# From Farm to Kitchen: How Gender Affects Production Diversity and the Dietary Intake of Farm Households in Ethiopia

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### Abstract

*Malnutrition in farm households remains a significant problem in many developing countries and is linked to a lack of diversity in diets. We explore how gender differences might affect household dietary diversity using the LSMS-ISA Ethiopia panel dataset. Drawing on a farm household framework, nonlinear panel models are estimated allowing for unobserved heterogeneity and production endogeneity using a control function. We use decomposition techniques to identify the impact of different potential sources of gender difference in dietary diversity. Our results provide evidence of significant gender effects in production diversity and in dietary diversity using the food variety score (FVS). For other indicators of dietary diversity, the evidence of gender effects is weaker. The decomposition results suggest that, after controlling for differences in characteristics, female-headed households are at a dietary diversity disadvantage. Gender differences in the relationship between production diversity, price and income and dietary diversity and the production diversity decisions appear to be the main drivers. The results also suggest that female preferences are more orientated towards ensuring greater dietary diversity in the household. Our evidence also suggests that a key driver of gender disadvantage in dietary diversity is related to whether food is sourced from the household's own production or the market. This implies that*

*part of the observed negative gender impact on dietary diversity may stem from differences in marketing and storage of own production through the year.*

**Keywords:** *Dietary diversity*; *Ethiopia*; *gender*; *production diversity*.

**JEL classifications:** *Q12, Q18, Q01.*

## 1. Introduction

Malnutrition is a global challenge affecting over 800 million people who mostly live in developing countries (FAO, 2016). Evidence from sub-Saharan Africa suggests that less diversified diets lead to micronutrient malnutrition which, in turn, leaves individuals susceptible to diseases in the short run and cognitive problems in the long run (Eckhardt, 2006). In Ethiopia, both food security and nutrition security are major problems. Diets are dominated by cereals, root and tuber crops with limited consumption of animal products, fruits and vegetables (Beyero *et al.*, 2015). Together these contribute to high levels of malnutrition and deaths, particularly for children aged under five (Ayele and Peacock, 2003).

Historically, policy-makers in Ethiopia have tended to consider malnutrition as a cross-cutting issue with improved nutrition best supported through wider health and livelihood interventions (Beyero *et al.*, 2015). However, in 2008, the National Nutrition Policy (NNP) was launched to improve nutrition and coordinate stakeholder decisions, reflecting the perspective that nutrition is a problem which needs to be addressed directly, as well as indirectly through other policies (Ersino *et al.*, 2018).

Despite a decade of double-digit economic growth, Ethiopia's economy is dominated by subsistence agriculture, which contributes 40% to gross domestic product and employs 80% of the population (UNDP, 2015). Agro-climatic conditions favour multiple cropping patterns (Alemayehu *et al.*, 2011) and most Ethiopian small-scale producers engage in diversified agricultural production. This practice is an important risk mitigation strategy and also crucial for soil fertility management (Di Falco *et al.*, 2010).

Subsistence agriculture serves a dual purpose in relation to the nutrition of farm households (Ruel *et al.*, 2013). First it can provide a direct source of healthy and diverse food (Hoddinott *et al.*, 2015; Romeo *et al.*, 2016). Second, agricultural output surplus to household needs can be sold to provide a source of income which can be spent on other things including, potentially, food produced elsewhere.

Research on the effect of production diversity on the dietary diversity of farm households has been relatively extensive, with evidence from Malawi, Tanzania and Kenya all finding a positive contribution of production diversity on consumption diversity,[1] albeit at different scales (Chavas and Falco, 2012; Jones *et al.*, 2014; Sibhatu *et al.*, 2015; Koppmair *et al.*, 2017).

Gender is also recognised as a key influence on the pathway through which farming decisions affect diet and the nutritional outcomes in farm households (Carletto *et al.*, 2015), Women are integral to agriculture and food production in Ethiopia, constituting between 45% to 75% of the agricultural labour force (FAO, 2011). There are well-known gender differences in agricultural production, including in relation to input use, access to resources and preferences (FAO, 2011; Croppenstedt *et al.*, 2013). Female farmers often have more limited access to resources and inputs relative to

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[1]We use the terms consumption diversity and dietary diversity interchangeably.

male farmers with plots owned by women less productive compared to plots owned by men (Udry, 1996; Sheahan and Barrett, 2017). Kasa *et al.* (2015) and Aregu *et al.* (2010) also suggest that male and female plot holders make different constrained crop choices. In particular, women are known for their 'food first' agenda and often grow traditional crops which are meant for home consumption and have limited or no market value (World Bank, 2009), while men target cash crops (Aregu *et al.*, 2010). As primary carers, women are most involved in the preparation of food and childcare. This burden is greater within female-headed households who bear responsibility for both domestic and farm work. In Kenya, female-headed households were found to allocate more scarce resources to their family's food needs, especially to their children, increasing the share of child welfare to income ratio (Onyango *et al.*, 1994). Specific interventions have used these insights to try and improve the welfare of households. For example, the Dairy Goat Development Project implemented by FARM AFRICA, distributed improved goat breeds to female-headed households, resulting in improved consumption of animal sourced food. This was a result of both direct consumption and increased income from selling live goats and milk products (Ayele and Peacock, 2003).

While the role of women in 'mediating' the relationship between agriculture and nutrition in the household is well recognised (Carletto *et al.*, 2015), previous studies have not explored how gender affects household dietary diversity in a systematic way, allowing for the different pathways through which such effects might occur. For example, using a simple dummy variable, a number of studies have considered whether the gender of the head of household influences the level of dietary diversity. Passarelli *et al.* (2018) show in Ethiopia that female-headed households have higher consumption diversity, with similar results found by Dillon *et al.* (2015) for Nigeria. Weaker evidence of such effects was found for Uganda by Tesfaye and Tirivayi (2020) while other authors found no significant effects, for example Hirvonen and Hoddinott (2017) in Ethiopia and Koppmair *et al.* (2017) in Malawi. There is some evidence suggesting more complex gender effects influencing the relationship between own production and household dietary diversity. Romeo *et al.* (2016) show that the impact of production diversity is higher for female-headed households, while Malapit *et al.* (2015) find significant interactions between production diversity and women's empowerment. However, neither study controls for the potential endogeneity of production diversity in the household or for gender differences in the other routes determining consumption diversity.

Our aim is, therefore, to explore how gender affects dietary diversity in the household allowing for differences in the pathways between own production, household income, market prices and household dietary outcomes. To frame the analysis, we use a farm household model with production diversity. This allows intuition from standard demand theory to guide our empirical model specification, an approach typically lacking in previous studies. We use the estimated models to explore whether there are significant gender differences in the pathways affecting consumption diversity within the household. Following this, by applying standard decomposition techniques – for example, considering the impact if female-headed households acted as if they were male – we explore the relative importance of different means through which gender affects dietary diversity choices.

In contrast to most previous empirical studies in Africa (Jones *et al.*, 2014; Dillon *et al.*, 2015) our analysis is based on panel data which allow unobserved heterogeneity and the potential endogeneity of household production to be taken into account. In particular, utilising the country-wide rich panel data set available for Ethiopia, we use

a two-step pooled Poisson control function procedure to estimate nonlinear models (Papke and Wooldridge, 2008; Wooldridge, 2012). Given the market imperfections which small-scale farm households face, theory suggests that consumption and production are likely to be simultaneously determined, so not accounting for this means causal effects may not be well identified (Strauss, 1986; De Janvry *et al.*, 1991). Despite this, many other studies have not accounted for the potential endogeneity of production decisions (e.g. Sibhatu *et al.*, 2015; Koppmair *et al.*, 2017).

In the next section, we review existing understanding of the impact of the relationship between own production, own consumption and nutrition in farm households, particularly in Ethiopia and more generally in sub-Saharan Africa. To explain how food prices, income from farming, and consumption of own production influence nutritional outcomes, the section introduces an adapted farm household model with missing markets and discusses how, via shadow prices, this framework can be used to frame empirical specifications consistent with and widely used in the existing literature. Section 3 describes the data used in the empirical analysis. In the fourth section our empirical strategy is presented while Sections 5 and 6 present the results and conclusions.

## 2. Dietary Diversity and Farm Household Decisions

### 2.1. Background

For small-scale subsistence farm households like those in Ethiopia, production diversity has been shown to be important for households' dietary diversity (Pellegrini and Tasciotti, 2014; Romeo *et al.*, 2016; Pingali and Sunder, 2017). A range of evidence supports the claim that farm household production decisions and, in particular, the range of crops grown has a direct impact on household consumption and nutrition (Koppmair *et al.*, 2017) and, more generally, the food security and income of households (Michler and Josephson, 2017). As a major share of a farm household's produce is consumed by themselves, it is often expected that households that engage in more diversified agricultural production will consume more diversified food (Beyero *et al.*, 2015). Other authors, such as Fleuret and Fleuret (1980), have argued that when households substitute food crops with cash crops, this decreases food supply and makes them more vulnerable to weather and market risks. Further, there is some evidence of a negative relationship between production diversity and consumption diversity, possibly as a result of the income advantage forgone from not specialising (Sibhatu *et al.*, 2015).

Other studies have focused on how gender affects farm production decisions and hence also household consumption. It is widely recognised that there are gender differences in the use of inputs, access to resources and preferences in agriculture (FAO, 2011; Croppenstedt *et al.*, 2013). Early studies focused on the difference in production outcomes between male and female operated plots (Udry, 1996) and a substantial amount of research considers gender and efficiency in production. From this there is evidence that female-controlled farms tend to be less productive than those controlled by men (Akresh, 2005; Alene *et al.*, 2008). Although recent estimates suggest women contribute almost 25% of the total agricultural labour force in Ethiopia (Palacios-Lopez *et al.*, 2015), the widespread use of traditional farming methods along with cultural taboos and traditions mean that agriculture is perceived primarily as a male occupation (Aboma, 2006; Gebru, 2011). In particular, the need for physical strength – for example, traction with the plough or the control over animals – is seen to favour

men, and typically women have been less involved in land preparation and cultivation (Gella and Tadele, 2015). In contrast, women are very important in other parts of agricultural production, including weeding, harvesting, threshing, sorting and storing (Aregu *et al.*, 2011; Palacios-Lopez *et al.*, 2015). For example, Palacios-Lopez *et al.* (2015) report that women contribute to almost 40% of the labour used in harvesting in Ethiopian agriculture.

Gender differences in production and production choices also arise from women typically having lower levels of available resources such as land and livestock, lower levels of education and more severe labour constraints. Female-headed households also tend to have fewer household members and a higher number of dependents. These households typically use lower levels of purchased inputs and have lower rates of adoption of new technologies (Peterman *et al.*, 2014). Female farmers can also have greater difficulty accessing services supporting agricultural production and decisions. Cultural norms that restrict interactions between women and men outside the family may help explain why female farmers make less use of extension services than men, restricting women's ability or willingness to participate in extension activities with male extension agents or other male farmers. Further cultural, legal barriers and a lack of access to collateral mean that female-headed households are also less likely to access credit. Finally, there is some evidence that lack of access to transport limits the mobility of women and their capacity to get crops to market, while differences are observed in marketing channels, with women sometimes excluded from more formal channels (Meinzen-Dick *et al.*, 2010). Gender differences in preferences may also impact production decisions (Charness and Gneezy, 2012). For example, experimental evidence shows that women are more risk averse and less inclined to competition than men (Croson and Gneezy, 2009; Falk and Hermle, 2018) while in the adoption of improved maize varieties, women considered taste as an important quality whereas men did not (Meinzen-Dick *et al.*, 2010).

One of the very few attempts to explore the relationship between gender, plot diversification and their interaction in Uganda showed that female-managed plots were less productive compared to male or mixed-managed plots (Covarrubias, 2015), although the interaction between female managers and crop diversity contributed positively to agricultural productivity. Similar research by Romeo *et al.* (2016) in Kenya has also provided some indicative evidence of a production diversity gender interaction although it is not directly estimated and no allowance is made for endogeneity (or for unobserved heterogeneity) found to be important in previous studies. The authors showed the link between gender and household dietary diversity in extremely poor households, indicating a stronger assocation between farm diversification and diet diversity in female-headed households than male-headed households (Romeo *et al.*, 2016).

As a range of different authors have pointed out, access to resources by women improves household welfare (Quisumbing, 1994; Brown, 1996), with the most important being access to land (Agarwal, 1994). Empowering women within the household is seen as a key strategy to ensure household nutrition security (Mekonnen *et al.*, 2005; Malapit *et al.*, 2015). The literature suggests that, coupled with their responsibility and engagement in household activities and food security, plots controlled by women contribute more to household nutrition as they produce a wider range and more different crops than their male peers. However, the literature suggests there are many factors that affect the mechanisms through which food is available in a given household and nutritional requirements are met (World Bank, 2009). To explore this

further, and condition the empirical analysis, the following section presents a simple farm household model that links the household's dietary diversity consumption choices with production.

### 2.2. The farm household model

Small-scale farm households face a range of market imperfections and transaction costs in input and output markets. As a result, in theory, a farm household's consumption (and hence nutritional) decisions should be expected to be jointly determined with its production decisions. We formulate the overall household's decision problem as equivalent to a utility maximization problem, subject to a linear budget constraint where prices are endogenous to the household. As noted by Deaton and Muellbauer (1980), the advantage of this type of approach is that it allows intuition from standard theory to be applied, helping in the specification and interpretation of the empirical models.

Here, we reinterpret the well-known unitary farm household model with missing markets developed by Strauss (1986), drawing on the approach used to capture product diversity in the Dixit and Stiglitz (1977) model of monopolistic competition. Following Strauss's notation, assume the household determines consumption, leisure and agricultural production choices to maximise its utility $U(q_0,q_1,q_2,\cdots,q_n,Z)$ subject to a budget constraint and implicit production function constraint $\sum_{i=0}^{L}p_iq_i=Y$, and $G(Q_1,\cdots,Q_m,V_1,\cdots,V_n,L;X)=0$, where $Y$ is full income defined as $p_LT+\sum_{j=1}^{M}p_j^Q Q_j-\sum_{j=1}^{M}v_iV_i-p_LL+E.$[2]

The other variables are defined as follows: $T,L,Q_j,V_i$, total available time, labour demand, agricultural outputs and inputs, $p_L,p_j^Q,v_i$ the respective prices, $E$ exogenous income, and $X$, a vector of structural characteristics of the household (including exogenous capital/land etc.). At the optimal solution, full income can be written as $Y=p_LT+\pi\left(p_j^Q,v_i,p_L,X\right)+E$, where $\pi(.)$ is a short-run profit function defined over prices where these may represent either exogenous market prices or, due to missing markets, shadow prices which are functions of exogenous variables and both production and preference parameters (Strauss, 1986).

To make the link to the household's dietary diversity decision, assume that commodities within the household's utility function are separable from non-agriculture commodities (indexed as 0) as in the standard Dixit and Stiglitz (1977) specification $U(q_0,DD(q_1,..,q_n),Z)$, where $DD(q_1,..,q_n)$ is the sub-utility function defined over food. This allows two-stage budgeting to be applied. At the lower level, demand for an individual food good in the household can be written as $q_i=q_i(p_1,..,p_n,\tilde{Y})$ where $\tilde{Y}=Y-p_0q_0$. The household's overall utility maximization problem is equivalent to $\max U(q_0,D,Z)$ subject to $p_0x_0+P.DD=Y$. Household demand for dietary diversity is therefore

$$DD=h\left(p_0,P,\tilde{Y},Z\right) \tag{1}$$

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[2]Here the household time constraint is included in the full income constraint. In this framework, tradeable and non-tradeable commodities can be incorporated in a symmetric way with the former prices being treated as exogenous and the latter endogenous to the household. A similar approach can incorporate simple restrictions on inputs.

where $DD$ is the food (dietary diversity) aggregate and $P$ an associated aggregate price index. As before, $P$ may include shadow prices for goods where markets are missing or imperfect, with shadow prices determined within the household.

The empirical specifications used below (and widely applied in the literature) where household consumption diversity is explained by production diversity can be motivated using equation (1), with production diversity capturing an important part of the variation in shadow prices across households. Consider the goods where markets are imperfect or missing. For these goods, demand within the household equals supply $Q_i^* = q_i(p_1, .., p_n, \tilde{Y})$. Hence, conditional on household production choices, the individual shadow prices can be written as $p_i^* = p_i(Q_1^*, .., Q_n^*, \tilde{Y})$ or

$$p_i^* = p_i(PD, \tilde{Y}) \qquad (2)$$

where $PD = PD(Q_1^*, .., Q_n^*)$ is a measure of aggregate production or household production diversity.

From equations (1) and (2) we can approximate household demand for dietary diversity as

$$DD = g(\tilde{P}, PD, Y, Z), \qquad (3)$$

where $\tilde{P}$ is an index of market prices. Many of the empirical specifications used in the existing literature can be linked to (3), as they emphasise prices, own production, income and other factors including gender (as in Jones *et al.*, 2014; Dillon *et al.*, 2015; Sibhatu *et al.*, 2015; Rajendran *et al.*, 2017). The derivation of (3) underlines the need to consider the potential endogeneity of production diversity in the empirical work.

Gender differences in equation (3) arise through various pathways. The presence of market imperfections is expected to induce gender differences in the shadow prices in equation (2) as these are driven by constraints on production, efficiency and preferences, where we know substantial gender differences exist. These, in turn, will result in gender differences in the values of production diversity. In addition, as production diversity, income and prices impact on shadow prices, we expect that the relationship between these variables and dietary diversity may differ by gender. Finally, the function $g(.)$ will also reflect preferences and the efficiency of producing meals from food products. The relative importance of market purchases of food relative to home production will also be reflected in this relationship. Hence, the impact of the right-hand side variables on consumption dietary diversity may vary across different households and specifically by gender.

## 3. Data

Our analysis is based on the latest Ethiopian Socioeconomic Survey (ESS) panel dataset. This has been made available from the Central Statistical Agency of Ethiopia as part of the World Bank's Living Standards Measurement Integrated Programme (LSMS) since 2011/12. The data are comprehensive, covering all regions in Ethiopia every 2 years and, at the time of analysis, three rounds of data are available (2011/12, 2013/14 and 2015/16) from the World Bank's data repository. The number of households studied has changed over time with subsequent rounds extending the sample to include additional urban households and areas. The data set contains a rich set of information on household characteristics, crop and livestock production systems, consumption and marketing and community information. It also includes two decades of average climatic information, both at the household's location and on plots

cropped by the household head. The ESS sample is drawn from a population frame that includes all rural and small-town areas of Ethiopia. The sample design provides representative estimates at the national level (excepting the nine zones excluded from the frame) for all rural-area households and for the combination of rural and small-town households.

From these data we constructed a number of standard measures of dietary diversity, namely, household dietary diversity score (HDDS), modified household dietary diversity score (MHDDS) and food variety score (FVS). HDDS is a qualitative measure of food consumption based on a household's access to a variety of foods and serves as a proxy for nutrient adequacy of the diet of individuals. Following a standard procedure by Swindale and Bilinsky (2006), HDDS was constructed based on a 7-day recall period of consumption of 12 different foods: cereals; roots and tubers; pulses, legumes and nuts; vegetables; fruit; meat, poultry and offal; fish and seafood; eggs; dairy products; oils and fats; sugar and honey; and condiments. Each food group was counted only once, resulting in a possible range of scores from 0 to 12 if all food types were used. The HDDS is, as various authors note, an important indicator of nutrition status of an individual or a household (Kennedy *et al.*, 2011). The other measures were constructed using analogous standard approaches. The difference between the HDDS and MHDDS is that the latter does not consider the consumption of what are considered unhealthy food items, such as condiments and fats and oils. The FVS considers the consumption of wider varieties of food items a given household has reported over the 7-day recall period. It is a count of the number of food types eaten in a given period and is a disaggregated version of the HDDS measure (Hatløy *et al.*, 1998). It therefore captures more nuanced differences in diet across households – for example, differences in the type of cereals/vegetables consumed – that the HDDS and MHDDS measures may not. In addition, we also disaggregated the HDDS and FVS values by source – that is, whether they came from the household's own agricultural production or from market sources.

A similar approach was followed to measure a household's agricultural production diversity, with the main production diversity measure (PD) calculated simply as the number of food groups produced by a particular household in the current production season. In addition, to account for plot level variation in production diversity, we also calculated the Simpson Index (SI). This index measures the evenness and richness (number) of species with respect to crops cultivated. Calculated as $1 - \sum a_j^2$ where $a_j$ represents the share of crop $j$ from the total area cultivated by a household $i$ calculated as $a_j = b_{ij}/A_i$ where $b_{ij}$ is the area covered by the $j$th crop and $A_i$ is the total cultivated land. The index ranges from 0 to 1 with higher values representing higher diversity at plot level (Smale, 2005; Covarrubias, 2015).

Table 1 and Figure S1 provide an overview of differences in per capita consumption, and dietary diversity across households. From these we see there is a small difference between female- and male-headed households in terms of per capita food and non-food expenditure. While male-headed households have higher per capita food expenditure, female heads have higher non-food expenditure. We also found that for both FVS and HDDS, male-headed households have higher dietary diversity from own production with the pattern of production and consumption dominated by cereals and pulses. Figure S1 further indicates that production and consumption of fruits, vegetables and that of animal source foods is low, while the percentage of households consuming vegetables and spices is higher than the percentage of households producing these items.

Table 1
Average food and non-food expenditure, consumption and production diversity scores

| | Female-headed households | | Male-headed households | | Mean diff. |
|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | t-value |
| Food value per capita (birr) | 290.9 | 2846.1 | 309.1 | 7012.4 | 0.09 |
| Non-food value per capita (birr) | 672.1 | 743.4 | 644.2 | 675.6 | −1.28 |
| FVS | | | | | |
|   Own FVS | 3.0 | 2.3 | 3.7 | 2.39 | 8.86*** |
|   Purchased FVS | 5.6 | 3.3 | 5.7 | 3.2 | 0.65 |
|   Other FVS | 0.4 | 1.0 | 0.3 | 0.7 | −4.74*** |
|   Total FVS | 9.1 | 3.9 | 9.7 | 3.8 | 4.62*** |
| HDDS | | | | | |
|   Own HDDS | 1.9 | 1.3 | 2.3 | 1.4 | 8.74*** |
|   Purchased HDDS | 3.8 | 1.8 | 3.9 | 1.8 | 1.30 |
|   Other HDDS | 0.3 | 0.7 | 0.2 | 0.6 | −4.67*** |
|   Total HDDS | 5.3 | 1.7 | 5.6 | 1.7 | 4.91*** |
|   MHHDS | 3.3 | 1.4 | 3.6 | 1.4 | 6.20*** |
| Production diversity | | | | | |
|   PD | 4.1 | 1.7 | 4.5 | 1.7 | 8.29*** |
|   Simpson index (SI) | 0.6 | 0.3 | 0.7 | 0.2 | 10.63*** |
| N | 1,236 | | 5,185 | | |

*Notes:* The last column reports the *t*-value associated with the test of equality of the female and male means.
*, ** and *** indicate significance at 10%, 5% and 1% levels.

As discussed above, equation (3) motivates why we expect dietary diversity to be influenced by food prices, income, consumption of own production, and gender. Consistent with other authors, we also expect a range of other factors will influence dietary diversity (Table 2). These include: household demography and resource endowments (Jones *et al.*, 2014; Carletto *et al.*, 2015; Dillon *et al.*, 2015; Sibhatu *et al.*, 2015; Rajendran *et al.*, 2017); household wealth, proxied by land and livestock numbers (Jones *et al.*, 2014; Hirvonen and Hoddinott, 2017; Tesfaye and Tirivayi, 2020); demographic factors such as education, household's head age, dependency ratio (Jones *et al.*, 2014; Tesfaye and Tirivayi, 2020); access to market (Hirvonen and Hoddinott, 2017); and the impact of shocks. In addition to total income, the availability of different sources of income such as remittances and non-agricultural incomes has also been found to play a role, as they are indicative of the availability of liquid cash that can be used for food purchases (Jones *et al.*, 2014).

As expected, Table 2 shows that male-headed households are, on average, better off than female-headed households, with higher education levels, more land and livestock, and more likely to have non-agricultural income.

## 4. Empirical Model

### 4.1. Model specification

A wide variety of econometric models have been used to explore empirically the links between production diversity and dietary diversity, from simple regression estimation

(Jones *et al.*, 2014), cross-country comparisons (Sibhatu *et al.*, 2015), to instrumental variable based methods that account for the endogeneity of production diversity (Dillon *et al.*, 2015; Hirvonen and Hoddinott, 2017). Following equation (3), the specification of the econometric model which explains household dietary diversity in household $i$ in period $t$ can be written as:

$$E(DD_{it}|PD_{it}, P_{it}, Y_{it}, G_{it}, X_{it}, c_i, v_{1it}) = \exp(\alpha_0 + \alpha_1 PD_{it} + \alpha_2 P_{it} + \alpha_3 Y_{it}$$
$$+ \delta_0 G_{it} + \delta_1 PD_{it}G_{it} + \delta_2 P_{it}G_{it} + \delta_3 Y_{it}G_{it} + X_{it}\beta + c_i + v_{1it}) \quad (4)$$

where $PD_{it}$, $P_{it}$, $Y_{it}$ and $G_{it}$, represent production diversity, a price index, household income and gender of household head. The coefficients $\alpha_1$ to $\alpha_3$ capture the relationships between production diversity, prices, income and household dietary diversity for male-headed households, while $\delta_0$ to $\delta_3$ represent the potential gender effects acting via the intercept, and the production diversity, prices and income. The vector $X_{it}$ contains the other exogenous variables discussed above which are expected to affect the dietary diversity while $c_i$ is the unobserved heterogeneity and $v_{1it}$ the remaining time-varying error.

There are a number of potential difficulties in estimating equation (4). The discrete count nature of the dependent variable makes the model non-linear. We expect that production diversity and hence its interaction with gender to be endogenous. Further the explanatory variables are likely to be correlated with the unobserved heterogeneity. To deal with these issues, we apply the two-step control function procedure for non-linear panel models (allowing for correlated random effects) where the endogenous variable is either continuous or discrete[3] (Wooldridge, 2007; Papke and Wooldridge, 2008).

In the first step, instruments are used to explain the endogenous variables, with time averages of exogenous explanatory variables used to account for correlated random effects. For production diversity we have

$$PD_{it} = \varphi_1 + \varphi_2 X_{it} + \varphi_3 z_{it} + \varphi_3 G_{it} + \varphi_4 - z_i + v_{2it}, t = 1, \cdots, T \quad (5)$$

where $X_{it}$ contains explanatory variables also used to explain consumption diversity, $z_{it}$ and $-z_i$ are the instrumental variables and plus time averages of all time variant explanatory variables, $v_{2it}$ is the error. The female dummy $G_{it}$ captures gender differences in the production diversity, which as discussed in Section 2, is one of the pathways through which differences in dietary diversity may arise.

In the second step, the main variable of interest, dietary diversity is modelled against a set of explanatory variables, averages of the time varying variables, plus estimated residuals from the first step. To control for correlation between the unobserved heterogeneity $c_i$ and the other parts of equation (4), we assume this can also be modelled as $c_i = \gamma_0 + \gamma_1 - z_i + \gamma_2(G_i - z_i) + a_i$, where $a_i$ is assumed to be normally distributed (conditional on the average values). As discussed in Section 2, differences in tastes, preferences and efficiency – for example, in cooking – is another possible source of gender difference in dietary diversity. Allowing the Mundlak household-level means for production diversity, price and income to vary by gender, controls (at least in part) for these potential differences Mundlak, 1978.

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[3]There is no established methodology that accounts for an endogenous count variable when the dependent variable in the main regression is also a count variable. Hence, we fit the model which assumes a continuous endogenous variable. The second-stage regression estimated will not be affected by the form the first-stage regressions assumed (Kelejian, 1971).

Table 2

Summary descriptive statistics for explanatory variables used in the econometric analysis

| | Female-headed households | | Male-headed households | | Mean diff. t-value |
|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | |
| Head education (% of households where head has formal education) | 17 | 38 | 45 | 49 | 21.7*** |
| Head age (years) | 49.3 | 13.8 | 45.8 | 15.0 | −7.5*** |
| Dependency ratio | 1.6 | 1.5 | 1.4 | 1.0 | −5.7*** |
| Land holding (ha) | 1.1 | 5.6 | 1.6 | 3.7 | 4.0*** |
| Livestock holding (TLU) | 2.6 | 2.9 | 3.9 | 9.50 | 5.2*** |
| Total income (birr) | 3941.7 | 6730.1 | 5649.4 | 10915.9 | 3.3*** |
| Distance to weekly market (km) | 7.4 | 13.4 | 7.5 | 12.1 | 0.3 |
| Ownership of non-agricultural business (% households) | 25 | 43 | 28 | 45 | 2.4* |
| Access to remittance (% of households with access) | 20 | 40 | 12 | 32 | −7.0*** |
| Experience of negative shock (% households experiencing negative shock) | 52 | 5 | 49 | 5 | −2.0* |
| Instrumental variables | | | | | |
| Annual rainfall (mm) | 917.5 | 271.5 | 914.7 | 270.2 | −0.3 |
| Plot distance (km) | 0.8 | 3.4 | 1.8 | 17.2 | 1.9 |
| Temperature (°C) | 18.9 | 3.2 | 19.1 | 3.2 | 2.2* |
| Elevation (masl) | 1940.3 | 532.3 | 1900.6 | 531.3 | −2.4* |
| Temperature–elevation interaction | 350457.8 | 54430.4 | 346,777 | 53609.9 | −2.2* |
| Cultivating steep slope plots (% households cultivating steep plots) | 1.8 | 13.3 | 1.8 | 13.3 | 0.1 |
| Regional dummies | | | | | |
| Tigray | 13 | 33 | 9 | 29 | −3.3*** |
| Amhara | 22 | 41 | 25 | 43 | 2.4* |
| Oromia | 21 | 40 | 21 | 40 | 0.2 |
| SNNPRs | 28 | 44 | 26 | 43 | −1.4 |
| Afar/Somali/Dire Dawa | 9 | 28 | 12 | 32 | 2.7* |
| Benshangul Gumuz/Gambella | 7 | 26 | 7 | 24 | −0.8 |
| N | 1,236 | | 5,185 | | |

*Notes:* The last column reports the *t*-value associated with the test of equality of the female and male means.
*, ** and *** indicate significance at 10%, 5% and 1% levels.

Hence the overall random components in equation (4) may be rewritten as $a_i + v_{1it}$. The endogeneity in equation (4) arises from the correlation between $a_1 + v_{1it}$ and the reduced form error in equation (5), $v_{2it}$. By assuming that $a_1 + v_{1it}$ is conditionally normally distributed, independent of the error from its projection on $v_{it2}$ (and of the other explanatory variables), then we can estimate the following equation:

$$E(DD_{it} | PD_{it}, P_{it}, Y_{it}, G_{it}, X_{it}, c_i, v_{2it}) = \exp(\tilde{\alpha}_0 + \alpha_1 PD_{it} + \alpha_2 P_{it} + \alpha_3 Y_{it} + \delta_0 G_{it}$$
$$+ \delta_1 PD_{it} G_{it} + \delta_2 P_{it} G_{it} + \delta_3 Y_{it} G_{it} + \beta X_{it} + \gamma_1 - z_i + \gamma_2 (G_i - z_i) + \rho v_{2it}) \quad (6)$$

where $\tilde{\alpha}_0$ is the combined intercept, and the term $v_{2it}$ is replaced by the residual from the first stage regression. In a control function approach for non-linear models, there is no established method by which one can conduct formal tests of endogeneity. However, Wooldridge (2012) and Papke and Wooldridge (2008) indicate that a $t$-test on the coefficient of the generalized residual, in our case $\rho$ in equation (6), serves as a robust test of endogeneity with a significant test implying endogeneity.[4] In summary, the econometric modelling allows for three sources of gender differences: first, via differences in the relationships between production diversity, income and prices and consumption dietary diversity; second, in the different impact of the Mundlak time average variables; and finally, via gender differences in production diversity decisions in equation (5).

### 4.2. Identification and confounding factors

Production diversity and the interaction variable involving production diversity and gender are potential endogenous variables in equation (6). A number of instrumental variables have been suggested and used in related literatures including climate indicators, previous shocks and dependent family members (Dillon *et al.*, 2015; Muriithi, 2015). Climatic and topographic variables are particularly effective here as Ethiopia is characterized by wide agro-climatic and topographic conditions affecting agriculture potential. These variables have been used as instruments previously, for example by Hirvonen and Hoddinott (2017).[5]

Therefore, drawing from the data available, we use rainfall, temperature, elevation, plot distance and the interaction between temperature and elevation as our instrumental variables. Temperature affects crop choices as one of the climate change indicators. Rainfall determines soil moisture on which the crops thrive and is one critical factor of agricultural production. In response to various risks involving weather, farmers decide on their crop portfolio.

The abundance or scarcity of rainfall influences the type of crops that are cultivated by a farmer (Bezabih and Di Falco, 2012). Di Falco and Chavas (2009) and Abraha (2007) have shown in Ethiopia that farmers cultivate dominant drought-tolerant crops (grass pea) with shortage of rainfall and less tolerant crops (wheat) when rainfall is not a problem. Plot to homestead distance proxies for transaction costs. The

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[4]In the empirical work below we have two endogenous variables, which requires us to run the procedure described separately for each endogenous variable. Since we have two first-stage regressions, two generalized residuals are also estimated and tested.

[5]As discussed in the introduction, the availability of panel data means that we can account for potential confounding factors model such as culture which could undermine the exogeneity of the instruments in a cross-sectional setting.

Table 3
Determinants of production diversity: Parameter estimates equation (4)

| | PD | SI | Gender × PD |
|---|---|---|---|
| Gender | −0.27*** (0.06) | −0.07*** (0.01) | 8.12*** (1.76) |
| Head education | 0.32*** (0.042) | 0.03*** (0.006) | 0.0134 (0.016) |
| Head age | −0.001 (0.004) | −0.0002 (0.0007) | 0.002 (0.003) |
| Dependency ratio | −0.021 (0.023) | −0.003 (0.004) | −0.011 (0.016) |
| Land holding | 0.016* (0.01) | 0.005*** (0.002) | 0.003 (0.002) |
| Livestock asset (TLU) | 0.005 (0.003) | −0.00004 (0.0001) | 0.001 (0.0008) |
| Distance to weekly market | 0.001 (0.001) | 0.0002 (0.0003) | 0.001 (0.001) |
| Owns non-agri. business | 0.11 (0.09) | 0.03** (0.013) | 0.081 (0.046) |
| Access to remittance | 0.004 (0.061) | −0.03*** (0.01) | −0.008 (0.038) |
| Experience of negative shock | 0.046 (0.042) | 0.004 (0.01) | 0.013 (0.023) |
| Rainfall | 0.002** (0.001) | −0.00001 (0.0001) | 0.002*** (0.0005) |
| Plot distance | −0.003* (0.002) | −0.0001 (0.0002) | 0.024* (0.002***) |
| Temperature | −0.13 (0.083) | −0.001 (0.013) | −0.027*** (0.006) |
| Elevation | −0.0004** (0.0002) | 0.00002 (0.00003) | −0.002*** (0.0005) |
| Temperature × elevation | 0.00003** (0.0000) | 0.000001* (6.18e−07) | 0.00001*** (3.21e−06) |
| Steep slope | 0.14 (0.13) | −0.024 (0.024) | 0.699 (0.512) |
| Joint IV significance | 37.45*** | 22.23*** | 15.31*** |
| Mundlak variables | Yes | Yes | Yes |
| Time dummies | Yes | Yes | Yes |
| Regional dummies | Yes | Yes | Yes |
| N | 6,421 | 6,421 | 6,421 |

**Notes:** Robust standard errors clustered at the household level; Round 1 (2011/12) for time dummies and Tigray region from regional dummies are the relevant omitted categories.
*, ** and *** indicate significance at 10%, 5% and 1% levels.

Table 4
Gender differences in dietary diversity: Parameter estimates equation (5)

| | HDDS | MHDDS | FVS |
|---|---|---|---|
| Gender | −0.132** (0.059) | −0.151** (0.069) | −0.223*** (0.080) |
| PD | 0.042*** (0.009) | 0.100*** (0.011) | 0.133*** (0.013) |
| Price | −0.005* (0.003) | −0.007** (0.003) | −0.004 (0.004) |
| Total income | −0.00003 (0.0001) | −0.00001 (0.0001) | −0.00012 (0.0001) |
| Gender × Income | 0.002* (0.001) | 0.001 (0.001) | 0.005*** (0.002) |
| Gender × PD | 0.022 (0.014) | 0.032* (0.016) | 0.040** (0.019) |
| Gender × Price | −0.003 (0.007) | 0.004 (0.008) | −0.002 (0.009) |
| Residual (PD) | 0.030*** (0.009) | −0.002 (0.011) | −0.057*** (0.013) |
| Residual (PD × Gender) | −0.028* (0.014) | −0.041** (0.017) | −0.053*** (0.020) |
| | | | |
| Gender interactions: Joint tests | | | |
| Income, PD, Price ($\chi_3^2$) | 6.58 | 4.37 | 11.06** |
| Dummy + Mundlak time averages ($\chi_4^2$) | 1.97 | 3.12 | 3.09 |
| Dummy + All interactions ($\chi_7^2$) | 7.86 | 4.58 | 12.22* |
| Other variables | Yes | Yes | Yes |
| Regional dummies | Yes | Yes | Yes |
| Time dummies | Yes | Yes | Yes |
| N | 6,421 | 6,421 | 6,421 |

*Notes:* Full results are provided in the Appendix S2. Additional variables include Head age, Head education, Dependency ratio, land and livestock holding, Distance to weekly market, Ownership of nonagricultural business and experience of negative shock, Time dummy. Robust standard errors clustered at the household level; Round 1 (2011/12) for time dummies and Tigray region from regional dummies are used as the relevant omitted categories.
*, ** and *** indicate significance at 10%, 5% and 1% levels.

frequency of travel and the time it takes to get to the plot effectively reduces daily working hours and increases the effort required in transporting inputs and outputs to and from plots (McCall, 1985). Hence, on nearby plots farmers will cultivate crops that are more demanding, needing close control and frequent management (Sheahan and Barrett, 2014). Therefore we assume that the average distance between the household and plots will affect production decisions and therefore production diversity. We have also used an interaction of these instrumental variables with gender of the household head to correct for the endogeneity of the interaction variable. Table 2 above includes a summary of the instrumental variables used in the analysis.

## 5. Results

Below we present four sets of results. In Table 3 the first-stage estimation results explaining production diversity are presented consistent with equation (5). Table 4 presents the second stage results explaining dietary diversity following equation (6). Tables 3 and 4 provide the statistical evidence on the extent of gender differences in the pathways explaining dietary diversity within the household. To judge the importance of any differences found in dietary diversity, Table 5 then uses the estimates from the preferred specifications for the three dietary diversity measures to explore the sources of diversity. First, average marginal effects for key variables (gender, production diversity, price, and income) are calculated at the overall sample means. Second, to calculate potential gender differences in dietary diversity after controlling for the observed characteristics in the sample, we apply a decomposition approach to calculate the average predicted dietary diversity for the male and female subsamples if male heads of households act as if they were female and female-headed households as if they were male (Even and Macpherson, 1990). Finally, motivated by the observed differences in dietary diversity by source of food (own production, market), we estimate further second-stage regression results exploring simple gender impacts on these different components.

### 5.1. Estimation results

The first and third columns of Table 3 contain the key results used as the basis for the second-stage regressions, with the Simpson index results are also included to allow some comparison between the different definitions of production diversity. The third column results explain the gender interaction effect, and therefore the estimated coefficients are difficult to interpret. In all cases some of the exogenous variables used as instruments are individually significant and they are jointly statistically significant with an $F$-test score of well above 10. For both the count and Simpson measures, female-headed households diversify their production less than male-headed households. For the other measures used, the pattern of significance differs somewhat across the production diversity measures, with education and land holding having a positive effect on production diversity as expected.

Table 4 presents the second-stage results for the three measures of dietary diversity, namely HDDS, MHDDS and FVS consistent with equation (6). As discussed, in contrast to much of the previous literature which relies on cross-section data, our estimates control for unobserved heterogenity across households due, for example, to differences in land and management quality as well as for potential endogeneity. We estimated two specifications for each measure: (i) a restricted model, including only

considered key variables of interest – that is, dietary diversity, production diversity, income, price index and the interaction between these variables with gender; (ii) the full (preferred) results, which account for observed and unobserved heterogeneity with time and regional dummies, where the set of variables included in $X$, observed heterogeneity, as shown in Table 2. Table S1 shows both sets of results, for comparison, which indicates that the reduced specification does not materially affect either the size or the significance of the estimates of the main effects.

Overall the evidence suggests, as expected, that production diversity and gender production diversity interaction are endogenous, with the estimated coefficients on the residuals from the production diversity and gender production diversity interaction regressions statistically significant at 5% in four/five out of the six estimations respectively (Table S1). After controlling for endogeneity, the results indicate that, consistent with the previous literature, production diversity improves dietary diversity regardless of the model specification and measurement of dietary diversity. The effect of the price index is negative with higher prices decreasing diet diversity in the Table 4 results but only significant for HDDS and MHDDS. Although positive, the overall impact of income from agriculture is only statistically significant for FVS.

In terms of the estimated gender effects, the individual gender dummy variable is individually significant and negative across all specifications (at least at 10%). In terms of the gender interactions there is some evidence (at 10%) that the interaction between gender and production diversity is positive for MHDDS and FVS, and stronger evidence of a positive interaction between gender and income for FVS. However, only in the FVS case is the joint significance test for the gender dummy plus all gender interactions rejected at the 10% significance level. This suggests that the more disaggregated nature of the FVS measure may be capturing more subtle gender differences in dietary diversity across households – for example, differences in the type of cereals/vegetables consumed, than when the more aggregated HDDS and MHDDS measures are used.

### 5.2. Marginal and decomposition analysis

Table 5 explores the relative importance of the different drivers of dietary diversity within the households. In the first part of the table, the estimates from Table 4 are used to calculate the average marginal effects for gender of the household head, production diversity, price and income at the overall sample means. Here the gender effect is negative across all the measures although the standard error indicates that it is not statistically significant at the overall sample mean. The impact of increasing production diversity is positive and statistically significant, with production diversity increasing dietary diversity by more than one food type for the FVS indicator and by a quarter to over a third of a food type using HDDS and MHDDS. An increase in price decreases dietary diversity, while income has a positive effect, although this latter effect is also insignificant at the mean sample values.

While indicative, the use of sample mean values ignores the impact of the distributions of actual covariate values within the sample. To provide better insights into the sources of gender differences in dietary diversity observed in Table 4, the second part of Table 5 reports on simple counterfactual experiments where we calculate the average predicted dietary diversity for the male and female subsamples if male heads of households act as if they were female and female-headed households as if they were male. Here we report results which reflect all the possible sources of gender difference

in the estimated models, first, via the estimated gender differences in the gender inter-actions with production diversity, income, prices and dietary diversity (i.e. allowing for the estimated $\delta_i$), second, allowing for the estimated gender differences in the impact of Mundlak time average variables, and finally via gender differences in pro-duction diversity decisions.

We focus on FVS, for which there is consistent evidence of statistically significant gender differences in the underlying coefficients from Table 4. For this measure the average predicted dietary diversity score for the male-headed household subsample is 9.67 (row 1) while for the subsample of female-headed households this is 9.1 (row 2). The overall gender difference of around half a food group (0.57) arises from differ-ences in the characteristics of male- and female-headed households as well as differ-ences in the estimated coefficients. If we apply the estimated male coefficients for production diversity, price and income (and the gender dummy) to the female sub-sample, the average prediction in the female subsample rises to 9.48 (row 7). Hence, in the female sample if the impact of production diversity, income and prices on con-sumption diversity was similar to that for male-headed households, consumption diet-ary diversity would increase by 0.38 of a food type. Similarly, if male-headed households responded in the same way as female-headed households to these vari-ables, average consumption dietary diversity would fall to 9.43 (row 3). Applying the standard decomposition approach to these differences, this suggests around 67% (42%) of the overall gender difference in average dietary diversity might be attributed to differences in these estimated coefficients from the perspective of the female (male) subsample (Even and Macpherson, 1990).

Rows 4 and 8 report the average predicted dietary diversity scores when the gender differences in the Table 4 female coefficients for production diversity, price and income, the gender dummy and the Mundlak time average variables are accounted for. For female-headed households applying the male coefficients to the female sub-sample reduces the average predicted FVS dietary diversity score to 9.35, while for male-headed households, applying the female coefficients increases the average predic-tion to 9.69. As discussed in Section 4, allowing the Mundlak time averages variables to vary by gender in part controls for differences in time invariant preferences. These results suggest that gender differences in these appear to partially counteract the nega-tive gender effect associated with the gender differences in coefficients on production diversity, price and income in the consumption diversity equation.

Finally, the gender differences in the production diversity equation (5) are included in the results in rows 5 and 6 and 9 and 10. These are calculated in two steps. First using the Table 3 estimates, the value of production diversity is predicted for each household in the sample assuming the head of household is female (if they are male) and vice versa. The second step uses these counter-factual predictions with the Table 4 estimated coefficients to predict the counterfactual average dietary diversity values as before. Hence these account for gender differences in both the dietary diversity and production diversity equations.

In this case consider the overall effects that include the gender differences for esti-mated coefficients for production diversity, price and income and the time averages (rows 6 and 10). Using the female subsample as the basis for comparison, applying the male coefficients gives an average predicted value for the female subsample as 9.71 (above the actual observed value for the male subsample). Using the male subsample, the average dietary diversity score falls to 9.32 (just above the actual female observed value). Decomposing the observed difference in dietary diversity scores as before but

Table 5

Average marginal effects and predicted consumption diversity by female- and male- headed households

| Variable | HDDS | MHDDS | FVS |
|---|---|---|---|
| | Average marginal effects | | |
| Gender | −0.12 (0.12) | −0.022 (0.09) | −0.18 (0.25) |
| PD | 0.25*** (0.05) | 0.39*** (0.04) | 1.3*** (0.11) |
| Price | −0.03* (0.01) | −0.02* (0.01) | −0.04 (0.031) |
| Total income | 0.003(0.002) | 0.001(0.001) | 0.01**(0.004) |
| | **Predicted consumption dietary diversity** | | |
| *Own coefficient values* | | | |
| 1. Males | 5.59 (0.02) | 3.82 (0.02) | 9.67 (0.05) |
| 2. Female | 5.33 (0.05) | 3.63 (0.03) | 9.10 (0.09) |
| *Male subsample predictions* | *Equation (6 ) only* | | |
| 3. Female coeffs $(\alpha_i + \delta_i)$ | 5.43 (0.12) | 3.75 (0.09) | 9.43 (0.27) |
| 4. Incl. gender averages diffs | 5.54 (0.17) | 3.88 (0.14) | 9.69 (0.50) |
| | *Equations (5) + (6)* | | |
| 5. Female coeffs.$(\alpha_i + \delta_i)$ | 5.37 (0.11) | 3.65 (0.08) | 9.07 (0.26) |
| 6. Incl. gender averages diffs | 5.48 (0.17) | 3.77 (0.13) | 9.32 (0.48) |
| *Female subsample predictions* | *Equation (6 ) only* | | |
| 7. Male coeffs $(\alpha_i)$ | 5.51 (0.11) | 3.71 (0.08) | 9.48 (0.25) |
| 8. Excl. gender averages diffs | 5.45 (0.12) | 3.63 (0.09) | 9.35 (0.27) |
| | *Equations (5) + (6)* | | |
| 9. Male coeffs. $(\alpha_i)$ | 5.58 (0.11) | 3.82 (0.08) | 9.84 (0.26) |
| 10. Excl. gender averages diffs | 5.52 (0.12) | 3.73 (0.09) | 9.71 (0.28) |

*Notes:* Standard errors are in parentheses. Average marginal effects represent marginal effects calculated at sample mean values using Table 4 estimates. Predicted consumption dietary diversity predictions are average of predicted values using Table 4 (and Table 3 estimates) for each individual household. Rows 1 and 2 (own coefficient values) represents the average by gender of predicted dietary diversity for each observation using actual covariate values (and predicted production diversity). Rows 3 and 4 represent the average predictions for the male subsample using the female estimates from equation (6), with row 4 allowing for differences in the Mundlak time averages by gender. Rows 5 and 6 represent the equivalent average predictions for the male subsample using the female estimates from equation (6) but adjusting the predicted production diversity to allow for the estimated gender effect in Table 3. Rows to 7–10 are similarly defined for the female subsample using the male estimated coefficients.

allowing for all the estimated gender differences from the model estimates suggest that 107% of the gender gap is 'explained' by the differences in estimates for female- and male-headed households, that is, the gender gap is predicted to be slightly larger than it is. Although the results are qualitatively the same when the male and female subsamples are used, as is common in these types of decomposition exercises, the exact quantitative results are sensitive to the sample used with 67% of the gap explained by the gender differences when the male subsample is the basis for comparison.

## 5.3. Dietary diversity by source: Own production and market

In addition to the overall gender differences found across the three dietary diversity measures, the descriptive analysis suggested different patterns of dietary diversity by

Table 6
Dietary diversity by source

| | HDDS | Own-HDDS | Purchased HDDS | FVS | Own FVS | Purchased FVS |
|---|---|---|---|---|---|---|
| Female | −0.117** (0.049) | −0.193*** (0.040) | 0.050 (0.057) | −0.031 (0.116) | −0.320*** (0.073) | 0.117 (0.104) |
| PD | 0.247*** (0.049) | 0.345*** (0.043) | 0.337*** (0.059) | 1.286*** (0.115) | 0.672*** (0.077) | 0.474*** (0.101) |
| Price | −0.031** (0.014) | −0.068*** (0.012) | −0.005 (0.015) | −0.036 (0.031) | −0.117*** (0.021) | 0.026 (0.025) |
| Total income | 0.001 (0.002) | 0.0004 (0.001) | 0.0003 (0.001) | 0.0004 (0.003) | −0.001 (0.002) | 0.001 (0.002) |
| Residual (PD) | 0.140*** (0.047) | −0.096** (0.041) | −0.173*** (0.057) | −0.598*** (0.113) | −0.309*** (0.075) | −0.242** (0.100) |
| Additional variables† | Yes | Yes | Yes | Yes | Yes | Yes |
| Mundlak variables | Yes | Yes | Yes | Yes | Yes | Yes |
| Time dummies | Yes | Yes | Yes | Yes | Yes | Yes |
| Regional dummies | Yes | Yes | Yes | Yes | Yes | Yes |
| N | 6,421 | 6,421 | 6,421 | 6,421 | 6,421 | 6,421 |

*Notes:* Robust standard errors clustered at the household level; Round 1 (2011/12) for time dummies and Tigray region from regional dummies are used as controls.

†Additional variables include Head age, Head education, Dependency ratio, land and livestock holding, Distance to weekly market, Ownership of non-agricultural business, access to remittance and experience of negative shock.

*, ** and *** indicate significance at 10%, 5% and 1% levels.

source of food group (own production and market) by gender of the head of house-hold. A final set of regressions are undertaken to explore the nature of these differ-ences. Table 6 shows the estimates with HDDS and FVS disaggregated by source, but for a simpler model specification, including the gender dummy only. Hence, in these regressions, production diversity is the only potential endogenous variable. These esti-mates are based on the same set of covariates as in our previous estimations.[6]

The results reveal some interesting patterns. As might be expected, the residual from the first stage equation is statistically significant, suggesting that production diversity is endogenous. Production diversity improves overall dietary diversity across all measures and sources, although the size of the effect is substantially larger for diet-ary diversity from own production. At first sight the fact that production diversity has a significantly positive effect on dietary diversity from the market appears puzzling. As is standard, the dietary diversity variable reflects household consumption over the last 7 days while the production diversity variable reflects decisions over the agricul-tural growing season. Hence, one possible explanation for this result is that it arises from habit formation and the different storability of certain foods. For example, households may produce spices and fresh vegetables such as tomatoes, but will typi-cally sell these when they are harvested as storage is difficult. However, if these goods are grown they may be incorporated into the household diets and hence households may be more likely to purchase these food groups via the markets when their own supply is not available.

In these simpler specifications the gender dummy is statistically significant and neg-ative for the dietary diversity from own production (for both measures), while this coefficient is not significant when the source is the market. This suggests that part of the negative overall gender impacts on dietary diversity shown in Table 5 may arise from differences in marketing and storage of own production through the year, with female-headed households possibly less able to store the commodities produced, lead-ing to the observed reduction in dietary diversity for own produced products.

## 6. Summary and Conclusions

Malnutrition in farm households remains a significant problem in many developing countries and is linked to a lack of diversity in diets. It is well recognised that there are significant gender differences in the use of inputs, access to resources, and prefer-ences in agriculture, with female-headed households often facing significant disadvan-tages relative to male heads. We explore how such gender differences might affect dietary diversity decisions in the household using three rounds of LSMS-ISA Ethiopia panel data.

Using a farm household model to structure the empirical analysis, we consider the different ways in which production diversity, prices and income may influence dietary diversity and how this in turn may differ between male- and female-headed house-holds. In particular, the analysis takes into account the role of unobserved differences in gender preferences, and how gender differences in production diversity decisions feed into the gender differences in dietary diversity.

Our non-linear panel models allow for both unobserved heterogeneity and the potential endogeneity of household production using a two-step pooled Poisson

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[6]Full results of Table 6 are provided in Appendix S2.

control function procedure. Drawing on standard decomposition techniques, we then use the results to judge the relative impact of the different sources of gender difference in dietary diversity, with the robustness of the results tested by using three standard measures of dietary diversity, namely household dietary diversity score (HDDS), modified household dietary diversity score (MHDDS) and food variety score (FVS). Finally, we explore the different patterns of dietary diversity by source of food group (own production and market) accounting for gender.

The results confirm both the need to account for production endogeneity and the strong effect that production diversity has on the dietary diversity of farm households. They also provide evidence of significant gender effects both in the production diversity and dietary diversity estimates, with particularly strong and consistent evidence of gender differences on dietary diversity when the FVS measure is used. For the other indicators, the overall evidence of gender effects is weaker, suggesting that the more disaggregated FVS measure is a better reflection of the more subtle gender differences.

The decomposition results suggest that, after controlling for differences in observed characteristics, female-headed households are overall at a disadvantage in terms of dietary diversity. For example, for the FVS measure the average predicted dietary diversity scores for female-headed households was smaller than the average for male-headed household. However, when the male characteristics were applied to the female subsamples, female-headed households' average predicted dietary diversity score was higher than the observed male dietary diversity score. Using more formal decomposition approaches the results suggest that for the sample of female household heads, 107% of the gender gap reflects the differences in estimates for female- and male-headed households.

The differences in the relationship between production diversity, price and income in the dietary diversity equation and in the production diversity decisions for male- and female-headed households appear to be the main drivers of these results. In contrast, allowing for the differential gender impact of the time averages in the dietary diversity equation tends to increase female-headed household dietary diversity. This is consistent with evidence that female preferences are more orientated towards ensuring good nutrition in the household and therefore empowering women is likely to improve household nutrition.

Our results suggest that a key driver of gender disadvantage in dietary diversity is related to whether food is sourced from the household's own production or the market. In particular, the gender dummy is statistically significant and negative for the dietary diversity from own production. This suggests that part of the negative overall gender impacts on dietary diversity may arise from gender differences in marketing and storage of own production through the year.

In summary, our results provide evidence of sources of gender inequality that influence dietary diversity which have not previously been highlighted in empirically based studies. Further, although there is evidence consistent with the idea that female empowerment will increase dietary diversity, the results suggest other factors and constraints may counteract these so that, overall, female-headed households may remain at a disadvantage even after controlling for the advantageous position that male heads have in terms of land, livestock, income and so on. Finally, the results suggest further research on the relationship between the source of food (market and own production) and the interaction with storage, marketing and habit formation within the household, would be useful in casting further light on gender differences in household dietary decisions.

**Supporting Information**

Additional supporting information may be found online in the Supporting Information section at the end of the article.

**Figure S1.** Production and consumption food groups (% households).
**Table S1.** Gender differences in dietary diversity: Parameter estimates equation (5).

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