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Estimation of food demand parameters in Ethiopia

A Quadratic Almost Ideal Demand System (QUAIDS) approach

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Abstract

In this study we analyse the structure of food demand in Ethiopia to better understand the evolution of food demand under volatile prices and household income vulnerability. In particular, this report aims to estimate the income and price elasticities of the demand of main agricultural and food commodities for Ethiopian households by using state of the art methods and recent data to inform the policy making process with better information. The income and price elasticities measure the responsiveness of quantity of food demanded to changes in income and prices, respectively, and hence contribute to the discussions about policies related to food security. Further, they are important inputs for structural models that are developed by the JRC to support the stakeholders in Ethiopia on nutrition and food security. Using a QUAIDS approach controlling for the potential endogeneity of both expenditure and prices and data from the 2015-2016 Ethiopian Socioeconomic Survey/LSMS-ISA, we find that cereals and animal products are superior (luxury) goods relative to other crops and manufactured food products that appear to be basic necessities. Further, cereals and animal products are elastic to price changes with high substitution effect, while manufactured foods and other crops are inelastic and unit elastic respectively to price changes with low substitution effect, thus confirming their status of essential foods for Ethiopian households. Finally, expenditure elasticities at regional level show a similar pattern that the national one, but price elasticities vary across regions.

1 Introduction

The Joint Research Centre (JRC), as the in-house knowledge service of the European Commission, has been supporting the cooperation between African countries and the EU for more than three decades. JRC has developed multi-faceted levels of cooperation for that purpose with the national governments, their agencies and universities to tackle local challenges more effectively. This cooperation is fully aligned with the principle of partnership set out in the Joint Africa-EU Strategy (JAES), and covers multiple priority areas. As part of these activities, JRC is currently running the project "Technical and scientific support to agriculture and food and nutrition security sectors (TS4FNS)" within the framework of the agreement signed between the Directorate General International Cooperation and Development (DG-DEVCO) and the JRC. The project aims to support the European Union Delegation (EUD) in its work with the Federal Democratic Republic of Ethiopia (FDRE) and the Ministries with evidence based policy making.

Within this context, this report aims to estimate the income and price elasticities of the demand of main agricultural and food commodities for Ethiopian households by using state of the art methods and recent data to inform the policy making process with better information. The elasticities are important to understand the structure of food demand in Ethiopia and hence directly contribute to the discussions about policies related to food security. Further, they are important inputs for structural models that are developed by the JRC to support the stakeholders in Ethiopia on nutrition and food security.

2 Literature review on demand systems1

The challenge of estimating demand functions is to maintain empirical applications coherent with microeconomic theory. Specifically, the literature on demand functions estimations had to deal with assumptions and restrictions from demand and consumer behaviour theories. The idea of using a system of equations estimated simultaneously to estimate demand functions was initially introduced by Stone in 1954. Stone developed the Linear Expenditure System (LES) to estimate the linear relationship between expenditure and prices by fulfilling the regularity conditions of demand theory and testing for some of the restrictions imposed by consumer theory, namely homogeneity and symmetry. Soon after, Theil (1965) developed the Rotterdam model, also a linear model.

The LES and Rotterdam's successful diffusion was linked to the simplicity of their estimation, which is due to linearity and the small number of parameters required. The LES and Rotterdam models perform well when substitution among goods is low. Because the elasticity of substitution is low at higher levels of aggregations, the performance of the two models is less robust with highly disaggregated bundles of goods.

Despite the LES and the Rotterdam models represented important steps forward in the estimation of demand functions, they soon showed some important drawbacks. There are some limiting constraints that they cannot overcome: i) the goods are Hicksian substitutes, meaning that they ignore the substitution among goods in the case of changing relative prices; ii) there is direct (linear) proportionality between price and expenditure changes; iii) expenditure elasticities are always positive, meaning that there do not capture inferior goods; iii) they assume constant marginal budget shares, meaning that the non-linearity of the Engel's curves is not considered and that flexibility is quite limited.

Since the LES and the Rotterdam models, a number of demand systems have been developed aiming to solve some of the constraints mentioned. The demand systems that followed the LES and Rotterdam models can be distinguished in two main groups.

The first group consists of demand systems aiming to achieve more flexible functional forms. That is, functional forms that respect consumer behavior theory but that do not assume a priori the type of relationship between expenditure (or income) and price elasticities.

The first group of demand systems achieved functional forms which are locally flexible. In other words, these demand systems have small regular regions consistent with microeconomic theory where elasticities have no restrictions and can take any value.

In this group of demand systems, the most diffused models with locally flexible functional forms are the Basic Translog (Chriestensen et al., 1975) and the Almost Ideal Demand System (AIDS) (Deaton and Muellbauer, 1980).

The Basic Translog can be estimated through the following expenditure share function:

$$w_i = \frac{\alpha_i + \sum_j \beta_{ij} \log\left(\frac{p_j}{m}\right)}{1 + \sum_k \sum_j \beta_{kj} \log\left(\frac{p_j}{m}\right)}$$

Where *m* is the total expenditure, w_i is the share of expenditure allocated to good *i* and p_j is the price of j_{th} commodity; while α and β are parameters to be estimated.

The AIDS model can be derived by log linearly transforming any cost function, therefore it has a flexible functional form. It can be estimated with the following function:

1 This section on the review of demand systems estimation methods is the result of the joint work carried out for the present study which focuses on Ethiopia and the parallel study on estimation of food demand parameters in Kenya (Vigani et al., 2019).

$$w_i = \alpha_i + \sum_j \gamma_{ij} \log p_j + \beta_i \log\left(\frac{m}{P}\right)$$

Where P is a price index and γ is to be estimated.

Both translog and AIDS models guarantee enough parameters to identify elasticities at a given point. However, locally flexible functional forms have small regular regions. Moreover, homogeneity, symmetry and adding-up conditions are not automatically satisfied. Finally, because the Engel-flexibility is limited to linearity in logarithms, these models have limited capacity to capture realistic income responses to price changes.

In order to achieve functional forms with larger regular regions and to allow for more general income responses, alternative models have been developed in the literature. These models, which constitute the second group of demand systems after the LES and Rotterdam models, improved the coherence with demand theory by considering the non-linearity of the Engel's curves.

Some models solved the problem of the non-linearity of Engel's curves by including in the demand function a quadratic term of the relationship between total expenditure and prices. For example, the Quadratic Expenditure System (QES) developed by Howe et al. (1979) is a generalization of the LES and the AIDS which improves the Engel-flexibility:

$$w_i = \frac{p_i\beta_i}{m} + \alpha_i\left(1 - \sum_{j=1}^{n} \frac{p_j\beta_j}{m}\right) + \frac{\left(p_i\gamma_i - \alpha_i \sum_{j=1}^{n} p_j\gamma_j\right)}{m} \prod_{j=1}^{n} p_j^{-2\alpha_j} \left(m - \sum_{j=1}^{n} p_j\beta_j\right)^2$$

However, the Engel-flexibility in the QES is still quite limited because of the linearity of marginal expenditure. Banks et al. (1997) extended the AIDS with a quadratic term, developing the Quadratic Almost Ideal Demand System (QUAIDS):

$$w_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \log p_j + \beta_i \log\left[\frac{m}{a(p)}\right] + \frac{d_i}{b(p)}\left\{\log\left[\frac{m}{a(p)}\right]\right\}^2$$

Rimmer and Powell (1996) nested the LES developing the An Implicitly Directly Additive Demand System (AIDADS). On the contrary to QES and QUAIDS the Engel-flexibility is improved by imposing less restrictive marginal expenditure shares:

$$q_i = \gamma_i + \frac{\alpha_i + \beta_i \exp(u)}{1 + \exp(u)}\left(m - \sum_{j=1}^{n} p_j\gamma_j\right)$$

Although the second group of models improved the flexibility of functional forms making demand systems more coherent with microeconomic theory, the question of which specification to use is still open and the choice is driven by empirical considerations, such as the level of aggregation of the data at hand.

Usually, different models provide different estimations and models' performance can be different for the estimation of expenditure rather than price elasticities. For example, as mentioned above, when income changes the AIDS model estimation of elasticities is less robust and particularly the income elasticity tends to be smaller as income increases (Abler, 2010).

Therefore, the choice of the right model depends also on the empirical application for which the use is intended. For example, in agricultural applications the use of demand systems is mainly aimed to obtain expenditure rather than price elasticities, as, in the long run, income is considered to be more important than prices for the changes in consumption patterns.

Finally, although the issues related to the coherence with microeconomic theory of the estimation of demand functions have been extensively dealt with, the more recent advancement regarding demand systems are taking into account the potential endogeneity of prices and expenditure.

Endogeneity in demand systems rise mainly because of the way prices are calculated. Commodity prices are often calculated as the ratio between the observed expenditure and quantity consumed. As Deaton (1988) observed, this method of calculating commodity unitary prices reflects market prices, but also the commodity’s quality.

This is not the only reason why endogeneity is a common ingredient in demand systems. Others are: i) measurement errors due to infrequent purchases; ii) unobserved commodity’s characteristics affecting demand behavior; iii) unobserved shocks common to prices and expenditure (Blundell and Robin, 1999). All these factors can result in expenditure or prices (or both) correlated with the errors, resulting in biased and inconsistent estimations and in biased shapes of the Engel curves.

If there is correlation between prices/expenditure and the error terms, Ordinary Least Squares (OLS) and Seemingly Unrelated Regressions (SUR) provide inconsistent estimators. However, such correlation can be accounted for with instrumental variables and augmented regression techniques (Hausman, 1978; Holly and Sargan, 1982).

3 Food Demand in Ethiopia: A Brief Survey

Ethiopia experienced rapid economic growth since 2005 with an average annual GDP growth around 10% which is twice higher the regional Sub-Saharan average (World Bank, 2018). Fast paced economic growth helped to reduce poverty (Bachewe et al., 2017) together with increasing coverage and quality of public services, such as health and education, and infrastructures (Tefera et al., 2014). Also the agricultural sector has benefited from these developments and contributed to the fast economic growth. The average annual growth of agricultural value added was 7.6% since 2004, with significant increase in land use and employment together with a total factor productivity growth of 2.3% (Bachewe et al., 2017). Ethiopia became the second largest grain producer in Sub-Saharan Africa. Cereal production increased more than twice and crop production has doubled since 2005 (FAO, 2018).

However, the increased agricultural production, the new public infrastructures and the high economic growth did not translated into improved food security (Vandercasteelen, 2018). Ethiopia still faces structural challenges that threaten food security and remains one of the most food insecure countries (Thome et al. 2017). The country still relies on large amounts of food aid, especially during the times of drought and price hikes (Ayenew and Kopainsky, 2013). The reasons are various and the most cited are: increasing food demand (Alem, 2011); strict over-valued exchange rate policy (Loening et al., 2009); severe limitations on food imports (Thome et al. 2017); dependence of agricultural production on weather (e.g. mostly rainfed agriculture and high rainfall variability); land degradation; low modern inputs usage (Ayenew and Kopainsky, 2013); slow agricultural transformation (Bachewe et al., 2018). Among these, climate variability (Berger et al., 2017), price volatility (Alem and Söderbom, 2012) and income vulnerability (Hill and Porter, 2017) are listed as the most important risk factors that undermine food security through out the country. For the purposes of this study we will focus on the latter two, while climate variability will be considered with its relation to rural income.

Price volatility directly affects the accessibility of food. Food inflation has historically been high in Ethiopia, mostly due to market imperfections (Ayenew and Kopainsky, 2013). Volatility in food prices despite the increasing agricultural production are caused by several reasons: volatility in world food prices (Loening et al., 2009), strict government controls on food imports (Thome et al. 2017), fast population growth and hence demand growth (World Bank, 2007), problems with infrastructure that disrupt internal supply chains (Ulimwengu et al., 2009; Vandercasteelen, 2018), etc. For example, Ethiopia was one of the most affected countries during the 2004-2008 global food price increase. In recent years food prices changed between -2% and +4% mostly on positive side (CSA, 2018a). More recently, the devaluation of the Birr has caused food prices to increase quickly (Berhane, 2017). The 12-month moving average of food price inflation increased to 16% from 9.5% in the pre-devaluation period (CSA, 2018a).

Despite the high economic growth, income inequality is still an important challenge for Ethiopia (Tefera et al., 2014). The Gini coefficient has stagnated since the early 2000s. 81% of Ethiopian population lives in urban areas and rely on income from agricultural production (CSA, 2018b). Hence, increasing prices of agricultural and food commodities might be expected to increase the household income. However, Wossen et al. (2018) shows that climate and price volatility generally worsens the income and food security status of rural househods. As mentioned before, most of the agricultural production in Ethiopia is rainfed and farmers critically rely on rain cycles for agricultural production. Any change in the rainfall thus affects agricultural production severely (Berger et al., 2017). Furthermore, households without any off-farm income are generally more prone to food insecurity (Abegaz, 2017). On the other hand, urban households also suffer from income vulnerability as most of the households rely on casual work in the services sector (Alem and Söderbom, 2012). Besides, unemployment rate in urban areas (16.8%) are significantly higher than the national average (5.6%) (CSA, 2015).

High price volatility of staple foods and income vulnerability significantly affect household consumption (Tafere et al., 2010). Especially small-holder farm households (Hill and Porter, 2017) and poorer households in urban areas are more affected (Alem and Söderbom, 2012). Thus, understanding how household food consumption would respond to income and price changes has important policy implications for food security. But there have been few attempts in the literature to parametrize household demand systems which are then used to estimate the income and price elasticities of food demand conditional on household characteristics.

We could identify 5 studies in the literature that estimating demand system for Ethiopia (see Table 1). These studies use AIDS (Ulimwengu et al., 2009), QUAIDS (Tafere et al., 2010; Alem, 2011), dynamic QUAIDS or generalized dynamic AIDS (Tefera et al., 2014) or other more general demand systems (Muhammad et al., 2011). They depend on household survey data from various years, except Muhammad et al. (2011) who use cross section country data. Note that each of them adopts a different estimation strategy and all but Tefera et al. (2014) ignore the expenditure endogeneity problem.

Table 1: Demand system estimations in the literature for Ethiopia

	Ulimwengu et al. 2009	**Tafere et al. 2010**	**Muhammad et al. 2011**	**Alem, 2011**	**Tefera et al. 2014**
Abbrev.	ULI	TAF	MUH	ALE	TEF
Year	2000	2005	2005	2000, 2004, 2009	1999, 2004, 2009
Data	EHICES	EHICES	ICPD	EUSS	ERHS
Model	AIDS	QUAIDS	Florida-Preference Independence and Florida-Slutsky	QUAIDS	dynamic QUAIDS, gen. dynamic AIDS
Estimator	SUR	2SLS	Maximum Likelihood	nonlinear SUR	2SLS; exp. endo. taken into account
Smp. Size		21595, Survey	144 country level	709, survey	1632,survey
Data source abbreviations					
EHICES: Ethiopia Household Income, Consumption, and Expenditure Survey					
EUSS: Ethiopian Urban Socioeconomic Survey					
ICPD: International Comparison Program Data					
ERHS: Ethiopia Rural Household Survey					

Source: Authors' own compilation

All these studies share a few commodities such as teff, pulses and/or oilseeds, vegetables and/or fruits, and animal products. The diversity in the data sources, estimation methods and models as well as commodities and commodity groups inevitably results in quite different findings. However it is possible to make a few generalizations from the reported elasticities:

- The more aggregated are the commodity groups, the lower the expenditure elasticities;
- Animal products generally have the highest expenditure elasticities;
- Studies that take into account for expenditure endogeneity report higher elasticities;
- Price elasticities are more heterogeneous and seem to be more sensible to the differences in data and model.

Furthermore, one should keep in mind that these studies cover a period of economic growth and transition in Ethiopia and each use data from a different part of this period. Hence, at least some part of the differences in the estimations might be due to the evolving demand patterns under a high growth rate of the domestic economy. For example more recent studies report a higher expenditure elasticity for animal products, fruits and vegetables which is consistent with the evidence presented in the literature on the evolution of demand patterns in developing countries.

Table 2: Expenditure and income elasticity estimations in the literature

Commodities					**Expenditure Elasticities**					**Uncompensated Price Elasticities**				
ULI	**TAF**	**MUH**	**ALE**	**TEF**	**ULI***	**TAF**	**MUH**	**ALE**	**TEF**	**ULI***	**TAF**	**MUH**	**ALE**	**TEF**
Cer	Tef	Cer	Tef	Tef	0.59	1.69	0.62	0.59	1.14	-0.84	-0.89	-0.46	-0.77	-1.12
	Whe		Whe	Whe		0.78		1.14	1.85		-0.98		-1.06	0.94
	Bar			Bar		-0.44			-1.56		-0.95			-2.58
	Mai		Mai	Mai		0.92		-1.13	0.64		-0.75		-1.48	2.47
	Sor			Sor		0.77			0.83		-0.66			-0.53
	Oce					-6.7					-1.07			
	Pce					2.33					-1.02			
P&L	Pul		Pul	P&O	0.44	1.03		0.55	2.19	-0.16	-0.95		-0.96	0.21
	Oil					0.63					-1.00			
Mea	Ani	Mea	Ani	Ani	0.8	1.31	0.82	2.48	2.28	1.32	-0.94	-0.6	-1.39	1.87
		Dai					0.85					-0.62		
	O&F	O&F				0.72	0.63				-0.98	-0.46		
Veg	F&V	F&V	F&V	F&V	0.23	0.87	0.68	1.09	1.41	-0.11	-0.98	-0.5	-1.07	-1.06
	Pep					0.41					-0.99			
	Ens					0.87					-0.99			
	Cof					0.88					-0.96			
	Roo		Roo			0.94					-0.99			
S&H	S&S				0.49	0.79				0.38	-0.99			
	Ofo	Ofo	Ofo	Ofo		0.16	2.28	1	-2.6		-0.98	-1.67	-0.26	-1.69
		Fis					0.71					-0.52		
		B&T					1.49					-1.09		
	Clo					0.74					-0.95			
	Ser					1.45					-0.68			
	Onf					1.38					0.87			

Commodity Abbreviations:					
Ani	Animal products	Mai	Maize	P&L	Pulses and Legumes
Bar	Barley	Mea	Meat	P&O	Pulses & Oilseeds
B&T	Beverages & Tobacco	O&F	Oils & Fats	Roo	Root crops
Cer	Cereals	Oil	Oilseeds	Ser	Services
Clo	Clothing and Shoes	Oce	Other cereals	Sor	Sorghum
Cof	Coffee/Tea/Chat	Ofo	Other Food	S&H	Sugar and honey
Dai	Dairy	Onf	Other Non-food	S&S	Sugar and Salt
Ens	Enset/Kocho/Bula	Pep	Pepper	Tef	Teff
Fis	Fish	Pce	Processed Cereals	Veg	Vegetables
F&V	Fruit & Vegetables	Pul	Pulses	Whe	Wheat

Source: Authors' elaboration

Notes: * National average for rural and urban
** See Table 1 for study abbreviation

4 Model and estimation method

For the estimation of food demand elasticities parameters using household survey data from Ethiopia the best strategy is to apply QUAIDS (Banks et la., 1997). The choice of QUAIDS is based on its flexible functional form which allows coherence with demand and consumer behaviour theory, and the possibility to account for the endogeneity between prices and expenditure.

Consider the following demand system in vector notation, which is the Banks et al. (1997) quadratic extension of the Deaton and Muellbauer's (1980) AIDS model:

$$w_i^h = \alpha_i + \gamma_i' \boldsymbol{p}^h + \beta_i\{x^h - a(\boldsymbol{p}^h, \boldsymbol{\theta})\} + \lambda_i \frac{\{x^h - a(\boldsymbol{p}^h, \boldsymbol{\theta})\}^2}{b(\boldsymbol{p}^h, \boldsymbol{\theta})} + u_i^h \quad (1)$$

Where w^h_i is the expenditure share of good i = 1, . . . ,N for household h = 1, . . . ,H; x^h is the household's total expenditure for food; p is a vector of food prices; u is the error term; and α, β, γ, θ are the parameters to be estimated.

a and *b* are non-linear price aggregator functions defined as:

$$a(\boldsymbol{p}^h, \boldsymbol{\theta}) = \alpha_0 + \boldsymbol{\alpha}' \boldsymbol{p}^h + \frac{1}{2} \boldsymbol{p}^{h\prime} \boldsymbol{\gamma} \boldsymbol{p}^h$$

$$b(\boldsymbol{p}^h, \boldsymbol{\theta}) = exp(\beta' \boldsymbol{p}^h)$$

The parameters α, β, γ, θ must satisfy the theoretical restrictions of additivity, homogeneity, symmetry, which are:

$$\sum_{i=1}^{n} \alpha_i = 1; \quad \sum_{i=1}^{n} \beta_i = 0; \quad \sum_{j=1}^{n} \gamma_{ij} = 0; \quad \sum_{i=1}^{n} \lambda_i = 0; \quad \text{and} \quad \gamma_{ij} = \gamma_{ji}$$

Equation (1) can be estimated with different estimators. A common approach is using seemingly unrelated regressions (SUR) with iterated feasible generalized nonlinear least-squares estimator (FGNLS) through nonlinear three-stage least squares (Poi, 2012), which allows the computation of expenditure and price elasticities controlling for households' heterogeneity. However, the main shortcoming of FGNLS is that non-linear least-squares are computationally demanding when a large number of parameters have to be estimated. This is a common situation when dealing with large and highly disaggregated consumption datasets with multiple goods. Moreover, the approach proposed by Poi (2012) does not address endogeneity.

A preferred alternative is the approach proposed by Lecocq and Robin (2015) to use the iterated linear least-squares (ILLS) estimator developed by Browning and Meghir (1991) and later generalized by Blundell and Robin (1999).

This approach is computationally attractive. It is based on the conditional linearity property – i.e. all equations in (1) are linear in all parameters conditional on the price aggregator functions – and it requires linear SUR to obtain consistent and asymptotically normal estimation of the demand system.

In the Lecocq and Robin's model (2015) the demographic variables to control for household heterogeneity are included through the translating approach. This approach allows to vary the level of demand according to household characteristics, by parametrizing the intercepts α's with sociodemographic variables s^h from the household survey, such that:

$$\boldsymbol{\alpha}^h = \boldsymbol{A}\boldsymbol{s}^h; \qquad \boldsymbol{A} = (\boldsymbol{\alpha}_i')$$

Lecocq and Robin's model (2015) allows accounting for endogenous prices and total expenditure by using instrumental variable techniques. The error $u^h{}_i$ is augmented with the error vector v^h predicted from estimating reduced forms for x^h and p^h:

$$u_i^h = \boldsymbol{\rho}_i \widehat{\boldsymbol{V}}^h + \varepsilon_i^h$$

The independent variables in the reduced form equations are the sociodemographic variables in s^h and the proper identifying instruments.

In Lecocq and Robin (2015) elasticities are calculated at the mean of the household sample.

Finally, for the purposes of this report, equation (1) is estimated for different levels of food basket disaggregation and for the main Ethiopian regions.

5 Data and empirical strategy

The data source of our empirical work is the 2015-2016 Ethiopian Socioeconomic Survey (ESS), which is a joint project between the Central Statistical Agency (CSA) of Ethiopia and the World Bank Living Standards Measurement Study – Integrated Surveys on Agriculture (LSMS-ISA) project2. We refer in our analysis to the third wave of the ESS (ESS3) with an initial sample size of 4954 households. The sample is a two-stage probability sample, where the first stage of sampling consisted on selecting primary sampling units, or CSA enumeration areas (EAs). The sample covers both urban and rural areas to allow for statistical inference to all of Ethiopia and to the population of urban and rural households. In particular the sample covers the 11 Ethiopian regions, 84 zones, 3272 rural households, 427 households in small-towns3 (urban) and 1255 households in mid- and large-sized towns (urban). The data are weighted to represent the national-level of rural areas, small-towns, and medium and large cities. The sample is representative at national level and for each of the most populous regions, but not for each of the small regions, namely Afar, Benshangul Gumuz, Dire Dawa, Gambella, Harari, and the Somalie region. However, estimates can be produced for the aggregation of all the smaller regions into one "other region" category (CSA 2012 and 2016).

The interviews were carried out using pen-and-paper (PAPI) as well as a computer-assisted personal interviewing (CAPI) method. Three questionnaires are available from the survey (i.e. household, community and agriculture). We refer in our study to the household questionnaire which provides information on demographics, education and health, labor and time use, food and non-food expenditure, and nonfarm income-generating activities among others. Specifically, the food and non-food consumption data include 70 food items, 12 basic household goods, 12 other expenditures and 3 types of education expenses.

Households report their food expenditures together with the consumed physical quantities either purchased, home-produced or received as gifts during the 7 days prior to the survey. Additionally they report their non-food and education expenditures for the previous month or year depending on the type of expenditure. We prepared the data on consumption to calculate total households' annual food, non-food and education expenditures. Food quantities were standardized to Kg/L using conversion factors that had been collected during a market survey conducted before the ESS3; commodity prices were calculated following the approach suggested by the CSA (CSA 2012) as the median price at the lowest geographical unit for which at least 10 price observations (prices actually paid by households who purchased the item) were available and the price was not more than 10 times the regional price and not less than 1/10 of the regional price. This is the method proposed by the Ethiopian CSA to calculate the prices to estimate the value of food produced at home or received as gifts; household food expenditure is then calculated for each item as the addition of the monetary value of food purchases and the quantities home-produced or obtained as a gift multiplied by the calculated commodity price. The data on consumption were merged with data on household size, the age and gender of the household head, his/her level of education, level of literacy, occupation and sector of activity to control for socio-economic factors.

From the initial sample of 4954 households 42 households (0.8% of the sample) not reporting any food consumption and 486 households (9.8% of the sample) for which at list the consumption of one food item reported in nonstandard units could not be converted to standard units were excluded from the sample. Furthermore, households for which consumption values were far too large compared to the household size were removed. We used the interquartile range (IQR) method to identify per capita consumption values falling outside of either 3 times the interquartile range (IQR) below

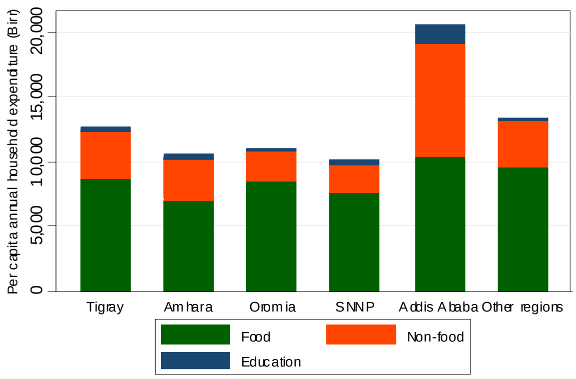
2 For more information on the LSMS and the LSMS-ISA go to www.worldbank.org/lsms

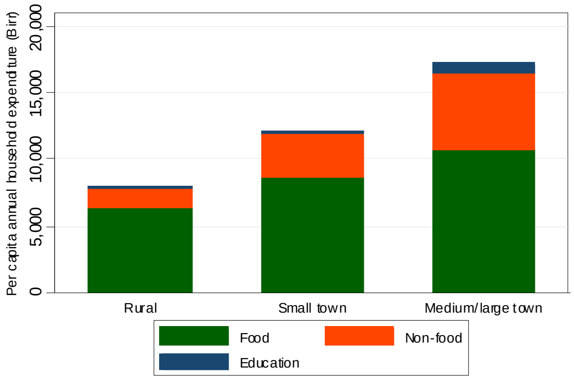
3 The CSA defines small towns based on population estimates from the 2007 Population Census; a town with the population of less than 10,000 is a small town.

the first quartile or 3 times the IQR above the third quartile4. Finally, some households for which some socio-economic data were missing were removed and a final dataset containing 2078 households is used in the study.

Considering that the principal goal of this study is to measure the effects of households' income and food prices on household food consumption patterns, Figure 1 shows the shares of total per capita household budget dedicated to food, non-food and educational expenses for the main Ethiopian regions (left) and for rural and urban areas (right). Per capita disposable budget in Addis Ababa is between 1.5 and two times higher than the budget in other regions. Moreover, while in Addis Ababa food represents around 51% of total expenditures, in the rest of the Ethiopian regions food expenditure shares range between 69% in Tigray to 77% in Oromia. Furthermore, in rural areas the average share of per capita expenditure dedicated to food amounts to some 81%, whilst in small towns and medium and large ones the shares amount to approximately 71% and 62% respectively.

Figure 1: Per capita total annual household expenditure for food, non-food and education by region (left) and by urban-rural areas (right), 2015-16

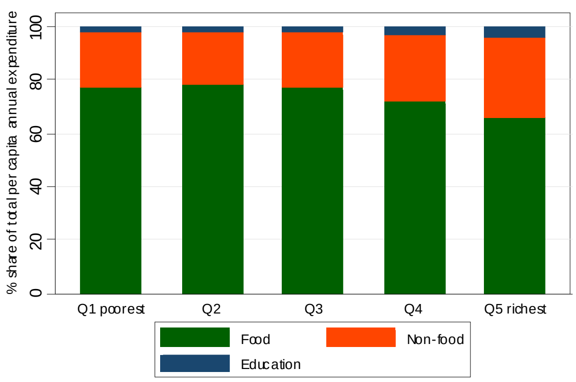




Note: Other regions are Afar, Benshangul Gumuz, Dire Dawa, Gambella, Harari, and the Somalie region.

From the income distribution perspective, the food consumption of the richest quintile of the population (Figure 2) represents about 66% of total homes expenditures while in the poorest quintiles the shares stay close to 80%.

Figure 2: Share of per capita total annual expenditure for food, non-food and education by consumption quintile, 2015-16



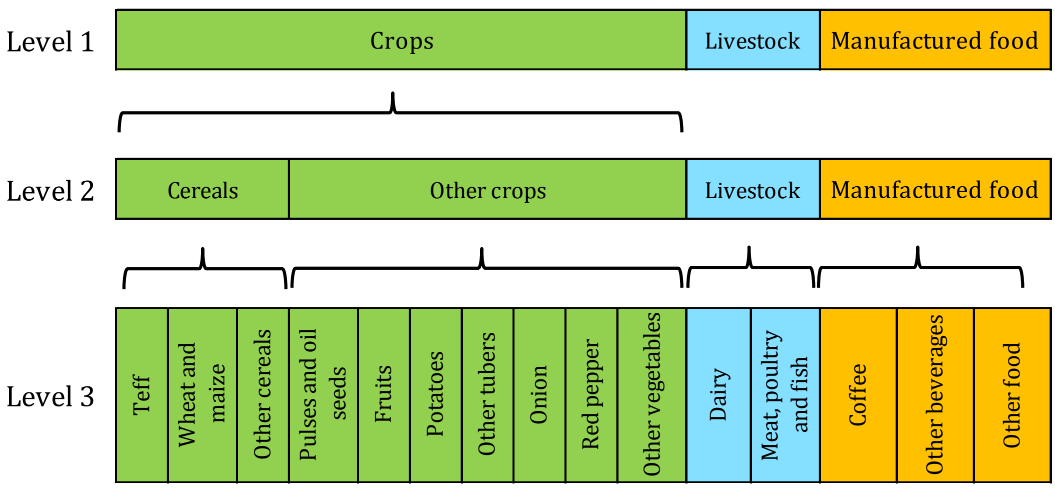
4 The Tukey outlier detection method considers the interquartile range defined as IQR =3rd quartile value – 1st quartile value and sets and upper threshold = 3rd quartile + IQR*factor and a lower threshold = 1st quartile – IQR*factor. Values above the upper threshold and below the lower threshold are identified as outliers. Since this method is independent of the statistical mean and standard deviation, it is not influenced by extreme values in the dataset (Tukey, 1977).

In this report, food demand systems are estimated with ILLS (Lecocq and Robin, 2015) for different levels of food items aggregation. Three levels of aggregation are used, from 1 (more aggregated) to 3 (less aggregated) (Figure 3).

Level 1 is the most aggregated, consisting of three food groups: crops, livestock products (including poultry and fishery) and manufactured foods (e.g. bakery products, oils, sugar). Level 2 distinguishes crops between cereals and all other food crops (e.g. pulses, nuts, tubers, stems, fruits and vegetables). Finally, Level 3 is the most detailed level with a total of 15 food groups.

The choice of the aggregation levels is mainly data driven. Starting from an initial list of 70 food items, 20 out of the 70 food items were removed because of insufficient observations. The remaining 50 food items were progressively aggregated to obtain the highest level of details possible, while maintaining a sufficient number of observations for each food group allowing the estimation of the demand system. The most detailed clustering of food items obtainable resulted in 15 food groups, which correspond to Level 3. For each level we had sufficient observations to estimate the demand system.

Figure 3: Aggregation levels of goods

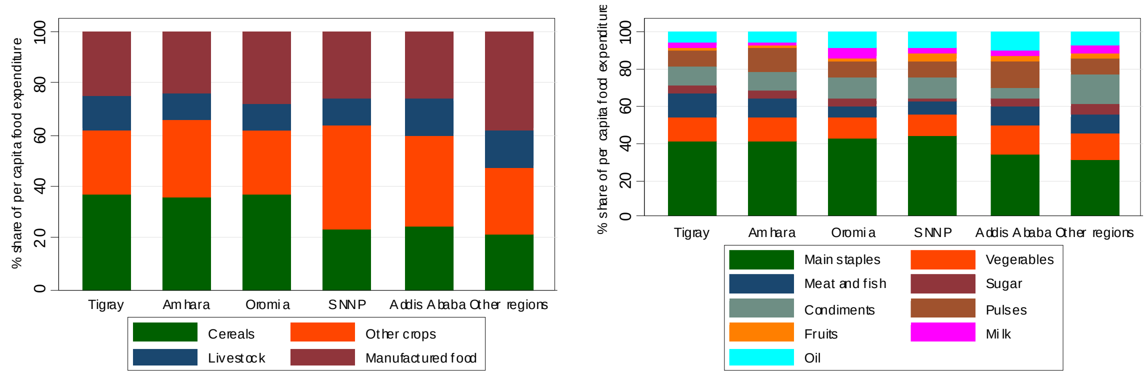


For each food item, expenditure shares (w^h_i) are calculated from the survey data as expenditure of food *i* on total household food expenditure, so that $\sum_{i=1}^{n} w_i^h = 1$.

The expenditure shares of each food group (i.e. Level 2) on total food expenditure are shown in Figure 4, left. Cereals and other crops are the most important food groups in the most populated Ethiopian regions. Across regions the share of cereals ranges from 21% to 37% of food expenditure, being the leading food group in all regions except for Addis Ababa and SNNP where other crops lead food consumption and other regions where other manufactured food leads expenditure. The share of other crops ranges between 25% and 40% across regions. The rest manufactured food represents the third group in terms of expenditure in the most populated regions (24% to 38%). At last place we find the share of expenditure of livestock products accounting for 10% to 14% across regions, with fish representing only a smaller share (0% to 2%) of the consumption of livestock products compared to meat (35% to 65%) in all regions. With respect to dairy products, most regions spend on them a smaller portion compared to meat, except for Oromia and SNNP regions with milk shares of 47% and 45% respectively of total expenditure on livestock products. On the right side of Figure 4 we look at the nutritional component of food consumption by considering the food groups as defined by the Word

Food Programme (WFP) for the calculation of the Food Consumption Score5 (FCS). In the FCS a food group is defined as a category of food items that have similar caloric and nutrient content. The category of "main staples" (Teff, wheat, maize and other cereals, potato, sweet potato, kocho, yam, cassava and bread among others) dominate food consumption across all Ethiopian regions with percentage shares on total food budget ranging from 31% to 44%. The categories of "vegetables" (11 to 16%), "pulses" (8 to 14%) and "meat and fish" (Eggs, goat & mutton meat, beef, poultry and fish) (7 to 12%) follow in most regions. Next in food expenditure share are either the category of "oils" (6 to 10%) or surprisingly condiments (salt, coffee, tea, beer and other beverages) (6 to 17%), while the consumption share of the categories of "sugar" (2 to 6%), "milk" (1 to 5%) and in particular "fruits" (1 to 3%) stay at the end.

Figure 4: Shares of per capita expenditure of food groups (Level 2, left and FCS, right) in total food expenditure, 2015-16



Furthermore, when looking at food consumption patterns across expenditure quintiles, the average food consumption share of per capita expenditure on main staples decreases from the poorest (49%) to the richest (30%) quintile groups. By contrast, the consumption share of meat and fish consistently increases from 2% in the poorest quintile to 15% in the richest.

The demand system estimation is corrected for household heterogeneity, by parametrizing the intercepts α^h with a vector of variables s^h. These variables are gender, education and age of the head of the household and the distance of the household from the nearest market (see table 3 for definitions).

In order to control for potential endogeneity of expenditure and prices, instrumental variable techniques have been used. Specifically, expenditure is instrumented using the household size in adult equivalent. On the contrary prices are instrumented with the price adjusted with the aggregate consumer price index (2009 is baseline year) provided by the Central Statistical Agency of Ethiopia.

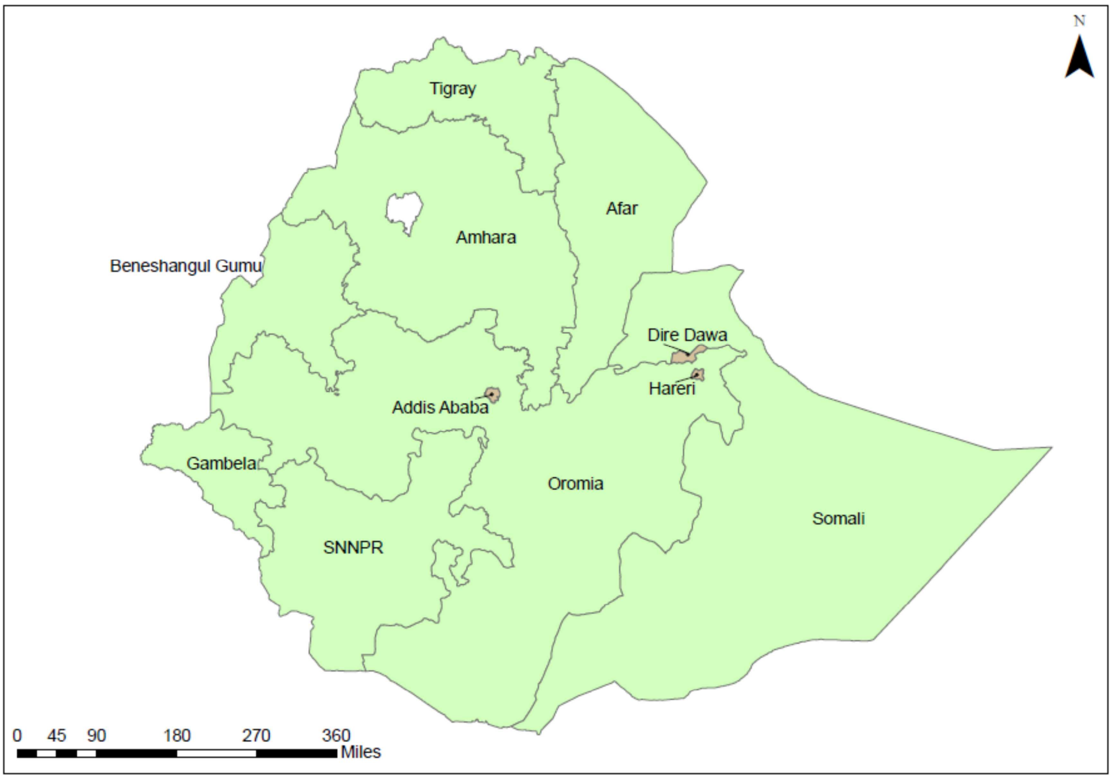
5 For more information on the Food Consumption Score (FCS) guidelines refer to https://documents.wfp.org/stellent/groups/public/documents/manual_guide_proced/wfp277333.pdf?_ga=2.213263124.1068765371.1558683099-471321110.1545404741 (WFP, 2015)

Table 3: Definition and sample average of demographic variables

Variable	Definition	Mean
HH size	Number of households members in adult equivalent	3.78
Gender	=1 if head of the HH is a woman; 0 otherwise	0.24
Education	=1 if the household head has formal education; 0 otherwise	0.01
Age	Age of the household head in year	39.78
Distance	Distance to the nearest market (km)	44.42

In addition, a series of regional dummy variables are included to control for potential heterogeneity of agro-ecological conditions and consumption patterns of the households. The regions are mapped in Figure 5. Rural and urban areas are also controlled for.

Figure 5: Regions of Ethiopia



6 Results and Discussion

The main objective of estimating the QUAIDS in equation (1) is to obtain expenditure and price elasticities for food items consumed by households in Ethiopia. Expenditure elasticity of demand measures the responsiveness of the quantity demanded for a food item to a change in the income of the household, while price elasticity of demand measures the responsiveness of the quantity demanded of a food item to a change in its price, *ceteris paribus*.

All estimations are conducted with instrumental variables techniques to control for the potential endogeneity of both expenditure and prices. Moreover, all estimations include socio-demographic variables to control for households heterogeneity.

Overall, it is worth noting that none of the estimated expenditure elasticities, at any level of food basket disaggregation nor in any region, have a negative sign, suggesting that there are no food items which are inferior goods but they are all normal goods – i.e. any increase in household income will raise the demand of any food item.

Table 4 shows the results of estimated elasticities for Level 1 food items – i.e. crops, animal products and manufactured food. The first column reports the results of expenditure elasticities – i.e. the coefficient represents the change in demand corresponding to a change in income. The second column reports the uncompensated price elasticities derived from ordinary (Marshallian) demand curves – i.e. the coefficient represents the change in demand corresponding to a change in food's price which affects the disposable income. The third column reports the compensated price elasticities which measure substitution effects between goods – i.e. the coefficient represents the change in demand corresponding to a change in food's price, ignoring the income effect.

Looking at the expenditure elasticities of the three groups of foods in table 4, the first striking difference that appears is between crops and animal products on one side and manufactured foods on the other side. The expenditure elasticity coefficients of crops and animal products are positive, larger than 1 and significant at 1% level. This suggests that both are superior goods, in that an increase in household income would result in a more than proportional increase of consumption of the two food groups. More specifically, a 1% increase in household income would result in 1.125% increase in crops consumption and in 1.235% increase in animal products consumption. In other words, these two products can be considered luxury goods, relative to other food products. On the contrary, the positive, lower than 1 and 1% significant coefficient of manufactured foods suggests that they are basic necessities. Changes in household income would result in less than proportional changes in consumption of manufactured foods and such low responsiveness suggests that these products are the ones satisfying the most of the basic nutritional needs of the household.

Looking at the price elasticities in table 4, crops and manufactured food are inelastic to uncompensated price changes, but animal products are elastic, suggesting that a 1% reduction in the price would result in a 1.135% increase in consumption of animal products. However, all three coefficients of compensated price elasticities are 1% significant and less than 1, suggesting that they all have a low substitution effect, including animal products.

Table 4: Elasticities estimates of Level 1 food items

			Expenditure elasticity	Uncompensated price elasticity	Compensated price elasticity
1	Crops		1.125***	-0.905***	-0.274***
		se	0.031	0.046	0.05
2	Animal products		1.235***	-1.135**	-0.983**
		se	0.100	0.349	0.348
3	Manufactured food		0.687***	-0.627***	-0.410*
		se	0.042	0.166	0.163
	Obs. 2078				

Notes: * Significant at the 10% level; ** Significant at the 5% level; *** Significant at the 1% level.

It is possible to better understand the results concerning crops by looking at the second level of aggregation in Table 5. The 1% significant expenditure elasticity coefficients show that cereals are superior goods, but other crops are actually necessity goods as a 1% increase of household income would lead to only 0.903% increase of other crops consumption. Moreover, the expenditure elasticity coefficients of animal products and manufactured foods remain almost unchanged. However, price elasticities changed. At level 2, cereals and animal products, which are superior goods, are elastic to price changes with high substitution effect, while manufactured foods are inelastic to price changes with low substitution effect, further confirming their status of essential foods for Ethiopian households.

Table 5: Elasticities estimates of Level 2 food items

			Expenditure elasticity	Uncompensated price elasticity	Compensated price elasticity
1	Cereals		1.345***	-1.562***	-1.192***
		se	0.058	0.272	0.272
2	Other crops		0.903***	-1.062***	-0.798***
		se	0.039	0.054	0.056
3	Animal products		1.229***	-1.478**	-1.326**
		se	0.098	0.49	0.489
4	Manufactured food		0.692***	-0.627***	-0.414*
		se	0.044	0.175	0.172
	Obs. 2078				

Notes: * Significant at the 10% level; ** Significant at the 5% level; *** Significant at the 1% level.

The third level of disaggregation of the food basket provides a much more detailed picture of the consumption patterns of Ethiopian households (Table 6).

First, cereals are confirmed as superior goods, as 1% increase of household income would lead to a 1.045% increase in teff consumption, 1.561% increase in wheat and maize consumption and 1.432% increase in the consumption of other cereals. Teff, wheat and maize are elastic to price changes (1.404% and 1.059% respectively), but while the former has a high substitution effect, wheat and maize are less substitutable.

On the contrary, other seeds such as pulses and nuts have a positive but less than 1 expenditure elasticity coefficient, suggesting that they are essential foods for Ethiopian diets, although price elasticity coefficients are not statistically significant.

Second, tubers and stems are superior goods, however, potatoes are quite inelastic to price changes while other tubers and stems, such as enset and sweat potatoes, have a very high substitution effect, suggesting that they can be considered luxury goods for Ethiopian households.

Third, fruits are superior goods with high substitution effect, but vegetables are necessity goods. More specifically, onions and red peppers have low price elasticity and low substitution effect suggesting that they are basic necessities, while other vegetables have much higher price elasticity and substitution effect, suggesting that they are less essential to households' diet.

Fourth, dairy products have a relatively high expenditure elasticity coefficient. Any increase in household income would lead to a more than proportional increase in dairy products consumption, therefore they can be considered luxury goods. On the contrary, meat, poultry and fishery are necessity goods although with a relatively high price elasticity and substitution effect.

Regarding manufactured foods, coffee and other beverages and stimulants are necessity goods but with high price elasticity and high substitution effect. This is not surprising as the group "other beverages and stimulants" includes chat and tea, but also soft drinks, beer and tella which are not essential to the household's nutritional needs.

The estimated elasticities in table 6 have been compared with the estimates of Tafere et al. (2010). Despite there is a slight difference in the definition of food items groups that can make the comparison difficult, our estimates are broadly in line. However, some key differences emerges: i) Tafere et al. (2010) estimation of the expenditure elasticity for teff (1.69) is higher than in table 6 (1.045); ii) Tafere et al. (2010) estimation of the expenditure elasticity for wheat (0.78) and maize (0.92) is lower than in table 6 (1.561). These few differences can be explained by the different estimators used (we use GMM estimator instead of 2SLS) and by the fact that Tafere et al. (2010) use household data for 2005 while in this report data are for 2015-2016.

Table 6: Elasticities estimates of Level 3 food items

			Expenditure elasticity	Uncompensated price elasticity	Compensated price elasticity
1	Teff		1.045***	-1.404***	-1.254***
		se	0.078	0.232	0.231
2	Wheat and maize		1.561***	-1.059***	-0.919**
		se	0.122	0.318	0.315
3	Other cereals		1.432***	-0.658	-0.593
		se	0.149	0.87	0.87
4	Pulses, nuts and seeds		0.971***	-0.272	-0.18
		se	0.071	0.656	0.656
5	Potatoes		1.014***	-0.690***	-0.671***
		se	0.14	0.164	0.164
6	Other tubers and stems		1.248***	6.591***	6.623***
			0.276	1.249	1.249
7	Fruits		1.206***	-1.150**	-1.125*
		se	0.188	0.446	0.446

			Expenditure elasticity	Uncompensated price elasticity	Compensated price elasticity
8	Onions		0.875***	-0.613***	-0.588***
		se	0.07	0.089	0.089
9	Red peppers		0.562***	-0.986***	-0.957***
		se	0.075	0.048	0.048
10	Other vegetables		0.829***	-1.127***	-1.087***
			0.082	0.133	0.133
11	Dairy		1.787***	-0.172	-0.11
		se	0.179	0.803	0.803
12	Meat, poultry and fishery		1.006***	-2.020**	-1.923**
		se	0.118	0.678	0.678
13	Coffee		0.874***	-1.046***	-1.002***
		se	0.102	0.103	0.103
14	Other beverages and stimulants		0.614***	-2.524***	-2.475***
			0.131	0.342	0.344
15	Other manufactured food		0.769***	-0.518**	-0.383*
		se	0.053	0.158	0.158
	Obs. 2078				

Notes: * Significant at the 10% level; ** Significant at the 5% level; *** Significant at the 1% level.

Finally, elasticities have been also estimated for the main regions in the sample (see Figure 5). Note that the regions of Afar, Benshangul Gumu, Gambela and Harari and the cities of Addis Ababa and Dire Dawa have been aggregated because of the low number of observations. Moreover, note that the estimations at regional level are done for Level 2 only, because data constraints would not allow consistent estimations of the demand system with the homogeneity and symmetry restrictions. Results of regional elasticities are shown in Table 7.

Expenditure elasticities at regional level in table 7 show a similar pattern that the national ones in Table 5. Cereals are superior goods in all regions, with consumption elastic to price changes and high substitution effect, especially for the Tigray region which uncompensated and compensated elasticity coefficients are 3.018 and 2.437 respectively, but with the exception of the Amhara region where cereals have a low substitution effect.

Other crops are basic necessities in all regions, but price elasticities of this food group vary. While the consumption of other crop is inelastic to price changes with a low substitution effect in Tigray, Amhara, Oromia and other regions, price elasticities are >1 in the SNPP region. In this region, a 1% increase in the price of crops different than cereals (e.g. pulses, tubers, fruits and vegetables) would reduce their consumption of about 1.017%. This suggests that other crops are less essential in SNPP.

Regarding animal products, they are confirmed superior goods in Tigray, Amhara, Oromia and other regions, where expenditure elasticity coefficients are positive, >1 and 1% statistically significant.

Finally, manufactured foods are confirmed necessity goods in all regions, with the exception of the SNNP region where coefficients are not statistically significant. Interestingly the uncompensated and compensated price elasticity coefficients of manufactured foods are quite large in Amhara and Oromia, suggesting that in these regions the substitution effect of manufactured foods is quite high, in contrast with other regions and the national level in Table 5.

Table 7: Regional elasticities estimates of Level 2 food items

			Expenditure elasticity	Uncompensated price elasticity	Compensated price elasticity
Tigray	Cereals		1.253***	-3.018***	-2.437***
		se	0.125	0.796	0.714
	Other crops		0.592***	-0.899***	-0.754***
		se	0.16	0.171	0.183
	Animal products		2.049	-7.206	-7.135
		se	1.761	14.256	14.318
	Manufactured food		0.793***	-0.797	-0.593
		se	0.23	0.658	0.726
	Obs.		244		
Amhara	Cereals		1.042***	-1.093**	-0.711
		se	0.079	0.424	0.384
	Other crops		0.933***	-0.890***	-0.536**
		se	0.059	0.16	0.177
	Animal products		1.878**	-1.198	-1.061
		se	0.582	2.36	2.35
	Manufactured food		0.704***	-3.037*	-2.908*
		se	0.184	1.417	1.461
	Obs.		279		
Oromia	Cereals		1.234***	-1.884***	-1.480**
		se	0.136	0.544	0.547
	Other crops		0.843***	-1.315***	-1.080***
		se	0.082	0.128	0.135
	Animal products		1.331***	-0.933	-0.766
		se	0.219	0.879	0.862
	Manufactured food		0.722***	-2.414***	-2.220**
		se	0.147	0.632	0.678
	Obs.		505		
SNNP	Cereals		1.311***	-1.786**	-1.31
		se	0.137	0.658	0.775
	Other crops		1.017***	-1.083***	-0.609**
		se	0.079	0.076	0.191
	Animal products		0.772	-3.457	-3.379
		se	0.4	2.832	2.925
	Manufactured food		-0.399	1.875	1.847
		se	2.528	6.285	6.157
	Obs.		472		
Other regions	Cereals		1.417***	-1.463**	-1.188**

		Expenditure elasticity	Uncompensated price elasticity	Compensated price elasticity
	se	0.131	0.446	0.432
Other crops		0.819***	-0.751***	-0.538***
	se	0.072	0.118	0.117
Animal products		1.213***	-1.909***	-1.695***
	se	0.126	0.469	0.472
Manufactured food		0.806***	-1.059***	-0.762***
	se	0.074	0.148	0.167
Obs.		578		

Notes: * Significant at the 10% level; ** Significant at the 5% level; *** Significant at the 1% level.

7 Conclusions and policy recommendations

Ethiopia witnessed a rapid economic growth and social development in the last decade with significant decline in poverty figures and unemployment. Agricultural sector had its fair share in this growth with significantly increased production. However, boosting production could not stimulate solutions to the problems with food and nutrition security for most parts and social groups of the country. Ethiopia remains as one of the most food insecure countries in the world. Reliance of agricultural production to weather conditions and low productivity are the most important reasons on the supply side. Market imperfections, strict limitations on agricultural trade and problems with infrastructure and organizational issues are the most important demand side drivers. Considering the income inequality and vulnerability as well as fast population growth, these problems translate into severe food insecurity in many areas of the country.

In this study we analysed the structure of food demand in Ethiopia to better understand the evolution of food demand under volatile prices and household income vulnerability. To this end we estimated the expenditure and price elasticities of food demand by using a QUAIDS approach. Estimation results give important clues about the importance of different food items for food security under different evolution paths of food prices, household income and agricultural production.

Negative income shocks to economy are likely to threaten food security by decreasing consumption of all cereals and livestock products as well as fruits and tubers more as the expenditure elasticity of these commodities are higher than 1. If these shocks are accompanied by price increases as in the last decade, cereals, meat, poultry & fish and fruit consumption are likely to decline further. Wheat and maize demand is particularly important under increasing prices since they have a higher income effect among the cereals. On the other hand, meat, poultry and fish has the highest price elasticity indicating the sensitivity of demand to the price changes. Manufactured food is the only food group that has low expenditure and price elasticity indicating that most of the basic food demand of the households is satisfied by the consumption of manufactured food.

Overall our findings suggest that cereals, tubers and meat, poultry & fish production are quite important for food security under income vulnerability and price volatility. On the other hand, since manufactured food demand is more inelastic to changes in prices and expenditure, and thus satisfies the basic nutritional needs of the households, nutritional quality of the manufactured food is very important.

Our estimations for the regions confirms our findings at the national level but also shows that there are some important differences in the structure of demand across regions. For example, in Amhara and SNNP, the income effect of cereals demand is quite high: demand is perfectly inelastic without the income effect and becomes elastic with income effect. That means cereal consumption affects the household expenditure significantly when the cereal prices change in these regions. This calls for special attention to cereal supply chains in these regions as any problem in supply chain might bring up important problems in food security. Second, the demand for animal products is perfectly inelastic in prices in all regions except the "other regions" while it is elastic in expenditure. That means, animal products consumption of most of the households in the regions are quite low, probably at subsistence level. Lastly, the regional estimations confirm that manufactured foods are necessity goods in all regions but SNNP. In Amhara and Oromia the demand for manufactured is highly elastic in prices and hence would decline significantly in case of price increases. Thus special attention needs to be given to supply chain of manufactured in these regions. Some caveats to take into account are related to the differences in the estimation of the expenditure elasticity for cereals with other studies which might be explained by the different estimators used (e.g. GMM vs 2SLS), the different commodity grouping (e.g. in our study processed cereals are part of other manufactured food) and different data, since our estimation refers to the 2015-2016 household survey data compared to other studies that use data from previous years.

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List of abbreviations and definitions

AIDS	Almost Ideal Demand System
CAPI	Computed Assisted Personal Interviewing
CSA	Central Statistical Agency
DG-DEVCO	Directorate General International Cooperation and Development
ESS	Ethiopian Socioeconomic Survey
EUD	European Union Delegation
FCS	Food Consumption Score
FDRE	Federal Democratic Republic of Ethiopia
FGNLS	Feasible Generalised nonlinear least-squares estimator (FGNLS)
GDP	Gross Domestic Product
ILLS	Iterated Linear least-squares (ILLS)
JAES	Joint Africa-EU Strategy
LES	Linear Expenditure System
LSMS-ISA	Living Standards Measurement Study – Integrated Surveys Agriculture
OLS	Ordinary Least Squares
QES	Quadratic Expenditure System
SUR	Seemingly Unrelated Regressions
WFP	Word Food Programme

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