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Intra-household decision-making, production diversity, and dietary quality: a panel data analysis of Ethiopian rural households

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Abstract

Considering that rural poor are mostly subsistence farmers, it seems plausible that production diversity could lead to better nutrition for these farmers. The association between production and dietary diversity is complex, and this complexity demands rigorous empirical analyses and more attention to gendered aspects of intra-household decision-making. We employ panel data analyses of 363 Ethiopian smallholders surveyed in 2014 and 2016 to test for this phenomenon, and to explore the association of women's participation in decision-making with both production and consumption diversity. Results show that, diversification can be a strategy to improve the diets, but only of rural poor who have limited non-farm income, who are distant to the markets and mostly subsistence oriented. Moreover, female participation in decision-making associates with higher diversity both in terms of production and consumption, but it does not modify the magnitude of the association between production and dietary diversity. Our analyses contribute to the enriching literature on the linkage between production diversification and dietary diversity. We study this complex relationship in-depth and show that the gendered aspect of intra-household decision-making is an important covariate for both production diversity and dietary quality.

Keywords Decision-making · Dietary diversity · Production diversity · Panel data · Ethiopia · Smallholder farmers

1 Introduction

Achieving zero hunger is the second goal of the Sustainable Development Goals (SDGs) of the United Nations Development Program (United Nations Development Programme 2019). Although the increase in agricultural productivity and overall economic growth have contributed to the decline in the number of undernourished people, today, more than 820 million people still experience hunger and around two billion experience moderate food insecurity. The numbers are rising in the African continent. The most recent data suggest that roughly 260 million people in Africa are undernourished (FAO, IFAD, UNICEF, WFP and WHO. 2019). Sub-Saharan Africa is home to the poorest population in the world, many of whom experience alarmingly high nutritional deficiencies (Ahmed et al. 2007; Barrett 2010). African Union (AU) initiated African Regional Nutrition Strategy (ARNS) 2005–2015 which provided guidance to many African countries to improve nutrition. ARNS 2015–2025 is an extension of the earlier strategy which also emphasize the importance of nutrition sensitive agricultural transformation that provides food security for poor (AU 2015).

Considering a high dependency of rural poor on agriculture, nutrition-sensitive agricultural research and programs have gained significant attention in the region. Considering that rural poor are mostly subsistence oriented, encouraging diversified farm production is perceived to be a promising strategy to achieve better dietary outcomes. Against this background, the association between production diversity and dietary diversity is tested in different settings. Recent impact evaluation studies show that nutrition sensitive agricultural programs have generally yielded positive outcomes, and observational studies have mostly identified production diversity and livestock ownership

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as most important determinants of dietary diversity (Ruel et al. 2018). Many studies report a positive association between on-farm diversification and the dietary status of rural households (Ecker 2018; Islam et al. 2018; Jones et al. 2014; Koppmair et al. 2016; Pellegrini and Tasciotti 2014), while some find mixed results depending on the country and measurement of dietary and diversification indicators (Sibhatu et al. 2015; Sibhatu and Qaim 2018a). When significant, the low magnitude of the reported association in these studies creates doubt if the strategy of increasing dietary diversity through production diversification would be effective. A review of literature predominantly from Sub-Saharan Africa by Jones (2017a) indicates existing positive association between agricultural diversification and dietary diversity. However, the review also highlights that based on the reported magnitudes of association between production diversity and dietary diversity, it would require unrealistic increases in the number of species produced to have a meaningful change in dietary diversity. Sibhatu and Qaim (2018b) have very similar conclusion. They report that an average farmer in Sub-Saharan Africa would need to grow nine additional species to increase dietary diversity by one food group. Other factors like access to market and alternative livelihoods like non-farm income are observed to have larger effects than production diversification in many cases (Dixon et al. 2001; Jones 2017a; Koppmair et al. 2016; Sibhatu et al. 2015). Moreover, the association between production diversity and dietary diversity is complex. Production diversity interacts with factors like availability of non-farm income, access to markets, and commercialization of the households. Therefore, the significance and magnitude of the association are situation specific (Islam et al. 2018; Sibhatu et al. 2015). We look into this interaction in detail and estimate marginal effects of production diversity at different specifications. In this paper, we mainly address the question of complex association between production and dietary diversity. We adopt and employ an approach by Brambor et al. (2006) that can also be followed in future studies that aim to investigate the association between production and dietary diversity in detail.

Production diversity is an ex-ante risk management strategy for risk-averse rural households (Just and Candler 1985). In Ethiopia, conservation of landraces and crop biodiversity in the fields can mitigate negative impacts of different weather associated shocks, promote productivity improvements, and contribute to food security (Di Falco and Chavas 2009). Like dietary diversity, farm production diversity is determined by various demographic, socioeconomic and infrastructural factors like household demographics, wealth, access to market and other infrastructural and institutional services. A factor, gender, is linked to various aspects of rural livelihoods like adoption of agricultural technologies and practices (Fisher and Carr 2015; Ndiritu et al. 2014), investment of generated income and credit (Carter et al. 2017; Garikipati 2008) and food security (Galiè et al. 2019; Larson et al. 2019; Malapit et al. 2019; Sariyev et al. 2020; Sraboni et al. 2014). Moreover, recent observational studies that investigate agriculture and nutrition linkage find that livestock ownership and production diversity are prominent for dietary diversity, and women's empowerment can be an important mediator (Ruel et al. 2018). As both diversification of production and diets are decisions that are outcomes of household decision-making processes in which household members belonging to different gender and sociodemographic background may intensively participate, it is reasonable to investigate the effect of female participation in decision-making on both production and dietary diversity. To the best of our knowledge, this covariate has been widely overlooked in similar studies with the exception of Jones et al. (2014) who only investigate if the gender of the head and women's control of income modify the association between farm and dietary diversity. ARNS 2015–2025 highlights the importance of empowering women - increasing their nutrition knowledge, productive skills, control of productive resources, and participation in intra-household decision-making – to achieve sustainable nutrition outcomes (AU 2015).

Considering the debatable link between production diversity and dietary diversity, the complexity of this association, and gendered preferences in decision-making that are likely to affect both livelihood outcomes, there are two objectives that we pursue in this study. The first objective is to estimate the association between production diversification and household dietary diversity, and rigorously investigate the significance and magnitude of the association in various settings. Secondly, we examine the association of women's participation in decision-making with both production diversification and household dietary diversity, respectively. We contribute to the growing literature on the association between production diversity and dietary diversity; we explore the complexity of the association in detail, and investigate the importance of gendered aspects of intra-household decision-making with regard to both livelihood outcomes.

The paper proceeds with detailed information of the materials employed and methods used in section 2; section 3 presents, interprets and discusses regression results; section 4 concludes the paper and highlights policy implications of the findings.

2 Data and methods

2.1 Data

The analyses are built on data from 363 Ethiopian households surveyed in 2014 and 2016. This is a randomly chosen sub-sample of farmers from a nationally representative survey that was conducted by the International Food Policy Research

Institute (IFPRI) for the Ethiopian Agricultural Transformation Agency (ATA) in 2012. This survey had a sample size of 3000 households in four main regions of Ethiopia.[1] Due to administrative and logistical constraints, our surveyed households were randomly chosen from the list of ATA survey farmers (i.e. 480 farmers) located in a radius of circa 150–200 km around the town of Hawassa. The area covers large parts of Southern Nations, Nationalities, and Peoples' (SNNP) and Oromia regions. Considering the diversity of agro-ecological zones, production systems, infrastructural endowments and market accessibility in the surveyed area, we believe that the findings from the sub-sample are suitable for drawing some wider conclusions. Although we have a balanced panel of 390 households, we limit the analyses to those 363 households where both genders are present, i.e. the cases where bargaining between genders may actually occur.

Enumeration was done by a team of trained enumerators using computer assisted personal interviews (CAPI). The questionnaire covered a wide array of household livelihood related characteristics including infrastructural and institutional access, adoption of agricultural technologies, land endowment, crop production, asset ownership, food consumption and so forth. Regarding decision-making, considering that households make various decisions that affect their livelihoods, households were asked questions regarding their decision-making behavior in each relevant questionnaire section. In the following subsections, we describe the methods used to extract our main variables from the most relevant sections of questionnaire. We conclude this section by describing the econometric estimation strategies used in the analyses, the results of which are reported and discussed in the following section.

2.2 Production diversity measures

We use three measures to capture production diversity and to check for the robustness of its association with dietary diversity. The first measure of production diversity used in the analyses is the Simpson's Index of Diversification (SID) that captures both crop species richness and evenness in the farmer's cultivated area. SID is calculated as:

$$SID = 1 - \sum_{i=1}^{n} S_i^2 \tag{1}$$

where

$$S_i = a_{ih}/A_h \tag{2}$$

where a_{ih} reflects the area dedicated to the production of crop i and A_h is the total cultivated area by household h. Thus, S_i captures the proportion of area dedicated to the cultivation of crop i in the total cropped area. SID ranges between zero and

one, with zero indicating that the household has no crop diversification and one meaning that the household has a completely diversified crop production in terms of richness and evenness. For example, a household that dedicates 75% of its cultivated area to one crop and 25% to another crop will have a lower SID score than another household who dedicates 50% to each crop, although they both grow the same number of crop species. In this measure of production diversity, we also capture the evenness concept of diversification. Thus, species grown in small plots like kitchen gardens are unlikely to lead to a meaningful change in the index. SID has been employed in recent similar studies (Jones et al. 2014; Linderhof et al. 2016; Mofya-Mukuka and Hichaambwa 2018).

The second measure is generated by simply counting the number of different crop and livestock species produced by the farmers in the past 12 months before the interview. This measure has been widely used to investigate the association between production and dietary diversity in several studies (Islam et al. 2018; Jones et al. 2014; Sibhatu et al. 2015; Sibhatu and Qaim 2018a). It has its limitations, as its dietary perspective is limited in cases where households produce inedible crops like cotton or where many crops that belong to the same food group are produced. That is why, we also calculate the food group production diversity (FGPD) in the households. We consider only nine food groups (i.e. cereals, pulses, tubers, vegetables, fruits, meat, fish, eggs, and milk products) for the third measure. Considering the difficulty of producing sweets, oils and fats, and spices by farmers, these groups are not considered in the indicator. Similar measures with varying specifications have been employed in recent studies (Chegere and Stage 2020; Koppmair et al. 2016; Pellegrini and Tasciotti 2014; Sibhatu and Qaim 2018a).

These three measures are used in the analyses to check for the robustness of the conclusions about the determinants of production diversity and its association with dietary quality at the household level. It also enables us to compare the magnitude and significance of the association of the three measures with dietary quality. In addition, we can evaluate the economic significance of the different diversification strategies, since each of the measures we employ has different qualities, such as capturing the evenness of production in addition to richness (i.e. SID) and representing the direct contribution to diverse diets (i.e. production diversity by food groups).

2.3 Dietary quality measure

Dietary diversity can be defined by simply looking at the variety of foods consumed from major food groups (Krebs-Smith et al. 1987). To capture the dietary quality of the surveyed households, we calculate the household dietary diversity score (HDDS). HDDS is an indicator of economic access to food which describes the household's ability to access

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[1] See Sawyer and Minot (2013) for more information regarding 2012 ATA baseline survey.

various food items (Kennedy et al. 2011). Diverse diets are associated with higher caloric availability at household level and better food access at an individual level (Hoddinott and Yohannes 2002). Considering the its association with per capita income and energy availability, Ruel (2003) finds dietary diversity practical to capture food security status. Dietary diversity is further significantly associated with nutrient adequacy which is an aspect of dietary quality for individuals (Foote et al. 2004; Krebs-Smith et al. 1987). At household level, it is associated with many nutritional indicators like protein, fat, carbohydrates and different vitamins; and individual dietary diversity is associated with higher micronutrient intake (Fongar et al. 2019). Thus, dietary diversity is a good proxy of individual's dietary quality. Moreover, considering that individual and household level dietary diversity scores are observed to be correlated in different settings (Cisse-Egbuonye et al. 2017; Fongar et al. 2019; Koppmair et al. 2016; Olney et al. 2009), it is safe to assume that HDDS is a good measure of a household's overall dietary quality.

Studies have used 24-h (e.g. Koppmair et al. 2016; M'Kaibi et al. 2017) and seven-day (e.g. Jones 2017b; Jones et al. 2014; Sibhatu and Qaim 2017) recall periods to capture dietary diversity. Regular fasting (i.e. not eating animal products on Wednesdays and Fridays) is practiced by some devoted Ethiopian Orthodox Christians. Considering this, seven-day recall that captures day-to-day variation in diets can be more relevant to capture dietary quality than the 24-h recall. Moreover, Sibhatu and Qaim (2018a) and Chegere and Stage (2020) highlighted tradeoffs associated with the two recall periods. Although, a seven-day recall is capable of capturing more of the daily variation in diets, it is also more likely to suffer from potential recall bias than the 24-h recall. Seven-day recall can capture foods that are consumed once or twice a week and are important for nutrition. These types of food are not likely to suffer recall biases. We opt to capture day-to-day variation in diets; HDDS is calculated from seven-day consumption recall data where food items are grouped into 12 food groups: cereals; white tubers and roots; vegetables; fruits; meat; eggs; fish and other seafood; legumes, nuts and seeds; milk and milk products; oils and fats; sweets; spices, condiments and beverages. Considering that the contribution of the last three food groups to dietary quality is debatable and have been excluded in recent studies (Islam et al. 2018; Sibhatu et al. 2015), as a sensitivity test, we also run the analyses on dietary diversity based on nine food groups (HDDS9) that better reflect micronutrient adequacy (Kennedy et al. 2011).

2.4 Other covariates

Both production diversification and dietary diversity may be influenced by different socioeconomic and demographic factors.

On the demographic characteristics, we control for sex, age and years of formal education of the household head, along with the household size and dependency ratio in all our analyses, thereby capturing overall human capital endowment of households which, in turn, determines many livelihood outcomes.

In the first part of the analyses, the main determinants of production diversification are investigated. We review the literature by Rehima et al. (2013), Sichoongwe et al. (2014), Isnansetyo et al. (2017), Burchfield and La Poterie (2018), Mekuria and Mekonnen (2018), and Mofya-Mukuka and Hichaambwa (2018) to identify relevant covariates and include them to the estimations. We include cultivated land area, agricultural asset value, non-farm income and total livestock units owned as household wealth indicators. Moreover, proximity to input and output markets may determine the diversification decision, thus we include time spent traveling to the nearest periodic market and input dealer. Considering the importance of institutional and technological endowments for rural livelihoods, access to an extension and the main information provided in the extension visits are included in an interaction term. On the technological aspects, the effect of irrigation and the adoption of crop rotation and intercropping practices are investigated.

In the second part of the analyses, we estimate the effect of the three production diversity measures on household dietary diversity (HDDS) where wealth indicators and market access variables from the first part remain, and a dummy indicating the receipt of remittance is added. Furthermore, the average share of crop harvest sold is calculated and added to control for the market orientation of the households. These variables are added based on the study objectives and review of existing literature (Hirvonen and Hoddinott 2017; Islam et al. 2018; Koppmair et al. 2016; Pellegrini and Tasciotti 2014; Sibhatu et al. 2015; Sibhatu and Qaim 2018a).

The second objective of the study is to estimate the effect of female participation in decision-making on two outcome variables, production diversity and dietary diversity. We look into intra-household decision-making processes regarding crop production and household expenditure in production diversity and dietary diversity models, respectively. Decision regarding household expenditure is a proxy for female involvement in consumption decision. In each decision-making process, households are divided into three categories (i.e. sole, joint, none) according to the female involvement in respective decisions. Firstly, if the decision on at least one crop grown or one type of household expenditure is made by female only, a household is assigned to the "sole" category in the respective decision variables. The "joint" category includes remaining households in which decision-making on at least one crop grown or one type of household expenditure is made jointly by male and female. Finally, all remaining households falls into the category "none" which indicates that the respective decisions in the households were made by male only.

2.5 Estimation methods

Considering that the production diversity measures of simple species count and food group count are count variables, we employ fixed-effects Poisson model to estimate the determinants of production diversification. For the SID measure, which is a fractional variable ranging from zero to one, we run the pooled fractional probit (PFP) to have robust estimates (Papke and Wooldridge 2008) and employ correlated random effects (CRE) by adding the time averages of all time-varying independent variables to control for unobserved heterogeneity (Mofya-Mukuka and Hichaambwa 2018).

In the second part of the analysis, we estimate the determinants of household dietary diversity. Here, the main variables of interest are production diversity and women's participation in decision-making regarding household expenditures. The results from model specification tests, such as Breusch-Pagan and Hausman tests (available on request), suggest that pooled specification is more appropriate for our data. Nevertheless, we need to consider that farm diversification is also a decision that households make and it is likely to be affected by same unobservable household characteristics like skills, motivation, bond between family members and tradition to care for the well-being of the family that may also influence dietary quality. The results in pooled specification can be over or under estimated. To overcome these potential biases, we take the advantage of panel data and focus on changes within household over-time while controlling for time invariant unobservable household characteristics by employing fixed-effects model and adding a year dummy that controls for any unobserved special events (Islam et al. 2018; Muriithi and Matz 2015). We report findings from both pooled and fixed-effects models. Our dependent variables, HDDS and HDDS9, are count variables and Poisson model is the most appropriate choice of estimation. When appropriate, we estimate the models with clustered standard errors[2] at the village level to account for within village correlation.

3 Results and discussion

3.1 Sample characteristics

We start the analyses by firstly summarizing the households in Table 1. There has been a significant increase in average number of crop and livestock species produced from the first survey round to the second. A significant increase is also observed in the average number of food groups produced. On average, households are observed to produce seven species that belong to three food groups. Mean dietary diversity significantly improved in the second round, which, however, is not the case when considering only 9 food groups. Looking into intra-household decision-making, from the first to the second round, there has been a significant increase in the average share of households where males decide regarding expenditures. This share has significantly fallen for the cases where only females are the decision makers. In the decision domains for both crop production and household expenditures, households mostly fall into the joint decision-making category. Average landholding, total livestock unit, and expenditure on durables and services have increased indicating improvements in the wealth statuses of the sampled households over the years. Moreover, on average, we observe significant increases in commercialization and adoption of crop rotation or intercropping practices. All these improvements may be associated with an observed increase in mean dietary diversity. We examine this association after studying the main determinants of production diversification.

3.2 Diversity in farm production

Table 2 reports the results from regression analyses where we estimate the determinants of production diversification at household level. Employing three measures of production diversification as left hand-side variables (LHV), we run PFP with CRE and fixed-effects models. Results indicate that area dedicated to crop production and adoption of crop rotation or intercropping practices associate with richness and evenness of cultivated crop species (i.e. SID) and the number of different crop and livestock species produced (i.e. species count). We also observe a negative association of non-farm income with these two outcome variables. This means that the households who are more dependent on agriculture are probably more motivated to diversify their agricultural production as an ex-ante risk management strategy. Moreover, involvement of women, be it sole or jointly, in decision-making processes regarding crop grown significantly and positively associates with the number of species and food groups produced. We do not observe any significant association when concentrating on SID that captures both the evenness and richness of crop species. This could be due to women being involved in the decision-making on a small part of the total cropped area, such as on the crops grown in the kitchen gardens. This changes the number of crops and crop groups grown, but, since kitchen gardens are relatively small, their contribution to SID is diluted. Figure 1 depicts the extent of crops where the decision to grow them is made solely by women (hereafter referred to as women's crop). In 50% and 62% of the cases, women's crops are grown in less than one-fifth of the total cultivated area in 2014 and 2016, respectively.

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[2] The are 29 clusters. To check for any potential over-rejection of null effect size, we employ procedure described in Cameron et al. (2008). We do so using clusterbs command in STATA 15 by Menger (2015). We run the model with 5000 bootstrap iterations. Overall, results do not change.

Table 1 Summary statistics

Variables	Description	Year: 2014	Year: 2016	Mean difference
Diversity indicators				
SID	Simpson's Index of Diversification.	0.54 (0.20)	0.56 (0.21)	0.01
Species count	Number of different crops and livestock species produced per HH in past 12 months.	7.16 (2.83)	7.75 (3.02)	0.58***
FGPD	Food group production diversity. Number of different food crops and animal products produced belonging to different food groups. Maximum of 9 food groups considered.	2.65 (1.16)	3.83 (1.30)	1.18***
HDDS	Household dietary diversity score.	6.36 (1.68)	6.71 (1.51)	0.35**
HDDS9	Household dietary diversity score based on nine food groups that better reflect micronutrient adequacy.	4.23 (1.38)	4.21 (1.34)	−0.02
Decision-making variables				
Decision-making regarding crop grown – None	=1 if there was no female participation in decision-making regarding any crop grown.	0.27 (0.44)	0.31 (0.46)	0.04
Decision-making regarding crop grown – Joint	=1 if there was a joint decision-making regarding at least one crop grown.	0.64 (0.48)	0.58 (0.49)	−0.06
Decision-making regarding crop grown – Sole	=1 if female solely made a decision on at least one crop grown.	0.09 (0.29)	0.12 (0.32)	0.03
Decision-making regarding household expenditure– None	=1 if there was no female participation in decision-making regarding any type of HH purchases.	0.03 (0.16)	0.14 (0.34)	0.11***
Decision-making regarding household expenditure – Joint	=1 if there was a joint decision-making regarding at least one any type of HH purchases.	0.56 (0.50)	0.57 (0.49)	0.01
Decision-making regarding household expenditure – Sole	=1 if female solely made a decision on at least one type of HH purchases.	0.41 (0.49)	0.29 (0.45)	−0.12***
Other household level socio-economic indicators				
Household (HH) head sex	= 1 if the HH head is Female.	0.14 (0.35)	0.15 (0.36)	0.01
HH head age	Age of the HH head (years).	44.20 (13.59)	47.26 (13.03)	3.06***
HH head edu	Years of formal schooling for the HH head (years).	3.23 (3.56)	3.20 (3.57)	−0.03
HH size	Number of HH members.	6.46 (2.19)	6.54 (2.26)	0.09
Landholding	Total land area of parcels owned or rented.	1.43 (1.17)	1.66 (1.55)	0.23**
Cultivated land	Total cultivated land area	1.32 (1.08)	1.56 (1.46)	0.24**
Market distance	Travel time; minutes it takes to get to the nearest periodic market.	52.40 (45.05)	47.27 (39.96)	−5.14
Agricultural asset value	Value of agricultural assets owned (1000 Ethiopian Birr (ETB)).	0.60 (1.46)	0.80 (1.69)	0.20
Non-farm income	Income from non-farm activities in past 12 months (1000 ETB).	2.60 (6.81)	3.62 (7.81)	1.02
Expenditure on durables and services	Total expenditure on durables and services in the past 30 days (1000 ETB).	0.13 (0.01)	0.22 (0.02)	0.09***
Total livestock unit	Total livestock unit owned. Factors are: cattle = 0.7, sheep and goats = 0.1, chicken = 0.01. (Harvest Choice 2011)	3.89 (4.34)	4.69 (4.71)	0.80**
Extension	= 1 if HH received extension in past 12 months.	0.70 (0.46)	0.69 (0.46)	−0.01
Rotation/Intercropping	HH is aware of and employs crop rotation or intercropping practices or both.	0.48 (0.50)	0.69 (0.46)	0.21***
Share sold	Average share of crop harvest sold (%) in past 12 months. Calculated for each crop grown and averaged at household level.	27.99 (22.59)	32.09 (23.79)	4.10**
Remittance	=1 if HH received any remittance in past 12 months.	0.08 (0.28)	0.10 (0.30)	0.02

Standard deviations in parenthesis. Average exchange rates: in 2014, 1 USD ≈ 19.7 ETB; in 2016, 1 USD ≈ 21.8 ETB (Exchange Rates UK 2019); *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

3.3 Production diversity, decision-making, and dietary quality

Table 3 shows the estimation results of pooled and fixed-effects Poisson models where our main right-hand side (RHS) variables of interest are production diversity measures and women's decision-making regarding purchased food. Left-hand side (LHS) variable is HDDS. We also employ HDDS9 as LHS variable and report results in Appendix Table 5. All production diversity measures are

Table 2 Production diversification: PFP with CRE and fixed-effects model estimates

Variables	PFP with CRE LHV: SID	Fixed-effects LHV: Species count	LHV: FGPD
Decision-making regarding crop grown – Joint	0.068	0.096***	0.149***
	(0.060)	(0.032)	(0.042)
Decision-making regarding crop grown – Sole	0.029	0.135**	0.163**
	(0.099)	(0.061)	(0.071)
Input distance	−0.000	−0.000	0.000
	(0.001)	(0.000)	(0.001)
Market distance	−0.001	−0.000	−0.000
	(0.001)	(0.001)	(0.001)
Agricultural asset value (1000 ETB)	−0.011	0.004	0.009
	(0.016)	(0.011)	(0.010)
Cultivated land (ha)	0.064**	0.046***	0.020
	(0.027)	(0.013)	(0.018)
Total livestock unit	0.014	0.029***	0.014**
	(0.009)	(0.006)	(0.007)
Non-farm income (1000 ETB)	−0.007**	−0.005**	−0.002
	(0.003)	(0.002)	(0.002)
Expenditure on durables and services (1000 ETB)	−0.065	0.100**	0.118**
	(0.107)	(0.045)	(0.050)
Rotation/Intercropping	0.154**	0.113***	0.046
	(0.060)	(0.036)	(0.041)
Irrigation	0.035	0.257***	0.062
	(0.145)	(0.083)	(0.092)
Extension	0.076	−0.018	0.010
	(0.082)	(0.045)	(0.053)
[Extension] x [Main information – crop management]	0.084	0.048	0.057
	(0.059)	(0.034)	(0.044)
Observations	726	726	726
Wald χ^2	141.45**	109.61***	279.88***

Robust standard errors in parenthesis. Estimation controls for head sex, head age, head education, HH size, dependency ratio, and year 2016 that are not reported due to space limitations. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

positively associated with HDDS in both pooled and fixed-effects specifications. In pooled specification, we observe that an increase in the number of species produced is associated with a 1.5% increase in the number of food groups consumed. Increasing the production by one food group is associated with a 3.4% increase in HDDS. In the fixed-effects specification, a unit increase in the number of species and food groups produced are associated with 1.1% and 2.1% higher HDDS, respectively. Overall, the magnitudes are very small. The magnitude of women's participation in decision-making regarding household expenditures is generally much larger than that

of production diversity measures. We observe that decision-making regarding household expenditures made jointly and by women only are associated with around 9% and 13% increases in HDDS, respectively. The results are similar when restricting diet diversity to nine food groups (see Appendix Table 5). Moreover, wealth indicators significantly and positively associate with dietary quality. Overall, we observe that wealth and women's participation in decision-making are robust determinants of dietary diversity. Market distance and commercialization are significantly associated with dietary quality in pooled specification, but not when concentrating on changes within households over time.

The magnitudes of association between different production diversity measures and dietary quality are small. Furthermore, diversification interacts with other household characteristics that modify these magnitudes. For example, if we compare a household with high non-farm income who is less dependent on agriculture with a household with no or very low non-farm income, production diversification can be more significant for the latter in terms of dietary quality. The same can be hypothesized when comparing mostly market-oriented household with highly subsistence-oriented households. This conditionality of the association demands the analysis to be extended before meaningful conclusions with better credibility can be reached.

3.4 Extended model of association between production and dietary diversity

The association of production diversity with dietary diversity is conditional on household characteristics. For example, the benefit of diversification for households that are highly market-oriented or that specialized in the production of specific crop or livestock is questionable. Considering the importance of a household's market orientation, we extend the model by adding an interaction term of the production diversity measures with market participation, which is captured by the average share of crop product sold. Household consumption is rarely attributable to only on-farm production. Considering that households in close distances to the markets have possibilities to also diversify their diets by purchasing from markets, it is plausible to hypothesize larger magnitudes of association between production diversity and dietary diversity for households that are further away from the markets. Moreover, the level of non-farm income can define the significance of on-farm production diversity for dietary quality. Diversification can reflect more gains in dietary diversity for households with limited or no income options outside agricultural production. Thus, we further interact market distance and non-farm income,

Fig. 1 Frequency histogram: the share of women's crop (i.e. solely decided by women) in total cropped area for households that fall into sole female decision category
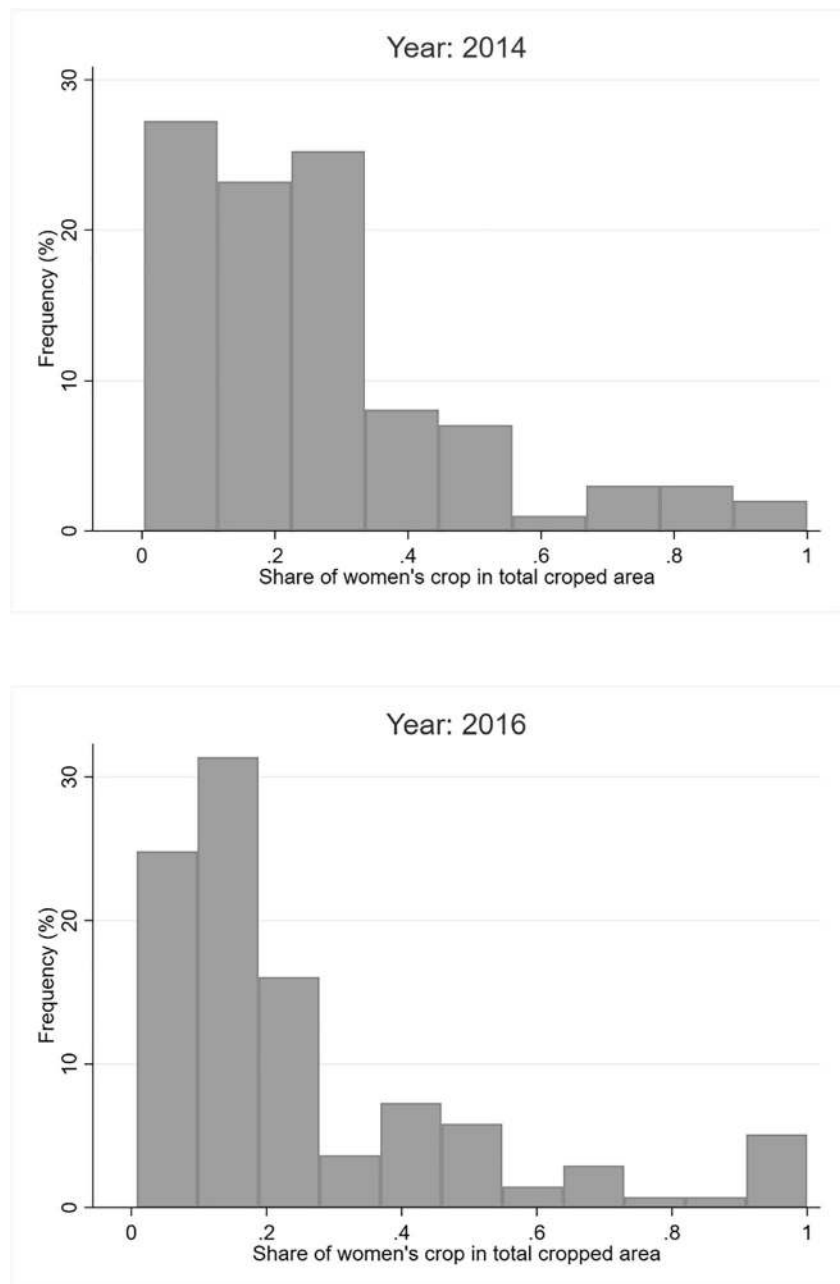
respectively, with diversity measures. Moreover, considering the foregone benefits from specialization in already highly diversified farms, we include a square of the diversity terms into the analyses. We extend our model to have a clearer understanding of the association between production and dietary diversity.

Table 4 reports the estimation results of the extended model of dietary quality. It is important to highlight that we cannot make any immediate conclusions from Table 4. Insignificant coefficient of interaction term neither means that there is no interaction nor the interaction term should be dropped. The coefficient of interaction term should

neither be interpreted as marginal effect nor assumed as meaningful conditional effect. This effect can be of opposite sign, significant and insignificant depending on the actual values of interacting variables (Ai and Norton 2003; Brambor et al. 2006). Although the coefficients of interaction terms are insignificant, it is possible that the marginal effect of production diversity is significant for a range of the other terms that are interacted with production diversity measures. The opposite is also true.

We follow the recommendation of Brambor et al. (2006) and calculate the marginal effect of production diversity indicators along with respective standard errors

Table 3 Dietary quality: pooled and fixed-effects Poisson model estimates

Variables	Pooled models			Fixed models		
	RHS: SID	RHS: species count	RHS: FGPD	RHS: SID	RHS: species count	RHS: FGPD
Production diversity	0.130**	0.015***	0.034***	0.126*	0.011**	0.021*
	(0.053)	(0.003)	(0.006)	(0.075)	(0.005)	(0.011)
Decision-making regarding household expenditure – Joint	0.063*	0.058*	0.063*	0.098**	0.103**	0.104**
	(0.037)	(0.035)	(0.036)	(0.048)	(0.047)	(0.047)
Decision-making regarding household expenditure – Sole	0.111***	0.103***	0.111***	0.129**	0.130**	0.136***
	(0.041)	(0.038)	(0.040)	(0.051)	(0.051)	(0.051)
Landholding	0.002	−0.000	0.004	0.007	0.005	0.008
	(0.007)	(0.007)	(0.007)	(0.012)	(0.011)	(0.011)
Total livestock unit	0.011***	0.010***	0.010***	0.011**	0.009*	0.010**
	(0.002)	(0.002)	(0.002)	(0.005)	(0.005)	(0.005)
Non-farm income (1000 ETB)	0.004***	0.004***	0.004***	0.003*	0.003**	0.003*
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
Expenditure on durables and services (1000 ETB)	0.103***	0.089***	0.082***	0.075**	0.061*	0.060*
	(0.024)	(0.024)	(0.026)	(0.037)	(0.036)	(0.036)
Remittance	0.041	0.034	0.033	0.044	0.042	0.044
	(0.026)	(0.024)	(0.026)	(0.044)	(0.045)	(0.044)
Market distance	−0.001**	−0.001**	−0.001**	−0.000	−0.000	−0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Share sold	0.001**	0.001**	0.001*	0.001	0.000	0.001
	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
Observations	726	726	726	726	726	726
Wald χ^2	727.89**	536.75**	641.70**	48.33***	53.08***	51.88***

Village level clustered and robust standard errors in parenthesis for pooled and fixed-effects models, respectively. Estimation controls for head sex, head age, head education, HH size, dependency ratio and year 2016 that are not reported due to space limitations. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

on HDDS in meaningful ranges of the modifying terms. Figure 2 depicts how the marginal effect of SID on dietary diversity changes depending on the values of non-farm income, market distance and share of harvest sold. It is also important to know how the study population falls within the reported ranges. Thus, we visualize the distribution of the households as histogram in the background. The marginal effect intervals (i.e. whiskers) that include zero implies that there is no statistical significance. The figure shows that SID is positively associated with dietary diversity when there is no or low non-farm income. The association becomes statistically insignificant above non-farm income of 10,000 ETB per year. In very close distances to the market, SID shows no association with dietary diversity. The magnitude of the association is larger when market is distant. Moreover, we find no significant association between SID and dietary diversity for highly market-oriented farmers.

A unit change in SID means full diversification, thus magnitudes of the association between production diversity and dietary quality can be interpreted more easily for the species count and food group count measures. We depict how the marginal effects of species count and FGPD on HDDS change depending on the values of non-farm income, market distance and share of the harvest sold in Figs. 3 and 4, respectively. We find significant association between species count and dietary quality when the closest market is distant, household is mostly subsistence oriented, and there is no or very low non-farm income. Within the 95% confidence interval (CI), a unit increase in species count associates, at highest, with consuming around 0.09 more food groups. In other words, an average farmer (i.e. in terms of other covariates than market distance) would need to grow eleven more species on top of already produced seven species to increase the dietary diversity by one unit. The literature has somewhat similar findings; Chegere and Stage (2020) find that an average household in Tanzania would need to produce nine more species to increase dietary diversity by one more food group. Moreover, meta- analysis by Sibhatu

Table 4 Extended model of dietary quality: fixed-effects Poisson model estimates

Variables	Fixed-effects models		
	SID	Species count	FGPD
Production diversity	−0.367	0.015	0.078**
	(0.250)	(0.016)	(0.036)
Production diversity square	0.531**	−0.000	−0.009*
	(0.256)	(0.001)	(0.005)
[Production diversity] x [non-farm income]	−0.007	−0.000	0.000
	(0.009)	(0.001)	(0.001)
[Production diversity] x [share sold]	−0.002	−0.000**	−0.000
	(0.002)	(0.000)	(0.000)
[Production diversity] x [market distance]	0.003**	0.000**	0.000**
	(0.001)	(0.000)	(0.000)
Market distance	−0.002**	−0.002**	−0.001*
	(0.001)	(0.001)	(0.001)
Share sold	0.001	0.003**	0.001
	(0.001)	(0.001)	(0.001)
Non-farm income	0.008	0.007	0.002
	(0.006)	(0.006)	(0.004)
Decision-making regarding household expenditure – Joint	0.096**	0.103**	0.106**
	(0.047)	(0.045)	(0.047)
Decision-making regarding household expenditure – Sole	0.126**	0.132***	0.135***
	(0.050)	(0.049)	(0.050)
Observations	726	726	726
Wald χ^2	66.00***	75.73***	67.81***

Robust standard errors in parenthesis. Estimation controls for head sex, head age, head education, HH size, dependency ratio, total livestock unit, landholding, monthly expenditure on durables and services, remittance and year 2016 that are not reported due to space limitations. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

and Qaim (2018b) also finds that in Sub-Saharan Africa, an average farmer would need to diversify the farm by nine more crop or livestock species in order to boost dietary diversity by one food group.

An increase in one food group produced is associated with better dietary diversity up to non-farm income of 14,000 ETB per year, and even then, the magnitude is very small (i.e. 0.06 at highest). Extending production by one additional food group is associated, at highest, with consuming 0.14 more food groups. We find that producing another crop or livestock or increasing production by one food group is associated with higher diet diversity for farmers that consume 50 to 70% of their production. This means that for mostly market-oriented farmers, there is no direct potential gain in dietary diversity from further diversification. The results are similar when HDDS is replaced by the HDDS9 specification (see Appendix Table 6, Figs. 5 and 6). We also interacted production diversity measures with decision-making variables to check if gendered decision-making aspects modify the magnitude of the association between production

and dietary diversity. Overall, there is no significant modification to the extended model. In spite of the fact that women's sole or joint decision-making related to household expenditures is better for dietary diversity than sole male decision-making, it does not modify the association between production diversity and dietary quality. This finding is similar to the finding from Malawi by Jones et al. (2014).

4 Conclusions and policy implications

Nutrition-sensitive agricultural research and programs have gained much attention in recent years which is justified considering that all forms of undernutrition can be widely observed in the poorest rural smallholders whose livelihoods, to a great extent, depend on agriculture. One example of such programs and research may include activities related to on-farm diversification that is believed to contribute to the diets of rural poor. So far, research has
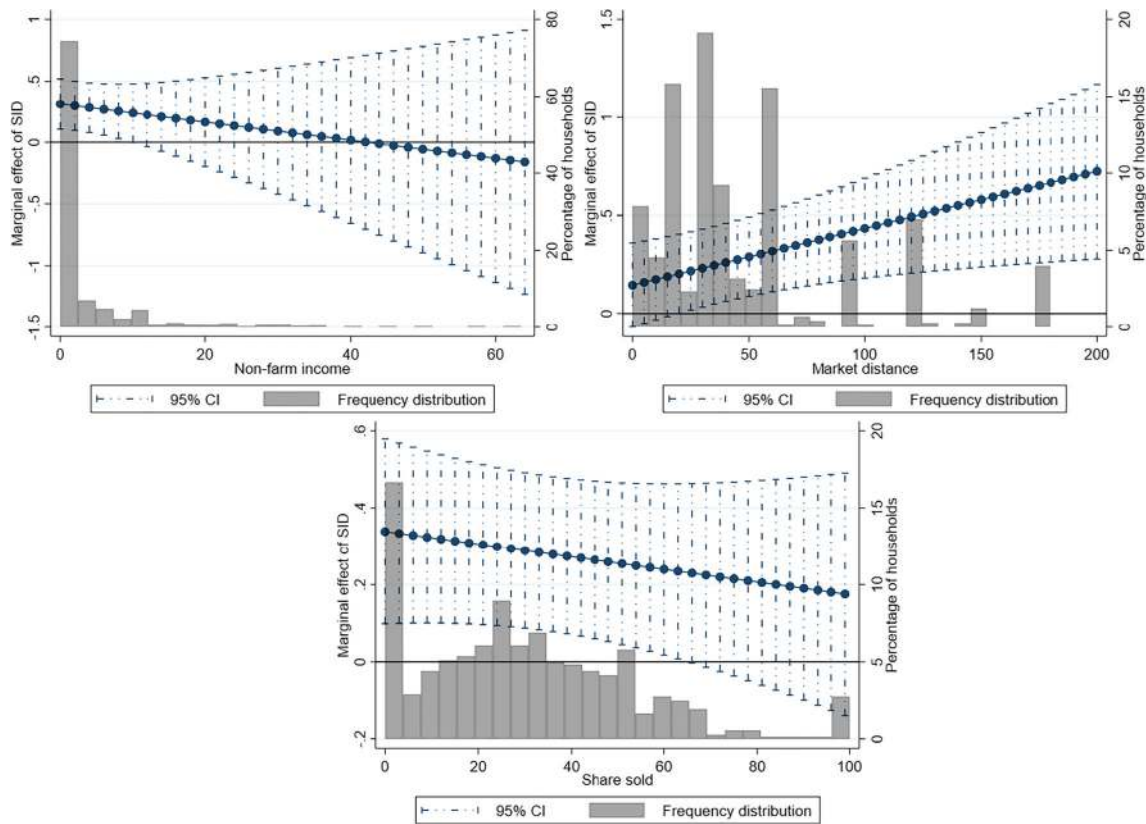
Fig. 2 The marginal effects of SID on HDDS along values of non-farm income, market distance, and share sold
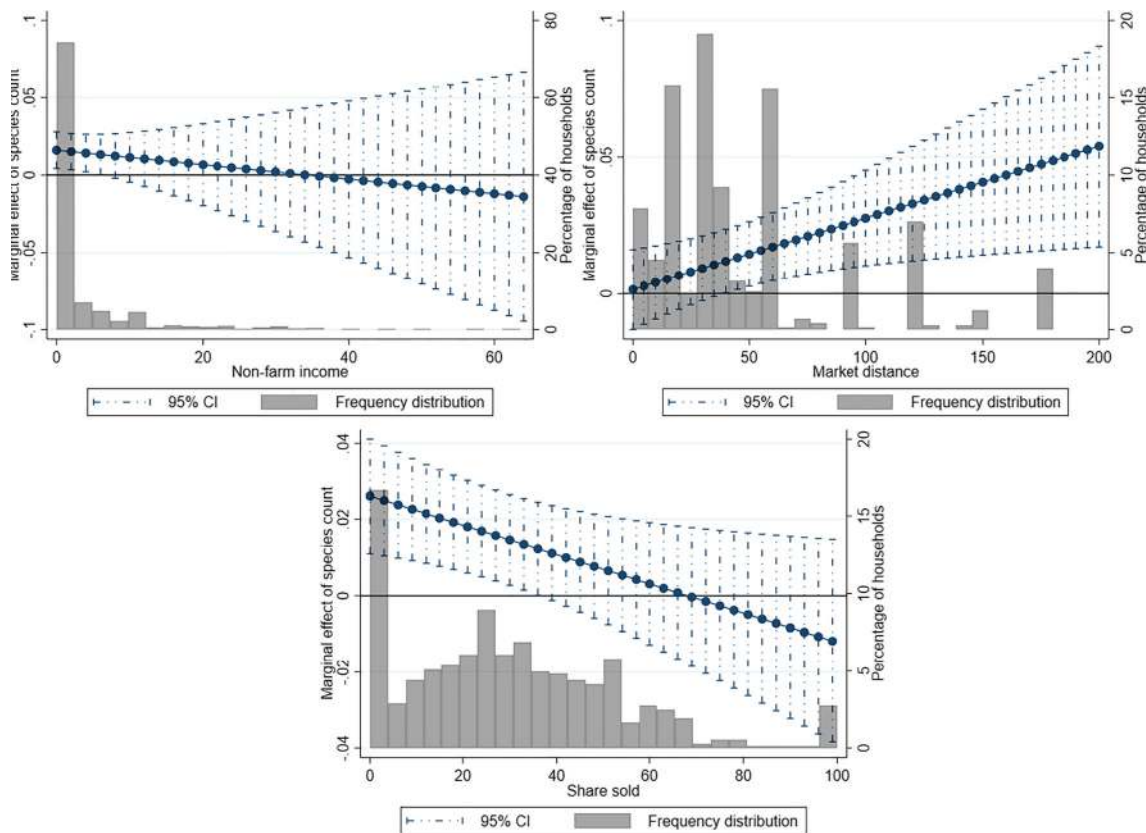

Fig. 3 The marginal effects of species count on HDDS along values of non-farm income, market distance, and share sold
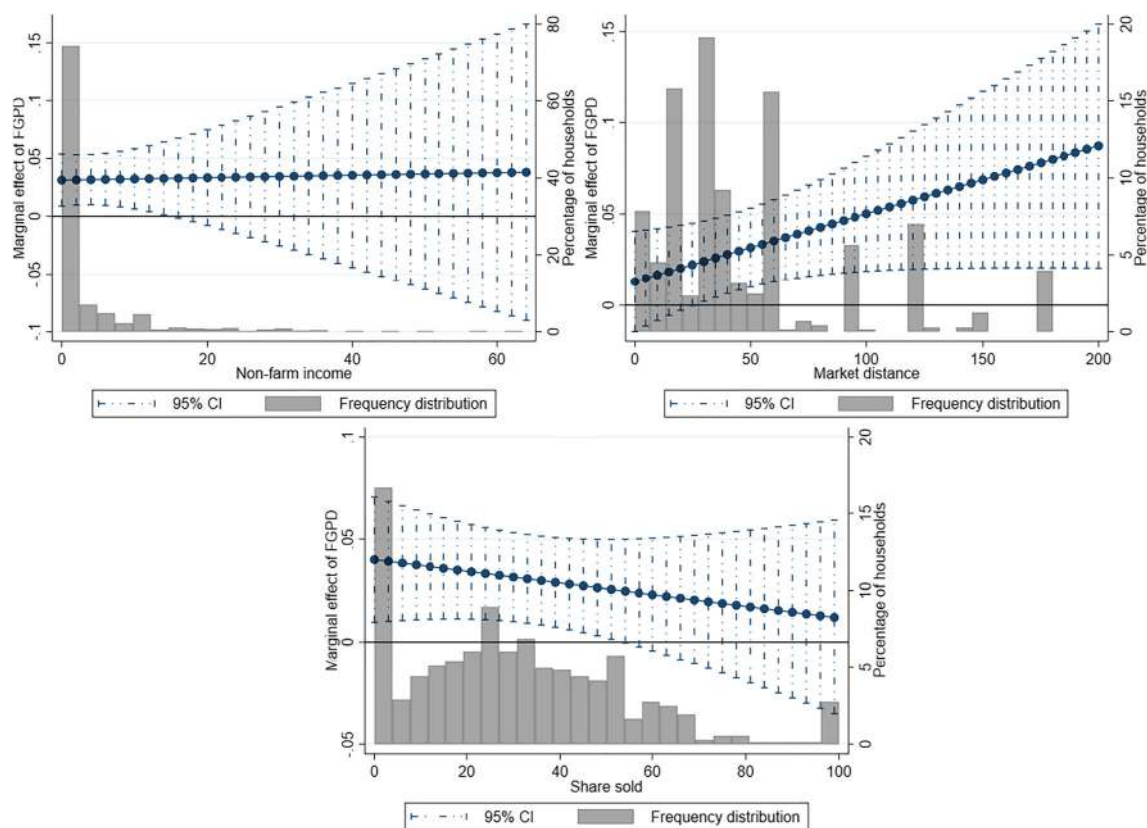
Fig. 4 The marginal effects of FGPD on HDDS along values of non-farm income, market distance, and share sold

found mixed results and significance of this association seems to be case specific.

Using panel data from Ethiopian rural households, we concentrated on production diversity at household level and looked into its association with dietary quality. Considering that this association is complex and likely to be significantly influenced by the availability of non-farm income, distance to markets and market orientation of the households, we employed regression models with interaction terms to gain more insight into the analysis. Doing so, we also highlighted the more detailed method of interpreting the results. Furthermore, as both production and dietary diversification are decisions made by households, we examine if female participation in decision-making is linked to both livelihood outcomes, and if it can modify the magnitude of the association between production and dietary diversity.

We added year dummies in household fixed-effect regression to be able to capture the effect of any special event that might have occurred from first to the second round of the survey and would affect all households equally. Nevertheless, the analyses are limited in controlling for time-variant unobservable heterogeneity that could bias the estimations. Thus, the results are cautiously interpreted as associations.

We found that the size of the cultivated area and adoption of crop rotation or intercropping practices are linked to household level production diversity. While non-farm income was negatively associated with species count and SID that captures both the evenness and richness of crop species, female participation in decision-making variables regarding the crops produced were associated with a higher species counts and food groups produced. In addition, female participation in decision-making was also associated with better dietary quality. On the relationship between production diversity and dietary quality, we found that diversification can be a strategy to improve diet of rural poor who is highly and directly dependent on agricultural income, who lives far from the markets, and is mostly subsistence oriented. Yet, even in these cases the viability of achieving better dietary quality through production diversification is highly questionable, as the low magnitudes of the association mean that unrealistic changes in production diversification would be required. Moreover, in respective domains, households with women's participation in decision-making are associated with higher production and dietary diversity than those with sole male decision-making. However, it does not modify the association between production and dietary diversity.

We highlighted in this article an important covariate, which is gendered aspects of intra-household decision-making, for

production diversity and dietary quality. We also highlighted the in-depth interpretation of the results when using interaction terms. Researchers should employ this in-depth approach to better assist practitioners. Furthermore, although we observe positive association between production diversity and dietary quality, this association is highly case specific. Development programs aiming to contribute to food security could adopt production diversification strategy only in rural areas with very limited market access and a lack of non-farm income possibilities; but even then, its viability is questionable. We find strong association between dietary diversity and female decision-making power and wealth indicators. Therefore, gender-inclusive social and economic development policies together with infrastructural and market development projects that contribute to household wealth and women's empowerment are recommended, as they are more promising than on-farm diversification in increasing the dietary quality.

Future literature could contribute to our knowledge base by concentrating more on district level production diversity that is likely to determine the market diversity and affordability at district level. Moreover, association between diversity in the district markets and district level food security should be rigorously investigated.

Compliance with ethical standards

Conflict of interest The authors declared that they have no conflict of interest.

Appendix

Table 5 Dietary quality (HDDS9): pooled and fixed-effects Poisson model estimates

Variables	Pooled model			Fixed effects model		
	SID	Species count	FGDS	SID	Species count	FGPD
Production diversity	0.139***	0.020***	0.051***	0.126	0.015**	0.033**
	(0.054)	(0.004)	(0.009)	(0.099)	(0.007)	(0.014)
Decision-making regarding household expenditure – Joint	0.107**	0.099**	0.105**	0.109*	0.111*	0.112*
	(0.049)	(0.047)	(0.049)	(0.066)	(0.064)	(0.065)
Decision-making regarding household expenditure – Sole	0.153***	0.141***	0.151***	0.122*	0.118*	0.126*
	(0.053)	(0.051)	(0.052)	(0.070)	(0.069)	(0.069)
Landholding	−0.005	−0.008	−0.002	0.012	0.009	0.013
	(0.008)	(0.008)	(0.009)	(0.018)	(0.017)	(0.017)
Total livestock unit	0.014***	0.012***	0.013***	0.013*	0.011	0.012
	(0.002)	(0.002)	(0.002)	(0.008)	(0.007)	(0.007)
Non-farm income (1000 ETB)	0.004***	0.005***	0.004***	0.004*	0.004*	0.004*
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Expenditure on durables and services (1000 ETB)	0.131***	0.114***	0.101***	0.097**	0.079*	0.076*
	(0.032)	(0.034)	(0.036)	(0.045)	(0.045)	(0.045)
Remittance	0.040	0.031	0.027	0.057	0.054	0.058
	(0.033)	(0.030)	(0.032)	(0.059)	(0.060)	(0.058)
Market distance	−0.000	−0.000	−0.001*	−0.000	−0.000	−0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Share sold	0.001*	0.001	0.001	0.001	0.000	0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Observations	726	726	726	726	726	726
Wald χ^2	432.38***	414.23***	432.84***	30.08**	37.23***	38.16***

Village level clustered and robust standard errors in parenthesis for pooled and fixed-effects models, respectively. Estimation controls for head sex, head age, head education, HH size, dependency ratio, and year 2016 that are not reported due to space limitations. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 6 Extended model of dietary quality (HDDS9): fixed-effects Poisson model estimates

Variables	Fixed-effects model		
	SID	Species count	FGPD
Production diversity	−0.573*	0.017	0.109**
	(0.315)	(0.020)	(0.047)
Production diversity square	0.803**	0.000	−0.012*
	(0.342)	(0.001)	(0.006)
[Production diversity] x [non-farm income]	−0.010	−0.001	0.001
	(0.012)	(0.001)	(0.001)
[Production diversity] x [share sold]	−0.002	−0.000*	−0.000
	(0.003)	(0.000)	(0.000)
[Production diversity] x [market distance]	0.003*	0.000**	0.000*
	(0.002)	(0.000)	(0.000)
Market distance	−0.002*	−0.002**	−0.001
	(0.001)	(0.001)	(0.001)
Share sold	0.001	0.003	0.002
	(0.001)	(0.002)	(0.002)
Non-farm income	0.010	0.012	0.001
	(0.008)	(0.008)	(0.005)
Decision-making regarding household expenditure – Joint	0.107*	0.110*	0.111*
	(0.065)	(0.063)	(0.064)
Decision-making regarding household expenditure – Sole	0.118*	0.120*	0.122*
	(0.069)	(0.067)	(0.068)
Observations	726	726	726
Wald χ^2	41.04**	55.65***	52.43***

Robust standard errors in parenthesis. Estimation controls for head sex, head age, head education, HH size, dependency ratio, total livestock unit, landholding, expenditure on durables and services, remittance, and year 2016 that are not reported due to space limitations. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
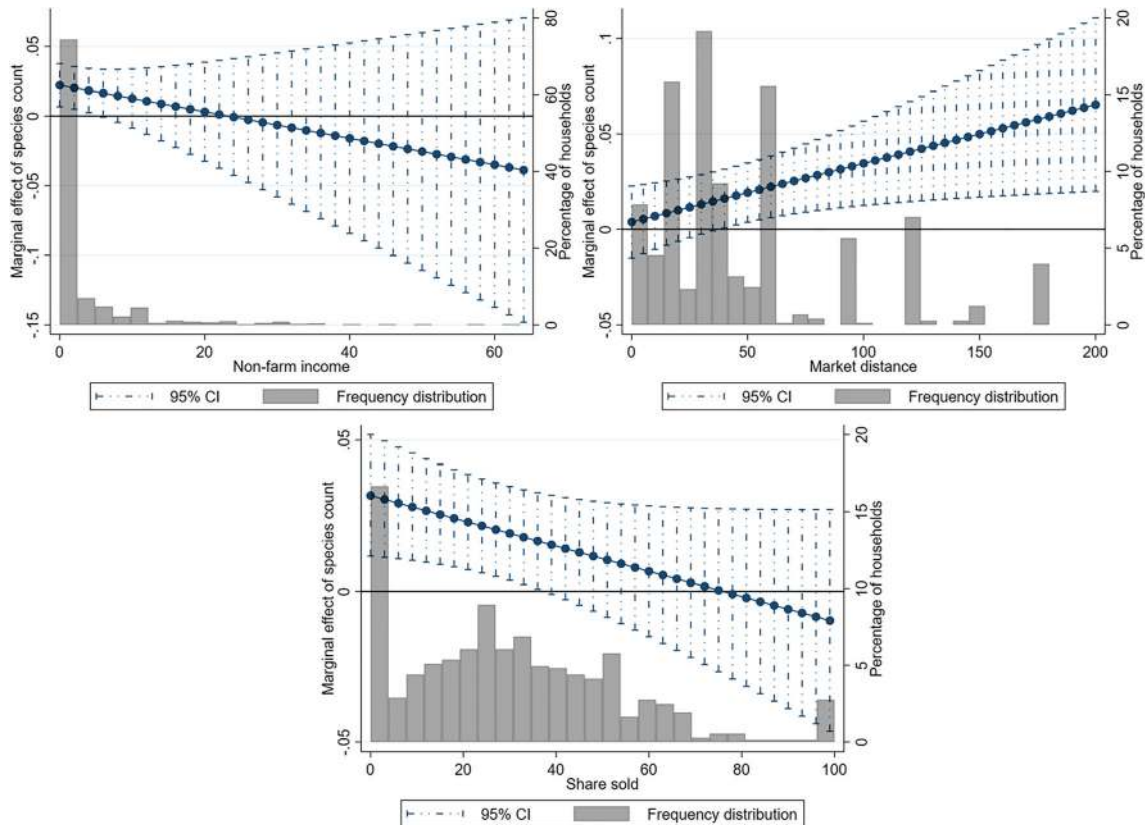

Fig. 5 The marginal effects of species count on HDDS9 along values of non-farm income, market distance, and share sold
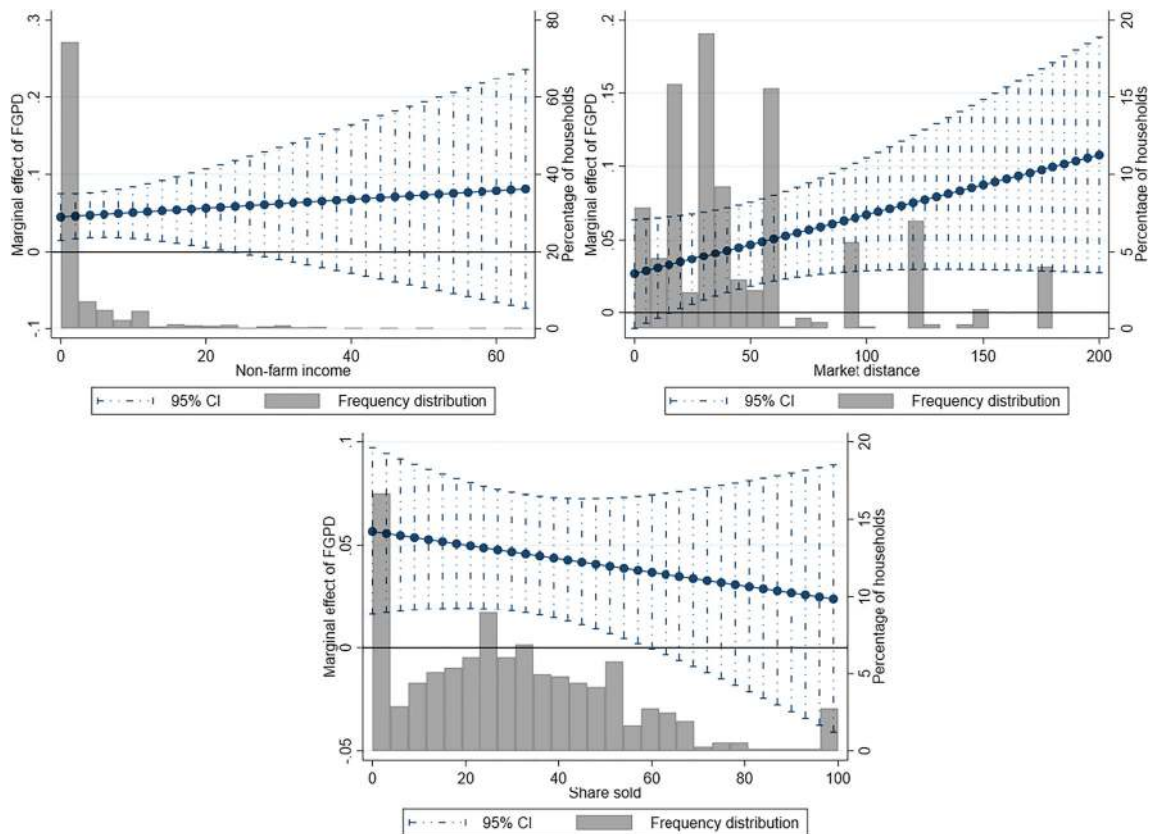
Fig. 6 The marginal effects of FGPD on HDDS9 along values of non-farm income, market distance, and share sold

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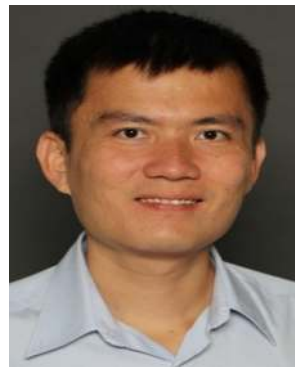
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