distance in minutes to the nearest market center	0.000677	1.10E+70	0.001	0.000
The household has media access	0.020862	648.0001	0.050	0.110
The household follows price information	0.129661	809.2487	0.124	0.116
The household participates in trainings/meetings	0.270681	1414.675	0.646	0.057
The rain at the beginning of the season was enough	-0.08754	515.5337	-0.281	0.052
The area is relatively desert/semi-desert	-0.29953	2775.224	-1.133	0.069
	12216		12268	

B. First-stage regression based on the linear model

Covariates	Dependent variable: Number of food groups produced
Excluded Instruments:	
Cultivation area, in hectare	0.514***
	(16.28)
Whether the rain was enough for growing	-0.0207
	(-0.69)
Included instruments:	
Purchased food was the main source of food	-0.260***
	(-7.35)
Household commercialization index	-0.0798
	(-1.00)
Distance in minutes to the closest market	0.000878***
	(4.98)
The household lives in desert or semi-desert areas	-0.300***
	(-10.09)
Years of schooling of the daughter	0.0109*
	(2.48)
Years of schooling of the mother	0.0122
	(1.53)
Age of the mother	-0.0000845
	(-0.06)
Household size	0.0129***
	(9.70)
The household head was illiterate	-0.0415
	(-1.40)
Male household head	-0.0347
	(-0.76)
Married household head	0.0701
	(1.36)
The household experienced food shortage in last summer	-0.0531
	(-1.55)
The household was poor relative to the dwellers in the village	-0.181***
	(-6.34)
Income from off-far activities	-0.00000766+
	(-1.68)
The household has media access	0.0415
	(0.64)
The household follows price information	0.181*
	(2.74)
The household participates in community	0.262***

meetings/training	
	(9.61)
Seasonal break, year 2017	0.563***
	(17.08)
Constant	2.682***
	(31.25)
R^2	0.1306
Joint significance of covariates: F (20, 8868)	63.56
Durbin-Wu-Hausman test of endogeneity: (p-values)	0.0000
Over-identification test:	
Hansen's J chi2(1)	1.15003
(p-value)	0.2835
Montiel-Pflueger robust weak instrument test:	
Effective F statistic	137.688
Critical value from 2SLS for 5 percent level of significance	5.271
N	8868

t statistics in parentheses. + p<0.10, * p<0.05, ** p<0.001, *** p<0.0001

C. Peasant Association Level mean production diversity as IV for PD

Covariates	Mundlak Fixed Effects IV linear model (7-day recall)		IV GMM Poisson model (24-hour recall), only 2017 survey (coefficients)		
	HDDS	CDDS	HDDS	DDS of lactating women	Other-adult DDS of women
Production diversity (instrument: Peasant Association level mean production diversity)	0.187+ (0.107)	0.690* (0.218)	-0.033 (0.065)	0.026 (0.116)	0.031 (0.148)
Purchased food was the main source of consumption for the household	0.085 (0.055)	0.042 (0.092)	-0.081* (0.031)	-0.105 (0.092)	0.012 (0.082)
Household commercialization index	0.489*** (0.100)	0.161 (0.206)	0.046 (0.059)	0.200+ (0.115)	0.075 (0.172)
Distance (in minutes) to the nearest mkt	-0.001* (0.000)	-0.000 (0.000)	0.000 (0.000)	-0.000 (0.000)	0.000 (0.000)
Desert or kola agroecology	0.095* (0.045)	0.030 (0.077)	0.038* (0.018)	-0.079 (0.060)	-0.029 (0.046)
The highest education level of a daughter in the family	0.019** (0.006)	-0.003 (0.013)	0.010** (0.003)	0.016* (0.008)	0.007 (0.007)
Education level of the mother	0.061*** (0.011)	0.018 (0.020)	0.014** (0.004)	-0.011 (0.009)	0.024* (0.010)
mother_age	-0.001 (0.002)	-0.002 (0.004)	0.000 (0.001)	-0.008* (0.003)	-0.003 (0.003)
Number of HH members	0.023* (0.009)	0.020 (0.024)	0.004 (0.006)	0.006 (0.017)	0.012 (0.010)
Dummy: if the HH head is illiterate =1; otherwise =0	-0.180*** (0.036)	-0.100 (0.078)	-0.013 (0.016)	-0.059 (0.041)	-0.067 (0.041)
Gender of the HH head: 1 = Male	-0.076 (0.052)	0.001 (0.106)	-0.002 (0.021)	0.017 (0.057)	0.003 (0.062)
Marital status of the head of the HH: 1 = Married; 0 = Other (divorsed, widow,	-0.033 (0.059)	-0.057 (0.135)	-0.013 (0.025)	0.063 (0.065)	-0.061 (0.070)
Dummy indicating if the HH faced food shortage last summer	-0.268*** (0.040)	-0.180* (0.069)	-0.084* (0.029)	-0.092 (0.056)	-0.082 (0.074)
Self-reported income level relative to HHs in the vellage: dummy = 1 if poor	-0.365*** (0.043)	0.015 (0.077)	-0.105*** (0.026)	-0.058 (0.067)	-0.018 (0.069)
(sum) ofFarmProfit	0.000 (0.000)	-0.000 (0.000)	0.000 (0.000)	-0.000+ (0.000)	-0.000 (0.000)
if the HH got info about agri. production	0.228* (0.078)	0.315* (0.151)	0.071* (0.033)	0.057 (0.084)	0.080 (0.084)

from radio, newspaper or bulletin					
Dummy indicating whether the HH gets price information from radio, newspaper or	0.246* (0.082)	-0.444* (0.175)	0.020 (0.040)	0.147+ (0.084)	0.025 (0.112)
Dummy for community meeting indicator: 1 = if the HH participated in community me	0.266*** (0.045)	-0.056 (0.067)	0.069** (0.020)	0.068 (0.045)	0.011 (0.050)
Dummy: the 2017 survey	-0.191** (0.054)	0.206+ (0.121)			
Overtime mean off-farm income	0.000* (0.000)	-0.000 (0.000)			
Overtime mean hired in labor days	0.000 (0.000)	0.001 (0.001)			
Overtime mean family labor used for production	0.000 (0.000)	-0.000 (0.000)			
Dummy: whether the child is male =1		0.108 (0.072)			
Age of children in months, average age when there are > 1 children		-0.003 (0.002)			
Dummy indicating whether the baby breast fed yesterday		0.179 (0.216)			
Constant	4.151*** (0.325)	0.929 (0.620)	1.472*** (0.222)	0.934* (0.380)	0.802 (0.522)
Observations	8889	1305	2203	645	620
r2					
r2_a					
chi2	1106.806	82.507			