The role of livestock in poverty reduction among Ethiopian households

By

Jonse Bane Boka

Dissertation Submitted to

the Department of Economics, College of Business and Economics, Addis Ababa University

in partial fulfillment of the Requirements for the degree of Doctor of

Philosophy in Economics

School of Graduate Studies

Addis Ababa University

Addis Ababa, Ethiopia

July, 2020

The role of livestock in poverty reduction among Ethiopian households

By

Jonse Bane Boka

Team of supervisors

Main supervisor: Pia Nilsson (Associate Professor)

Deputy supervisor: Pär Sjölander (Professor)

Deputy supervisor: Alemu Mekonnen (Associate Professor)

ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

APPROVAL SHEET

This is to certify that the dissertation prepared by Jonse Bane Boka, titled: "**The role of livestock in poverty reduction among Ethiopian households**" and submitted to the Economics Department, College of Business and Economics of Addis Ababa University in partial fulfilment of the requirements for the Degree of Doctor of Philosophy in Economics complies with the regulations of the university and meets the accepted standards with respect to originality and quality.

Signed by the examining committee:

Examiner________________________________Signature________________Date _________

Examiner________________________________Signature________________Date _________

Main Supervisor: Pia Nilsson (Associate Professor) **Signature ____________Date __________**

Deputy Supervisor: Pär Sjölander (Professor) **Signature ____________Date __________**

Deputy Supervisor: Alemu Mekonnen (Associate Professor) **Signature __________Date ________**

____

Chair of Department or Graduate Program Coordinator

ACKNOWLEDGEMENTS

My academic life has been full of ups and downs where I could not reach this level had it not been due to Mercy of God through His son Jesus Christ who has died for me on the cross. I praise God the Almighty for His mercy, provision and protection throughout my life!

In writing this dissertation, I benefited from supports of several persons and institutions. My deepest gratitude and appreciation go to my main supervisor, Pia Nilsson (associate professor of economics) for her true contributions to my dissertation works. I always appreciate her compassionate, relentless, unwavering and constant supports throughout this research. She is one of intelligent, hardworking, committed, humble, kind and positive thinking academicians I have ever met. She shared my academic as well as family burdens. I had a nice time writing my dissertation under her guidance. I have learned a lot from her. I would like to say thank you for all your roles! I hope, we will work together in the future.

I would also like to say thank you to Professor Pär Sjölander for his comments on my papers at each stage. He was ready to support whenever necessary. Thank you Professor Pär Sjölander for your supports and critical comments.

It is with great pleasure and respect to appreciate the supports, comments and encouragements from Alemu Mekonnen (Associate Professor of economics at Addis Ababa University). He is one of the exemplary academicians at the Economics Department of AAU. I have respected your friendly and fatherly advices since long time.

My lovely wife, Abeba Ajema (Toti), deserves special thanks as she really cares for me not only during the hardship time of this PhD study but also since we have married. She is also loving mother for our kids: Eyasu, Fenet and Kaleb. I am blessed for always have you on my side. I love you!

My earnest thanks also go to Evangelist Negero Assefa who constantly prays for me and my family. He is the blessing for my family and the whole nation. Thank you, brother, for your encouragement and moral supports.

I also thank several individuals at JIBS particularly Mikaela Backman for willing to read and comment on draft version of my first paper. I also benefited from her comments on my second paper. Monica Bartels also deserves recognitions for her commitments in arranging accommodation, logistics and access to office at JIBS. She is one of the individuals who made my stay in Sweden so pleasant. Thank you, Monica!

I thankfully recognize the financial support I got from the Swedish International Development Cooperation Agency (Sida) via AAU to visit Jonkoping International Business School (JIBS) to attend a course and contact my supervisors. Financial support from IFPRI during this dissertation writing is also acknowledged.

I highly appreciate Professor Pramila Krishnan of Oxford University for her critical and very useful comments on my three papers. Thank you, a lot, for your significant comments, which help me to improve the papers in the dissertation.

Finally, I am also grateful to Professor Yves Surry from The Swedish University of Agricultural Sciences in Uppsala (Sweden) for providing me invaluable comments on the third paper of the dissertation.

Jonse Bane
Addis Ababa, Ethiopia
June, 2020

DEDICATION

This dissertation is dedicated to my respected and beloved wife, Abeba Ajema (Toti), and our lovely kids: Eyasu, Fenet and Kaleb.

DECLARATION

I declare that this dissertation is my original works except where explicit references are made to the works of others and none of the papers in the dissertation has been submitted to any degree offering institutions including Addis Ababa University for another degree or other purposes.

Table of Contents

Lists of Tables

Lists of Figures

Acronyms

AIDS	Almost Ideal Demand Systems
ASFs	Animal Sourced Foods
CAPI	Computer-Assisted Personal Interview
CDF	Cumulative Distribution Function
CE	Cow Equivalent
CSA	Central Statistical Agency of Ethiopia
DD	Dietary Diversity
EAs	Enumeration Areas
ESS	Ethiopian Socio-economic Survey
ETB	Ethiopian Birr
FAO	Food and Agricultural Organization of the United Nations
FCS	Food Consumption Scores
FE	Fixed Effects
HCE	Household Consumption Expenditure
HH	Household
HICE	Household Income and Consumption Expenditure
HW	Heien and Wessells (1990)
HWMS	Household Welfare Monitoring Survey
IV	Instrumental Variable

LSMS-ISA	Living Standard Measurement Study-Integrated Surveys on Agriculture
PDF	Probability Density Function
PPS	Probability Proportional to Size
QUAIDS	Quadratic Almost Ideal Demand System
SUR	Seemingly Unrelated Regression

1. Chapter one: introduction of the dissertation

1.1. Background of the dissertation

Over the last decades, the economies of sub-Saharan African (SSA) countries, including that of Ethiopia, have registered a noticeable economic growth. Between 2012 and 2016, Ethiopia achieved an average annual growth rate of GDP of 9.4 percent. The Ethiopian agricultural sector contributes to over 37 percent of the country's GDP and accounts for about 70 percent of export revenues. Furthermore, it employs more than 75 percent of the country's labor force (National Planning Commission, 2016). This indicates that agriculture is one of the most important sectors that contributes significantly to the economic growth of the country. Consequently, the Ethiopian government has emphasized the agricultural sector as the main pillar and engine of the economy in its consecutive economic development strategies over the last three decades (Alemu et al., 2002; Diao & Pratt, 2007; Lavers, 2012; Berhanu & Poulton, 2014).

Since the turn of the millennium, Ethiopia has achieved some key milestones in terms of reduced poverty, child and maternal mortality and malnutrition. According to the Central Statistical Agency (CSA) of Ethiopia, in 2000, over 44 percent of the population were below the absolute poverty line with a higher poverty rate reported in the rural areas (45 percent) compared to urban areas (37 percent). In 2015, the share of the population living below the poverty line declined to 23.5 percent with a higher rate still reported in the rural areas (25.6 percent) compared to urban centers (14.8 percent) (CSA, 2018). The country has also registered a reduction in child and maternal mortality. Despite such improvements, in 2017, Ethiopia registered maternal mortality of 14,000 per 100,000 live births (WHO, 2019), which is one of the highest in SSA. According to the Human Development index of the UNDP (2019), Ethiopia ranks 173th out of 189 countries making it one of the least developed countries in the world. Ethiopia is also still one of the poorest countries in the world with lower per capita income, lower level of literacy, shorter average life expectancy, lower proportion of households having access to electricity, pure drinking water and health facilities and a higher rate of child and maternal mortality. It is this background that motivates this dissertation, focusing on understanding the role of the livestock sector in improving the overall welfare of households in Ethiopia.

1.2. Motivations and contributions of the dissertation

At the global level, livestock is one of the most important components of the agricultural sector, accounting for about 40 percent of agricultural output, generating 15 percent of total food energy and 25 percent of dietary protein (FAO, 2009). In developing countries, the sector generates more than 30 percent of agricultural GDP and over 70 percent of rural households partly or fully depend on the sector for their livelihoods (Biasca, 2014). Similarly, Ethiopia's livestock accounts for nearly 30 percent of agricultural GDP indicating that it is one of the key components of the agricultural sector of the country (National Planning Commission, 2016). Thus, at the macro level, improved livestock productivity could strengthen the contribution of the agricultural sector to the country's overall economic growth.

In developing countries like Ethiopia, nearly 75 percent of smallholders keep livestock as their means of livelihoods (FAO, 2010). This implies that improved performance of the livestock sector could play an essential role in achieving inclusive and sustainable economic growth, contributing to poverty reduction and food and income security (Peden et al., 2003; Upton, 2004; Ali, 2007; Diao & Pratt, 2007; Herrero et al., 2013; Do et al., 2019), particularly for the rural landless, women and the youths (Upton, 2004; Pica-Ciamarra et al., 2011). Livestock rearing has been shown to improve the dietary diversity of farm households via the provision of protein-dense animal source foods (ASFs) that supply micro and macro nutrients, which are essential for the healthy growth and development of children, mainly during the first 1000 days of their life (Dror & Allen, 2011; Jin & Iannotti, 2014; Azzarri et al., 2015; Darrouzet-Nardi et al., 2016; Jodlowski et al., 2016; Muslimatun & Wiradnyani, 2016; Workicho et al., 2016; Hetherington et al., 2017). Livestock can also generate additional incomes that households can use to purchase better quality foods that they may not produce themselves (Pica-Ciamarra et al., 2011). Thus, owning and diversifying livestock improves dietary qualities and varieties directly through consumption of ASFs from own production and indirectly by consumption of purchased foods using incomes from sales of livestock and its byproducts. Moreover, rearing livestock increases crop yields via supply of natural fertilizers and draft power (Herrero et al., 2013; Smith et al., 2013) and via the use of improved crop technologies that households can purchase using incomes from livestock sales (Pica-Ciamarra et al., 2011). Besides, farm households can use livestock as collateral to borrow money and invest in on-farm and off-farm income generating activities, which spurs agricultural growth and income diversification (Costales et al., 2010; Bettencourt et al., 2015). Livestock also serves as insurance against risks and shocks (Hoddinot, 2006; Herrero et al., 2013). Thus, livestock is an essential asset of farm households and a key component of the agricultural sector of developing economies like Ethiopia.

Ethiopia has a high potential for livestock production due to its agro-ecological and environmental conditions (Abate et al., 2012; Negassa et al., 2012; Shapiro et al., 2015). However, despite its high potential, livestock productivity is currently low in Ethiopia (FAO, 2018). This could indicate that the country has not yet fully utilized the opportunities brought by the livestock sector for poverty reduction and enhancement of the welfare of farm households (Diao & Pratt, 2007; Negassa et al., 2012; Herrero et al., 2014).

During the Imperial era and Derge regime, there were projects- and programs-based livestock development strategies such as the first, second and fourth livestock development projects covered periods 1971-1991 (Roseboom et al., 1994; Ahmed et al., 2004); dairy rehabilitation and development project (Kebebe, 2019); smallholder dairy development pilot project and national livestock development project (Ahmed et al., 2004) and agricultural growth program (AGP)-livestock market development project (Kebebe, 2019). This indicates that there was no comprehensive and clear national level livestock development policies and strategies. Similarly, since the 1992 economic reforms, the Ethiopian government has no clear livestock development policies and strategies except incorporating livestock related issues into overall national development policies and strategies of the country, which as the rule of game have focused on crop production to ensure food security and reduce poverty among farm households (Doss & Morris, 2000; Minten & Barrett, 2008; Kassie et al., 2011; Simtowe et al., 2011; Asfaw et al., 2012; Abebaw & Haile, 2013). Such livestock related issues in the overall development strategy using few paragraphs have focused on animal health via extension services but ignored technology related constraints facing smallholder livestock owners (Pica-Ciamarra, 2005). However, recently, the country has introduced livestock development roadmap (Shapiro et al., 2015). The Ethiopian livestock has also faced challenges from climate changes (Megersa et al., 2014) and limited availability of improved technologies (Bachewe et al., 2018).

Recognizing its high potential and significant roles at the macro and micro levels and the critical challenges facing the livestock sector, the Ethiopian government has emphasized the importance of the sector by developing a livestock development roadmap[1] to guide improvements in production and productivity. An important part of this development strategy is to spur and support investment in improved livestock technologies and management (Shapiro et al., 2015). In this regard, the results of this dissertation can provide relevant results to inform policymaking.

Consumption of ASFs among Ethiopian smallholders is one of the lowest in developing countries, and it is limited to a few types of livestock products (Worku et al., 2017). The result is a low dietary diversity of farm households and a high level of malnutrition among children, mainly in the rural areas (Hirvonen, 2016; Hirvonen & Hoddinott, 2017). Literature points out that low dietary diversity is an indicator of household and individual level food insecurity and lack of access to a variety of foods (Steyn et al., 2006). However, previous studies (e.g., Ayenew et al., 2018; Ecker, 2018; Sibhatu & Qaim, 2018; Tesfaye & Tirivayi, 2020) tend to focus on the role of crop or farm diversification in improving farm households' dietary diversity and welfare and less attention is devoted to the role of livestock ownership and diversification in improving dietary diversity and welfare of farm households. To the author's best knowledge, there are limited[2] previous studies (mostly based on cross-sectional data and hence did not take into account the endogeneity problems and some of them are case studies that do not represent the country) that examine the

[1] The livestock development roadmap has emphasized technology adoption by smallholder farmers in three areas: crossbred dairy cows, red meat and milk feedlot and poultry development. The crossbred dairy cow technology adoption is one of the focus of this dissertation.

[2] In Ethiopia, there is case study in pastoral areas of Borena zone (Oromia region) that linked livestock diversification to food security, which is not representative of the country. There is another study in Ethiopia that dealt with consumption of ASFs and dietary diversity of households (Workicho et al., 2016).

influence of livestock diversification on farm households' dietary diversity and welfare. The first paper of the dissertation contributes to the literature by linking livestock diversification to dietary diversity and welfare of farm households using nationally representative panel data.

The Ethiopian livestock sector is characterized by low productivity (FAO, 2018) due to, among other factors, limited availability of improved livestock technologies and only few farm households have practiced improved livestock management and technologies (Bachewe et al., 2018; Kebebe, 2019). Improved livestock management refers to utilizing improved animal feeds (such as crop residues, greens feeds like elephant grass, purchased feeds from factories including supplements such as salt, urea-treated straw, minerals) and animal health like vaccination (McClaran, 2000; Musaba, 2010; Birhan & Adugna, 2015; Birhanu et al., 2017; Shikuku et al., 2017). Improved livestock technologies include adoption of improved breeds or crossbreds and breeding strategies such as artificial insemination (AI) using improved semen (Abdulai & Huffman, 2005; Shikuku et al., 2017). Even though improved livestock management and technologies are shown to be effective in increasing livestock productivity, their adoption is still limited among smallholder farmers in Ethiopia. This can be attributed to lack training and limited formal infrastructures for information exchange including policy research centers and extension agents in rural areas (Bachewe et al., 2018). Thus, one of the focuses of governments of developing countries including Ethiopia and development partners is to increase livestock productivity (e.g., that of meat, dairy products and poultry production). This can be achieved via promotion of improved livestock technologies such as adoption of crossbred dairy cows and utilization of artificial insemination (AI) and practicing improved livestock managements such as utilization of improved animal feeds and livestock health (Udo et al., 2011; Alvarado et al., 2018).

So far, the literature has emphasized the role of peer effects in facilitating adoption of crop production technologies (Krishnan & Patnam, 2013; Genius et al., 2014; Wollni & Andresson, 2014; Mekonnen et al., 2018). The focus has also been on spillover effects from commercial farm establishments to neighboring smallholder crop producers in Africa (Deininger & Xia, 2016; Herrmann, 2017; Lay et al., 2018; Ali et al., 2019; Glover & Jones, 2019). However, less attention is given to the role of spatial proximity of smallholder livestock owners to peer farmers and commercial farms (who own livestock) in facilitating diffusion of improved livestock technologies and managements. The second paper of the dissertation contribute to the literature by filling this gap and examining the role of peer influences to spur adoption of improved livestock technologies and managements. To address these influences, the study combines the 2015/16 ESS and 2014/15 large and medium commercial farm surveys to form a unique georeferenced dataset that enable the study of peer influences at the farm level.

In Ethiopia, low livestock production and productivity coupled with low per capita income of the country have constrained the consumption of ASFs, which is at the expense of health benefits to the population at large but mainly for children. However, similar to other developing countries, the share of food expenditure on staple foods such as cereals has started to fall gradually while the share of food expenditure of protein-dense foods, including ASFs, has increased in Ethiopia (Worku et al., 2017). This indicate that consumption behaviors of Ethiopian households have started to shift from starchy foods to more protein-rich food items such as ASFs. This is where the third paper positions itself focusing on analyzing consumption patterns and demand elasticities of ASFs.

In a developing country context, several studies have estimated expenditure and price elasticities for different foods including ASFs (Ecker et al., 2010; Chen & Abler, 2014; Chen et al., 2016; Chengappa et al., 2016; Delport et al., 2017; Colen et al., 2018). However, only a few studies have estimated price and expenditure elasticities and analyzed consumption patterns of ASFs by location (urban vs. rural) (e.g., Worku et al., 2017). The author is unaware of previous studies that have estimated demand elasticities of ASFs by expenditure quintiles and literacy levels. Thus, the third paper of the dissertation adds to the current literature by examining consumption patterns of ASFs and estimating their demand elasticities by location, expenditure quintiles and literacy level using the Ethiopian household consumption expenditure (HCE) survey of 2015/16. Results point at significant differences in consumption patterns and responsiveness of households to changes in prices and expenditures on ASFs in different locations and expenditure quintiles. Results can be used to inform the development of food and price policies in Ethiopia.

This dissertation contributes to the existing literature by analyzing and providing a deeper understanding of the welfare effects associated with the ownership and diversification of livestock as well as the factors that work to improve the adoption of improved livestock technologies and management among smallholder farmers. Specifically, this dissertation contributes to the existing literature by examining i) the role of livestock ownership and diversification in terms of improved dietary diversity and welfare of farm households, ii) the role of peer influences to facilitate the adoption of improved livestock technologies and managements among smallholder livestock owners and, iii) how consumption patterns and demand elasticities of ASFs vary depending on urbanization, income level and changes in prices.

1.3. Objectives

The general objective of the dissertation is to examine the livestock sector in terms of the role of livestock diversification on welfare and dietary diversity of farm households; the role of spatial spillover effects in livestock technology adoption; and the variation in consumption patterns of ASFs and their demand elasticities by location, expenditure quintiles and literacy.

Specifically, the study aims to address and identify:

- The influence of livestock diversification on households’ dietary diversity and welfare.

- The role of spatial spillovers from peer farmers and commercial farms on smallholders' adoption of improved livestock technology and managements.
- Variation in consumption patterns and demand elasticities of ASFs by location (urban vs. rural), income quintiles and literacy level.

1.4. Data and estimated models

Data

The first paper uses three rounds of nationally representative Ethiopian socio-economic survey (ESS), which traces the same households over three panel time periods (2011/12, 2013/14 and 2015/16). It is an official dataset generated by the CSA of Ethiopia in association with the World Bank Living Standard Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA). In selecting the households, the survey adopted a two-stage sampling technique. In the first stage, the survey stratified the country into regions. Enumeration areas (EAs)[3] were selected from each region using probability to population proportion sampling where more EAs were selected from regions with many EAs. In the second stage, 12 households[4] were randomly selected from each EA. The information in the datasets was collected at community, household and individual levels. ESS used three different questionnaires: household questionnaire, community questionnaire and agricultural questionnaires. The household section of the questionnaire contains information on socio-economic variables, quantity of different food items consumed by a household during the last 7 days prior to the survey date. The questionnaires covered more than 80 foods consumed across the country and these food items come from own production, purchases and foods consumed away from home mainly by urban respondents. The agricultural questionnaires used in the survey have three major parts: post planting, post harvesting and livestock sections. The livestock questionnaire generated information on the number and types of livestock owned, livestock production and consumption, sales of livestock and livestock products and livestock managements. The strengths of these datasets are that they are nationally representative panel data containing rich information that cover important perspectives (e.g., consumption, production and household characteristics) collected at community, household and individual levels. Since, the datasets contain rich information, the study is able to link livestock ownership and diversification to dietary diversity and welfare of farm households and study these issues over time. However, the panel is relatively short (2011/12, 2013/14 and 2015/16) and does not provide a ground for analyzing spatial spillovers in a long-run perspective. In this regard, the study points at important perspectives to be addressed in future studies as new data become available. The second limitation

[3]Enumeration area (EA) is a specific location demarcated for random sampling of households per such EA and it may be the same as a kebele (the lowest administrative unit) or less than the kebele.

[4] 15 households were selected per EA in medium (population size of 10,000 to 100,000 residents) and large (over 100,000 residents) sized urban centers.

of the ESS datasets is that as with other observational data, it may not generate accurate information on crop and livestock production as well as consumption of various commodities.

The second paper utilizes two geocoded nationally representative surveys to form a unique dataset. The first is the most recent ESS survey data of 2015/16, which is the subset of the panel dataset used in the first paper. The second is the large and medium commercial farm survey data of 2014/15 that covers the population of commercial farms. Both surveys are conducted by the CSA and they cover the entire country. Because GPS coordinates for commercial farms are only available for the 2014/15 medium and large farm survey, this study delimits to the recent round of ESS survey data of 2015/16. Both the ESS and the commercial farm datasets have GPS coordinates at household level (for ESS data) and farm level (for commercial farms). This enable computation of the nearest Euclidean distances between i) a smallholder livestock owner and its nearest commercial farm establishment and ii) a smallholder livestock owner and its nearest peer farmer who own livestock and has practiced improved livestock technologies. These nearest Euclidean distances are used to proxy spatial spillovers between smallholder farmers and their peers and commercial farm establishments and they reflect the spatial diffusion of improved livestock technologies among farms.

The ESS dataset has several strengths. It covers different agro-ecological zones of the country and it contains information on important perspectives (socio-economic characteristics, consumption, assets, shocks, livestock ownership, etc.) at various levels (community, household, individual and plot). In compiling the data, the CSA adopted a careful data collection procedure by using computer-assisted personal interviewing (CAPI) to gather the data. However, the most important quality of these data is that they are georeferenced, which makes it possible to analyze peer influences linked to livestock technology adoption, which is a key focus of this dissertation. Livestock technology adoption also links to various socio-economic characteristics of households. The limitation of the datasets is that they contain missing values, mainly on livestock production and management, and that the medium and large commercial farm survey data is only available with GPS coordinates for the 2014/15 round. This delimits the scope of the analysis in that a panel dataset cannot be formed.

The third paper uses the Ethiopian HCE survey data of 2015/16, collected from 30,299 national representative households randomly selected from across the country. Households are selected from 2,106 enumeration areas (EAs) (864 EAs from rural areas and 1,242 EAs from urban centers). Over 66 percent of the sampled households included in the survey are located in urban areas. For sampling purposes, the CSA divided the country into three major categories: ‘rural’, ‘major urban centers’, and ‘other urban centers’.[5] It employed a two-stage cluster sampling technique to select

[5]Urban centers are defined (at least for the HCE survey) as, regardless of their residents, i) all administrative capitals (regions, zones, and woredas), ii) residential areas with urban dwellers’ kebele, which is not in i) above, and iii) localities with 1,000 or more residents not included in i) and ii) above.

EAs from "rural" areas and "major urban centers" whereas a three-stage cluster sampling method were used for selecting EAs from 'other urban centers'. In all cases, probability proportional to size sampling technique was used to sample EAs and 'size' refers to the total number of households reported by the Ethiopian Population and Housing Census of 2007. Finally, households were systematically sampled from the selected EAs. Thus, the CSA followed a stratified two- and three-stage cluster sampling technique based on PPS to sample EAs and a systematic sampling technique to select households. The dataset of the HCE survey of 2015/16 covered about 30,300 households from all regions of the country and it is nationally representative with information on all types and amounts of food consumed in and outside households. The limitation of the HCE dataset is that it did not collect information on market prices of the food items included in the dataset. The datasets also generated information at a single point in time and it is therefore not possible to account for consumption seasonality facing farm households during different months of the year.

Estimated Models

The first paper estimates the relationship between livestock diversification and dietary diversity and the welfare of farm households. Estimating such relationships is challenging due to endogeneity problems that may arise from unobservable individual characteristics and natural biophysical conditions, which could simultaneously affect both livestock diversification and dietary diversity (Verkaart et al., 2017). There may also exist reverse causation that runs from livestock diversification to dietary diversity and vice versa. This paper applies a Fixed Effects (FE) Instrumental Variable (IV) approach where the fixed part of the model removes time- and household-invariant unobservable characteristics while the IV part of the model addresses the endogeneity problem that arises from reverse causation that runs from livestock/production diversity to dietary diversity and vice versa. This follows recent studies that have applied similar FE-IV approaches to handle endogeneity problems that arise from different sources (see for instance, Tesfaye & Tirivayi, 2020).

The second paper in the dissertation examines the spillover effects of peer farmers and commercial farmers on the adoption of improved livestock technologies and management among neighboring smallholders. Methodologically, it is challenging to analyze such knowledge spillover influences as common factors in the neighborhoods are often correlated, which results in unobserved neighborhood characteristics. The central problem in estimating spatial spillover effects among peers in the same neighborhood is the difficulty to differentiate between contextual and true neighborhood effects, also referred to as the simultaneity problem (Manski, 1993). Previous studies have applied various approaches including IV estimation techniques. However, it is a difficult task to find appropriate instruments. Consequently, this paper applies a two-level multilevel model that account for simultaneity problems via correlated random effects and that alleviate correlations between individual and contextual factors.

The third paper applies censored QUAIDS to estimate demand systems for ten goods (five are ASFs and the remaining five are non-ASFs). Price and expenditure elasticities of ASFs are generated by location, expenditure quintiles and literacy level. Since there exist a plethora of zeros in the consumption of ASFs, this paper employs the two-step Shonkwiler and Yen (1999) approach. In the first-step, a standard probit model is estimated by regressing dichotomous variables (that takes one if a household consumed a good under consideration and zero otherwise) on several explanatory variables. Then a probability density function (PDF) and a cumulative distribution function (CDF) are generated for each household to be used in the second step estimation. The PDF and CDF are included in all equations in the demand system in the second step as correction terms to address data censoring in the dependent variable (the budget share). Finally, the system is estimated using the seemingly unrelated regression (SUR) framework. The endogeneity problem in the demand system is addressed using Blundell and Robin's (1999) two-step approach where total food expenditure is regressed on prices, socio-economic characteristics of households, assets owned and several dummies for physical environments (regions and land topography). Residuals generated from the first step estimation procedure are then used as additional explanatory variables to correct for the endogeneity problem.

1.5. Summary of findings and policy implications

The first paper of the dissertation links livestock diversification to dietary diversity and the welfare of farm households. The literature points out that dietary diversity is an indicator of food security and nutritional adequacy at household and individual levels (Steyn et al., 2006). Recent studies (e.g., Ayenew et al., 2018; Ecker, 2018; Sibhatu & Qaim, 2018; Tesfaye & Tirivayi, 2020) have mainly focused on the role of farm and/or crop diversification on farm households' dietary diversity and welfare. However, the role of livestock diversification in enhancing dietary diversity and the welfare of farm households has received less attention in the literature. The first paper aims to fill this gap by examining the influences of livestock diversification on farm households' dietary diversity and welfare using three rounds of the nationally representative panel data from the ESS. Following recent studies (e.g., Tesfaye & Tirivayi, 2020), this paper applies a FE-IV approach to account for endogeneity problems arising from livestock diversification. The findings indicate that there is a positive association between livestock diversification and farm households' welfare and dietary diversity. Specifically, increasing livestock diversification by one percent results in an improvement in households' dietary diversity by about 0.2 percent and welfare by ranges of 40 to 70 percent. These findings are similar with results of previous studies in the sense that they link farm diversity to dietary diversity but they are unique as this paper links livestock diversity (measured using various indices) and farm households' welfare and dietary diversity (measured using various indices) in the context of Ethiopia using nationally representative panel data that address the endogeneity problem. The policy implications derived from this paper are that promoting livestock diversification could provide a viable pathway to improve dietary quality and variety as well as to reduce malnutrition and poverty among Ethiopian smallholder farmers.

The second paper in the dissertation examines the role of spatial proximity on improved livestock technology adoption using two nationally representative datasets: the 2015/16 household level ESS dataset and the large and medium commercial farm survey of 2014/15 that covers the population of commercial farms. The paper applies a multilevel model to handle simultaneity problems and alleviate correlations between individual and contextual factors. The findings reveal that smallholder livestock owners learn from their peer farmers in adopting improved livestock technology and improved livestock management. However, the findings indicate that negative effects of commercial farms on smallholder farmers may outweigh the potential benefits of these commercial farms to smallholders as they do have marginal positive spillover effects on livestock vaccination, rather, area expansion by commercial farms reduces likelihoods of owning improved livestock breeds. Results of this paper are unique in the sense that empirical studies are scant on the role of spatial proximity in facilitating improved livestock technology adoption management in the context of Ethiopian smallholder farmers. It is important to understand peer effects, because they provide knowledge for future advisory assignment to spur uptake and improve the economic viability of the livestock sector. Such knowledge can assist to inform agricultural advisors or implementing institutions (with limited resources) in the training and appropriate targeting of farmers and farmer groups. A policy implication is that strengthening existing farmer networks can help in achieving a more widespread livestock technology diffusion and improved livestock management in the Ethiopian livestock sector. Hence, development strategies could be formulated to promote the expansion of networks and collaborations among smallholder livestock farmers and with commercial farms.

The third paper analyzes consumption patterns of ASFs and estimates demand elasticities by location, expenditure quintiles and literacy level. In order to handle interdependence of food consumption and a plethora of zeros in consumption of ASFs, this paper employs censored QUAIDS to the Ethiopian HCE survey of 2015/16, conducted by the Central Statistical Agency (CSA) of Ethiopia. This paper finds that Ethiopian households consume only a few ASFs and mainly dairy products. In addition, there is considerable variation in consumption level of ASFs and demand elasticities by location, expenditure quintiles and education level. Demand elasticity estimates also show that demand for ASFs is highly responsive to changes in prices and household expenditures compared to staple foods. The findings also indicate that meat groups (except other meats such as internal organs) are luxury foods while dairy products are normal for all Ethiopian households in rural and urban areas. An increase in prices of ASFs more harshly affect poorer households compared to richer ones. These results are consistent with findings of previous studies but they provide detailed information on consumption patterns and elasticity estimates of ASFs by location (urban vs. rural), expenditure quintiles and literacy level. The difference in consumption patterns and responsiveness of households to changes in prices of and expenditure on ASFs in different locations (urban vs. rural areas) and expenditure quintiles could serve in designing appropriate food and price policies.

The dissertation forwards the following areas for future research:

I. The role of Livestock diversification in consumption smoothing and reducing vulnerability to shocks
II. Does market access substitute livestock diversification in influencing households' dietary diversity?
III. Livestock diversification and its roles in reducing multidimensional poverty.
IV. Roles of research centers in facilitating diffusion of improved livestock technologies and livestock management.
V. Analysis of interdependency of prices of livestock products and non-livestock products.

References

Abate, D., Belete, S., Wegi, T., Usman, S., Wamatu, J., & Duncan, A. J. (2012). Characterization of the livestock production systems and the potential of feed-based interventions for improving livestock productivity in Sinana district, Bale highlands, Ethiopia.

Abdulai, A., & Huffman, W. E. (2005). The diffusion of new agricultural technologies: The case of crossbred-cow technology in Tanzania. *American Journal of Agricultural Economics*, *87*(3), 645-659.

Abebaw, D., & Haile, M. G. (2013). The impact of cooperatives on agricultural technology adoption: Empirical evidence from Ethiopia. Food Policy, 38, 82-91.

Ahmed, M., Gebremedhin, B., Ehui, S. (2004). Determinants of Adoption of Improved Forage Technologies in Crop-livestock Mixed Systems: Evidence from the Highlands of Ethiopia.

Alemu, Z. G., Oosthuizen, L. K., & Van Schalkwyk, H. D. (2002). Agricultural development policies of Ethiopia since 1957. *South African Journal of Economic History*, *17*(1-2), 1-24.

Ali, D., Deininger, K., & Harris, A. (2019). Does large farm establishment create benefits for neighboring smallholders? Evidence from Ethiopia. *Land Economics*, *95*(1), 71-90.

Ali, J. (2007). Livestock sector development and implications for rural poverty alleviation in India. *Livestock Research for Rural Development*, *19*(2), 1-15.

Alvarado, F., Escobar, F., Williams, D. R., Arroyo-Rodríguez, V., & Escobar-Hernández, F. (2018). The role of livestock intensification and landscape structure in maintaining tropical biodiversity. *Journal of Applied Ecology*, *55*(1), 185-194.

Asfaw, S., Kassie, M., Simtowe, F., & Lipper, L. (2012). Poverty reduction effects of agricultural technology adoption: a micro-evidence from rural Tanzania. Journal of Development Studies, 48(9), 1288-1305.

Ayenew, H. Y., Biadigilign, S., Schickramm, L., Abate-Kassa, G., & Sauer, J. (2018). Production diversification, dietary diversity and consumption seasonality: panel data evidence from Nigeria. BMC Public Health, 18(1), 988.

Azzarri, C., Zezza, A., Haile, B. & Cross, E. (2015). Does Livestock Ownership Affect Animal Source Foods Consumption and Child Nutritional Status? Evidence from Rural Uganda. Journal of Development Studies 51, 1034–1059

Bachewe, F. N., Minten, B., Tadesse, F., & Taffesse, A. S. (2018). The evolving livestock sector *in Ethiopia: Growth by heads, not by productivity* (Vol. 122). Intl Food Policy Res Inst.

Berhanu, K., & Poulton, C. (2014). The political economy of agricultural extension policy in Ethiopia: economic growth and political control. Development Policy Review, 32(s2), s197-s213.

Bettencourt, E. M. V., Tilman, M., Narciso, V., Carvalho, M. L. D. S., & Henriques, P. D. D. S. (2015). The livestock roles in the wellbeing of rural communities of Timor-Leste. *Revista de Economia e Sociologia Rural*, *53*, 63-80.

Biasca, R. (2014). The role of livestock for ACP countries: challenges and opportunities ahead. Brussels

Birhan, M., & Adugna, T. (2015). Livestock feed resources assessment, constraints and improvement strategies in Ethiopia.

Birhanu, M. Y., Girma, A., & Puskur, R. (2017). Determinants of success and intensity of livestock feed technologies use in Ethiopia: Evidence from a positive deviance perspective. *Technological Forecasting and Social Change*, *115*, 15-25.

Chen, D & Abler, D (2014). Demand growth for animal products in the BRIIC countries. *Agribusiness*, 30(1), 85–97.

Chen, D., Abler, D., Zhou, D., Yu, X., & Thompson, W. (2016). A meta-analysis of food demand elasticities for China. *Applied Economic Perspectives and Policy*, *38*(1), 50-72.

Chengappa PG, Umanath, M, Vijayasarathy, K, Babu, P & Manjunatha, AV (2016). Changing demand for livestock food products: An evidence from Indian households. *Indian Journal of Animal Sciences*, 86(9), 1055–1060.

Colen, L, Melo, PC, Abdul-Salam, Y, Roberts, D, Mary, S, Gomez, S & Paloma, Y (2018). Income elasticities for food, calories and nutrients across Africa: A meta-analysis. *Food Policy*, 77, 116–132.

Conley, T. G., & Udry, C. R. (2010). Learning about a new technology: Pineapple in Ghana. *American Economic Review*, *100*(1), 35-69.

Costales, A. C., Pica-Ciamarra, U., & Otte, J. (2010). Social Consequences for Mixed Crop–Livestock Production Systems in Developing Countries. *Livestock in a changing landscape, Volume 1: drivers, consequences and responses*, 249-267.

Darrouzet-Nardi, A. F., Miller, L. C., Joshi, N., Mahato, S., Lohani, M., & Rogers, B. L. (2016). Child dietary quality in rural Nepal: effectiveness of a community-level development intervention. *Food Policy*, *61*, 185-197.

Deininger, K., & Xia, F. (2016). Quantifying spillover effects from large land-based investment: the case of Mozambique. *World Development*, *87*, 227-241.

Delport, M, Louw, M, Davids, T, Vermeulen, H & Meyer, F (2017). Evaluating the demand for meat in South Africa: an econometric estimation of short term demand elasticities. *Agrekon*, 56(1), 13–27.

Diao, X., & Pratt, A. N. (2007). Growth options and poverty reduction in Ethiopia–An economy-wide model analysis. *Food Policy*, *32*(2), 205-228.

Doss, C. R., & Morris, M. L. (2000). How does gender affect the adoption of agricultural innovations? The case of improved maize technology in Ghana. Agricultural economics, 25(1), 27-39.

Dror, D. K., & Allen, L. H. (2011). The importance of milk and other animal-source foods for children in low-income countries. *Food and nutrition bulletin*, *32*(3), 227-243.

Ecker, O & Qaim, M (2011). Analyzing nutritional impacts of policies: an empirical study for Malawi. *World Development*, 39(3), 412–428.

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

FAO (2009). The state of food and agriculture: Livestock in the balance. FAO, Rome, Italy

FAO (2010). The State of Food and Agriculture: Livestock in the Balance. FAO, Rome, Itay.

FAO (2018). FAOSTAT. Rome, Italy.

Genius, M., Koundouri, P., Nauges, C., & Tzouvelekas, V. (2014). Information transmission in irrigation technology adoption and diffusion: Social learning, extension services, and spatial effects. *American Journal of Agricultural Economics*, *96*(1), 328-344.

Glover, S., & Jones, S. (2019). Can commercial farming promote rural dynamism in sub-Saharan Africa? Evidence from Mozambique. *World Development*, *114*, 110-121.

Worku, I. H., Dereje, M., Minten, B., & Hirvonen, K. (2017). Diet transformation in Africa: The case of Ethiopia. *Agricultural economics*, *48*(S1), 73-86.

Herrero, M., Grace, D., Njuki, J., Johnson, N., Enahoro, D., Silvestri, S., & Rufino, M. C. (2013). The roles of livestock in developing countries. Animal, 7(s1), 3-18.

Herrero, M., Havlik, P., McIntire, J., Palazzo, A., & Valin, H. (2014). African Livestock Futures: Realizing the potential of livestock for food security, poverty reduction and the environment in Sub-Saharan Africa.

Herrmann, R. T. (2017). Large-scale agricultural investments and smallholder welfare: A comparison of wage labor and outgrower channels in Tanzania. *World Development*, *90*, 294-310.

Hetherington, J. B., Wiethoelter, A. K., Negin, J., &Mor, S. M. (2017). Livestock ownership, animal source foods and child nutritional outcomes in seven rural village clusters in Sub-Saharan Africa. *Agriculture & Food Security*, *6*(1), 9.

Hirvonen, K. (2016). Rural–urban differences in children's dietary diversity in Ethiopia: A Poisson decomposition analysis. *Economics Letters*, *147*, 12-15.

Hirvonen, K., & Hoddinott, J. (2017). Agricultural production and children's diets: Evidence from rural Ethiopia. *Agricultural Economics*, *48*(4), 469-480.

Hoddinott, J. (2006). Shocks and their consequences across and within households in rural Zimbabwe. *The Journal of Development Studies*, *42*(2), 301-321.

Jin, M., &Iannotti, L. L. (2014). Livestock production, animal source food intake, and young child growth: The role of gender for ensuring nutrition impacts. *Social Science & Medicine*, *105*, 16-21.

Jodlowski, M., Winter-Nelson, A., Baylis, K., & Goldsmith, P. D. (2016). Milk in the data: food security impacts from a livestock field experiment in Zambia. *World Development*, *77*, 99-114.

Karamba, W. R., Quiñones, E. J., & Winters, P. (2011). Migration and food consumption patterns in Ghana. *Food Policy*, *36*(1), 41-53.

Kassie, M., Shiferaw, B., & Muricho, G. (2011). Agricultural technology, crop income, and poverty alleviation in Uganda. World development, 39(10), 1784-1795.

Kebebe, E. (2019). Bridging technology adoption gaps in livestock sector in Ethiopia: A innovation system perspective. *Technology in Society*, *57*, 30-37.

Koppmair, S., Kassie, M., & Qaim, M. (2017). Farm production, market access and dietary diversity in Malawi. *Public Health Nutrition*, *20*(2), 325-335.

Krishnan, P., & Patnam, M. (2013). Neighbors and extension agents in Ethiopia: Who matters more for technology adoption? *American Journal of Agricultural Economics*, *96*(1), 308-327.

Lavers, T. (2012). ‘Land grab’as development strategy? The political economy of agricultural investment in Ethiopia. *Journal of Peasant Studies*, *39*(1), 105-132.

Lay, J., Nolte, K., & Sipangule, K. (2018). *Large-scale farms and smallholders: Evidence from Zambia* (No. 310). GIGA Working Papers

Martínez-García, C. G., Dorward, P., & Rehman, T. (2013). Factors influencing adoption of improved grassland management by small-scale dairy farmers in central Mexico and the implications for future research on smallholder adoption in developing countries. *Livestock Science*, *152*(2-3), 228-238.

McClaran, M. P. (2000). Improving Livestock Management in. In *Wilderness Science in a Time of Change Conference: Missoula, Montana, May 23-27, 1999* (Vol. 5, No. 15, p. 49). United States Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Megersa, B., Markemann, A., Angassa, A., Ogutu, J. O., Piepho, H. P., & Zaráte, A. V. (2014). Impacts of climate change and variability on cattle production in southern Ethiopia: Perceptions and empirical evidence. *Agricultural Systems*, *130*, 23-34.

Megersa, Bekele, André Markemann, Ayana Angassa, and Anne Valle Zárate. (2014). The role of livestock diversification in ensuring household food security under a changing climate in Borana, Ethiopia, Food Security 6 (1):15-28.

Mekonnen, D. A., Gerber, N., & Matz, J. A. (2018). Gendered social networks, agricultural innovations, and farm productivity in Ethiopia. *World Development*, *105*, 321-335.

Mekonnen, H., Dehninet, G., & Kelay, B. (2010). Dairy technology adoption in smallholder farms in "Dejen" district, Ethiopia. *Tropical Animal Health and Production*, *42*(2), 209-216.

Minten, B., & Barrett, C. B. (2008). Agricultural technology, productivity, and poverty in Madagascar. World Development, 36(5), 797-822.

Musaba, E. C. (2010). Analysis of factors influencing adoption of cattle management technologies by communal farmers in Northern Namibia. *Livestock Research for Rural Development*, *22*(6), 104.

Muslimatun, S., & Wiradnyani, L. A. A. (2016). Dietary diversity, animal source food consumption and linear growth among children aged 1–5 years in Bandung, Indonesia: A longitudinal observational study. *British Journal of Nutrition*, *116*(S1), S27-S35

Mwangi, M., & Kariuki, S. (2015). Factors determining adoption of new agricultural technology by smallholder farmers in developing countries. *Journal of Economics and Sustainable Development*, 6(5).

National Planning Commission (2016). Database of the National Planning Commission, Addis Ababa, Ethiopia

Negassa, A., Rashid, S., Gebremedhin, B., & Kennedy, A. (2012). Livestock production and marketing. Food and agriculture in Ethiopia: Progress and policy challenges, 159-190.

Nguyen, M. C., & Winters, P. (2011). The impact of migration on food consumption patterns: The case of Vietnam. *Food Policy*, *36*(1), 71-87.

Peden, D. G., Tadesse, G., & Mammo, M. (2003). Improving the water productivity of livestock: An opportunity for poverty reduction. ILRI.

Pica-Ciamarra, U. (2005). Livestock policies for poverty alleviation: Theory and practical evidence from Africa, Asia and Latin America (No. 855-2016-56211).

Pica-Ciamarra, U., Tasciotti, L., Otte, J., &Zezza, A. (2011). Livestock assets, livestock income and rural households: cross-country evidence from household surveys.

Quddus, M. A. (2012). Adoption of dairy farming technologies by small farm holders: practices and constraints. *Bangladesh Journal of Animal Science*, *41*(2), 124-135.

Roseboom, J., N. Beintema, N., Pardey P.G. (1994)., Statistical Brief on the National Agricultural Research System of Ethiopia, International Service for National Agricultural Research (ISNAR), The Hague, The Netherland.

Ruel, M. (2003). Operationalizing dietary diversity: A review of measurement issues and research priorities. *The Journal of Nutrition*, 133, 3911S–3926S.

Shapiro, B.I., Gebru, G., Desta, S., Negassa, A., Nigussie, K., Aboset, G. and Mechal, H. (2015). Ethiopia livestock master plan. ILRI Project Report. Nairobi, Kenya: International Livestock Research Institute (ILRI).

Sharma, A., & Chandrasekhar, S. (2016). Impact of commuting by workers on household dietary diversity in rural India. *Food Policy*, *59*, 34-43.

Shikuku, K. M., Valdivia, R. O., Paul, B. K., Mwongera, C., Winowiecki, L., Läderach, P., ... & Silvestri, S. (2017). Prioritizing climate-smart livestock technologies in rural Tanzania: A minimum data approach. *Agricultural systems*, *151*, 204-216.

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

Simtowe, F., Kassie, M., Diagne, A., Asfaw, S., Shiferaw, B., Silim, S., & Muange, E. (2011). Determinants of agricultural technology adoption: The case of improved pigeonpea varieties in Tanzania. Quarterly Journal of International Agriculture, 50(892-2016-65202), 325-345.

Smith, J. Sones, K., Grace, D., MacMillan, S., Tarawali, S., and Herrero, M. (2013). Beyond milk, meat, and eggs: Role of livestock in food and nutrition security. International Livestock Research Institute, Nairobi, Kenya.

Stawski, R. S. (2013). Multilevel analysis: an introduction to basic and advanced multilevel modeling.

Steyn, N. P., Nel, J. H., Nantel, G., Kennedy, G., &Labadarios, D. (2006). Food variety and dietary diversity scores in children: are they good indicators of dietary adequacy? *Public Health Nutrition*, *9*(5), 644-650.

Tesfaye, W., & Tirivayi, N. (2020). Crop diversity, household welfare and consumption smoothing under risk: Evidence from rural Uganda. *World Development*, *125*, 104686.

Udo, H. M. J., Aklilu, H. A., Phong, L. T., Bosma, R. H., Budisatria, I. G. S., Patil, B. R., ... & Bebe, B. O. (2011). Impact of intensification of different types of livestock production in smallholder crop-livestock systems. *Livestock Science*, *139*(1-2), 22-29.

Upton, M. (2004). *The role of livestock in economic development and poverty reduction* (No. 855-2016-56231).

Verkaart, S., Munyua, B. G., Mausch, K., &Michler, J. D. (2017). Welfare impacts of improved chickpea adoption: A pathway for rural development in Ethiopia? *Food Policy*, *66*, 50-61.

Wollni, M., & Andersson, C. (2014). Spatial patterns of organic agriculture adoption: Evidence from Honduras. *Ecological Economics*, *97*, 120-128.

Workicho, A., Belachew, T., Feyissa, G. T., Wondafrash, B., Lachat, C., Verstraeten, R., &Kolsteren, P. (2016). Household dietary diversity and Animal Source Food consumption in Ethiopia: evidence from the 2011 Welfare Monitoring Survey. *BMC Public Health*, *16*(1), 1192.

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

2. Chapter Two: Paper I - Does livestock diversification influence households' dietary diversity and welfare? Evidence from Ethiopia

Jonse Bane Boka

Department of Economics,

Addis Ababa University

jonseboka@yahoo.com; jonse.bane@aau.edu.et

Abstract

Farm households in developing countries often face low dietary diversity and high levels of malnutrition as their diets are dominated by a few staple foods. The literature tends to focus on crop diversification to improve diets and welfare of smallholders with less emphasis on the role of livestock diversification on diet variety and quality. Based on the Ethiopian Socio-economic Survey (ESS) and using a fixed effects instrumental variable approach, the current study analyzes the welfare and dietary diversity effects associated with livestock diversification. The findings reveal that livestock diversification and income from sales of livestock and its products play a significant role in improving farm households' welfare and dietary diversity. Besides, access to markets contributes to variety in households' diets. Thus, strategies that promote livestock diversification and improve market access could provide a viable pathway to reduce malnutrition and poverty among Ethiopian smallholders.

Keywords: livestock diversification; dietary diversity; welfare; Ethiopia

JEL codes: Q12, Q18

2.1. Introduction

Globally, livestock accounts for about 40 percent of agricultural output, generates 15 percent of total food energy and 25 percent of dietary protein (FAO, 2009). In developing countries, including Ethiopia, the livestock sector generates nearly 30 percent of agricultural GDP and over 70 percent of rural households partly or fully depend on the sector for their livelihoods (Biasca, 2014). Livestock ownership boosts crop production and productivity via the supply of manure and draft power and serves as collateral and insurance against shocks and risks (Herrero et al., 2013; Smith et al., 2013). Livestock can also generate additional household incomes from sales of livestock, its byproducts and animal rental and transportation services (Pica-Ciamarra et al., 2011). Such incomes can be used to buy improved crop production technologies and/or better-quality diets. Thus, livestock play an essential role in improving livelihoods of smallholder farmers. Yet, in many developing countries, including Ethiopia, markets for perishable animal source foods (ASFs) are often not well developed because of weak or non-existent transportation facilities like refrigerators and poor rural road networks. In such situations, livestock ownership and diversification can provide households with protein dense ASFs to improve their diets (Dror & Allen, 2011; Jin & Iannotti, 2014; Muslimatun & Wiradnyani, 2016). Improved dietary diversity (DD) indicates households' access to a variety of foods (dietary quality) and it serves as a proxy for individual level nutrient adequacy (Steyn et al., 2006). Studies show that better dietary quality is positively associated with nutrient intake via consumption of variety of diets, which improves welfare, nutritional status and per capita calorie consumption (Ruel, 2003; Leroy et al., 2015). Thus, dietary diversity can serve as an indicator to measure and follow nutrient adequacy, child growth and malnutrition and food security.

Previous studies link farm diversity to household dietary diversity either by omitting livestock species or merging them with crop species to create a single index such as the count index, the Simpson index, the Shannon-Wiener index or the composite index (Jones et al., 2014; Sibhatu et al., 2015; Jones, 2017; Romeo et al., 2016; Hirvonen & Hoddinott, 2017; Koppmair et al., 2017; Ayenew et al., 2018; Ecker, 2018; Sibhatu & Qaim, 2018). One limitation with such approaches is that merging crop and livestock species into a single index makes it difficult to separate the welfare and dietary diversity effects of crop and livestock diversities. One exception, which constitutes an advancement in the topic is Zanello et al. (2019) who use cross sectional data from Afghanistan to separately link crop and livestock diversity to dietary diversity. However, their study addresses the relationship at one point in time and does not consider the welfare effects associated with livestock diversity in panel data context. There exist other similar studies that link livestock ownership to households' dietary diversity but the results are mixed.[6] Studies by Headey and Hirvonen (2016) and Headey et al. (2017), for instance, find a negative association between livestock ownership and the health of household members mainly via children being exposed to

[6]See for instance Rawlins et al. (2014), Azzarri et al. (2015), Jodlowski et al. (2016), Workicho et al. (2016), Hetherington et al. (2017) and Murendo et al. (2018).

pathogens from livestock and their excreta.[7] Also, because livestock rearing is labor intensive, livestock ownership requires more energy of children and women, which could negatively affect their welfare (Randolph et al., 2007; Herrero et al., 2013).[8] Previous studies also have a tendency to focus on project or program-based interventions and/or use data collected from specific target groups (Jodlowski et al., 2016 in Zambia; Rawlins et al., 2014 in Rwanda; Ayele & Peacock, 2003 in Ethiopia and Nilsson et al., 2019 in Rwanda).

Since results of previous studies are mixed and often very context specific there is a need for additional country specific studies to understand the associations between livestock diversification and welfare indicators. There are clear policy implications of this research as it can further help to understand how to better design livestock policies and strategies in terms of improved productivity and consumption of ASFs. This research also adds to the current debate on the role of specialization vs. diversification in creating the necessary preconditions for improved welfare among small scale farmers in developing countries (Michler & Josephson, 2017). To the author's knowledge, there are no previous studies that address outcomes in terms of both DD and welfare associated with livestock diversification. To address this, the present study uses three rounds of the nationally representative ESS datasets, which enable one to follow the same households over time (2011/12, 2013/14 and 2015/16). By controlling for endogeneity problems using an instrumental variable (IV) approach, this paper finds that diversifying livestock has positive and significant effects on farm households' welfare and dietary diversity. Thus, instead of increasing the number of animals already owned, diversification of types of animals is more important to improve welfare and variety of diets of farm households.

The remaining sections of this paper are organized as follows: section 2.2 provides background of the paper. Section 2.3 reviews the literature and the underlying arguments linking livestock diversification to household welfare and dietary diversity. Section 2.4 describes the data and variables used to empirically address the stated hypotheses. Section 2.5 provides a description of the estimated model and justification for instrumental variables. Section 2.6 presents estimation results and discussion and section 2.7 concludes the paper.

2.2. Background

Over the last three decades, Ethiopia has witnessed several improvements in terms of reduced child mortality and poverty. In 2000, about 44 percent of the population were under absolute poverty with the highest levels in rural areas (45 percent) but relatively lower levels in urban areas (37 percent). After 15 years, the overall level has declined to 23.5 percent, but it is still high in rural compared to urban areas, 25.6 percent versus 14.8 percent (CSA, 2018). Despite these

[7] See also George et al. (2015) and Mbuya et al. (2015).

[8] Studies have also found no significant association between livestock ownership and dietary quality for adult and children (see for instance, Mosites et al., 2016; Dumas et al., 2018).

improvements, household's food consumption is still dominated by a few staple foods (teff, maize, sorghum, wheat) and roots and tubers (potatoes, sweet potatoes and *enset*) and a significant share of households' food expenditure is spent on staple foods. Over 75 percent of the consumed calories are from carbohydrate (cereals, roots and tubers) and little from proteins and fat, which is around 10 percent each (Sheehy et al., 2019). Hence, the intake of protein and essential micronutrients such as calcium, vitamins (A, B-12), iron and zinc are largely insufficient in the country as consumption of ASFs is still low. This is despite the country's large livestock population (Bachewe et al., 2018; Sheehy et al., 2019), and the results is often an uneven calorie intake linked to high seasonality in the sources of calories during post-harvest and lean season (Hirvonen et al., 2016).

The agricultural sector is at the center of livelihood options for households in developing countries and diversified farming activities can result in positive effects on their welfare (Johnston & Mellor, 1961; Timmer, 2002; Acharya, 2006). There is a large body of literature on off-farm and on-farm diversification highlighting the role of risks, uncertainties and missing markets as some of the most important underlying motives for diversification[9] (Barrett et al., 2001; Lanjouw & Lanjouw, 2001). Households diversify their agricultural and non-agricultural activities to minimize production-, consumption- and income related risks. These include production related risks mainly arising from climate change; market risks associated with price shocks and regulatory related risks linked to changes in policies, regulations and food safety (Meraner et al., 2015). Hence, incomplete or missing markets for insurance and credit coupled with factors external to the households, makes diversification including that of livestock, a rational strategy to hedge for consumption and production related external shocks (Kurosaki & Fafchamps, 2002).

There is a debate on the role of specialization vs. diversification in improving agricultural productivity and in creating the necessary preconditions for improved welfare in the context of developing countries (Kurosaki, 2003; Kim et al., 2012; Yang et al., 2018; Bellon et al., 2020). Farm households in developing countries may specialize or diversify their farm activities depending on natural environments and ownership of assets (natural, human, financial, social, informational) (Yang et al., 2018). However, farm households in poor countries need to cope with several risks and shocks related to climate changes, price volatility, diseases and pests (Barrett et al., 2001; Lanjouw & Lanjouw, 2001; Meraner et al., 2015). These shocks and risks are mainly major reasons behind needs for an increasing emphasis on households' diversification rather than specialization strategies in recent literature (Michler & Josephson, 2017; Yang et al., 2018) and policies/strategies for rural development (Tegegn, 2015). Farm diversification is also a good strategy to ensure food and nutrition security, contribute to poverty reduction and better environmental management and increase income of farm households in developing countries

[9] Households also diversify their income sources motivated by higher income from non-farm income sources and high-value agricultural activities such as horticulture and livestock fattening and poultry (Bigsten et al., 2011).

(Taffesse et al., 2011; FAO, 2012). Recent studies (e.g. Bellon et al., 2020) find that farm diversification is more beneficial for farm households in developing countries than specialization.

2.3. Conceptual framework and welfare effects associated with livestock diversification

Livestock diversification has the potential to influence dietary diversity and welfare through series of direct and indirect channels or mechanisms. The direct channels are via consumption of protein dense ASFs (dairy products, meats and eggs) from own production. For households in remote rural areas with poor road networks, limited access to markets and few possibilities to earn off-farm income, on-farm diversification, including diversity in livestock species, can reduce the risk of facing micronutrient deficiencies (Ecker & Qaim, 2011). Moreover, in the presence of risks and in the absence of credit and formal insurance, livestock may facilitate not only diversification into non staple activities, but also entry into new production activities with higher expected returns (Bigsten et al., 2011). In the absence of formal credit, livestock may enable households to overcome liquidity constraints and facilitate investments in new technologies (Imai, 2003; Pica-Ciamarra et al., 2011).

Several studies examine the effects of livestock ownership on household and/or individual level DD via the direct channel. Using project or program-based data, studies find positive effects of livestock provision to poor households on their DD via consumption of ASFs in Zambia (Jodlowski et al., 2016); Nepal (Darrouzet-Nardi et al., 2016); and Ethiopia (Ayele & Peacock, 2003). Similar studies with a focus on other sub-Saharan (SSA) countries find that livestock ownership leads to higher consumption of corresponding ASFs that in turn improves DD (Azzarri et al., 2015; Workicho et al., 2016; Hetherington et al., 2017). Studies have also found a positive association between livestock ownership and improvements in dietary diversity and quality at household and individual (mainly childhood) levels (Jin & Iannotti, 2014; Headey & Hirvonen, 2016; Murendo et al., 2018; Zanello et al., 2019). Hence, there seems to be an agreement that different types of on-farm diversification strategies to improve welfare and DD at the individual and household levels, mainly from increases in consumption of ASFs (Kumar et al., 2015; Malapit et al., 2015; Dillon et al., 2015; Koppmair et al., 2017).

Livestock diversification may also influence households' DD and welfare through series of indirect channels via the provision of natural fertilizers to improve soil fertility, draft power and better possibilities to invest in improved crop production technologies that work to improve crop production and productivity (Powell et al., 1998; Herrero et al., 2013; Smith et al., 2013). For subsistence farmers at the lower end of the income scale, improved crop productivity and on-farm diversification provides improved quality and diversity in their diets (Ecker & Qaim, 2011). A diversified livestock may also lead to additional income from sales of the animals and their byproducts, including rental incomes (e.g., renting out a bull for ploughing) and income from animal-based transportation services. Farm households can use such incomes to buy consumption products that they cannot produce themselves or production inputs used as supplements in their own production (Jin & Iannotti, 2014; Jodlowski et al., 2016; Dumas et al., 2018). However, the income-welfare channel is also dependent on households' access to markets for food, livestock and agricultural inputs as well as how such markets are appropriately functioning. Both direct and indirect channels are depicted in figure 1.

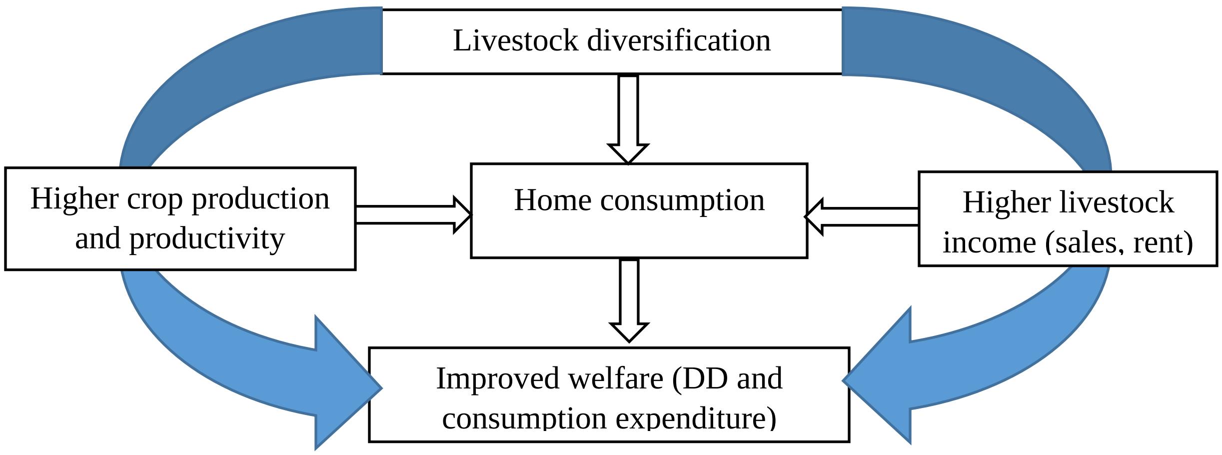


Figure 1:underlying mechanisms for effects of livestock diversification on welfare and DD

Source: adopted from Herforth (2010)

There may also be a negative association between livestock ownership and welfare as exposure to livestock excreta can adversely affect wellbeing. Previous studies have established this channel as, for instance, in Ethiopia by Headey & Hirvonen (2016). They find that keeping poultry overnight in the same dwelling units as the members of the household is negatively associated with children's health. Using observational data from three developing countries (Bangladesh, Ethiopia and Vietnam) Headey et al. (2017) find a negative association between exposure to animal feces and children's health in all the three countries. Similar results are found for Bangladesh (George et al. 2015) and Zimbabwe (Mbuya et al., 2015) showing that children's exposure to animals is associated with higher risks of clinical diseases like diarrhea. Hence, it is vital to account for such negative influences in a study of the welfare effects associated with livestock rearing. In this paper, they are controlled for by considering housing conditions measured by a compound housing quality index built using principal component analysis technique.

2.4. Data and measurement of variables

2.4.1. Data

This paper uses three rounds of nationally representative panel data provided by the Ethiopian Socio-economic Survey of 2011/12, 2013/14 and 2015/16 collected by the Central Statistical

Agency (CSA) of Ethiopia in collaboration with the World Bank Living Standard Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA). In constructing the survey, the sampling procedure followed a two-stage probability sampling technique. In the first stage, the country was stratified into regions and enumeration areas (EAs)[10] were selected from each region using the probability to population proportion sampling where more EAs were selected from regions with several EAs. In the second stage, 12 households were randomly selected from each EA. The surveys collected data on various perspectives from the same households during the three rounds of the survey years. The questionnaire used for data collection has different sections including: household, livestock, post planting and post harvesting. The household section contains information such as the quantity of different food items consumed during the last 7 days prior to the survey date for a specific household. Over 80 food items consumed across the country were covered by the questionnaire and food items are from own production, purchases, gifts and expenditure on foods consumed away from home (or prepared foods purchased from hotels, restaurants, cafes, small local food catering, etc. mainly relevant for urban respondents). The livestock questionnaire includes questions on types and number of livestock owned, production and sales of livestock and livestock products and other issues related to livestock management. These data are used to construct a set of diversity measures as described below. The ESS datasets are used by several previous studies (see for example, Tesfaye & Tirivayi, 2018).

Annex 2.3 presents some descriptive statistics showing the share of the surveyed households (in percent) who owned different types of livestock. Nearly three in four households' owned cattle but the share of households owning cattle declined over the course of the surveys. Most of the households have small ruminants (goats and sheep) and a significant number of households have poultry but with a slightly declining trend over time. The share of households owning equines (donkeys, horses and mules) increased quite drastically between 2013 and 2015 indicating the increasing importance of such animals for transporting people and non-agricultural and agricultural products to markets, grain mills and from farms to homes. For some owners, such animals provide transport services via animal drawn carts in exchange for cash (Fuller & Aye, 2012). Thus, these animals are key income sources mainly for the youth in small towns and rural areas.

2.4.2. Measuring livestock diversity

The independent variable in focus is livestock diversification, which can be measured using different indices. For instance, Zanello et al. (2019) measure livestock diversity using a count index where the number of groups of livestock species owned by the households are counted to indicate livestock diversity. Similar to previous studies, this paper also divides livestock owned into the following animal sub-groups based on species and their importance/function to the households:

---

[10]Enumeration area (EA) is a specific location demarcated for random sampling of households per such EA and it may be the same as a kebele (the lowest administrative unit) or less than a kebele.

cattle (large ruminants), sheep and goats (small ruminants), equines (mules, horses and donkeys), camel and poultry (Dinar & Mendelsohn, 2011). To control for the effects of crop diversity on DD and welfare, studies have also included a crop[11] diversity index by dividing crops produced by households into seven sub-groups (cereals; roots and tubers; oil seeds; pulses and nuts; fruits; vegetables; other crops and spices).

One limitation of using the livestock count index is that it gives equal weights to all livestock groups meaning that it assumes that they are equally important to a household, regardless of their size and functions, which is not always the case. Alternative measures of diversity, like the Shannon-Wiener index and the composite index, address this limitation by considering both the richness (count) and the distribution or relative frequency of each animal group (evenness). The Shannon-Wiener index for livestock (SW_L) can be expressed (in cow equivalent (CE)) as follows:

$$SW_L = -\sum_{i=0}^{n} \mathrm{S}_i \ln(\mathrm{S}_i) \quad (1)$$

where S_i is the share/relative frequency of each group of livestock $l, \dots, n$ in the total number of livestock owned (in CE) and the index is multiplied by a negative number to make it positive, so it is convenient for interpretation. The value of the index ranges from zero (where S_l=1) indicating absence of diversity to LN (S) indicating all animal groups are equally/evenly distributed. One limitation with the Shannon-Wiener index is that its maximum value depends on the number of groups and hence it is impossible to compare situations with different numbers of groups. Hence, this study uses a composite index[12] of the following type to address this issue:

$$CI_L = (SW_L) * (1 - 1/n) \quad (2)$$

The measure in Equation 2 considers the number of groups of livestock owned, such that it can be used to compare different households with different groups of livestock.

Table 2.1 present some descriptive statistics showing that, on average, households owned about 2.1 groups of livestock in terms of CE (out of five groups) with a declining trend over the course of the surveys. On the one hand, the total number of livestock owned in CE has increased but on the other hand, the livestock count index has declined indicating that livestock diversification is limited among farming households. This is also reflected by the average Shannon-Wiener index for livestock, which is less than the simple count index (that also reveals an uneven distribution of ownership of livestock groups) (Tesfaye & Tirivayi, 2020). That is, households have more of some

[11] Since land allocated to each crop is not available, it is impossible to compute the Shannon-Wiener index for crop diversity. Hence, we use only the crop count in our model

[12] The advantage of the composite index over the Shannon-Wiener index is that it weights the Shannon-Wiener index by the number of groups (n) so that it is possible to compare households with different groups of livestock.

groups and very few or none of the other groups. Thus, farming households in Ethiopia are characterized by limited livestock diversification. The average crop count index shows that a household cultivated about 2.5 groups (out of seven groups) and the crop diversification has no clear trends over the panel years. In most part of the country, smallholders are engaged in mixed farming where they cultivate crops and rear livestock.

Table 2.1: Summary statistics for livestock and crop diversities: 2011-2015

Types of indices	2011	2013	2015	Pooled
Livestock count index	2.104	2.063	2.059	2.073
Livestock Shannon-Wiener index	0.312	0.306	0.346	0.323
Livestock composite index	0.203	0.202	0.275	0.228

Source: Author's computations based on 2011/12, 2013/14 and 2015/16 ESS data

2.4.3. Measurement of dietary diversity and welfare

The two outcome variables of the current study are household level welfare defined as monthly real consumption expenditure per adult equivalent and dietary diversity as measured using various indices and food consumption score (FCS). The latter measures access to food at household level and adequacy of diets at individual level. Although there is an agreement that dietary diversity is a key component of healthy diets, there is no consensus on its measurements. Nutrition and health related literature has measured it using a simple count of number of food groups consumed by households during a reference period (see, for instance, Ruel, 2003). However, as mentioned earlier, count indices face some limitations as they give equal weights to different food groups. As such, a count index does not consider that food groups differ in their nutritional contents. For instance, two groups with the same number of food items may differ in their proportion of cereals versus protein rich food types such as meat and egg. Hence, alternative measures of dietary diversity such as the Simpson index, the Shannon-Wiener index and the composite index are used by previous literature in development economics (Nguyen & Winters, 2011; Karamba et al., 2011; Sharma & Chandrasekhar, 2016). Following FAO (2010) guidelines and the approach in Jones et al. (2014), Sibhatu et al. (2015), Hirvonene and Hoddinott (2017) and Ecker (2018), the present study uses expenditure shares, rather than a count of food groups, to construct a measure of dietary diversity. Using the ESS survey data, these indices are created by considering 12 food groups consumed over the last 7 days prior to the survey date (FAO, 2010; Jones et al., 2014; Sibhatu et al., 2015; Hirvonen & Hoddinott, 2017).[13]One limitation with the ESS survey is that the first and second rounds included fish and seafood into meat groups and edible oils and fats into pulses and oil seeds. Therefore, only 10 food groups are considered in the construction of the two dietary diversity indices: the Shannon-Wiener index of dietary diversity (SW_{DD}) and the composite index of dietary diversity(CI_{DD}), which are defined as:

[13]The 12 groups are cereals and cereal products; starchy roots and tubers; vegetables; fruits; meat groups; fish and seafood; eggs; nuts and pulses; milk and milk products; edible oils and fats; sugars; spices and condiments.

$$SW_{DD} = -\sum_{f=0}^{m} \mathrm{S}_f \ln(\mathrm{S}_f) \tag{3}$$

$$CI_{DD} = (SW_{DD}) * (1 - 1/m) \tag{4}$$

Interpretations are like those in equations (1) and (2) above in the sense that S_f in Equation (3) denotes the share of expenditure on each food group $f, \dots, m$ in the total food expenditure and the value of the Shannon – Wiener index ranges from zero (S_f=1) to LN (S). The composite index (CI_{DD}) in Equation (4) is included to consider the number of food groups, such that it can be used to compare different households with different food groups.

Dietary diversity can also be measured using FCS[14]. This is measured based on dietary diversity and frequency of consumption of different food groups over the last 7 days recall before the survey. Using this approach, the number of days (frequency) of each food group consumed over 7 days is multiplied by its respective weight and FCS is obtained by adding the resulting values. Thus, this paper measures dietary diversity using food Shannon – Wiener and composite indices, which are based on the share of expenditure of each food group in the total food expenditure and FCS that uses the frequency of food groups that a household consumes over the last 7 days before the date of the survey. Recent studies use FCS as measure of dietary diversity (e.g., Zanello et al., 2019).

The second outcome variable is welfare defined as real total expenditure per adult equivalent. Following Jodlowski et al. (2016), Nilsson (2019) and Tesfaye and Tirivayi (2020) consumption expenditure (both food and non-food) is used to indicate overall welfare of the households and it follows the argument that income may be an unreliable welfare indicator as it is typically subject to seasonality and varies a lot over the year (Lipton & Ravallion, 1995). There may also be measurement issues linked to farmers' abilities to recall past crop or livestock sales and the associated prices (Ellis, 1998). The variable used to indicate total annual consumption expenditure is given in the ESS data and the measure includes total food and non-food consumption expenditure at the household level. Food consumption expenditure is computed as the sum of food consumption from own production, market purchase and gifts over the last seven days before the

[14]FCS is based on eight food groups where each food group is assigned a weight based on its protein, vitamin and micronutrient densities. The food groups and corresponding weights are: main staple foods (cereals, roots and starchy tubers) (weight=2); pulses (legumes and nuts) (weight=3); fish and meat groups (beef, goat, poultry, eggs, fish) (weight=4); milk and dairy products (weight=4); fruits (weight=1); vegetables including green leaves(weight=1); oil and fats (weight=0.5); and sugar/sweets (including honey) (weight=0.5) and condiments (weight=0) (WFP, 2008).

commencement of the survey and total expenditure is then converted into an average monthly real expenditure per adult equivalent.[15]

Table 2.2 displays descriptive statistics for the measures of dietary diversity and welfare outlined above. The food count index shows a declining trend over the panel years with an average of about 5.24 (out of ten food groups). This indicates that food consumption of Ethiopian households is mainly dominated by a few staple foods (cereals, tubers and roots) with limited consumption of ASFs, fruits and vegetables (Worku et al., 2017). A skewed distribution in food consumption is revealed by the Shannon-Wiener index, which is smaller than the food count index and thus lend support to the view presented in comparable studies (see e.g., Zanello et al., 2019; Tesfaye & Tirivayi, 2020). As indicated in Table 2.2, per adult monthly expenditure in real term has been increasing over the course of the panel with the average expenditure of about 503 Birr (which is around 16 USD per month per adult equivalent using current exchange rate of 1 USD = 32 Birr).

Table 2.2: Summary statistics for households' dietary diversity and real per capita expenditure

Items	2011	2013	2015	Pooled
Food consumption count (out of ten)	5.295	5.244	5.183	5.241
Dietary diversity Shannon-Wiener index	1.143	1.115	1.065	1.108
Dietary diversity Composite index	0.924	0.900	0.857	0.894
Real per adult expenditure per month (in Birr)	452.00	462.65	502.65	472.43

Source: Author's computations based on 2011/12, 2013/14 and 2015/16 ESS data

Table 2.3 presents household FCS that range from 1 to 112. The average FCS is a little over 41. Using World Food Program's cut-off points (WFP, 2008), Table 2.3 also indicates whether food consumption is acceptable or not. Nearly 23.5 percent of households have poor diets with a declining trend over the course of the panel. More than 31 percent of households have borderline diets. Thus, about 55 percent of surveyed households have no acceptable diets over the survey years. This finding is consistent with previous studies in the context of other developing countries like Afghanistan (Zanello et al., 2019).

Table 2.3: Food consumption scores and acceptability of household diets

		Level of acceptability of household diets (in %)		
Year	FCS (Average)	Poor	Borderline	Acceptable
2011	40.53	24.96	30.45	44.59
2013	41.49	23.11	29.89	47.00

[15]The total consumption expenditure is converted into real value by dividing it by aggregate consumer price index reported in the ESS datasets. Finally, real total expenditure is divided by adult equivalent in the household to take care of intra-household expenditure inequalities (Tesfaye &Tirivayi 2020) and converted into monthly by dividing it by 12. The log of per adult equivalent consumption is used to account for heteroscedasticity and size effects.

2015	41.38	22.28	32.70	45.02
Pooled	41.13	23.45	31.01	45.54

Source: Author's computations based on 2011/12, 2013/14 and 2015/16 ESS data

2.4.4. Controls

In addition to the key explanatory variables described earlier, a set of household and regional level controls are included in the estimations (defined and summarized in Annex 2.1). The first is a set of socioeconomic indicators (age and educational attainment of the head of the household) and indicators of households' asset ownership. Two asset indices are included to control for the potential of both positive and negative influences linked to livestock rearing. The first is a compound housing quality index estimated using principal component analysis with regard to housing conditions (e.g., rooms excluding kitchen, bathroom and not shared with livestock; types of materials for roofing, flooring and walls; waste disposal; toilet facilities; etc.). The rationale for its inclusion is the possibility of negative health effects of livestock rearing under poor housing conditions (Headey & Hirvonen, 2016) and whether better housing quality improves farm households' welfare. The second is a comparable compound index estimated with regard to households' ownership, for example, of mobile phones, radios, TVs, sofas, and farm equipment.

Land (in ha) and livestock owned (as measured in CE[16]) are included to control for land holding and livestock size effects, access to productive inputs and collateral (Abdulai & CroleRees, 2001), market access and the cost of marketing farm output is controlled for via the distance to markets (Ellis, 2000). Lastly, households' real income from sales of livestock and its byproducts and a measure of crop diversification are included together with regional dummy variables. The selection of control variables broadly follows the approach in previous studies (see for instance, Ellis, 2000; Barrett et al., 2001; Nilsson et al., 2019).

Descriptive statistics are presented in Annex 2.4 showing the total number of livestock owned (in terms of CE) by livestock groups. Total number of livestock owned has increased between 2013 and 2015 with an average of 3.8 livestock. There is an increase in number of large ruminants, equines and camels owned with higher increment observed for equines as these animal groups support households through providing transport services.

[16]CE is calculated based on the method developed by Storck et al. (1991) and compiled by Njuki et al. (2011). Using this approach, CE assigns different weights for different livestock types using the metabolic body weight of a cow of 250kg as unity (cow=1) and converting all other livestock types to CE equivalents as per the following weights: ox=1.1, heifer=0.5, bull=0.6, calf=0.2, sheep=0.1, goat=0.09, donkey=0.5, horse=0.8, mule=0.7, camel=1.1 and poultry=0.01.

2.5. Estimated model and instrumental variables

2.5.1. Estimated model

If production and consumption decisions are non-separable, as assumed here, households' production factors directly affect their consumption decisions (Singh, et al., 1986; Dillon et al. 2015). This relationship, which is obtained by maximizing farm Household's utility function subject to resource constraints, can be expressed as:

$$C_{ht} = f(\boldsymbol{P}, \boldsymbol{Q}, \boldsymbol{M}, \boldsymbol{H}) \qquad (5)$$

where C_{ht} denotes the consumption of household h at time t; $\boldsymbol{P}$ denotes a vector of prices including output and input prices, transaction costs and interest rate; $\boldsymbol{Q}$ is a vector of agricultural outputs and $\boldsymbol{M}$ denotes a vector of household income from outside agriculture. Finally, $\boldsymbol{H}$ represents a vector of household characteristics. Since prices and transaction costs are usually not reported in the available survey data, which is the case for the ESS data used in the present study, such influences are controlled for via community fixed effects (Kumar et al., 2015; Zanello et al., 2019; Tesfaye & Tirivayi, 2020). This follows the rationale that households in the same village face similar transaction costs (Renkow et al., 2004). Using this framework and following recent studies with a similar focus (e.g., Zanello et al., 2019; Tesfaye & Tirivayi, 2020), this paper links two outcome variables: household DD (measured by the FCS, the Shannon – Wiener index and the food composite index) and household welfare (measured by real monthly total expenditure per adult equivalent) to livestock diversification (measured by count, Shannon – Wiener and composite indices).

Estimating the relationships between livestock diversification, dietary diversity and welfare is challenging because of the likely existence of unobservable linked to individual characteristics (e.g., ability to rear livestock and motivation to diversify) and natural prerequisites for livestock rearing (biophysical conditions). These unobserved factors could simultaneously affect both livestock diversification and dietary diversity (Verkaart et al., 2017) and there may also exist reverse causation that runs from livestock diversification to dietary diversity and vice versa. The empirical approach to handle these issues is to estimate a fixed-effects IV model. The FE-panel model removes time-invariant unobservable household characteristics such as ability to rear livestock and motivation to diversify livestock groups, which could lead to a selection bias in owning livestock and could also be correlated with outcome variables and hence lead to an endogeneity problem (Verkaart et al., 2017). The IV is used to address the same problem, but it arises from reverse causation that runs from livestock/production diversity to DD and vice versa. For instance, on the one hand, more livestock diversity leads to higher household welfare and on the other hand, better-off households are more likely to own and diversify livestock types (Tesfaye & Tirivayi, 2020). Thus, this paper uses FE-IV to handle endogeneity problems that arise from different sources. The departure for a such model is the standard fixed-effects panel model, which takes the following type:

$$y_{it} = \beta_0 + \gamma D_{it} + \theta C_{it} + \rho R_{it} + u_i + \tau_t + \varepsilon_{it} \quad (6)$$

where y_{it} denotes the outcome variables (either dietary diversity (SW_{DD} or CI_{DD} or FCS) or welfare); D_{it} indicates a measure of livestock diversification (either the livestock count index, the Shannon – Wiener index (SW_L) or the composite index(CI_L)) and γ is a vector of corresponding coefficients; C_{it} denotes a vector of household-level controls and θ a vector of its associate coefficient estimates; R_{it} denotes a vector of regional controls and ρ a vector of its associate coefficient estimates; u_i is the individual-level fixed effect, τ_t is the time-specific fixed effect and ε_{it} denotes an idiosyncratic error term.[17]To address the issues discussed earlier, the model is estimated using a fixed-effects instrumental variable approach (FE-IV). The first stage IV equation can be specified as:

$$D_{it} = \beta_0 + \beta_1 Z_{it} + \beta_2 C_{it} + \beta_3 R_{it} + v_{it} \quad (7)$$

whereD_{it}, C_{it} and $R_{it}$are as indicated earlier and Z_{it} is a vector of instrumental variables that are correlated with D_{it} but uncorrelated with idiosyncratic error ε_{it}.

2.5.2. Instrumental variables

The selection of IVs follows the approach in previous studies with a focus on social interactions and neighborhood effects that attempts to improve identification between contextual factors and household outcomes (see for example, Conley & Udry, 2010; Krishnan & Patnam, 2013). An IV is considered valid if it is exogenous in the sense that it is uncorrelated with the idiosyncratic error term. It is considered relevant if it is correlated with livestock diversification but is not directly correlated with the outcome variables, but is only indirectly correlated via livestock diversification.

Three sets of IVs are applied in this paper. All the three IVs are simultaneously used in the estimated models discussed in sub-section 2.5.1 (equation 7). The first IV is average livestock diversity indices (as defined in Section 2.4.2) of neighbors at the community/EA level excluding the household under investigation. The key argument here is that livestock diversification decision of a household is more likely affected by its neighbors' decisions to diversify livestock indicating that average neighbors' livestock diversity is correlated with livestock diversity of the household, but not directly correlated with outcome variables (DD and welfare). This indicates that this instrument is relevant (that is, it is correlated with household's diversification) and it is valid[18] as

[17] The Hausman test indicates that a fixed effects model is preferred over a random effects model.
[18] However, validity of this IV could be criticized from two fronts, first, neighbors' livestock diversification can affect welfare of the household under investigation via gifts of livestock products to the household.

it is not directly correlated with outcome variables (welfare indicators). Recent studies in similar context have used such IV in Nigeria (Dillon et al., 2015); Afghanistan (Zanello et al., 2019) and rural Uganda (Tesfaye & Tirivayi, 2020). The second IV is climate related variable such as average deviation of wet season rainfall from their annual mean that highly affects livestock production and diversification throughout the year compared to other means of livelihoods of farm households such as crop production (Kibrom & Jensen, 2020). This follows similar approaches in Dillon et al. (2015), Hirvonen and Hoddinott (2017) and Tesfaye and Tirivayi (2020). The third set of IV is the distance of the household to the nearest grazing land livestock. The paper computes the distance using household coordinates. Michler and Josephson (2017) linked crop diversity and poverty dynamics in Ethiopia using IV method where distance of each village to the nearest farmers' cooperative is used to instrument crop diversity. Similarly, Bellon et al. (2020) use distance to nearest city as IV for crop diversification.

2.5.3. Tests of endogeneity and validity of IVs

Table 2.4 presents diagnostic tests including validity tests for IVs (exogeneity and relevance) using F-tests for excluded IVs, Kleibergen-Paap and Sargan-Hansen tests. Hausman tests (with the null hypothesis that the random effects model is preferred to the fixed effects model) clearly reject the null hypothesis at less than 1 percent level of significant indicating that the appropriate model is FE-IV. The endogeneity[19] test (Wu-Hausman) statistic indicates that the null hypothesis of exogeneity of livestock diversification is rejected at less than 1 percent indicating that livestock diversification as measured by various indices is endogenous. Thus, this paper fits the FE-IV model for three outcome variables (the Shannon – Winer index, the food composite index and the real total expenditure per adult equivalent) with three measures of livestock diversification (count index, livestock Shannon-Wiener index and livestock composite index) as independent variables in three separate models to check robustness of the results to different measurements. Control variables are included in all the models (see Tables 2.5 to 2.8).

For all the FE-IV models with different outcome and independent variables the F-test for excluded IVs (with null hypothesis that all the excluded IVs are jointly zero) indicates that the null hypothesis is rejected and hence excluded IVs (average neighbor measures of livestock, distance to the nearest grass land and wet season rainfall deviation from the annual mean) are valid. Besides, the Kleibergen-Paap Wald statistic (test for weak IV) is statistically significant and greater than

---

Second, neighbors' livestock diversification may also affect welfare of the household by affecting supply in the local market. Such criticisms are not strong enough to reject validity of this IV as gifts are limited to few occasions like death of family members (Zanello et al., 2019) and hence accounts for less than 3 percent of total expenditure. Most of the gifts are from urban centers in the form of remittances. In addition, neighbors in a community are too small to affect local markets where farmers from several villages are participating. Thus, neighbors' livestock diversification is relevant as well as valid IV.

[19] The endogeneity test is carried out using pooled IV regression (ivregress).

ten (usual threshold value) and this indicates the IVs are correlated with the endogenous variables and hence they are relevant. Finally, the Sargan-Hansen (Hansen J) statistic tests over-identification, which states that the IVs are uncorrelated with an idiosyncratic error term (that is, the null hypothesis: the IVs are exogenous). The Sargan-Hansen test statistic reported in table 2.4 reveals that for all models, at least one of our IVs is exogenous. Thus, all the test results indicate that IVs used in this paper are valid and relevant.

Table 2.4: Summary of test results for endogeneity and validity of IVs

Dependent variables	Independent variables	Wu-Hausman statistic	F test for excluded IVs	Kleibergen-Paap Wald statistic	Sargan-Hansen (Hansen J) statistic
Composite index of diversity	Livestock count index	92.31***	16.92***	16.92***	2.41
	SW_L	77.54***	47.22***	47.22***	1.9
	CI_L	87.42***	48.50***	48.50***	1.05
Shannon-Wiener index	Livestock count index	16.66***	14.47**	14.47**	0.98
	SW_L	12.06***	37.01***	37.01***	1.2
	CI_L	10.21***	36.92***	36.92***	1.31
Real total expenditure per adult	Livestock count index	58.55***	12.78**	12.78**	1.71
	SW_L	92.27***	19.23***	19.23***	1
	CI_L	87.42***	19.34***	19.34***	2.71

***, ** indicate statistical significance at the 1 percent and 5 percent level of significance

Source: Author's computations based on 2011/12, 2013/14 and 2015/16 ESS data

Note: the difference between livestock count index and Shannon – Wiener and composite indices is that the count index simply counts the number of groups of livestock owned whereas Shannon – Wiener and composite indices are defined using share of each animal group in total livestock groups owned (in CE) by taking into account both richness and evenness.

Bivariate correlations between food consumption indices and livestock diversity indices indicate that correlations between measures of DD and welfare and livestock diversity indices are statistically significant, but the magnitude of the coefficients is smaller (see Annex 2.2). Simple correlation may not capture the true effects as it does not control for other covariates that potentially affect DD and welfare of households.

2.5.4. Hausman Taylor model for robustness

As a robustness check, time-invariant variables like regional dummies are included using the Hausman Taylor estimator.[20] This is an IV approach that allows for the inclusion of time-fixed

[20] See Baltagi et al. (2003) for a specification of the model.

variables and it uses the within transformation of the exogenous time-varying variables as IVs for time-varying endogenous variables (Baltagi & Liu, 2012). Although it serves as a robustness test, one limitation of the Hausman Taylor approach is that it imposes the strict assumption that some regressors are uncorrelated with time invariant unobservable characteristics and the idiosyncratic error term.

2.6. Estimation results and discussions

2.6.1. Effects of livestock diversification on dietary diversity

Table 2.5 displays the effects of livestock diversification (count, Shannon-Wiener and composite indices) on dietary diversity as measured by the food composite index (Equation 4). The results indicate that livestock ownership has significant but smaller effects on DD of farm households whereas livestock count index is statistically insignificant in explaining DD as measured by composite index. However, the other two measures of livestock diversification (the Shannon – Wiener and composite indices) have positive and significant effects on households' dietary diversity indicating that increasing evenness in livestock diversification across different animal groups plays an important role in improving farm households' dietary diversity. In particular, if livestock diversification (as measured by livestock composite index) increases by one percent, dietary diversity would increase by about 0.2 percent. Besides, owning more livestock has positive and statistically significant effects on DD of farm households. Similarly, higher income from sales of livestock and livestock products is positively associated with households' dietary diversity. Thus, ensuring higher income from livestock and improved livestock diversity contribute to improvement in households' welfare in terms of increasing variety of diets. Access to market is also an important factor in improving households' DD indicating that improving market access is another essential aspect to enhance households' dietary diversity. This finding is in line with previous studies in developing countries (Koppmair et al., 2017; Stifel & Minten, 2017). Housing quality as measured by housing index has positive effects on dietary diversity of farm households. Ownership of fixed assets including farm equipment has also positive effects on households' dietary diversity. The education level of the head of the household is another factor that improves diet varieties of the household.

Table 2.5: Effects of livestock ownership on DD (food composite index): OLS and FE-IV results

Independent variables	Pooled OLS estimates			FE-IV estimates		
Livestock count index	0.001 (0.003)			0.034 (0.035)		
Livestock diversity index (SW_L)		0.0074 (0.010)			0.128** (0.063)	
Livestock diversity index (CI_L)			0.004 (0.014)			0.184** (0.089)
Livestock owned (in CE)	0.0061*** (0.0016)	0.0063*** (0.0015)	0.0062*** (0.0015)	0.011 (0.0079)	0.0085*** (0.0032)	0.0092*** (0.0034)

Livestock owned (in CE^2)	-0.0001*	-0.00011*	-0.0001*	-0.0002	-0.0002**	-0.0002**
	(5.63e-05)	(5.66e-05)	(5.81e-05)	(0.0002)	(8.50e-05)	(8.48e-05)
Crop count index	0.0028	0.0028	0.0036*	0.0011	0.0010	0.0010
	(0.0021)	(0.0021)	(0.0022)	(0.0024)	(0.0025)	(0.0025)
Ln (livestock income)21	0.0027***	0.0029***	0.0031***	0.0032***	0.0026***	0.0027***
	(0.00081)	(0.0008)	(0.0008)	(0.0012)	(0.0009)	(0.0009)
Ln (household size)	-0.0035	-0.0028	-0.0050	0.0139	0.0100	0.0103
	(0.0066)	(0.0066)	(0.0070)	(0.0131)	(0.0126)	(0.0126)
Ln (age of head)	-0.495***	-0.497***	-0.395**	0.410	0.482	0.461
	(0.181)	(0.180)	(0.188)	(0.366)	(0.367)	(0.366)
Ln (age of head squared)	0.0645***	0.0648***	0.0514**	-0.0488	-0.0581	-0.0553
	(0.0239)	(0.0238)	(0.0249)	(0.0486)	(0.0485)	(0.0484)
Education head, primary=1	0.0410***	0.0411***	0.0431***	0.0247**	0.0285***	0.0289***
	(0.0065)	(0.0064)	(0.0066)	(0.0102)	(0.0101)	(0.0102)
Education head, secondary=1	0.0375**	0.0373**	0.0368**	0.00813	0.00321	0.00560
	(0.0149)	(0.0149)	(0.0152)	(0.0323)	(0.0348)	(0.0346)
Education head, tertiary=1	0.107***	0.107***	0.110***	0.0467	0.0350	0.0393
	(0.0207)	(0.0207)	(0.0222)	(0.0582)	(0.0647)	(0.0639)
Fixed asset index	0.0105***	0.0105***	0.0100***	0.00288*	0.00379**	0.00387**
	(0.0020)	(0.0020)	(0.0020)	(0.0016)	(0.0017)	(0.0017)
Housing quality Index	0.0248***	0.0245***	0.0245***	0.0143***	0.0144***	0.0142***
	(0.0027)	(0.0027)	(0.0028)	(0.0034)	(0.0036)	(0.0036)
Ln (area owned)	0.0017	0.0018	0.0024	0.0013	0.0013	0.0011
	(0.0026)	(0.0026)	(0.0028)	(0.0040)	(0.0043)	(0.0042)
Ln (distance to output market)	-0.0069	-0.0069	-0.0090	-0.0160**	-0.0163**	-0.0163**
	(0.0066)	(0.0066)	(0.0068)	(0.0071)	(0.0072)	(0.0072)
Year dummy (2011=1)	0.0286***	0.0279***	0.0332***	0.0355***	0.0306***	0.0297***
	(0.0082)	(0.0082)	(0.0086)	(0.0097)	(0.0108)	(0.0110)
Year dummy (2013=1)	0.0334***	0.0327***	0.0349***	0.0263***	0.0240***	0.0229***
	(0.0061)	(0.0061)	(0.0063)	(0.0074)	(0.0072)	(0.0075)
Regional dummy						
Tigray=1	-0.0885***	-0.0879***	-0.0903***			
	(0.0108)	(0.0108)	(0.0113)			
Amhara=1	-0.0767***	-0.0763***	-0.0741***			
	(0.0078)	(0.0078)	(0.0082)			
Oromia=1	-0.0204***	-0.0202***	-0.0198**			
	(0.0079)	(0.0079)	(0.0082)			
SNNP=1	-0.0085	-0.0087	-0.0082			
	(0.0084)	(0.0083)	(0.0087)			
Constant	1.547***	1.551***	1.347***	-0.278	-0.429	-0.398
	(0.336)	(0.335)	(0.350)	(0.683)	(0.691)	(0.690)
Observations	6,515	6,515	6,122	6,024	5,656	5,656
R-squared	0.130	0.130	0.130			

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

[21] Income from sales of livestock and livestock products

Table 2.6 shows the results of pooled OLS and FE-IV that deal with the association between livestock diversification measured using various indices and households' dietary diversity (as measured by the Shannon – Wiener index (Equation 3)) to check for robustness of the results to different measures of dietary diversity. In line with results reported in Table 2.5, increasing diversity of livestock across different groups of animals (cattle, small ruminants, equines, camels and poultry) are important in enhancing households' dietary diversity. Similarly, in accordance with results reported in Table 2.5, livestock income has positive and statistically significant effects on dietary diversity of farm households. Hence, an increase in income from sales of livestock and its products along with increasing livestock diversification are important in improving dietary diversity and varieties of diets of farm households. Better housing quality has also positive and significant effects on households' dietary diversity. Moreover, improved access to markets is another significant factor that improves farm households' DD indicating that improving market access is another key factor in enhancing households' dietary diversity.

Socio-economic characteristics of households have positive effects on DD of farm households. For instance, education level of head of the household is positively associated with better households' diet variety. Similarly, higher housing quality as measured by housing index has positive effects on dietary diversity of farm households. Ownership of fixed assets including farm equipment has also positive effects on households' dietary diversity. Finally, access to market is positively associated with dietary diversity. This finding is in line with previous studies that emphasize the role of market access in improving dietary diversity (Koppmair et al., 2017)

Table 2.6: The effects of livestock ownership on DD (as measured by Shannon – Wiener index): OLS and FE-IV

Independent variables	Pooled OLS estimates			FE-IV estimates		
Livestock count index	0.0004			0.0367		
	(0.0031)			(0.0348)		
Livestock diversity index (SW_L)		0.0112			0.138**	
		(0.0095)			(0.0641)	
Livestock diversity index (CI_L)			0.0089			0.197**
			(0.0135)			(0.0904)
Livestock owned (in CE)	0.0053***	0.0056***	0.0058***	0.0118	0.0091***	0.0098***
	(0.0015)	(0.0015)	(0.0015)	(0.0079)	(0.0033)	(0.0035)
Livestock owned (in CE^2)	-0.0001*	-0.0001*	-0.0001**	-0.0002	-0.0001**	-0.0002**
	(5.64e-05)	(5.65e-05)	(5.81e-05)	(0.0002)	(9.03e-05)	(8.99e-05)
Crop count index	0.0036*	0.0035*	0.0042**	0.0017	0.0015	0.0015
	(0.0021)	(0.0021)	(0.0021)	(0.0025)	(0.0026)	(0.0026)
Ln (livestock income)	0.0024***	0.0025***	0.0027***	0.0031**	0.0024***	0.0026***
	(0.0008)	(0.0008)	(0.0008)	(0.0012)	(0.0009)	(0.0009)
Ln (household size)	-0.0104	-0.0096	-0.0114*	0.0093	0.0067	0.0070
	(0.0065)	(0.0066)	(0.0069)	(0.0132)	(0.0128)	(0.0128)
Ln (age of head)	-0.448***	-0.450***	-0.373**	0.431	0.512	0.490
	(0.172)	(0.172)	(0.184)	(0.382)	(0.384)	(0.383)
Ln (age of head squared)	0.0585**	0.0589***	0.0487**	-0.0520	-0.0627	-0.0597
	(0.0228)	(0.0228)	(0.0243)	(0.0508)	(0.0507)	(0.0506)

Education head, primary=1	0.0405***	0.0405***	0.0426***	0.0245**	0.0283***	0.0287***
	(0.00639)	(0.00638)	(0.00651)	(0.0105)	(0.0106)	(0.0106)
Education head,	0.0335**	0.0332**	0.0332**	0.0117	0.0067	0.0093
secondary=1	(0.0147)	(0.0147)	(0.0150)	(0.0342)	(0.0371)	(0.0369)
Education head, tertiary=1	0.0963***	0.0959***	0.102***	0.0523	0.0419	0.0466
	(0.0192)	(0.0191)	(0.0203)	(0.0541)	(0.0595)	(0.0587)
Fixed asset index	0.0090***	0.0090***	0.0086***	0.0026*	0.0035**	0.0036**
	(0.0018)	(0.0018)	(0.0018)	(0.0016)	(0.0016)	(0.0016)
Housing quality Index	0.0209***	0.0206***	0.0208***	0.0129***	0.0130***	0.0128***
	(0.0027)	(0.0027)	(0.0027)	(0.0035)	(0.0036)	(0.0036)
Ln (area owned)	-0.0002	-2.44e-05	0.0007	0.0010	0.0010	0.0008
	(0.0026)	(0.0026)	(0.0028)	(0.0041)	(0.0044)	(0.0044)
Ln (distance to output	-0.0108*	-0.0107	-0.0127*	-0.0164**	-0.0170**	-0.0169**
market)	(0.0065)	(0.0065)	(0.0066)	(0.0074)	(0.0075)	(0.0075)
Year dummy (2011=1)	0.0372***	0.0362***	0.0414***	0.0401***	0.0348***	0.0337***
	(0.0080)	(0.0081)	(0.0085)	(0.0098)	(0.0111)	(0.0112)
Year dummy (2013=1)	0.0348***	0.0339***	0.0364***	0.0269***	0.0245***	0.0233***
	(0.0060)	(0.0060)	(0.0063)	(0.0074)	(0.0073)	(0.0076)
Regional dummy						
Tigray=1	-0.0955***	-0.0952***	-0.0978***			
	(0.0110)	(0.0109)	(0.0114)			
Amhara=1	-0.0649***	-0.0647***	-0.0631***			
	(0.0077)	(0.0076)	(0.0080)			
Oromia=1	-0.0238***	-0.0240***	-0.0239***			
	(0.0077)	(0.0077)	(0.0080)			
SNNP=1	-0.0007	-0.0013	-0.0011			
	(0.0081)	(0.0080)	(0.0084)			
Constant	1.558***	1.564***	1.406***	-0.196	-0.367	-0.334
	(0.319)	(0.318)	(0.342)	(0.714)	(0.724)	(0.723)
Observations	6,515	6,515	6,122	6,024	5,656	5,656
R-squared	0.110	0.110	0.112			

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The third robustness check is done by estimating pooled OLS and FE-IV for the model where DD is measured using the FCS (Table 2.7). Results of the FE-IV model indicate that after controlling for livestock ownership and livestock income, livestock diversification (as measured by the Shannon-Wiener and composite indices) are positive and statistically significant determinants of dietary diversity (as measured by the FCS). For instance, increasing livestock diversity index by one, results in an increase in the FCS by about 14 to 23 units and the effect is statistically significant at the 5 percent level. This finding is in line with previous studies in developing countries (Zanello et al., 2019). Income from sales of livestock and its products has a positive effect on households' dietary diversity. Thus, livestock diversification and income from livestock and its products are important in improving households' dietary diversity. In addition, access to market and higher education of the head of the household are other factors that help in improving DD of farm households. Housing quality index is also important in enhancing diet varieties of households in developing countries.

Table 2.7: The effects of livestock ownership on DD (measured by FCS): pooled OLS and FE-IV

Independent variables	Pooled OLS estimates			FE-IV estimates		
Livestock count index	0.383			2.264		
	(0.276)			(2.260)		
Livestock diversity index (SW_L)		1.968**			14.32**	
		(0.821)			(6.739)	
Livestock diversity index (CI_L)			2.966**			22.67**
			(1.178)			(9.529)
Livestock owned (in CE)	0.991***	0.995***	0.978***	0.852**	0.907***	0.973***
	(0.106)	(0.102)	(0.103)	(0.365)	(0.236)	(0.236)
Livestock owned (in CE^2)	-0.0147***	-0.0147***	-0.0145***	-0.0155***	-0.0166***	-0.0171***
	(0.0023)	(0.0023)	(0.0023)	(0.0054)	(0.0041)	(0.0039)
Crop count index	0.505**	0.474**	0.417**	0.520**	0.489**	0.519**
	(0.198)	(0.199)	(0.203)	(0.216)	(0.217)	(0.226)
Ln (livestock income)	0.277***	0.273***	0.299***	0.222**	0.222***	0.239***
	(0.0729)	(0.0720)	(0.0741)	(0.0891)	(0.0743)	(0.0785)
Ln (household size)	1.823***	1.759***	1.880***	1.549	1.783*	1.985*
	(0.541)	(0.540)	(0.587)	(1.079)	(1.021)	(1.086)
Ln (age of head)	-32.66**	-32.44**	-31.48*	9.667	13.10	25.08
	(16.15)	(16.16)	(17.09)	(25.62)	(25.72)	(27.93)
Ln (age of head squared)	4.177*	4.149*	3.979*	-0.934	-1.470	-3.076
	(2.133)	(2.135)	(2.260)	(3.421)	(3.437)	(3.752)
Education head,	1.260**	1.281**	1.129*	0.559	0.488	0.573
primary=1	(0.573)	(0.572)	(0.591)	(0.753)	(0.756)	(0.792)
Education head,	2.881*	2.912**	1.908	0.120	0.214	0.893
secondary=1	(1.471)	(1.478)	(1.552)	(1.954)	(1.851)	(1.915)
Education head,	8.850***	8.894***	7.576***	5.336	5.361	7.949**
tertiary=1	(1.753)	(1.752)	(2.039)	(3.855)	(3.842)	(3.651)
Fixed asset index	0.162	0.161	0.0637	0.0156	0.0382	0.0639
	(0.132)	(0.132)	(0.124)	(0.131)	(0.136)	(0.150)
Housing quality Index	1.633***	1.660***	1.625***	0.578**	0.465	0.473
	(0.230)	(0.229)	(0.244)	(0.279)	(0.290)	(0.305)
Ln (area owned)	0.0126	0.0290	0.144	-0.232	-0.185	-0.143
	(0.175)	(0.169)	(0.191)	(0.287)	(0.283)	(0.314)
Ln (distance to output	-0.499	-0.501	-0.450	-0.959*	-0.950*	-0.994*
market)	(0.571)	(0.571)	(0.587)	(0.541)	(0.553)	(0.577)
Year dummy (2011=1)	0.141	0.243	0.549	-0.141	-0.873	-1.337
	(0.635)	(0.637)	(0.667)	(0.602)	(0.708)	(0.825)
Year dummy (2013=1)	1.517***	1.610***	1.875***	0.165	-0.487	-0.820
	(0.551)	(0.549)	(0.573)	(0.572)	(0.639)	(0.760)
Regional dummy						
Tigray=1	-6.422***	-6.312***	-7.005***			
	(0.798)	(0.794)	(0.836)			
Amhara=1	-4.351***	-4.214***	-4.792***			
	(0.652)	(0.650)	(0.692)			
Oromia=1	0.827	0.970	0.520			
	(0.678)	(0.681)	(0.720)			
SNNP=1	-9.600***	-9.387***	-9.652***			
	(0.698)	(0.693)	(0.735)			
Constant	101.8***	101.5***	100.1***	18.96	13.47	-8.497

	(30.28)	(30.31)	(31.97)	(48.14)	(47.93)	(51.89)
Observations	7,775	7,775	7,194	7,046	7,046	6,516
R-squared	0.171	0.172	0.164			

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

2.6.2. Effects of livestock diversification on welfare

Table 2.8 summaries the effects of different measures of livestock diversification on welfare (as measured by real expenditure per adult equivalent). The results of FE-IV show that increasing number of livestock owned has no significant effects on the welfare of households indicating that merely increasing the number of livestock owned is not welfare enhancing per se. Coefficients of measures of livestock diversities (count and Shannon-Wiener and composite indices) are positive and statistically significant at less than 1 percent. Increasing livestock diversification and improving evenness of the diversification have different effects on welfare of households. For instance, adding one more group of livestock results in a 15 percent increase in total consumption expenditure per adult equivalent. An increase in evenness of livestock diversity by one percent leads to a rise in total consumption expenditure per adult equivalent by about 42 percent for the Shannon – Wiener index and by more than 74 percent for the composite index. Thus, diversifying livestock ownership to various groups can serve as welfare improving strategy among smallholders in developing countries including Ethiopia.

Thus, encouraging more diversification of livestock owned is more beneficial for households in terms of enhancing welfare compared to simply increasing number of livestock already owned in large number is less effective. Two key conclusions can be drawn from these results. The first is that livestock diversification is better for the welfare of households than simply owning higher number of similar livestock. The second is that encouraging more equitable or even distribution of livestock diversification rather than adding more group of livestock already owned in large numbers generates further benefits in terms of improving households' welfare.

Table 2.8. Summary of effects of livestock ownership on welfare: results of pooled OLS and FE-IV

Independent variables	Pooled OLS estimates			FE-IV estimates		
Livestock count index	0.0480***			0.149**		
	(0.0093)			(0.0756)		
Livestock diversity index (SW_L)		0.144***			0.428**	
		(0.0289)			(0.207)	
Livestock diversity index (CI_L)			0.187***			0.742***
			(0.0413)			(0.287)
Livestock owned (in CE)	0.0251***	0.0286***	0.0274***	-0.00282	0.00629	0.00283
	(0.0032)	(0.0031)	(0.00311)	(0.0101)	(0.00580)	(0.00613)
Crop count index	-0.0068	-0.0036	-0.0046	0.0085	0.0110	0.0140*
	(0.0065)	(0.0065)	(0.0067)	(0.0078)	(0.0077)	(0.0079)
Ln (age of head)	-0.116***	-0.117***	-0.104***	1.498	1.479	2.081*
	(0.0267)	(0.0268)	(0.0277)	(1.068)	(1.056)	(1.074)

Ln (household size)	-0.491***	-0.489***	-0.495***	-0.560***	-0.542***	-0.540***
	(0.0202)	(0.0201)	(0.0214)	(0.0421)	(0.0382)	(0.0395)
Education head	0.112***	0.114***	0.108***	0.0540**	0.0514**	0.0479**
(primary=1)	(0.0182)	(0.0182)	(0.0185)	(0.0237)	(0.0236)	(0.0243)
Education head	0.176***	0.179***	0.168***	0.174***	0.161***	0.144***
(secondary=1)	(0.0375)	(0.0375)	(0.0386)	(0.0473)	(0.0473)	(0.0488)
Education head	0.344***	0.345***	0.318***	0.129	0.109	0.135
(tertiary=1)	(0.0746)	(0.0749)	(0.0791)	(0.0930)	(0.0914)	(0.0955)
Fixed asset index	0.0259***	0.0255***	0.0220**	-0.0076	-0.0075	-0.0055
	(0.0091)	(0.0091)	(0.0089)	(0.0074)	(0.0074)	(0.0076)
Housing quality index	0.0854***	0.0859***	0.0841***	0.0315***	0.0312***	0.0335***
	(0.0088)	(0.0089)	(0.00914)	(0.0108)	(0.0110)	(0.0117)
Ln (distance to market)	-0.0188**	-0.0178**	-0.0219***	-0.163***	-0.170***	-0.171***
	(0.0081)	(0.0087)	(0.00830)	(0.0565)	(0.0573)	(0.0604)
Regional dummy						
Tigray=1	-0.0221	-0.0051	-0.0131			
	(0.0338)	(0.0335)	(0.0349)			
Amhara=1	-0.179***	-0.165***	-0.164***			
	(0.0298)	(0.0295)	(0.0308)			
Oromia=1	0.122***	0.136***	0.137***			
	(0.0297)	(0.0295)	(0.0307)			
SNNP=1	-0.0365	-0.0202	-0.0166			
	(0.0334)	(0.0335)	(0.0345)			
Year dummy (2011=1)	0.199***	0.190***	0.181***	0.0720***	0.0629**	0.0605**
	(0.0262)	(0.0261)	(0.0267)	(0.0259)	(0.0264)	(0.0275)
Year dummy (2013=1)	0.230***	0.217***	0.214***	0.0726**	0.0593*	0.0381
	(0.0250)	(0.0249)	(0.0257)	(0.0300)	(0.0336)	(0.0370)
Constant	5.381***	5.437***	5.406***	1.760	1.944	0.787
	(0.111)	(0.120)	(0.115)	(1.974)	(1.953)	(1.992)
Observations	6,586	6,586	6,186	6,573	6,573	6,173
R-squared	0.228	0.227	0.224			

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

2.6.3. Robustness check using Hausman Taylor model

Table 2.9 presents the results of Hausman Taylor model that confirm that livestock diversification has positive and significant effects on dietary diversity (as measured by the Shannon – Wiener index, the composite index and the FCS) as well as households' welfare as measured by real consumption expenditure per adult equivalent. This indicates that the results of this paper are robust to different model specifications, to different measurements of dietary diversity and livestock diversity and to the inclusion of a set of initial conditions (time-fixed indicators of natural preconditions for livestock rearing). Thus, livestock diversification could be a viable strategy to improve households' diet diversity and welfare via consumption of ASFs and generating additional incomes that households use to buy better quality foods. As indicated in the results presented in Annex 2.5, cattle ownership has positive effects on welfare whereas other livestock groups individually do not affect welfare and DD. Thus, instead of having more of a specific group of livestock, diversification plays a key role in livelihoods of farm households.

Table 2.9: Estimation results of Hausman Taylor model for a robustness check

Independent variables	Food composite index	Food Shannon index	FCS	welfare
Livestock composite index	0.0317**	0.0344**	1.780*	0.0347**
	(0.0152)	(0.0155)	(1.060)	(0.0160)
Livestock owned (in CE)	0.0019	0.00200	0.381***	0.0183***
	(0.0012)	(0.00122)	(0.102)	(0.00364)
Crop count index	0.0026	0.0033*	0.0708	0.0122**
	(0.0018)	(0.0018)	(0.159)	(0.0056)
Ln (livestock income)	0.0022***	0.0020***	0.287***	0.0057***
	(0.0007)	(0.0007)	(0.0589)	(0.0021)
Ln (age of head)	0.564*	0.508	53.29*	2.591***
	(0.318)	(0.324)	(27.23)	(0.970)
Ln (square of age of head)	-0.0764*	-0.0687	-7.188**	-0.350***
	(0.0419)	(0.0427)	(3.589)	(0.128)
Ln (household size)	-0.0147**	-0.0204***	2.016***	-0.500***
	(0.0068)	(0.0068)	(0.602)	(0.0212)
Education head (primary=1)	0.0218***	0.0200***	0.228	0.0668***
	(0.00531)	(0.00536)	(0.468)	(0.0166)
Education head (secondary=1)	0.0498***	0.0424***	0.753	0.197***
	(0.0112)	(0.0113)	(0.986)	(0.0350)
Education head (tertiary=1)	0.0463**	0.0357	2.555	0.245***
	(0.0222)	(0.0225)	(1.944)	(0.0692)
Fixed asset index	0.00951***	0.00874***	0.290**	0.0172***
	(0.00131)	(0.00133)	(0.113)	(0.00404)
Housing quality index	0.0256***	0.0228***	1.639***	0.0805***
	(0.00244)	(0.00247)	(0.216)	(0.00766)
Ln (land owned in ha)	0.00474*	0.00343	0.428**	0.0438***
	(0.00245)	(0.00248)	(0.216)	(0.00766)
Ln (distance to market)	-0.00297	-0.00758**	-0.663*	-0.0881***
	(0.00387)	(0.00386)	(0.358)	(0.0126)
Year dummy (2011=1)	-0.00139	-0.00732	2.181***	0.195***
	(0.00670)	(0.00681)	(0.578)	(0.0206)
Year dummy (2013=1)	-0.0273***	-0.0337***	1.366**	0.232***
	(0.00663)	(0.00674)	(0.571)	(0.0203)
Regional dummy				
Tigray=1	-0.0252**	-0.0266**	-7.054***	-0.0814**
	(0.0117)	(0.0117)	(1.081)	(0.0379)
Amhara=1	-0.0247***	-0.00876	-6.382***	-0.370***
	(0.00943)	(0.00939)	(0.874)	(0.0306)
Oromia=1	0.0465***	0.0481***	-0.0630	-0.0400
	(0.00959)	(0.00956)	(0.889)	(0.0311)
SNNP=1	0.0400***	0.0474***	-11.45***	-0.237***
	(0.00994)	(0.00991)	(0.919)	(0.0322)
Constant	-0.413	-0.218	-54.22	4.726***
	(0.595)	(0.607)	(50.97)	(1.816)
Observations	6,121	6,121	6,088	6,121

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

2.7. Conclusion and policy implication

In developing countries including Ethiopia, diets are dominated by only a few staple foods and rural households in these countries are more vulnerable to malnutrition due to limited diversity in their own production. Developing countries are also characterized by poor market access due to weak or non-existent transportation facilities like refrigerators and underdeveloped rural road networks. In such a situation, livestock diversification enhances households' DD and welfare by providing protein and essential micronutrient rich ASFs and supplementing household income to purchase non-perishable goods from rural markets. So far, literature has focused on roles of crop diversification in improving households' DD and welfare (see for instance, Tesfaye & Tirivayi, 2020) indicating that livestock diversification as welfare enhancing strategy is less emphasized. Thus, this paper contributes to the existing literature that links livestock diversification to DD and welfare of households by focusing on the role of diversifying livestock ownership on improving households' DD and consumption expenditure. This paper uses panel data from ESS covering three rounds (2011/12, 2013/14 and 2015/16) collected from across the country using two-stage sampling technique. The paper applies IV based panel data models (FE-IV and Hausman-Taylor) to control for endogeneity problem arising from livestock diversification. The paper also measures livestock diversity and DD using different indicators to check for robustness of the results to various measures of outcome and main independent variables.

The findings of the paper reveal that food variety is low for Ethiopian households indicating that nearly 55 percent of households do not have acceptable diets. The estimation results show that livestock diversification has positive and statistically significant effects on DD and welfare of households. Specifically, increasing livestock diversification by one percent results in an improvement in households' dietary diversity by about 0.2 percent and welfare by the range of 40 to 70 percent. These findings are similar with results of previous studies in the sense that they link farm diversity to dietary diversity but unique in some aspects as no previous studies have analyzed the effects of livestock diversity on farm households' welfare and dietary diversity in the context of Ethiopia. This indicates that livestock diversification plays an important role in improving households' DD and welfare. Besides, income from sales of livestock and livestock products has positive effects of DD of households. Access to market is also another important factor in improving dietary diversity and welfare of farm households indicating that market access is another essential factor that enhances households' welfare and variety of diets. The policy implication is that designing strategies that promote livestock diversification and improve market access could be one viable pathway to improve DD and welfare of farm households and thereby reducing malnutrition and poverty in Ethiopia. The possible future research areas include: the role of Livestock diversification in consumption smoothing and reducing vulnerability to shocks; does market access substitute livestock diversification in influencing households' dietary diversity? And livestock diversification and its roles in reducing multidimensional poverty.

References

Abdulai, A., & CroleRees, A. (2001). Determinants of income diversification amongst rural households in Southern Mali. *Food Policy*, *26*(4), 437-452.

Acharya, S. S. (2006). Sustainable agriculture and rural livelihoods. *Agricultural Economics Research Review*, 19(347-2016-16775), 205-218.

Ayele, Z., & Peacock, C. (2003). Improving access to and consumption of animal source foods in rural households: the experiences of a women-focused goat development program in the highlands of Ethiopia. *The Journal of Nutrition*, *133*(11), 3981S-3986S.

Ayenew, H. Y., Biadigilign, S., Schickramm, L., Abate-Kassa, G., & Sauer, J. (2018). Production diversification, dietary diversity and consumption seasonality: panel data evidence from Nigeria. *BMC Public Health*, *18*(1), 988.

Azzarri, C., Zezza, A., Haile, B. & Cross, E. (2015). Does Livestock Ownership Affect Animal Source Foods Consumption and Child Nutritional Status? Evidence from Rural Uganda. *Journal of Development Studies* 51, 1034–1059

Bachewe, F. N., Minten, B., Tadesse, F., & Taffesse, A. S. (2018). *The evolving livestock sector in Ethiopia: Growth by heads, not by productivity* (Vol. 122). Intl Food Policy Res Inst.

Baltagi, B. H., Bresson, G., &Pirotte, A. (2003). Fixed effects, random effects or Hausman–Taylor?: A pretest estimator. *Economics letters*, *79*(3), 361-369.

Baltagi, B. H., & Liu, L. (2012). The Hausman–Taylor panel data model with serial correlation. *Statistics & Probability Letters*, *82*(7), 1401-1406.

Barrett, C., Reardon, T., Webb, P., 2001. Nonfarm income diversification and household livelihood strategies in Rural Africa: concepts, dynamics and policy implications. *Food Policy*, 26 (4)

Baye, K., Hirvonen, K., Dereje, M., & Remans, R. (2019). Energy and nutrient production in Ethiopia, 2011-2015: Implications to supporting healthy diets and food systems. *PloS One*, *14*(3).

Bellon, M. R., Kotu, B. H., Azzarri, C., & Caracciolo, F. (2020). To diversify or not to diversify, that is the question. Pursuing agricultural development for smallholder farmers in marginal areas of Ghana. *World Development*, *125*, 104682.

Bellon, M. R., Ntandou-Bouzitou, G. D., & Caracciolo, F. (2016). On-farm diversity and market participation are positively associated with dietary diversity of rural mothers in Southern Benin, West Africa. *PloS One*, *11*(9), e0162535.

Biasca, R. (2014). The role of livestock for ACP countries: challenges and opportunities ahead. Brussels

Bigsten, A., & Tengstam, S. (2011). Smallholder diversification and income growth in Zambia. *Journal of African Economies*, *20*(5), 781-822.

Darrouzet-Nardi, A. F., Miller, L. C., Joshi, N., Mahato, S., Lohani, M., & Rogers, B. L. (2016). Child dietary quality in rural Nepal: effectiveness of a community-level development intervention. *Food Policy*, *61*, 185-197.

CSA (2018). The Federal Democratic Republic of Ethiopia. The 2015/16 Ethiopian household consumption – expenditure (HCE) survey results for country level. Addis Ababa, Ethiopia

Conley, T. G., & Udry, C. R. (2010). Learning about a new technology: Pineapple in Ghana. *American Economic Review*, *100*(1), 35-69.

Dillon, A., McGee, K., & Oseni, G. (2015). Agricultural production, dietary diversity and climate variability. *The Journal of Development Studies*, *51*(8), 976-995.

Dror, D. K., & Allen, L. H. (2011). The importance of milk and other animal-source foods for children in low-income countries. *Food and Nutrition Bulletin*, *32*(3), 227-243.

Dinar, A., & Mendelsohn, R. O. (Eds.). (2011). *Handbook on climate change and agriculture*. Edward Elgar Publishing.

Dumas, S. E., Kassa, L., Young, S. L., & Travis, A. J. (2018). Examining the association between livestock ownership typologies and child nutrition in the Luangwa Valley, Zambia. *PloS One*, *13*(2), e0191339.

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

Ecker, O., & Qaim, M. (2011). Analyzing nutritional impacts of policies: an empirical study for Malawi. *World Development*, *39*(3), 412-428.

Ellis, F. (1998). Household strategies and rural livelihood diversification. *The journal of Development Studies*, *35*(1), 1-38.

Ellis, F. (2000). *Rural livelihoods and diversity in developing countries*. Oxford university press.

FAO (2009). The state of food and agriculture: Livestock in the balance. FAO, Rome, Italy

FAO (2010). Guidelines for measuring household and individual dietary diversity. Research and Extension, FAO, Vialedelle Terme di Caracalla, 00153 Rome, Italy.

FAO (2012). Crop diversification for sustainable diets and nutrition: The role of FAO's Plant Production and Protection Division: Technical report. Plant Production and Protection Division, Food and Agriculture Organization of the United Nations, Rome, Italy.

Fuller, R. J., &Aye, L. U. (2012). Human and animal power–The forgotten renewables. *Renewable Energy*, *48*, 326-332.

George, C. M., Oldja, L., Biswas, S. K., Perin, J., Lee, G. O., Ahmed, S., ... & Bhuyian, S. I. (2015). Fecal markers of environmental enteropathy are associated with animal exposure and caregiver hygiene in Bangladesh. *The American Journal of Tropical Medicine and Hygiene*, *93*(2), 269-275.

Headey, D., & Hirvonen, K. (2016). Is exposure to poultry harmful to child nutrition? An observational analysis for rural Ethiopia. *PLoS One*, *11*(8), e0160590.

Headey, D., Nguyen, P., Kim, S., Rawat, R., Ruel, M., & Menon, P. (2017). Is exposure to animal feces harmful to child nutrition and health outcomes? A multicountry observational analysis. *The American Journal of Tropical Medicine and Hygiene*, *96*(4), 961-969.

Herforth, A. (2010). Promotion of traditional African vegetables in Kenya and Tanzania: a case study of an intervention representing emerging imperatives in global nutrition. Cornel University, Ithaca, NY.

Herrero, M., Grace, D., Njuki, J., Johnson, N., Enahoro, D., Silvestri, S., & Rufino, M. C. (2013). The roles of livestock in developing countries. Animal, 7(s1), 3-18.

Hetherington, J. B., Wiethoelter, A. K., Negin, J., &Mor, S. M. (2017). Livestock ownership, animal source foods and child nutritional outcomes in seven rural village clusters in Sub-Saharan Africa. *Agriculture & Food Security*, *6*(1), 9.

Hirvonen, K. (2016). Rural–urban differences in children’s dietary diversity in Ethiopia: A Poisson decomposition analysis. *Economics Letters*, *147*, 12-15.

Hirvonen, K., &Hoddinott, J. (2017). Agricultural production and children's diets: Evidence from rural Ethiopia. *Agricultural Economics*, *48*(4), 469-480.

Hirvonen, K., Taffesse, A. S., & Hassen, I. W. (2016). Seasonality and household diets in Ethiopia. *Public Health Nutrition*, 19(10), 1723-1730.

Imai, K. (2003). Is livestock important for risk behaviour and activity choice of rural households? Evidence from Kenya. *Journal of African Economies*, *12*(2), 271-295.

Jin, M., & Iannotti, L. L. (2014). Livestock production, animal source food intake, and young child growth: The role of gender for ensuring nutrition impacts. *Social Science & Medicine*, *105*, 16-21.

Jodlowski, M., Winter-Nelson, A., Baylis, K., & Goldsmith, P. D. (2016). Milk in the data: food security impacts from a livestock field experiment in Zambia. *World Development*, *77*, 99-114.

Johnston, B. F., & Mellor, J. W. (1961). The role of agriculture in economic development. The *American Economic Review*,51(4), 566-593.

Jones, A. D. (2017). On-farm crop species richness is associated with household diet diversity and quality in subsistence-and market-oriented farming households in Malawi. *The Journal of Nutrition*, *147*(1), 86-96.

Jones, A. D., Shrinivas, A., & Bezner-Kerr, R. (2014). Farm production diversity is associated with greater household dietary diversity in Malawi: findings from nationally representative data. *Food Policy*, *46*, 1-12.

Karamba, W. R., Quiñones, E. J., & Winters, P. (2011). Migration and food consumption patterns in Ghana. *Food Policy*, *36*(1), 41-53.

Kibrom, A., A. and Jensen, N. D. (2020). Access to markets, weather risk, and livestock production decisions: Evidence from Ethiopia. Strategy support program, working paper 138.

Kim, K., Chavas, J. P., Barham, B., & Foltz, J. (2012). Specialization, diversification, and productivity: a panel data analysis of rice farms in Korea. *Agricultural Economics*, 43(6), 687-700.

Koppmair, S., & Qaim, M. (2017). Farm production diversity and individual-level dietary diversity. Response to: ‘Not all dietary diversity scores can legitimately be interpreted as proxies of diet quality’ by Verger et al. *Public Health Nutrition*, *20*(11), 2070-2072.

Koppmair, S., Kassie, M., &Qaim, M. (2017). Farm production, market access and dietary diversity in Malawi. *Public Health Nutrition*, *20*(2), 325-335.

Krishnan, P., & Patnam, M. (2013). Neighbors and extension agents in Ethiopia: Who matters more for technology adoption? *American Journal of Agricultural Economics*, *96*(1), 308-327.

Kumar, N., Harris, J., & Rawat, R. (2015). If they grow it, will they eat and grow? Evidence from Zambia on agricultural diversity and child undernutrition. *The Journal of Development Studies*, *51*(8), 1060-1077.

Kurosaki, T. (2003). Specialization and diversification in agricultural transformation: the case of West Punjab, 1903–92. *American Journal of Agricultural Economics*, *85*(2), 372-386.

Kurosaki, T., & Fafchamps, M. (2002). Insurance market efficiency and crop choices in Pakistan. *Journal of Development Economics*, *67*(2), 419-453.

Lanjouw, J., Lanjouw, P., (2001). The rural nonfarm sector: issues and evidence from developing countries. *Agricultural. Economics*, 26 (1), 1–23

Leroy, J. L., Ruel, M., Frongillo, E. A., Harris, J., & Ballard, T. J. (2015). Measuring the food access dimension of food security: a critical review and mapping of indicators. *Food and Nutrition Bulletin*, *36*(2), 167-195.

Lipton, M., & Ravallion, M. (1995). Poverty and policy. *Handbook of Development Economics*, *3*, 2551-2657.

Malapit, H. J. L., Kadiyala, S., Quisumbing, A. R., Cunningham, K., & Tyagi, P. (2015). Women’s empowerment mitigates the negative effects of low production diversity on maternal and child nutrition in Nepal. *The Journal of Development Studies*, *51*(8), 1097-1123.

Mbuya, M. N., Tavengwa, N. V., Stoltzfus, R. J., Curtis, V., Pelto, G. H., Ntozini, R., ... & Morgan, P. (2015). Design of an intervention to minimize ingestion of fecal microbes by young children in rural Zimbabwe. *Clinical infectious diseases*, *61*(suppl_7), S703-S709.

Meraner, M., Heijman, W., Kuhlman, T., & Finger, R. (2015). Determinants of farm diversification in the Netherlands. *Land Use Policy*, *42*, 767-780.

Michler, J. D., & Josephson, A. L. (2017). To specialize or diversify: agricultural diversity and poverty dynamics in Ethiopia. *World Development*, *89*, 214-226.

Mosites, E., Thumbi, S. M., Otiang, E., McElwain, T. F., Njenga, M. K., Rabinowitz, P. M., ... & Walson, J. L. (2016). Relations between household livestock ownership, livestock disease, and young child growth. *The Journal of Nutrition*, *146*(5), 1118-1124.

Murendo, C., Nhau, B., Mazvimavi, K., Khanye, T., & Gwara, S. (2018). Nutrition education, farm production diversity, and commercialization on household and individual dietary diversity in Zimbabwe. *Food & Nutrition Research*, 62.

Muslimatun, S., & Wiradnyani, L. A. A. (2016). Dietary diversity, animal source food consumption and linear growth among children aged 1–5 years in Bandung, Indonesia: A longitudinal observational study. *British Journal of Nutrition*, *116*(S1), S27-S35.

Nguyen, M. C., & Winters, P. (2011). The impact of migration on food consumption patterns: The case of Vietnam. *Food Policy*, *36*(1), 71-87.

Nilsson, P., Backman, M., Bjerke, L., & Maniriho, A. (2019). One cow per poor family: Effects on the growth of consumption and crop production. *World Development*, *114*, 1-12.

Njuki, J., Poole, E. J., Johnson, N. L., Baltenweck, I., Pali, P. N., Lokman, Z., & Mburu, S. (2011). Gender, livestock and livelihood indicators. Version 2.

Pica-Ciamarra, U., Tasciotti, L., Otte, J., &Zezza, A. (2011). Livestock assets, livestock income and rural households: cross-country evidence from household surveys.

Powell, J. M., Pearson, R. A., & Hopkins, J. C. (1998). Impacts of livestock on crop production. *BSAP Occasional Publication*, *21*, 53-66.

Rawlins, R., Pimkina, S., Barrett, C. B., Pedersen, S., &Wydick, B. (2014). Got milk? The impact of Heifer International's livestock donation programs in Rwanda on nutritional outcomes. *Food Policy*, *44*, 202-213.

Renkow, M., Hallstrom, D. G., & Karanja, D. D. (2004). Rural infrastructure, transactions costs and market participation in Kenya. *Journal of Development Economics*, *73*(1), 349-367.

Ruel, M. (2003). Operationalizing dietary diversity: A review of measurement issues and research priorities. *The Journal of Nutrition*, 133, 3911S–3926S.

Randolph, T. F., Schelling, E., Grace, D., Nicholson, C. F., Leroy, J. L., Cole, D. C., ... & Ruel, M. (2007). Invited review: role of livestock in human nutrition and health for poverty reduction in developing countries. *Journal of Animal Science*, *85*(11), 2788-2800.

Romeo, A., Meerman, J., Demeke, M., Scognamillo, A., & Asfaw, S. (2016). Linking farm diversification to household diet diversification: evidence from a sample of Kenyan ultra-poor farmers. *Food Security*, *8*(6), 1069-1085.

Sharma, A., & Chandrasekhar, S. (2016). Impact of commuting by workers on household dietary diversity in rural India. *Food Policy*, *59*, 34-43.

Sheehy, T., Carey, E., Sharma, S., & Biadgilign, S. (2019). Trends in energy and nutrient supply in Ethiopia: a perspective from FAO food balance sheets. *Nutrition journal*, *18*(1), 46.

Sibhatu, K. T., Krishna, V. V., & Qaim, M. (2015). Production diversity and dietary diversity in smallholder farm households. *Proceedings of the National Academy of Sciences*, *112*(34), 10657-10662.

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

Smith, J. Sones, K., Grace, D., MacMillan, S., Tarawali, S., and Herrero, M. (2013). Beyond milk, meat, and eggs: Role of livestock in food and nutrition security. International Livestock Research Institute, Nairobi, Kenya.

Steyn, N. P., Nel, J. H., Nantel, G., Kennedy, G., &Labadarios, D. (2006). Food variety and dietary diversity scores in children: are they good indicators of dietary adequacy? *Public Health Hutrition*, *9*(5), 644-650.

Singh, I., Squire, L., & Strauss, J. (1986). Agricultural household models: Extensions, applications, and policy. Baltimore, MD: Johns Hopkins University Press.

Stifel, D., & Minten, B. (2017). Market access, well-being, and nutrition: evidence from Ethiopia. *World Development*, *90*, 229-241.

Storck, H., B. Emana, B. Adnew, A. Borowiccki, S. Woldehawariat (1991). Farming Systems and Resource Economics in the Tropics: Farming System and Farm Management Practices of Smallholders in the Hararghe Highland, vol. II, WissenschaftsverlagVauk, Kiel, Germany.

Taffesse, A. S., Dorosh, P., & Gemessa, S. A. (2012). Crop production in Ethiopia: Regional patterns and trends. *Food and agriculture in Ethiopia: Progress and policy challenges*, 53-83.

Tegegn, G. G. (2015). Ethiopian livestock masterplan: roadmaps for growth and transformation. Addis Ababa, Ethiopia

Timmer, C. P. (2002). Agriculture and economic development. *Handbook of Agricultural Economics*, *2*, 1487-1546.

Taylor, J. E., & Adelman, I. (2003). Agricultural household models: genesis, evolution, and extensions. *Review of Economics of the Household*, *1*(1-2), 33-58.

Tesfaye, W., & Tirivayi, N. (2018). The impacts of postharvest storage innovations on food security and welfare in Ethiopia. *Food Policy*, *75*, 52-67.

Tesfaye, W., &Tirivayi, N. (2020). Crop diversity, household welfare and consumption smoothing under risk: Evidence from rural Uganda. *World Development*, *125*, 104686.

Verkaart, S., Munyua, B. G., Mausch, K., &Michler, J. D. (2017). Welfare impacts of improved chickpea adoption: A pathway for rural development in Ethiopia? *Food Policy*, *66*, 50-61.

Workicho, A., Belachew, T., Feyissa, G. T., Wondafrash, B., Lachat, C., Verstraeten, R., &Kolsteren, P. (2016). Household dietary diversity and Animal Source Food consumption in Ethiopia: evidence from the 2011 Welfare Monitoring Survey. *BMC Public Health*, *16*(1), 1192.

Worku, I. H., Dereje, M., Minten, B., & Hirvonen, K. (2017). Diet transformation in Africa: The case of Ethiopia. *Agricultural Economics*, *48*(S1), 73-86.

WFP (2008). Food consumption analysis: Calculation and use of the food consumption score in food security analysis. *United Nations Vulnerability Analysis and Mapping Branch*.

Yang, L., Liu, M., Min, Q., & Li, W. (2018). Specialization or diversification? The situation and transition of households' livelihood in agricultural heritage systems. *International Journal of Agricultural Sustainability*, *16*(6), 455-471.

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

Annex for chapter two

Annex 2.1: Summary statistics of variables used in the estimations

Variables	Obs.	Mean	Std. Dev.	Min.	Max
Food count index (ten groups)	9,735	5.240	1.606	1	10
Shannon-Wiener index of dietary diversity	9,735	1.107	.367	0	2.041
Composite index of dietary diversity	9,735	0.893	.341	0	1.811
Livestock owned (in CE)	9,735	2.941	4.590	0	87.14
Livestock count index (five groups)	8,260	2.073	1.137	0	5
Shannon-Wiener index of livestock diversity	8,260	0.323	.326	0	1.405
Composite index of livestock diversity	7,535	0.228	.230	0	1.124
Crop count index (seven groups)	7,056	2.531	1.557	0	7
Age of head (in years)	9,703	46.195	15.360	13	100
Female dummy (=1)	9,714	0.259	.438	0	1
Household size (in number)	9,735	4.984	2.328	1	16
Primary education of head (=1)	9,735	0.274	.446	0	1
Secondary education of head (=1)	9,735	0.035	.185	0	1
Tertiary education of head (=1)	9,735	0.036	.186	0	1
Primary education of female members (=1)	9,735	0.473	.499	0	1
Secondary education of female members (=1)	9,735	0.063	.244	0	1
Tertiary education of female members (=1)	9,735	0.024	.153	0	1
Real per capita monthly expenditure in Birr	9,735	472.430	414.487	53.737	13397.02
Index for fixed assets owned	9,733	-0.736	2.210	-2.844	31.273
Housing Index	9,735	-0.501	1.333	-2.764	15.105
Land area owned (in ha)	8,489	1.318	5.571	.0003	426.765
Distance to the nearest road in km	9,728	16.36	21.976	0	271
Distance to the nearest market	9,728	66.341	50.494	0.3	283.3
Regional dummy Tigray	9,735	0.104	.306	0	1
Regional dummy Amhara	9,735	0.221	.415	0	1
Regional dummy Oromia	9,735	0.200	.400	0	1
Regional dummy SNNP	9,735	0.246	.430	0	1
Instrumental Variables					
Average number of livestock owned by neighbors	8,260	1.877	.713	0	4.272
Distance to the nearest grass land in km	8,826	15.29	51.59	.00	202.21
Deviation of rain from annual average in mm	9,728	390.191	198.485	75	1029

Source: Author's computations based on 2011/12, 2013/14 and 2015/16 ESS data

Annex 2.2: Correlation between livestock diversity indices and DD and welfare

Items	Food Shannon-Wiener index	Food composite index	Food consumption score	Expenditure per adult equivalent	Livestock count index	Livestock SW	Livestock composite index

Food Shannon-Wiener index	1.00						
Food composite index	0.99	1.00					
p-value	0.00						
Food consumption score	0.38	0.42	1.00				
p-value	0.00	0.00					
Real expenditure per adult equivalent	0.25	0.30	0.34	1.00			
p-value	0.00	0.00	0.00				
Livestock count index	0.05	0.04	0.13	0.03	1.00		
p-value	0.00	0.00	0.00	0.01			
Livestock Shannon-Wiener index	0.09	0.07	0.11	0.01	0.82	1.00	
p-value	0.00	0.00	0.00	0.36	0.00		
Livestock composite index	0.08	0.07	0.10	0.04	0.86	0.98	1.00
p-value	0.00	0.00	0.00	0.00	0.00	0.00	

Source: Author's computations based on 2011/12, 2013/14 and 2015/16 ESS data

Annex 2.3: Household's ownership of livestock groups (share in %)

Livestock groups	2011	2013	2015	Pooled
Cattle	80.8	77.1	67.7	74.5
Small ruminants	59.1	60.1	51.5	56.5
Poultry	53.0	52.7	48.2	51.0
Equines	12.8	12.1	34.0	20.8
Camel	4.8	4.3	4.5	4.5
Total livestock	70.0	79.9	82.9	77.4

Source: Author's computations based on 2011/12, 2013/14 and 2015/16 ESS data

Annex 2.4: Number of livestock owned (in CE): 2011-2015

Type of livestock	2011	2013	2015	Pooled
Large ruminants (cattle)	2.685	2.584	3.021	2.771
Small ruminants (goats and sheep)	0.496	0.532	0.496	0.508
Equines (horses, donkeys and mules)	0.082	0.085	0.364	0.184
Camel	0.314	0.272	0.337	0.308
Poultry (all types)	0.027	0.028	0.033	0.029
Total livestock owned	3.603	3.501	4.252	3.800

Source: Author's computations based on 2011/12, 2013/14 and 2015/16 ESS data

Annex 2.5: Effects of livestock groups on DD and welfare: FE-results

Independent variables	Composite index	Shannon index	Welfare
Crop count	0.000992	0.00182	0.0106
	(0.00400)	(0.00437)	(0.00753)
Share cattle	0.0200	0.0205	0.110**
	(0.0274)	(0.0302)	(0.0475)
Share small ruminants	-0.0504	-0.0533	0.0427
	(0.0336)	(0.0371)	(0.0542)
Share equines	-0.0564	-0.0636	-0.0723
	(0.0507)	(0.0566)	(0.0820)
Share camel	0.0403	0.0474	-0.114
	(0.0759)	(0.0813)	(0.151)
Share poultry	-0.0279	-0.0292	0.0230
	(0.0320)	(0.0353)	(0.0529)
Ln (household size)	0.0189	0.0128	-0.515***
	(0.0191)	(0.0209)	(0.0354)
Ln (age of head)	0.807	0.858	1.365
	(0.608)	(0.681)	(1.048)
Ln (age squared of head)	-0.0975	-0.105	-0.134
	(0.0807)	(0.0904)	(0.141)
Education head (primary=1)	0.0114	0.00993	0.0563**
	(0.0131)	(0.0144)	(0.0232)
Education head (secondary=1)	0.0104	0.000375	0.175***
	(0.0280)	(0.0307)	(0.0466)
Education head (tertiary=1)	-0.0284	-0.0533	0.0898
	(0.0504)	(0.0543)	(0.0902)
Fixed asset index	0.00421	0.00433	-0.00655
	(0.00261)	(0.00276)	(0.00724)
Housing index	0.0254***	0.0251***	0.0277**
	(0.00611)	(0.00665)	(0.0108)
Ln (distance to market)	-0.0802**	-0.0887**	-0.118**
	(0.0379)	(0.0423)	(0.0572)
Year dummy (2013=1)	-0.0178	-0.0258*	0.0720***
	(0.0139)	(0.0153)	(0.0255)
Year dummy (2015=1)	-0.0673***	-0.0803***	0.127***
	(0.0142)	(0.0157)	(0.0255)
Constant	-0.577	-0.416	2.060
	(1.143)	(1.281)	(1.939)
Observations	6,586	6,586	6,586
R-squared	0.033	0.033	0.088

*** p<0.01, ** p<0.05, * p<0.1

Source: Author’s computations based on 2011/12, 2013/14 and 2015/16 ESS data

3. Chapter Three: Paper II -Do smallholder livestock owners benefit from spatial spillovers? Evidence from Ethiopia

Jonse Bane

Department of Economics
Addis Ababa University, Ethiopia
jonseboka@yahoo.com; jonse.bane@aau.edu.et

Abstract

This paper investigates whether spatial proximity between smallholder livestock owners and their peer farmers and commercial farm establishments can serve as a channel for the diffusion of improved livestock technologies and management in Ethiopia. Two recent nationally representative surveys are combined to construct a geocoded dataset that enables the distinction of geographical distances at the farm level. A multilevel model is used to address simultaneity problems and to alleviate correlations between individual and contextual factors. The findings indicate that livestock owners learn from their peer farmers about improved livestock technologies adoption and livestock managements. The existence of commercial farms has positive effects only on certain aspects of livestock managements like livestock vaccination among smallholder livestock owners. However, area expansion by commercial farms negatively affects ownership of exotic breeds. Hence, policies that strengthen existing farmers' networks can achieve more widespread livestock technology diffusion and improved livestock management among smallholder livestock owners. However, the country should rethink strategies that promote the expansion of commercial farms, as it could occur at the expense of smallholders.

Keywords: livestock; neighborhood effects; technology adoption; Ethiopia
JEL codes: Q12; Q16; Q18

3.1. Introduction

Ethiopia is ranked first in Africa and fifth in the world in terms of cattle owned by households (Bachewe et al., 2018). However, the country's yields from livestock in terms of meat and dairy are much lower than those of many of its neighboring countries (FAO, 2018). These low yields are often attributed to limited technology adoption and poorer livestock management, which constrain growth in agricultural productivity (BenYishay & Mobarak, 2018). An underperforming livestock sector prevents the rural population from having sufficient access to micronutrients and high value protein from milk and meat, which is often limited in the diets of the poorest segments of the population (Murphy & Allen, 2003; Rodriguez-Artalejo & Lopez-Garcia, 2015; Hetherington et al., 2017). The importance of livestock in the asset portfolio of Ethiopian smallholders and increased demand for ASFs suggest that boosting the performance of the livestock sector can play an important role in poverty alleviation and increase in dietary quality and variety (Alary et al., 2011; Herrero et al., 2013; Hänke & Barkmann, 2017). Livestock can be used as collateral to enable on- and off-farm investments to spur agricultural growth and income diversification. It can also provide households with additional incomes from animal by-products (Abdulai & CroleRees, 2001; World Bank, 2007; McDermott et al., 2010; Hänke & Barkmann, 2017).

There has been an increasing focus on the potential for livestock intensification via the promotion of the ownership of exotic/improved livestock breeds[22] and improved livestock management[23] in a developing country context (Udo et al. 2011; Alvarado et al., 2018). Such approaches include strategies to improve the productivity of dairy cows through the adoption of improved livestock technologies (ownership of exotic/cross breeds and practicing controlled breeding strategies such as artificial insemination (AI) with quality semen) and through the improved management of animal feeding and livestock vaccination. Although such technologies and methods of livestock management are often shown to be effective, sustainable and relatively widespread among commercial farms, a limited share of Ethiopia's smallholder livestock farmers breed their animals using such technologies due to a limited supply of improved breeds of dairy cows and quality semen (Kebebe, 2019). This approach to breeding is often attributed to a lack of relevant technologies and training and limited formal infrastructures for information exchange, including policy induced research centers and extension agents in rural areas (Bachewe et al. 2018; Kebebe, 2019). Farmers obtain information about available livestock technologies from extension agencies

---

[22] Improved livestock breeds can be accessed by purchasing exotic/hybrid livestock or applying quality semen via artificial insemination (AI). While the former is expensive because owning improved breeds is costly, the latter is cheaper as government focuses on expanding uses of better-quality semen via AI (Shapiro et al., 2015).

[23] Improved livestock management includes two components: animal feeds (cut crop residues, greens feeds like elephant grass, purchased feeds from factories mainly supplements such as salt, urea-treated straw, minerals) and animal health mainly vaccination (Musaba, 2010; Birhan & Adugna, 2015).

and through their social interactions with peer farmers (Krishnan & Patnam, 2013). There is strong support for the importance of extension agents as an information channel to spur technology transfer in agriculture, including in the livestock sector (e.g., Rivera & Alex, 2003; Wossen et al., 2017).

Over the last half century, the Ethiopian governments introduced project- and program-based livestock development strategies including the first, second and fourth livestock development projects covered periods 1971-1991 (Roseboom et al., 1994; Ahmed et al., 2004); Dairy Rehabilitation and Development Project (Kebebe, 2019); Smallholder Dairy Development Pilot Project and National livestock development project (Ahmed et al., 2004) and Agricultural growth program (AGP)-Livestock Market Development Project (Kebebe, 2019). This indicates that there was no comprehensive and clear national level livestock development policies and strategies. After the 1992 economic reforms, development strategies of the Ethiopian government have focused on improving crop production and productivity to ensure food and income security of farm households (Asfaw et al., 2012). In the subsequent overall development policies and strategies, livestock related issues were indicated using few paragraphs in the strategy documents. The main emphasis of the strategies on livestock is improving animal health via extension services but ignored technology related constraints facing smallholder livestock owners (Pica-Ciamarra, 2005). Recently developed livestock development roadmap has focused on investment in improved livestock technologies and management (Shapiro et al., 2015).

However, few studies have addressed the role of informal networks and knowledge and information spillover effects among neighboring farms in the diffusion of improved livestock technologies such as improved dairy cows and quality semen and improved livestock management techniques. The focus of the current study is on roles of spatial proximity in facilitating adoption of improved livestock technologies (owning exotic/improved breeds and practicing controlled breeding strategies) and improved livestock management (improved animal feeding and livestock vaccination). Thus, this paper contributes to the literature by investigating the role of knowledge diffusion in the adoption of improved livestock technologies and livestock management in local communities for a sample of smallholder livestock farmers and a population of commercial farms in Ethiopia. It applies a multilevel model that addresses simultaneity problems and alleviates correlations between individual and contextual factors.

Previous studies with this focus have mainly addressed determinants of the adoption of crop and dairy technologies in a developing country context (Jera & Ajayi 2008; Mekonnen et al., 2010; Quddus, 2012; Martínez-García et al., 2013; Mwangi & Kariuki, 2015). Less attention has been given to the potential role of spatial spillover effects among smallholder livestock farmers, which are also sometimes referred to as peer effects (Conley & Udry, 2010). The relevant literature has developed two main focuses. The first emphasizes the importance of peer effects in shaping farmers' decisions to adopt new technologies and farming practices in crop production in developing countries (Conley & Udry, 2010; Krishnan & Patnam, 2013; Schoneveld, 2014; Wollni & Andresson, 2014; Mekonnen et al., 2018). The second focus deals with the effects of spatial proximity between smallholder crop producers and commercial farm establishments in Africa (Deininger & Xia, 2016; Herrmann, 2017; Lay et al., 2018; Ali et al., 2019; Glover & Jones, 2019). Arguments posed in the latter body of work conclude that commercial farm establishments have modest positive effects on crop yields and the adoption of fertilizers and improved seeds. In both lines of research, the focus has been on spatial spillover effects on the adoption of improved crop production techniques (line planting and applications of chemical fertilizers and improved seeds) and the creation of on- and off-farm wage employment mainly by commercial farm establishments.[24] The research has largely overlooked the livestock sector despite its great potential to contribute to poverty reduction and the diversification of the rural economy (Reardon et al. 1992; FAO, 2018). In a related study, Staal et al. (2002) analyzed the importance of the spatial proximity of smallholder livestock farmers to urban centers and road networks for the adoption of dairy cows in Kenya. Amlaku et al. (2012) similarly examined the role of farmers' networks in dairy production in Ethiopia.

This paper combines two sets of recent nationally representative survey data to form a georeferenced dataset at the farm level. The first is the 2015/16 household level Ethiopian Socioeconomic Survey (ESS) and the second is the large and medium commercial farm survey of 2014/15, which covers the population of commercial farms generated by the Central Statistics Agency (CSA). Two main challenges arise in research on social learning and technology adoption. The first concerns the identification of relevant peers to include in a learning reference group. Amlaku et al. (2012), for instance, measure networks from the number of people in the social network of the head of household. However, not all individuals in a network own dairy cows and a group may not serve as a proper learning reference. This paper uses physical distance between smallholder livestock farms and their peers who own high-yield breeds and practice improved breeding strategies and livestock managements and neighboring commercial farms that own livestock. The second challenge involves distinguishing learning effects of peer group members from other influences at the neighborhood level, which is also referred to as the reflection problem (Manski, 1993).

This paper follows the approach outlined in Mundlak (1978) and Snijders and Berkhof (2006) by applying a two-level multilevel model with semi-demeaned estimated equations. In using this approach, within and between effects are estimated separately and the presence of level-two endogeneity is controlled for. The findings indicate that smallholder livestock owners learn from their peer farmers in adopting improved livestock technologies (owning exotic or improved breeds

[24] Much of the literature on spatial spillovers and agglomeration effects in the context of developing countries including Ethiopia has emphasized non-farm activities and the performance of non-farm rural enterprises (Rijkers et al., 2010; Ali & Peerlings, 2011; Artz et al., 2016; Owoo & Naude, 2017; Nilsson, 2019).

and improved breeding strategies) and in exercising improved livestock management practices (improved animal feeding methods and livestock vaccination). However, the effects of commercial farm establishments are mixed in the sense that stallholder livestock farmers benefit from commercial farms in certain aspect of livestock management like vaccinating livestock whereas area expansion by commercial farms is negatively associated with the ownership of exotic breeds by reducing availability of feed, which is in line with results of previous studies (Bujko et al., 2016).

The remaining sections of this paper is organized as follows. Section 3.2 provides brief background. Section 3.3 deals with data, variables and estimated model. Section 3.4 presents estimation results and discussions. Section 3.5 provides conclusions and policy implications of the paper.

3.2. Background

3.2.1. Spatial spillovers in the Ethiopian livestock sector

In Ethiopia, large commercial farm investments have a long history dating to the Imperial Era. However, their success has been criticized as they displaced tenants, were less productive than smaller farms and created limited employment opportunities in local communities during the Imperial Era (Abebe, 1990; Rahmato, 2014) and became inefficient following the nationalization policies of the Derge Regime (Abebe, 1990). In recent years, they have continued to displace a significant number of smallholder farmers and have been less successful in advancing the economies of developing countries such as Ethiopia (Keeley, 2014).

There are mixed views on whether commercial farm investments have the potential to generate positive spillover effects to neighboring smallholders. Opponents of large farm investments in developing countries such as Ethiopia argue that negative spillover effects result when opportunistic and speculative urban elites expel smallholders from their lands and waters and keep these resources in an unproductive state for several years (Borras & Franco, 2012; Sitko & Jayne, 2014). According to Bujko et al. (2016), there is also a high degree of corruption in land acquisitions, which has redistributed fertile land from productive to speculative investors. This redistribution has reduced both private and communal grazing lands and resulted in a reduction of livestock owned by smaller farms. However, most of the existing research tends to support the view that commercial farm establishments generate positive spillover effects to neighboring smallholders through a series of direct and indirect benefits. As direct benefits, local farms can secure employment opportunities with large commercial farms, providing them new knowledge about breeding techniques and cash income, which they can then use to purchase improved livestock breeds, obtain AI from commercial farms and improve their own techniques. As indirect benefits, local farmers, in being not directly tied to commercial farms via employment, can benefit from observational learning about new agricultural technologies (improved seeds and chemical fertilizers) and better farming practices such as row-planting (Adewumi et al., 2013; Deininger & Xia, 2016). Hence, in the realm of livestock, effects primarily occur via production relations where commercial farm establishments hire local farmers to look after livestock at their farm establishments. Commercial farms engaged in livestock rearing (e.g., exotic cows) may also sell some of their animals to their neighbors. Since this knowledge tends to be non-rival and non-excludable, it may not be contained within commercial farms but spread to neighboring smallholder livestock rearing communities. This spread may positively affect a range of outcomes for local communities by, for instance, improving dairy productivity and increasing the likelihood of owning exotic breeds and exercising improved practices such as controlled breeding, the use of quality feed and livestock vaccination.

There is a strong support for the importance of neighborhood effects in the adoption of agricultural technologies. Most related studies have focused on the adoption of organic dairy farming (e.g., Lewis, et al., 2011; Hailu & Deaton, 2016; Yang & Sharp, 2016; Läpple et al., 2017).[25] The most relevant, given the focus of the present paper, are studies that address neighborhood effects from commercial farm establishments to smallholders in Ethiopia or similar countries. Ali et al. (2019) analyze spatial spillover effects of the closest large commercial farm in terms of yields and the utilization of fertilizers for Ethiopian smallholder crop farmers. The authors find modest positive effects on yields and input uses, mainly in terms of chemical fertilizers. Riera and Swinnen (2015), also focusing on Ethiopia, find positive spillover effects from the production of castor on crop yields of smallholder farmers via improved access to inputs and technical assistance. A related study by Mekonnen et al. (2018) finds positive effects of being a member of social networks on the adoption of line-planting among Ethiopian farmers.

A related question concerns the role of the knowledge diffused via formal channels such as extension agents. Krishnan and Patnam (2013) investigate both social learning effects and the effects of extension agents on the adoption of fertilizers and improved seeds among Ethiopian smallholders. The authors find extension agents to have a positive effect in initial stages of adoption but find the effects of neighbors to be persistent in encouraging crop technology adoption. However, such formal information channels are not widespread among smallholder livestock owners in rural Ethiopia, and in the 2013/14 ESS survey, only a very small share of smallholder livestock farmers report having access to livestock extension services, indicating that the Ethiopian agricultural extension system is focused on crop production. In the absence of widespread formal channels for knowledge diffusion, informal networks, face-to-face contact and physical

[25] Other related studies include Godtland et al. (2004) who found positive spillover effects from farmer field schools to smallholder potato producers in Peru in terms of improved yields; Conley and Christopher (2001) who analyzed the effects of social learning via networks on agricultural technology adoption in Ghana and found positive peer effects; and Conley and Udry (2010) who reported positive social learning effects of neighboring farmers in the adoption of new pineapple production technologies in Ghana.

interactions become particularly important ways to diffuse new technologies (McCormick, 1999). Such informal networks form the basis of observational learning farmers, through which can learn by observing their neighbors, retain information, and replicate observed behaviors (Hagerstrand, 1967; Wake, et al., 1988).

Existence of commercial farm establishments in the neighborhoods of smallholder livestock owners benefits the latter via direct and indirect channels. Direct mechanisms are that local farms could get employment opportunities in commercial farms where local farmers take care for animals in commercial farms. Since knowledge is non-rival and non-excludable, it may not be contained only within commercial farms rather it spreads to nearby smallholder livestock rearing communities. This spillover may positively affect milk productivity and adoption of improved livestock technologies and managements. The indirect channels are that commercial farm establishments have built infrastructures that smallholders use to better access markets that helps them to purchase improved livestock technologies. Smallholder livestock owners can also learn about new livestock production techniques like adoption of new breeds and better livestock management from their peer farmers via networks. The basic idea is that farmers are more likely to adopt new practices or technologies by the presence of neighboring adopters as a result of knowledge diffusion and lower costs of learning (Läpple et al., 2016). Moreover, when peer farmers and commercial farm establishments are engaged in livestock rearing, they may sell these animals to local communities and increase ownership of improved breeds.

Previous studies thus show strong support for the role of social learning (i.e., interactions among smallholders and farms belonging to learning reference groups) in the adoption of new crop technologies, including modern inputs, production technologies and organic practices. Similar results are given by studies on spillover effects of commercial farms in the adoption of improved crop production technologies among smallholders in Mozambique, Zambia and Nigeria (Adewumi et al., 2013; Deininger & Xia, 2016; Herrmann, 2017; Lay et al., 2018; Glover & Jones, 2019). However, there is little information on the role of such effects in the adoption of new livestock technologies such as exotic cows and high-yield breeding via AI and improved livestock management practices such as quality livestock feeding and livestock vaccination. To the author's knowledge, studies on spatial spillover effects between commercial and smallholder livestock farms and their peers are largely missing. The objective of this paper is therefore to provide initial evidence to inform policy and better understand ways to improve the performance of the Ethiopian livestock sector. For instance, the costs of informing a large heterogeneous population of rural smallholder livestock farmers about new breeding techniques are usually high. Information on which types of farms serve as a learning reference could also be used to better inform extension agents (Genius et al., 2014).

3.3. Data, variables and estimated model

3.3.1. Data

Two nationally representative datasets are combined to enable the measurement of spatial proximity at the farm level. The first dataset is the 2014/15 commercial farm establishment survey collected by the CSA, which covers over 9,656 commercial farms operating across all nine regions and two city administrations in Ethiopia. Of these farms, nearly 51 percent were engaged in crop production and 49 percent were engaged in both crop and livestock production (see annex 3.5 for a map of the farms) and this paper uses only commercial farms who own livestock. The second dataset is the ESS dataset collected by the CSA in collaboration with the World Bank. Both datasets are geocoded at the farm level to enable the computation of Euclidean distances between commercial farm establishments and the surveyed smallholder farmers included in the ESS dataset. The latest round of the ESS was conducted across the country in 2015/16 and covers 4,954 households randomly selected from 433 enumeration areas (EAs), of which 290, 43 and 100 enumeration areas were selected from rural areas, small towns and large towns and cities, respectively. The selection of households follows a two-stage probability sampling approach. In the first stage, EAs are selected based on the probability proportion to the size of EA populations. In the second stage, 12 households are randomly selected from each EA[26]. Thus, both two-stage and simple random sampling techniques are used to construct the dataset. For rural areas, data collection is done at two points (between September and December 2015 for post-planting and between February and April 2016 for post-harvest), and one visit is made to selected households in urban areas (between February and April 2016).

The most relevant variables for the purposes of this paper are the GPS coordinates of each sampled household and commercial farm establishment, demographic variables and information on livestock ownership and management by households. Community level variables such as access to roads and markets and whether an extension agent lives in a given community or not are also used in the paper. The analysis only considers those households that own livestock[27].

3.3.2. Estimated model

Investigating the role of knowledge spillovers among neighboring farms in livestock technology adoption and improved livestock management is challenging from a methodological viewpoint, as many types of correlations exist between common neighborhood factors. That is, individuals

[26] An enumeration area (EA) is a specific location demarcated for the random sampling of households per EA and may be include one or less than one kebele (the lowest administrative unit).

[27] To determine if sample selection exists, this paper apply the Heckman sample selection model using the IMR (into multilevel model). The results of the Heckman model are reported in Annex 3.4. The results indicate that there is no selection bias.

residing in the same physical environment are more likely to act in the same manner, indicating that households located within the same geographical areas behave more similarly than they do to households in different areas. In this context, endogeneity typically arises when unobserved neighborhood characteristics are correlated with the independent variables that affect the outcome variables studied (in our case, milk productivity, technology adoption and livestock management). This phenomenon makes it difficult to distinguish the role of learning or social interactions from other geographically associated characteristics, including the socioeconomic status of a neighborhood and its natural prerequisites for livestock rearing (Lanjouw, et al., 2001). In such situations involving hierarchical data structures, applying OLS estimation technique may lead to incorrect statistical inferences due to the violation of independence assumption. For such a nested dataset, one can apply a fixed effects model (i.e., OLS with group dummies), but it is impossible to differentiate the effects of observable and unobservable group characteristics when using such a model. In addition, while not the case for the multilevel model, inferences to population groups cannot be made with the fixed effects model (Stawski, 2013).

Following Manski (1993), econometric challenges with testing for spatial spillover effects in agricultural technology adoption have been discussed by several studies (for instance, Conley & Christopher, 2001; Conley & Udry, 2010; Krishnan & Patnam, 2013). The main focus of estimating neighborhood effects is to distinguish between contextual and true neighborhood effects arising from simultaneity problems, i.e., alleviating level-two endogeneity. While IV estimation techniques may be applied, obtaining valid instruments is a challenge in itself and this approach is limited in addressing correlated effects where households behave in similar ways as a result of unobservable neighborhood characteristics.

This paper follows the approach given in Mundlak (1978) and Snijders and Berkhof (2006) by applying a two-level multilevel model with semi-demeaned estimated equations. In using this approach, it is possible to separate within and between components of such a model by estimating them separately. The rationale is to include level-two means in the equation to disentangle within- and between-clusters effects. The multilevel model is specified so that household level outcome variables (e.g., milk productivity, ownership of exotic breeds and adoption of AI) are a function of a set of (*i)* household level characteristics including most importantly, the Euclidean distance to the nearest commercial farm establishments as described above (Deininger & Xia, 2016; Ali et al., 2019) and *ii)* a set of neighborhood characteristics (e.g. average number of technology adopters) and controls for natural prerequisites for agriculture and livestock rearing. A random effect at the Woreda level is included to capture unobserved contextual neighborhood factors. The estimated two-level multilevel model can be specified as:

$$y_{ij} = \alpha_0 + \gamma \boldsymbol{Z_{ij}} + v_j^y + \epsilon_{ij} \quad (1)$$

where y_{ij} denotes the outcome variables (indicators of technology adoption, livestock management and milk yields as defined in Table 3.1) of household i nested in Woreda j; $\boldsymbol{Z}_{ij}$ is a vector of household socioeconomic and neighborhood characteristics including distance variables and the area cultivated by the nearest commercial farm.[28] Moreover, v_j^y and ϵ_{ij} are residuals for the Woreda and household levels, respectively. Residuals are assumed to be normally distributed: $v_j^y \sim N(0, \sigma_{v(y)}^2)$ and $\epsilon_{ij} \sim N(0, \sigma_{e(y)}^2)$. Following the multilevel literature, residuals of each level are assumed to be uncorrelated with the predictor variables $\boldsymbol{Z}_{ij}$. Although the model allows for heterogeneity in terms of level effects across Woredas, the assumption of no correlation between level residuals and predictor variables may not hold if there are unobservable neighborhood factors that influence the probability of adoption and/or the outcome of adoption. Natural preconditions for livestock rearing differ markedly across geography, and spatially variable unobserved factors may exist but not be accounted for. This endogeneity problem can be addressed by modelling natural resource allocation and adoption jointly. A two-level random intercept model for natural resource allocation can be expressed as:

$$Z_{ij} = \theta \boldsymbol{W}_{ij} + v_j^{(z)} \quad (2)$$

where $\boldsymbol{W}_{ij}$ is a vector of explanatory variables defined at the neighborhood level (the average number of technology adopters; the existence of extension agents in the community; and community access to different facilities such as roads, farmers' training centers, large weekly markets, etc.), its associated coefficients θ and the neighborhood level residual $v_j^{(z)}$. The models specified in (1) and (2) are simultaneous equation models linked through residuals at the neighborhood level with covariances $\sigma_\epsilon^{(yz)}$ and $\sigma_v^{(yz)}$, respectively. To alleviate the endogeneity problem related to natural resource allocation, $\boldsymbol{W}_{ij}$ must contain at least one variable that is not included among the predictor variables $\boldsymbol{Z}_{ij}$. It is important to note that while this approach serves as a robust means to test for cross-level endogeneity, it may not fully consider the bias that could result from same-level endogeneity (i.e., correlations between observed and unobserved neighborhood characteristics) still persist and hence interpretation of the results as an effect is taken with a caution.

3.3.3. Control variables

Several control variables are included to capture moderating socio-demographic and human capital related influences (e.g., age, gender, education, household size). Our choice of variables follows approaches used in previous studies with a similar focus (see, e.g., Hailu & Deaton, 2016). A set of variables is included to control for contextual factors, including climate (location by agro-

[28] Data and definitions for the agri-environmental climate zones considered are available at http://koeppen-geiger.vu-wien.ac.at/present.htm

climatic zone), the size of the nearest city and distance to the nearest grassland. These variables are created using spatial joins in ArcView using publicly available georeferenced data.[29] Finally, the existence of an extension agent in a community is accounted for to control for knowledge and information transmitted via formal channels. Community level variables such as the average number of adopters and access to facilities such as extension service centers (also known as farmers' training centers), livestock health centers, access to markets, access to roads, etc. at the community level are used to control for contextual effects. Summary statistics and definitions of the dependent and independent variables are presented in Table 3.1.

Summary statistics by region are presented in the annex for chapter three. They show that most of the livestock owners are rural dwellers, have large families and are mostly illiterate (65 percent). Moreover, most of the households that own livestock have a higher average age (48 years) and mainly have male household heads (79 percent) (see Annex 3.1). Of the households that own livestock, only 7 percent have exotic/cross breeds (see Annex 3.2). This indicates that most households own local breeds with a limited number of households owning improved livestock breeds. On average, each of these households owns roughly three heads of exotic or cross breed livestock and thus owns fewer exotic breeds than an average household in SSA countries. Moreover, only roughly 6 percent of households that own livestock have practiced controlled breeding methods such as AI and controlled mating, indicating that most households are practicing traditional modes of breeding with no or limited capacity to breed higher quality cows that produce more milk per day. Similarly, a limited proportion of households that own livestock (roughly 7 percent) have utilized improved animal feed for their livestock. Since most households do not own exotic or better breeds of cows and few practiced controlled breeding or feed their cows with quality animal feed, levels of milk productivity per cow are low (roughly 1.7 liters per day) for both exotic/improved and local breed cows (see Annex 3.3). Milk productivity per day for exotic/cross breed cows is 2.5 liter per day, which is low even by SSA country standards (FAO, 2018). This low productivity could imply that ownership of exotic cows does not increase milk productivity unless accompanied by improved livestock management (quality animal feeding and health). For households that own exotic cows and feed them quality animal feed, levels of milk productivity per cow per day are higher (over 4 liters), indicating that the use of higher quality feed is among the factors that contribute to low levels of milk productivity in Ethiopia.

Table 3.1. Summary statistics and definitions of variables

Variables	Obs.	Mean	Std. Dev.
Milk yield per day per cow	1,466	2.17	6.29
Number of cows milked	3,221	0.73	1.30
Number of cows milked squared	3,221	2.23	17.38
Number of months a cow is milked	1,828	5.80	2.72

[29] Distances are computed using data from https://africaopendata.org/dataset/ethiopia-shapefiles and https://mapcruzin.com/free-ethiopia-arcgis-maps-shapefiles.htm

Number of households in woreda adopting technologies (exotic breeds and improved breeding methods)	4,832	1.65	4.86
Household size (in numbers)	4,473	4.71	2.35
Age of head of household (in years)	4,122	46.44	15.35
Sex of head of household (share of male heads)	4,257	0.70	0.46
Education of head of household (share)			
Illiterate	4,098	0.54	0.50
Primary	4,098	0.29	0.45
Secondary	4,098	0.08	0.28
Tertiary	4,098	0.09	0.29
Households that own exotic breeds (share)	2,600	0.07	0.25
Households that use improved feed (share)	2,242	0.07	0.26
Households that practice improved breeding strategies (share)	2,656	0.05	0.22
Households that vaccinate their livestock (share)	2,647	0.44	0.50
Whether an extension agent lives in the village (share of yes	4,481	0.65	0.48
responses=1)	4,481	0.02	1.55
Access to different facilities at the community level (PCA)			
Distance between a household and the nearest HH practicing improved livestock breeding methods (in km)	4,258	20.85	21.53
Distance between a household and the nearest HH who owns exotic breeds (in km)	4,258	22.03	22.42
Distance between a household and the nearest HH who uses better animal feed (in km)	4,258	27.83	26.02
Distance between a household and the nearest HH who vaccinates his/her livestock (in km)	4,258	7.84	12.61
Population size of the city (>200,000 dwellers)	4,256	345,968	823,290
Distance between a household and the nearest grassland area (in km)	4,256	4.54	3.86
arid steppe dummy (=1)	4,256	0.07	0.26
arid dessert dummy (=1)	4,256	0.02	0.13
Distance between a household and the nearest commercial farm (in km)	4,258	39.05	34.01
Area cultivated by the nearest commercial farm (ha)	4,351	415.22	1,068.89
Land area owned by smallholders (ha)	2,891	1.37	8.16
Share of regional states (share)			
Tigray	4,351	0.12	0.32
Amhara	4,351	0.21	0.41
Oromia	4,351	0.21	0.41
SNNP	4,351	0.24	0.43
Other regions	4,351	0.22	

All distance variables are based on our own computations using the ESS (2015/16), the ESS (2015/16) survey and publicly available GIS data from The World Bank and Africa Open Data.

3.3.4. Main variables

In this paper, five outcome variables are considered to capture the effects of the spatial proximity of smallholder livestock owners to peer farmers and commercial farm establishments. The first four are binary variables indicating if a household owns exotic animals; practices-controlled breeding strategies; utilizes improved animal feed; and vaccinates livestock. Dependent variables are selected following Bachewe et al. (2018) who used comparable indicators to analyze determinants of the adoption of modern livestock inputs in Ethiopia. While they apply similar indicators of intensification, they do not consider neighborhood effects as a main factor that affects these outcome variables. The last dependent variable is an indicator of milk production defined as the daily amount of milk[30] (in liter) produced per cow to address outcomes of food security and productivity (Lampe & Sharp, 2015; Nilsson et al., 2019).

Independent variables employed in the multilevel model used in this paper are categorized into main interest and control variables. Main interest variables include the shortest Euclidean distance between a household that owns livestock and its peer farmers who adopt improved livestock technologies. The second interest variable is the shortest Euclidean distance between a household that owns livestock and commercial farm establishments. This approach follows the rationale that face-to-face contact and social interactions are local phenomena that sharply attenuate with distance (Genius et al., 2014). Since both the ESS and commercial farm survey datasets include GPS coordinates, Euclidean distances between commercial farm establishments and a household and its peers were computed. These distances are used to proxy spatial spillover effects from commercial farm establishments and peer farmers to smallholder livestock owners in terms of increasing milk productivity, the decision to own exotic or cross breeds, practicing improved breeding strategies, utilizing improved feed and vaccinating livestock.

Using the Euclidean distance as a proxy for the true physical distance may not be the most accurate approach since, naturally, it may not be possible to walk or travel in a straight line (as birds fly) to a specific location. More realistic measures include the cost distance measure and road distance measure. However, such measures cannot be calculated for the ESS dataset due to data limitations. Available road distance network layers for Ethiopia are less detailed and not highly reliable for rural areas, and the existing data do only provide a road cover network of main roads. However, in low-density rural areas, fewer roads are present and actual distances travelled by farmers are shorter than distances travelled by road, implying that Euclidean distances may actually serve as a reasonable approximation (Duranton & Overman, 2005).

[30] This indicator is measured as a continuous variable of milk yields per day per cow.

3.3.5. Defining neighborhoods

In constructing the multilevel model, the administrative units of Woreda[31] are used to define neighborhoods. However, if the Woreda level and its administrative borders does not coincide with true neighborhoods and the relevant underlying social or economic processes, the model may not be correctly specified (Duranton & Overman, 2005). Previous studies have shown that equivalent micro-data for a study region can produce different results depending on the unit of aggregation used (Arbia, 2001; Briant et al., 2010; Owen et al., 2016). In choosing the appropriate level of aggregation, we use the Intra-class Correlation Coefficient (ICC) to test the strength of correlations among level-one outcome variables at higher levels in the data, including the more aggregated regional administrative unit. The ICC for the tested units can be specified as:

$$ICC = \frac{\delta_W^2}{\delta_W^2 + \delta_R^2} \quad (3)$$

where σ_W^2 and σ_R^2 denote the variance at the Woreda and regional levels, respectively. The ICC ranges from zero to one, denoting the level bearing no information (value of zero) to all units in a level being identical (value of one).

Table 3.2: Estimated ICCs for different administrative units.

Levels	ICC	Std. Err.	Obs.
Region	0.028	0.025	138
Woreda/region	0.091	0.059	6
Kebele/Woreda/region	0.248	0.033	5

A comparison of the OLS (linear) and multilevel models using the likelihood ratio (LR), which follows the chi-squared distribution, indicates that for all five models, the multilevel model is preferred to the simple OLS model. Table 3.3 presents the results of comparing the OLS and multilevel models. The null hypothesis states that OLS is preferred to the multilevel model, and hence rejecting the null means that the multilevel model is superior to the OLS.

Table 3.3: LR test for selecting the OLS model or multilevel model

Models	LR statistic
Milk yield	47.88***
Ownership of exotic breeds	31.23***
Practicing controlled breeding	26.96***

[31] The analysis is done at woreda level as number of groups per kebele is small. Besides, better variation in some variables like number of livestock technology adopters, agro-ecology, access to facilities is observed at woreda compared to kebele level.

Utilizing improved feed	42.06***
Vaccinating livestock	59.37***

H_0: the linear model (OLS) is preferred over the multilevel model

*** significant at 1% level of significance

3.4. Regression results and discussios

3.4.1. Spillover effects and milk productivity

Table 3.4 presents estimation results of OLS and multilevel models for milk productivity. Being positioned closer to smallholder neighbors who own exotic breeds is associated with greater milk productivity, as smallholder farmers learn from their neighbors how to increase milk productivity by utilizing better animal feed and adopting improved breeding strategies. The number of livestock technologies used (ownership of exotic breeds and use of improved breeding strategies) in a community has no effects on milk productivity, indicating that it is only the existence of peer farmers using improved livestock technologies that matters regardless of their numbers. However, the proximity of smallholder livestock owners to commercial farm establishments has no effects in improving milk productivity of smallholders. This absence may occur because commercial farms use more advanced livestock management methods in terms of feeding, quality and timing; maintaining cow hygiene; health; etc.

Thus, key factors that increase milk productivity of smallholder livestock owners could have an influence via knowledge and information spillovers from peer farmers who have adopted improved livestock technologies and practiced improved livestock management practices. However, proximity to commercial farm establishments is not beneficial to smallholders in terms of increasing milk yields.

Some socio-economic characteristics play a role in increasing milk productivity. For instance, households with heads who have completed high school have higher milk productivity than households with illiterate heads, indicating that education may improve the milk productivity of farm households. However, household size, age and gender of the head of household are not significantly associated with increasing milk productivity. Ownership of more cows is associated with higher milk yields, but a decreasing rate is observed with economies of scale in cow ownership, which disappears at a certain level of cow ownership due to inefficiency. The number of months a cow is milked has no effects on milk productivity. Market size, which is measured using the population size of the closest city of 200,000 or more residents, has some effect in improving milk productivity per cow. This effect indicates that households positioned closer to urban centers benefit from growing demand for dairy products due to urbanization and increasing money incomes (Worku et al., 2017).

Households using improved livestock management methods such as feeding their cows improved animal feed have achieved higher milk productivity per cow than those not using better animal feeds. This achievement is in line with previous studies (Leng, 1991; Khan et al., 2009). Similarly, households that own exotic breeds produce more milk per cow than households that do not own exotic/cross breed cows, which is also consistent with the findings of previous studies (Duncan et al., 2013). In addition, households that practice improved animal breeding strategies achieve higher milk productivity. Thus, improved livestock technologies coupled with improved livestock management could play a key role in increasing milk productivity of farm households in developing countries like Ethiopia.

Table 3.4: Estimation results of OLS and multilevel models for milk yields

Independent variables	Dependent var.: Ln (milk yield)	
	OLS	Multilevel
Ln (distance to nearest HH who owns exotic breeds)	-0.0246**	-0.0255**
	(0.0123)	(0.0128)
Ln (distance to nearest HH who practices improved breeding)	-0.0049	-0.0114
	(0.0139)	(0.0154)
Ln (distance to nearest HH who uses better feed)	-0.0382***	-0.0349**
	(0.0116)	(0.0138)
Ln (distance to nearest HH who vaccinates livestock)	0.0009	-0.0026
	(0.0112)	(0.0137)
Ln (distance between the HH and the nearest commercial farm)	-0.0107	-0.0078
	(0.0238)	(0.0302)
Ln (area cultivated by commercial farms in ha)	0.0028	0.0054
	(0.0105)	(0.0145)
Number of milked cows	0.179***	0.162***
	(0.0258)	(0.0276)
Number of milked cows squared	-0.0088***	-0.0076***
	(0.0012)	(0.0015)
Number of months a cow is milked	-0.0106	-0.0066
	(0.0275)	(0.0259)
Number of months a cow is milked squared	0.0023	0.0020
	(0.0023)	(0.0020)
Number of technology adopters in a community	0.0058	0.0021
	(0.0047)	(0.0118)
Ln (household size)	0.0458	0.0597
	(0.0421)	(0.0460)
Ln (age of household head in years)	2.097*	2.275
	(1.266)	(1.433)
Ln (age of household head squared in years)	-0.271	-0.296
	(0.166)	(0.187)
Sex of household head (male=1)	-0.0276	-0.0558
	(0.0560)	(0.0525)
Education level of household head (primary=1)	0.0634	0.0664
	(0.0479)	(0.0454)
Education level of household head (secondary=1)	0.230*	0.215**
	(0.138)	(0.107)

Education level of household head (tertiary=1)	-0.118	-0.105
	(0.0987)	(0.134)
Ownership of exotic/cross breeds (=1)	0.181**	0.154**
	(0.0879)	(0.0730)
Utilizing improved animal feed (=1)	0.144**	0.134*
	(0.0720)	(0.0756)
Practicing improved breeding strategies (=1)	0.168**	0.214***
	(0.0844)	(0.0794)
Vaccinating livestock (=1)	-0.102**	-0.0799*
	(0.0462)	(0.0426)
Extension agent lives in the community (=1)	0.129***	0.141**
	(0.0481)	(0.0702)
Access to community level facilities (PCA)	0.0654***	0.0651***
	(0.0242)	(0.0244)
Ln (total population of the nearest city with > 200,000 inhabitants)	0.0806***	0.0706**
	(0.0238)	(0.0346)
Ln (distance to the nearest grass land area)	0.0295	0.0267
	(0.0223)	(0.0275)
Dummy for arid steppe (=1)	0.0379	0.0160
	(0.0548)	(0.0965)
Dummy for arid dessert (=1)	0.109	0.169
	(0.0845)	(0.238)
Ln (area owned by smallholders)	-0.0027	-0.0040
	(0.0055)	(0.0065)
Regional dummy (Tigray=1)	-0.172**	-0.210*
	(0.0706)	(0.118)
Regional dummy (Amhara=1)	-0.346***	-0.338***
	(0.0698)	(0.103)
Regional dummy (Oromia=1)	-0.0404	-0.0314
	(0.0669)	(0.0970)
Regional dummy (SNNP=1)	-0.151**	-0.157
	(0.0681)	(0.0981)
Constant	-5.020**	-5.194*
	(2.422)	(2.756)
Woreda random effects	-	-1.381***
		(0.107)
Household random effects	-	-0.524***
		(0.0223)
F/Wald-statistic	11.25***	146.73***
Observations	1,234	1,234
R-squared	0.142	
Number of groups		239

Robust standard errors are shown in parentheses

*** p<0.01, ** p<0.05, * p<0.1

The Wald test, which is equivalent to the F-test used in the OLS regression model, indicates that the overall significance of model for milk productivity (Table 3.4) and improved livestock technology adoption and improved livestock management (Tables 3.5 and 3.6) are appropriate in fitting the data. The average deviation from the overall mean (β_0) is measured by random effects, which also capture unobservable heterogeneity. These random effects are observed at the Woreda level and are statistically significant for most of the models, indicating significant spatial dependencies where random effects are introduced to control for such spatial dependencies. The intra-class correlation coefficient (ICC), which is defined as the ratio between the cluster variance and total variance, measures the proportion of the total variance in outcome variables (e.g., milk productivity) accounted for by Woreda level random effects. The ICC can also be interpreted as the correlation between observations made within the same geographical location. Naturally, household level factors account for more of the variation in the dependent variables than high/Woreda level factors.

3.4.2. Spillover effects and adoption of improved livestock technologies

Table 3.5 presents the standard and multilevel probit models for livestock technology adoption. In line with our expectations, shorter distances between a household and smallholder neighbors (or peer farmers) who own exotic breeds are positively and significantly associated with a higher likelihood of a household owning exotic or cross breeds Similarly, the closer a household is positioned to peer farmers who practice improved livestock breeding strategies, the higher that household's likelihood of adopting improved livestock breeding strategies. This outcome may indicate that the spatial proximity of smallholders to peer farmers who adopt improved livestock technologies (owning exotic breeds and practicing improved breeding strategies) can serve as a source of knowledge and information for farm households in developing countries such as Ethiopia. In other words, there may be knowledge spillovers linked to the ownership of exotic breeds and the use of improved breeding strategies among rural households. In addition, a higher number of households adopting livestock technologies in a community is positively associated with a greater likelihood of owning exotic breeds and adopting improved livestock breeding strategies. Thus, smallholder livestock owners may learn from their peer farmers about the adoption of improved livestock technologies.

However, the spatial proximity of smallholders to commercial farm establishments does not help smallholder livestock owners adopt improved livestock technologies, indicating an absence of knowledge spillovers from commercial farms to livestock owners. Rather, the expansion of cultivated areas by commercial farm establishments is negatively associated with the likelihood of owning exotic breeds, as the presence of more cultivated areas reduces the availability of animal feed mainly from grassland areas. Thus, when commercial farms are positioned closer to smallholder livestock owners, there is a tendency for households to reduce the amount of livestock owned (including exotic breeds) and to engage in wage employment with commercial farm establishments (Ali, et al., 2019; Glover & Jones, 2019). This tendency indicates that the existence of commercial farms may induce households to diversify to income sources outside of their own agricultural specialties, which may enhance rural dynamism through participation in off-farm income generating activities. Expansion in cultivated areas by commercial farms induces adoption of improved breeding strategies as shortage in grazing lands (due to expansion of cultivated areas) that could result in shift from local livestock breeds to improved breeds.

The results of the multilevel probit model also indicate that the probability of owning exotic breeds is positively and significantly associated with the education levels of household heads, as those who have completed high school are more likely to own exotic breeds. This finding is in line with a previous study conducted in Ethiopia (Bachewe et al., 2018). However, household head gender and age and household size are not significantly associated with the likelihood of owning exotic breeds. No socioeconomic variables (education level, sex and age of household head and household size) are significantly associated with the likelihood of using improved livestock breeding strategies.

Households that practice improved livestock management methods are more likely to own exotic animals. For instance, households that practice controlled breeding methods such as artificial insemination (AI) are more likely to own exotic cows than households that do not practice controlled breeding systems, likely due to their greater experience and higher incomes. Market size as measured by the population of the nearest city is positively associated with ownership of exotic/cross breed animals and of mainly cows, indicating that farmers with access to large consumer bases are more likely to own better animal breeds. Household head education is positively associated with owning exotic breeds but is not associated with breeding strategies. Similarly, several socioeconomic characteristics such as household size and household head age and gender have no significant effects on the probability of owning exotic animals. Access to extension services is not significantly associated with the likelihood of adopting improved livestock technologies. This outcome could be due to poor livestock extension services, which prevent smallholders from obtaining relevant information from a country's extension system. However, having access to various facilities at the community level such as road networks and market centers is positively associated with the probability of owning exotic breeds.

Table 3.5: Estimation results of standard and multilevel probit models for livestock technology adoption

Independent variables	Owning exotic breeds		Practicing improved livestock breeding strategies	
	Standard probit	Multilevel probit	Standard probit	Multilevel probit
Ln (distance to the nearest HH who owns exotic breeds)	-0.102*** (0.0267)	-0.197*** (0.0534)	-	-
Ln (distance to the nearest HH who practices improved breeding strategies)	-	-	-0.181*** (0.0333)	-0.332*** (0.0721)
Ln (distance to the nearest commercial farm)	0.114* (0.0617)	0.206 (0.131)	-0.105 (0.0828)	-0.250 (0.179)
Ln (area cultivated by commercial farms in ha)	-0.101*** (0.0267)	-0.209*** (0.0601)	0.113*** (0.0387)	0.211** (0.0979)

Ln (household size)	0.163	0.296	0.134	0.286
	(0.145)	(0.297)	(0.165)	(0.347)
Ln (age of household head in years)	0.203	2.732	5.477	13.10
	(4.473)	(8.361)	(5.481)	(11.00)
Ln (age of household head squared in years)	-0.00561	-0.319	-0.718	-1.719
	(0.584)	(1.091)	(0.719)	(1.437)
Sex of household head (male=1)	0.200	0.443	-0.213	-0.307
	(0.150)	(0.320)	(0.173)	(0.344)
Education dummy, primary (=1)	0.386***	0.798***	-0.0153	-0.172
	(0.113)	(0.246)	(0.139)	(0.294)
Education dummy, secondary (=1)	0.191	0.410	0.361*	0.530
	(0.183)	(0.407)	(0.211)	(0.458)
Education dummy, tertiary (=1)	-0.293	-0.562	0.496	0.842
	(0.350)	(0.831)	(0.323)	(0.753)
Dummy for owning exotic/cross breeds (=1)	-	-	1.350***	2.671***
			(0.149)	(0.306)
Practicing improved breeding strategies (=1)	1.451***	2.650***	-	-
	(0.168)	(0.306)		
Utilizing improved animal feed (=1)	0.233	0.465	0.573***	1.053***
	(0.150)	(0.296)	(0.170)	(0.345)
Vaccinating livestock (=1)	0.0453	0.0481	0.284**	0.481*
	(0.0943)	(0.202)	(0.125)	(0.260)
Extension agent lives in the community (=1)	-0.0500	-0.149	-0.00217	-0.0445
	(0.134)	(0.292)	(0.171)	(0.417)
Access to community level facilities (PCA)	0.0920**	0.212**	-0.0274	0.0373
	-0.0500	-0.149	-0.00217	-0.0445
Number of neighbors who own exotic breeds	0.0493***	0.113***	-	-
	(0.0181)	(0.0369)		
Number of neighbors who practice improved breeding strategies	-	-	0.203***	0.384***
			(0.0314)	(0.0827)
Ln (total population of the nearest city)	0.130**	0.242*	-0.0141	0.0432
	(0.0607)	(0.123)	(0.0834)	(0.186)
Ln (distance to the nearest grassland area)	0.00107	-0.00931	-0.0124	-0.00660
	(0.0557)	(0.116)	(0.0748)	(0.175)
Ln (area owned by smallholders in ha)	-0.00558	-0.0149	-0.0260	-0.0233
	(0.0138)	(0.0284)	(0.0185)	(0.0411)
Regional dummy (Tigray=1)	0.289	0.833*	0.766***	1.092*
	(0.236)	(0.500)	(0.259)	(0.577)
Regional dummy (Amhara=1)	0.392*	1.042**	0.332	0.235
	(0.231)	(0.462)	(0.233)	(0.531)
Regional dummy (Oromia=1)	0.274	0.791*	0.165	-0.236
	(0.225)	(0.460)	(0.253)	(0.594)
Regional dummy (SNNP=1)	0.174	0.626	0.179	-0.142
	(0.222)	(0.477)	(0.233)	(0.547)
Constant	-4.271	-10.61	-10.47	-25.63
	(8.371)	(15.73)	(9.777)	(21.20)
Woreda level random effects	-	-0.486	-	0.234
		(0.381)		(0.192)
Wald statistic	174.58***	167.13***	236.67***	171.22***
Observations	1,912	1,912	1,912	1,912

Number of groups	256	256

Robust standard errors are shown in parentheses
*** p<0.01, ** p<0.05, * p<0.1

3.4.3. Spillover effects and improved livestock management

Table 3.6 presents the results of standard and multilevel probit models on the likelihood of practicing improved livestock management methods (utilizing improved animal feed and vaccinating livestock). The findings indicate that the spatial proximity of smallholder livestock owners to peer farmers who practice improved livestock management methods may serve as a channel for information diffusion on improved livestock management, as the shortest Euclidean distance is inversely related to the probability of adopting improved livestock managements. This outcome indicates that farm households may learn from their smallholder neighbors (or peer farmers) about using improved animal feeds and vaccinating livestock. The number of households vaccinating their livestock is positively associated with the probability of a household in a local community vaccinating livestock. Similarly, households are more likely to learn from commercial farm establishments about vaccinating livestock. However, smallholder livestock owners may not learn from commercial farms about utilizing improved animal feed, as commercial farm establishments may use improved and mechanized technologies to feed their animals. In short, smallholder livestock owners are more likely to learn from their peer farmers than from commercial farm establishments about improved livestock management methods.

The findings presented in Table 3.6 also indicate that probability of adopting improved animal feed is not associated with socioeconomic characteristics (sex and age of household heads and household size). However, household head education is positively associated with the probability of utilizing improved livestock feed. Similarly, household education head is positively associated with the probability of vaccinating livestock. Male-headed households are more likely to vaccinate their livestock than households headed by females. These findings are in line with a previous study conducted in Ethiopia (Bachewe et al., 2018). This alignment indicates that households with more educated heads are more likely to use modern livestock management methods in terms of using better animal feed and improving livestock health. Types of livestock technologies in terms of improved breeding strategies also matter in selecting improved livestock management methods, as households practicing improved livestock breeding strategies are more likely to adopt such livestock management approaches. That is, households using controlled breeding are more likely to use better animal feed and vaccinate their animals than households not practicing controlled breeding.

Farm land is an important asset for rural households, and hence owning larger plots of land is positively and significantly associated with the likelihood of adopting improved animal feed, as access to more land affords farmers more freedom to grow high quality animal feeds. Access to community level facilities such as roads, markets and extension agents has no effects on the probability of adopting improved animal feeds. However, existence of extension agents is positively and significantly associated with probability of vaccinating livestock, which witnesses that the extension services of the country have focused on livestock health mainly vaccination but less emphasis is given to improved livestock technology adoption.

Table 3.6: Estimation results of standard and multilevel probits for improved livestock managements

Independent variables	Utilizing improved animal feed		Vaccinating livestock	
	Standard probit	Multilevel probit	Standard probit	Multilevel probit
Ln (distance to the nearest HH who utilizes improved animal feed)	-0.286*** (0.0275)	-0.542*** (0.0621)	-	-
Ln (distance to the nearest HH who vaccinates livestock)	-	-	-0.329*** (0.0226)	-0.479*** (0.0502)
Ln (distance to the nearest commercial farm)	0.0402 (0.0752)	0.0812 (0.166)	-0.118*** (0.0393)	-0.216** (0.102)
Ln (area cultivated by commercial farms in ha)	-0.0389 (0.0337)	-0.103 (0.0779)	0.0112 (0.0200)	0.0314 (0.0491)
Ln (household size)	0.106 (0.139)	0.273 (0.297)	-0.134 (0.0854)	-0.144 (0.161)
Ln (age of household head in years)	1.738 (3.935)	3.161 (8.447)	1.680 (2.400)	2.377 (4.622)
Ln (age of household head squared in years)	-0.255 (0.517)	-0.487 (1.109)	-0.221 (0.315)	-0.305 (0.605)
Sex of household head (male=1)	0.0654 (0.151)	0.0541 (0.321)	0.294*** (0.0919)	0.508*** (0.169)
Education dummy, primary (=1)	0.144 (0.125)	0.320 (0.263)	0.192*** (0.0710)	0.243* (0.133)
Education dummy, secondary (=1)	0.194 (0.222)	0.376 (0.436)	0.366*** (0.137)	0.526** (0.260)
Education dummy, tertiary (=1)	0.506* (0.300)	1.036* (0.582)	0.506** (0.258)	0.691 (0.446)
Practicing improved breeding methods (=1)	0.530*** (0.169)	1.085*** (0.368)	0.389** (0.153)	0.696** (0.283)
Owning exotic/cross breeds (=1)	0.0669 (0.153)	0.109 (0.331)	0.00589 (0.125)	0.159 (0.243)
Utilizing improved animal feed (=1)	-	-	0.158 (0.124)	0.451* (0.250)
Vaccinating livestock (=1)	0.185* (0.107)	0.447* (0.234)	-	-
Extension agent lives in the community (=1)	-0.184 (0.146)	-0.375 (0.331)	-0.197* (0.101)	-0.514** (0.243)
Access to community level facilities (PCA)	0.105** (0.0515)	0.195 (0.124)	0.00370 (0.0345)	0.0389 (0.0807)
Number of neighbors who use improved feed	0.0168 (0.0120)	0.0444 (0.0339)	-	-

Number of neighbors who vaccinate animals	-	-	-0.0285***	-0.0571***
			(0.00566)	(0.0196)
Ln (total population of the nearest city)	0.0279	0.0700	-0.0870**	-0.115
	(0.0680)	(0.150)	(0.0436)	(0.113)
Ln (distance to the nearest grassland area)	-0.0820	-0.173	-0.00538	0.00577
	(0.0589)	(0.126)	(0.0367)	(0.0922)
Ln (area owned by smallholders in ha)	0.0330**	0.0675**	-0.0159*	-0.0256
	(0.0148)	(0.0330)	(0.00910)	(0.0218)
Regional dummy (Tigray=1)	0.0674	0.198	0.576***	0.862**
	(0.247)	(0.551)	(0.147)	(0.372)
Regional dummy (Amhara=1)	-0.213	-0.488	0.359***	0.425
	(0.253)	(0.545)	(0.124)	(0.322)
Regional dummy (Oromia=1)	0.0189	0.0571	0.594***	0.878***
	(0.215)	(0.470)	(0.117)	(0.308)
Regional dummy (SNNP=1)	-0.0785	-0.145	0.355***	0.403
	(0.217)	(0.489)	(0.109)	(0.303)
Constant	-4.677	-8.577	-2.175	-3.294
	(7.502)	(16.08)	(4.576)	(8.848)
Woreda level random effects	-	-0.259	-	0.0863
		(0.317)		(0.117)
Wald statistic	250.17***	184.69***	398.90***	170.37***
Observations	1,912	1,912	1,912	1,912
Number of groups		256		256

Robust standard errors are shown in parentheses
*** p<0.01, ** p<0.05, * p<0.1

3.5. Conclusions and policy implications

This paper analyzes benefits of spatial proximity as measured by the shortest Euclidean distance between smallholder livestock owners and neighboring peer farmers using improved livestock technologies and management methods and commercial farm establishments in terms of affecting milk productivity of smallholder livestock owners and their decisions to adopt improved livestock technologies (owning exotic animals and practicing controlled breeding) and practicing improved management methods (using improved feed and vaccinating livestock). The article uses two nationally representative datasets (the 2015/16 ESS on smallholders and 2014/15 commercial farm survey) collected by the CSA. It employs a multilevel model and thus addresses problems commonly reported in the literature as peer effects (identification, correlations between individual outcomes and geographic variables and endogeneity). It presents three key findings. First, smallholders located closer to peer farmers who adopt improved livestock technologies have higher milk yields. Second, the closer households are to peer farmers using improved livestock technologies, the higher their probability of adopting such technologies. Third, the shorter the distance between a household and its neighbors practicing improved livestock management approaches (improved animal feed and vaccinating livestock), the higher the household's probability of adopting such management methods. Thus, there are spatial spillovers among smallholder livestock owners in terms of increasing milk yields, adopting improved livestock technologies and practicing improved livestock management methods. Spatial proximity to commercial farms has no effects on milk productivity but it is negatively associated with the likelihood of owning exotic breeds, as the expansion of cultivated areas by commercial farms reduces the availability of grazing lands. However, the existence of commercial farms has positive effects on the probability of vaccinating livestock. Market access is positively associated with milk productivity and improved livestock management practices.

The following conclusions can be drawn from these results. First, there is a positive association between peer effects on adopting improved livestock technologies and improved livestock management among smallholder livestock owners and their neighbors. However, there are no positive spillover effects from commercial farms in terms of the diffusion of livestock technologies. Second, smallholders may also learn about adopting improved livestock management methods from their peers. Third, peer farmers rather than commercial farms have spillover effects in increasing milk productivity. Fourth, population size as a measure of market size plays a key role in enhancing milk yields. As a policy implication, providing incentives (like subsidies) to model farmers could lead to knowledge spillovers to nearby farmers in terms of improving technology adoption, increasing milk productivity, and encouraging the adoption of improved livestock management methods. Improving access to markets (large cities) will also be essential to enhancing milk productivity and livestock management. One possible future research area is the roles of research centers in facilitating adoption of improved livestock technologies and management.

References

Abdulai, A., & CroleRees, A. (2001). Determinants of income diversification amongst rural households in southern Mali. *Food Policy*, 26(4), 437–452.

Abebe, H. G. (1990). Generating Marketed Surplus of Food through State Farms: A Critical Evaluation of the Ethiopian Experience, Institute for Social Studies, The Hague.

Adewumi, M. O., Jimoh, A., & Omotesho, O. A. (2013). Implications of the Presence of Large Scale Commercial Farmers on Small Scale Farming in Nigeria. The Case of Zimbabwean Farmers in Kwara State. *Knowledge Horizons. Economics*, *5*(4), 67-73

Ahmed, M., Gebremedhin, B., Ehui, S. (2004). Determinants of Adoption of Improved Forage Technologies in Crop-livestock Mixed Systems: Evidence from the Highlands of Ethiopia.

Alary, V., Corniaux, C., & Gautier, D. (2011). Livestock's contribution to poverty alleviation: How to measure it? *World Development*, *39*(9), 1638-1648.

Ali, D., & Peerlings, J. (2011). Value added of cluster membership for micro enterprises of the handloom sector in Ethiopia. *World Development*, *39*(3), 363-374.

Ali, D., Deininger, K., & Harris, A. (2015). Using national statistics to increase transparency of large land acquisition: Evidence from Ethiopia. The World Bank.

Ali, D., Deininger, K., & Harris, A. (2019). Does large farm establishment create benefits for neighboring smallholders? Evidence from Ethiopia. *Land Economics*, *95*(1), 71-90.

Alvarado, F., Escobar, F., Williams, D. R., Arroyo-Rodríguez, V., & Escobar-Hernández, F. (2018). The role of livestock intensification and landscape structure in maintaining tropical biodiversity. *Journal of Applied Ecology*, *55*(1), 185-194.

Amlaku, A., Sölkner, J., Puskur, R., & Wurzinger, M. (2012). The impact of social networks on dairy technology adoption: evidence from Northwest Ethiopia. *International Journal of AgriScience*, *2*(11), 1062-1083.

Arbia, G. (2001). The role of spatial effects in the empirical analysis of regional concentration. *Journal of Geographical Systems*, *3*(3), 271-281.

Artz, G. M., Kim, Y., & Orazem, P. F. (2016). Does agglomeration matter everywhere?: new firm location decisions in rural and urban markets. *Journal of Regional Science*, *56*(1), 72-95.

Asfaw, S., Kassie, M., Simtowe, F., & Lipper, L. (2012). Poverty reduction effects of agricultural technology adoption: a micro-evidence from rural Tanzania. *Journal of Development Studies*, 48(9), 1288-1305.

Bachewe, F. N., Minten, B., Tadesse, F., & Taffesse, A. S. (2018). *The evolving livestock sector in Ethiopia: Growth by heads, not by productivity* (Vol. 122). Intl Food Policy Res Inst.

BenYishay, A., & Mobarak, A. M. (2018). Social learning and incentives for experimentation and communication. *The Review of Economic Studies*, *86*(3), 976-1009.

Birhan, M., & Adugna, T. (2015). Livestock feed resources assessment, constraints and improvement strategies in Ethiopia.

Bjørkhaug, H., & Blekesaune, A. (2013). Development of organic farming in Norway: A statistical analysis of neighbourhood effects. *Geoforum*, *45*, 201-210.

Boncinelli, F., Bartolini, F., Brunori, G., & Casini, L. (2016). Spatial analysis of the participation in agri-environment measures for organic farming. *Renewable Agriculture and Food Systems*, *31*(4), 375-386.

Borras Jr, S. M., & Franco, J. C. (2012). Global land grabbing and trajectories of agrarian change: A preliminary analysis. *Journal of Agrarian Change*, *12*(1), 34-59.

Briant, A., Combes, P. P., & Lafourcade, M. (2010). Dots to boxes: Do the size and shape of spatial units jeopardize economic geography estimations? *Journal of Urban Economics*, *67*(3), 287-302.

Bujko, M., Fischer, C., Krieger, T., & Meierrieks, D. (2016). How institutions shape land deals: The role of corruption. *Homo Oeconomicus*, *33*(3), 205-217.

Conley, T. G., & Udry, C. R. (2010). Learning about a new technology: Pineapple in Ghana. *American Economic Review*, *100*(1), 35-69.

Conley, T., & Christopher, U. (2001). Social learning through networks: The adoption of new agricultural technologies in Ghana. *American Journal of Agricultural Economics*, *83*(3), 668-673.

Deininger, K., & Xia, F. (2016). Quantifying spillover effects from large land-based investment: the case of Mozambique. *World Development*, *87*, 227-241.

Diez-Roux, A. V. (2000). Multilevel analysis in public health research. *Annual Review of Public Health*, *21*(1), 171-192.

Duncan, A. J., Teufel, N., Mekonnen, K., Singh, V. K., Bitew, A., & Gebremedhin, B. (2013). Dairy intensification in developing countries: effects of market quality on farm-level feeding and breeding practices. *Animal*, *7*(12), 2054-2062.

Duranton, G., & Overman, H. G. (2005). Testing for localization using micro-geographic data. *The Review of Economic Studies*, *72*(4), 1077-1106.

FAO (2018). FAOSTAT. Rome, Italy.

Fitzgerald, A., Fitzgerald, N., & Aherne, C. (2012). Do peers matter? A review of peer and/or friends' influence on physical activity among American adolescents. *Journal of Adolescence*, 35(4), 941-958.

Genius, M., Koundouri, P., Nauges, C., & Tzouvelekas, V. (2014). Information transmission in irrigation technology adoption and diffusion: Social learning, extension services, and spatial effects. *American Journal of Agricultural Economics*, *96*(1), 328-344.

Glover, S., & Jones, S. (2019). Can commercial farming promote rural dynamism in sub-Saharan Africa? Evidence from Mozambique. *World Development*, *114*, 110-121.

Godtland, E. M., Sadoulet, E., Janvry, A. D., Murgai, R., & Ortiz, O. (2004). The impact of farmer field schools on knowledge and productivity: A study of potato farmers in the Peruvian Andes. *Economic Development and Cultural Change*, *53*(1), 63-92.

Hagerstrand, T. (1968). Innovation diffusion as a spatial process. Chicago University Press

Hailu, G., & James Deaton, B. (2016). Agglomeration effects in Ontario’s dairy farming. *American Journal of Agricultural Economics, 98*(4), 1055-1073.

Hänke, H., & Barkmann, J. (2017). Insurance function of livestock, Farmers coping capacity with crop failure in southwestern Madagascar. *World Development*, *96*, 264-275.

Herrero, M., Grace, D., Njuki, J., Johnson, N., Enahoro, D., Silvestri, S., & Rufino, M. C. (2013). The roles of livestock in developing countries. *Animal*, *7*(s1), 3-18.

Herrmann, R. T. (2017). Large-scale agricultural investments and smallholder welfare: A comparison of wage labor and outgrower channels in Tanzania. *World Development*, *90*, 294-310.

Hetherington, J. B., Wiethoelter, A. K., Negin, J., & Mor, S. M. (2017). Livestock ownership, animal source foods and child nutritional outcomes in seven rural village clusters in Sub-Saharan Africa. *Agriculture & Food Security*, *6*(1), 9.

Jera, R., & Ajayi, O. C. (2008). Logistic modelling of smallholder livestock farmers' adoption of tree-based fodder technology in Zimbabwe. *Agrekon*, *47*(3), 379-392.

Kebebe, E. (2019). Bridging technology adoption gaps in livestock sector in Ethiopia: A innovation system perspective. *Technology in Society*, *57*, 30-37.

Keeley, J., W. M. Seide, A. Eid and A. L. Kidewa. 2014. "Large-Scale Land Deals in Ethiopia: Scale, Trends, Features and Outcomes to Date." International Institute for Environment and Development, London.

Khan, M. J., Peters, K. J., & Uddin, M. M. (2009). Feeding strategy for improving dairy cattle productivity in small holder farm in Bangladesh. *Bangladesh Journal of Animal Science*, *38*(1-2), 67-85.

Krishnan, P., & Patnam, M. (2013). Neighbors and extension agents in Ethiopia: Who matters more for technology adoption? *American Journal of Agricultural Economics*, *96*(1), 308-327.

Lampe, M., & Sharp, P. (2015). Just add milk: a productivity analysis of the revolutionary changes in nineteenth-century D anish dairying. *The Economic History Review*, *68*(4), 1132-1153.

Lana, A., Rodriguez-Artalejo, F., & Lopez-Garcia, E. (2015). Dairy consumption and risk of frailty in older adults: a prospective cohort study. *Journal of the American Geriatrics Society*, *63*(9), 1852-1860.

Lanjouw, P., Quizon, J., & Sparrow, R. (2001). Non-agricultural earnings in peri-urban areas of Tanzania: Evidence from household survey data. *Food Policy*, 26(4), 385–403.

Läpple, D., Holloway, G., Lacombe, D. J., & O’Donoghue, C. (2017). Sustainable technology adoption: a spatial analysis of the Irish Dairy Sector. *European Review of Agricultural Economics*, *44*(5), 810-835.

Läpple, D., Renwick, A., Cullinan, J., & Thorne, F. (2016). What drives innovation in the agricultural sector? A spatial analysis of knowledge spillovers. *Land Use Policy*, *56*, 238-250.

Lay, J., Nolte, K., & Sipangule, K. (2018). *Large-scale farms and smallholders: Evidence from Zambia* (No. 310). GIGA Working Papers

Leng, R. A. (1991). Feeding strategies for improving milk production of dairy animals managed by small-farmers in the tropics. *Feeding dairy cows in the tropics. (Eds. Speedy, A. & Sansoucy, R.). Proceedings of the FAO Expert Consultation held in Bangkok, Thailand*, 82.

Lewis, D. J., Barham, B. L., & Robinson, B. (2011). Are there spatial spillovers in the adoption of clean technology? The case of organic dairy farming. *Land Economics*, *87*(2), 250-267

Lewis, D. J., Barham, B. L., & Zimmerer, K. S. (2008). Spatial externalities in agriculture: Empirical analysis, statistical identification, and policy implications. *World Development*, *36*(10), 1813-1829.

Manski, C. F. (1993). Identification of endogenous social effects: The reflection problem. *The Review of Economic Studies*, *60*(3), 531-542.

Martínez-García, C. G., Dorward, P., & Rehman, T. (2013). Factors influencing adoption of improved grassland management by small-scale dairy farmers in central Mexico and the implications for future research on smallholder adoption in developing countries. *Livestock Science*, *152*(2-3), 228-238.

McCormick, D. (1999). African enterprise clusters and industrialization: Theory and reality. *World Development*, 27(9), 1531– 1551.

McDermott, J. J., Staal, S. J., Freeman, H. A., Herrero, M., & Van de Steeg, J. A. (2010). Sustaining intensification of smallholder livestock systems in the tropics. *Livestock Science*, 130(1-3), 95-109.

Mekonnen, D. A., Gerber, N., & Matz, J. A. (2018). Gendered social networks, agricultural innovations, and farm productivity in Ethiopia. *World Development*, *105*, 321-335.

Mekonnen, H., Dehninet, G., & Kelay, B. (2010). Dairy technology adoption in smallholder farms in "Dejen" district, Ethiopia. *Tropical Animal Health and Production*, *42*(2), 209-216.

Mundlak, Y. (1978). On the pooling of time series and cross section data. *Econometrica: Journal of the Econometric Society*, 69-85.

Murphy, S. P., & Allen, L. H. (2003). Nutritional importance of animal source foods. *The Journal of Nutrition*, *133*(11), 3932S-3935S.

Musaba, E. C. (2010). Analysis of factors influencing adoption of cattle management technologies by communal farmers in Northern Namibia. *Livestock Research for Rural Development*, *22*(6), 104.

Mwangi, M., & Kariuki, S. (2015). Factors determining adoption of new agricultural technology by smallholder farmers in developing countries. *Journal of Economics and Sustainable Development*, 6(5).

Nilsson, P. (2019). Spatial spillovers and households' involvement in the non-farm sector: evidence from rural Rwanda. *Regional Studies*, *53*(5), 731-740.

Nilsson, P., Backman, M., Bjerke, L., & Maniriho, A. (2019). One cow per poor family: Effects on the growth of consumption and crop production. *World Development*, *114*, 1-12.

Owen, G., Harris, R., & Jones, K. (2016). Under examination: Multilevel models, geography and health research. *Progress in Human Geography*, *40*(3), 394-412.

Owoo, N. S., & Naudé, W. (2017). Spatial proximity and firm performance: evidence from non-farm rural enterprises in Ethiopia and Nigeria. *Regional Studies*, *51*(5), 688-700.

Pica-Ciamarra, U. (2005). Livestock policies for poverty alleviation: Theory and practical evidence from Africa, Asia and Latin America (No. 855-2016-56211).

Quddus, M. A. (2012). Adoption of dairy farming technologies by small farm holders: practices and constraints. *Bangladesh Journal of Animal Science*, *41*(2), 124-135.

Rahmato, D. (2014). The Perils of Development from Above: Land Deals in Ethiopia. *African Identities*, 12(1), 26-44.

Reardon, T., Delgado, C. L., & Matlon, P. (1992). Determinants and effects of income diversification amongst farm households in Burkina Faso. *Journal of Development Studies*, 28(1), 264– 296.

Riera, O., & Swinnen, J. (2015). *Household level spillover effects from biofuels: Evidence from Ethiopia* (No. 1008-2016-79987).

Rijkers, B., Söderbom, M., & Loening, J. L. (2010). A rural–urban comparison of manufacturing enterprise performance in Ethiopia. *World Development*, *38*(9), 1278-1296.

Rivera, W.M., and G. Alex. (2003). Extension Reform for Rural Development. Washington, DC: World Bank.

Roseboom, J., N. Beintema, N., Pardey P.G. (1994)., Statistical Brief on the National Agricultural Research System of Ethiopia, International Service for National Agricultural Research (ISNAR), The Hague, The Netherland.

Schoneveld, G. C. (2014). The geographic and sectoral patterns of large-scale farmland investments in sub-Saharan Africa. *Food Policy*, *48*, 34-50.

Shapiro, B.I., Gebru, G., Desta, S., Negassa, A., Nigussie, K., Aboset, G. and Mechal, H. (2015). Ethiopia livestock master plan. ILRI Project Report. Nairobi, Kenya: International Livestock Research Institute (ILRI).

Sitko, N. J., & Jayne, T. S. (2014). Structural transformation or elite land capture? The growth of “emergent” farmers in Zambia. *Food Policy*, *48*, 194-202.

Snijders, T. A. B., & Berkhof, J. (2006). Diagnostic checks for multilevel models. In J. de Leeuw (Ed.), Handbook of multilevel analysis (pp. 141–175). New York: Springer.

Staal, S. J., Baltenweck, I., Waithaka, M. M., DeWolff, T., & Njoroge, L. (2002). Location and uptake: integrated household and GIS analysis of technology adoption and land use, with application to smallholder dairy farms in Kenya. *Agricultural Economics*, *27*(3), 295-315.

Stawski, R. S. (2013). Multilevel analysis: an introduction to basic and advanced multilevel modeling.

Udo, H. M. J., Aklilu, H. A., Phong, L. T., Bosma, R. H., Budisatria, I. G. S., Patil, B. R., ... & Bebe, B. O. (2011). Impact of intensification of different types of livestock production in smallholder crop-livestock systems. *Livestock science*, *139*(1-2), 22-29.

UNDP. 2013. "An Assessment of Operation and Performance of Commercial Farmers in Ethiopia." United Nations Development

Wake, J. L., Kiker, C. F., & Hildebrand, P. E. (1988). Systematic learning of agricultural technologies. *Agricultural Systems*, *27*(3), 179-193.
Wollni, M., & Andersson, C. (2014). Spatial patterns of organic agriculture adoption: Evidence from Honduras. *Ecological Economics*, *97*, 120-128.
Worku, I. H., Dereje, M., Minten, B., & Hirvonen, K. (2017). Diet transformation in Africa: The case of Ethiopia. *Agricultural economics*, *48*(S1), 73-86.
World Bank (2007). World development report 2008: agriculture for development. New York, NY: Oxford University Press
Wossen, T., Abdoulaye, T., Alene, A., Haile, M. G., Feleke, S., Olanrewaju, A., & Manyong, V. (2017). Impacts of extension access and cooperative membership on technology adoption and household welfare. *Journal of Rural Studies*, *54*, 223-233.
Yang, W. & Sharp, B. (2016). Spatial analysis of dairy yields response to intensive farming in New Zealand. In: Integrated nutrient and water management for sustainable farming. (Eds L.D. Currie and R. Singh). http://flrc.massey.ac.nz/publications.html. Occasional Report No. 29.

Annex for chapter three

Annex 3.1: Socio-demographic variables of households (HH) owning livestock

Regions	HHs (number)	HH size (average)	Age of household head (average)	Sex of household head (male-%)	Illiterate %)	Primary (%)	Secondary and higher (%)
Tigray	275	5.36	49.92	76.00	67.18	31.30	1.53
Afar	115	5.68	44.94	72.17	77.67	15.53	6.80
Amhara	586	4.91	48.36	84.44	83.21	15.18	1.61
Oromia	608	5.68	47.95	76.32	53.66	38.33	8.01
Somali	201	5.88	49.86	76.62	78.76	18.13	3.11
Benshangul Gumuz	82	5.18	45.02	81.71	53.75	35.00	11.25
SNNP	754	5.68	46.84	79.31	56.35	37.57	6.08
Gambella	43	6.05	45.21	79.07	54.76	21.43	23.81
Harari	101	5.99	47.64	82.18	66.67	30.30	3.03
Dire Dawa	113	5.17	48.20	76.99	68.87	27.36	3.77
Total sample	**2,878**	**5.49**	**47.82**	**79.01**	**65.44**	**29.38**	**5.18**

Source: author's computations based on the 2015/16 ESS data.

Annex 3.2: Ownership of exotic cows and use of modern livestock management methods by region

Regions	Exotic/improved livestock (average)	HHs owning exotic breeds (%)	HH practicing controlled breeding (%)	HH using improved feed (%)	HHs vaccinating livestock (%)
Tigray	2.76	10.55	13.09	8.87	54.91

Afar	5.00	0.87	0.00	12.82	11.50
Amhara	3.19	9.04	6.83	3.15	40.96
Oromia	2.71	7.40	6.25	8.51	51.16
Somali	11.50	2.99	5.47	8.82	29.85
Benshangul Gumuz	1.50	2.44	7.32	0.00	67.07
SNNP	2.26	5.04	4.51	5.82	46.08
Gambella	1.00	2.33	0.00	0.00	21.43
Harari	3.39	17.82	7.92	34.94	30.69
Dire Dawa	1.67	2.65	6.19	10.23	72.57
Total sample	**3.07**	**6.81**	**6.25**	**7.41**	**45.19**

Source: author's computations based on the 2015/16 ESS data.

Annex 3.3. Milk productivity per day per cow and households practicing modern livestock management

Regions	Total number of cows	Exotic breeds	Controlled breeding	Improved feed	Exotic cows + improved feed	Vaccinating livestock
Tigray	1.50	2.47	1.93	2.66	4.71	1.51
Afar	1.66	na	na	1.00	na	2.00
Amhara	1.35	1.78	2.02	2.91	4.7	1.42
Oromia	1.94	4.51	2.41	3.12	5.67	1.74
Somali	1.99	2.33	2.18	2.11	na	1.86
Benshangul Gumuz	1.40	na	1.94	na	na	1.40
SNNP	1.66	2.96	2.64	1.46	2.17	1.67
Gambella	2.20	2.00	na	na	na	2.00
Harari	2.20	3.36	4.00	2.25	3	2.13
Dire Dawa	1.94	2.00	2.33	1.71	na	1.95
Total sample	**1.69**	**2.48**	**2.33**	**2.24**	**4.05**	**1.65**

Source: author's computations based on the 2015/16 ESS data.

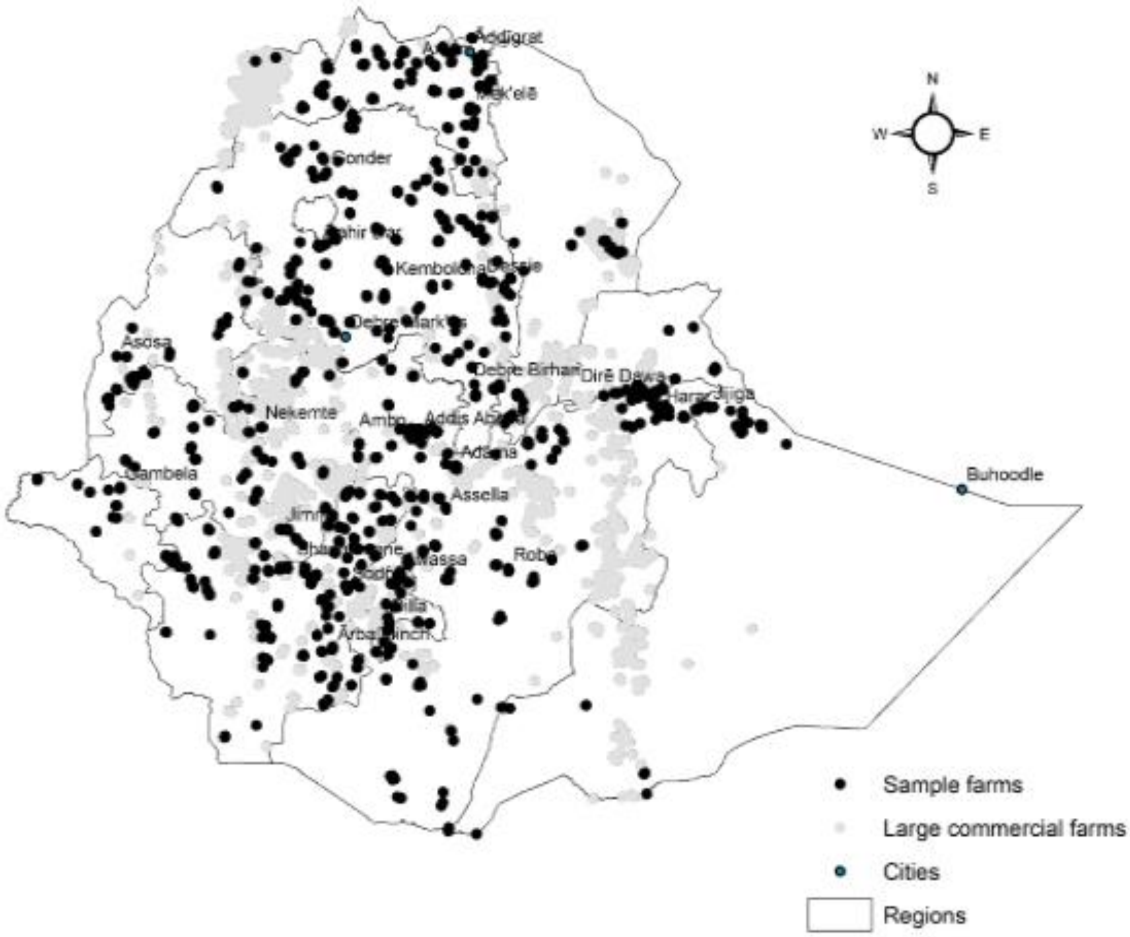
Annex 3.4: Correcting for selection bias via Heckman two-step estimation: milk yields

Independent variables	Multilevel
Number of milked cows	0.162***
	(0.0276)
Number of milked cows squared	-0.0076***
	(0.0015)
Number of months a cow is milked	-0.0066
	(0.0259)
Number of months a cow is milked squared	0.0020
	(0.0020)
Number of technology adopters in a community	0.0021
	(0.0118)
Ln (household size)	0.0597

	(0.0460)
Ln (age of household head in years)	2.275
	(1.433)
Ln (age of household head squared in years)	-0.296
	(0.187)
Sex of household head (male=1)	-0.0558
	(0.0525)
Education level of household head (primary=1)	0.0791
	(0.0513)
Education level of household head (secondary=1)	0.278**
	(0.120)
Education level of household head (tertiary=1)	-0.0645
	(0.149)
Variable from PCA on technology and livestock management	0.0633***
	(0.0177)
Sample selection variable	-0.890
	(0.922)
Extension agent lives in the community (=1)	0.172**
	(0.0860)
Access to community level facilities (PCA)	0.0668**
	(0.0261)
Ln (distance to the nearest HH that own exotic breeds)	-0.0224
	(0.0139)
Ln (distance to the nearest HH that practices improved breeding)	-0.0132
	(0.0167)
Ln (distance to the nearest HH that uses better feed)	0.0255
	(0.0155)
Ln (distance to the nearest HH that vaccinates livestock)	0.0115
	(0.0145)
Ln (total population of the nearest city with > 200,000 inhabitants)	0.0578
	(0.0388)
Ln (distance to the nearest grass land area)	0.0363
	(0.0319)
Ln (distance between the HH and the nearest large farm)	-0.00156
	(0.0341)
Ln (area cultivated by large farms in ha)	-0.00347
	(0.0178)
Regional dummy (Tigray=1)	-0.280**
	(0.138)
Regional dummy (Amhara=1)	-0.365***
	(0.116)
Regional dummy (Oromia=1)	-0.109
	(0.112)
Regional dummy (SNNP=1)	-0.207*
	(0.110)
Constant	-0.666
	(0.746)

Woreda level random effect	-1.347***
	(0.112)
Household level random effects	-0.483***
	(0.0235)
Observations	
Number of groups	224

Standard errors are shown in parentheses
*** p<0.01, ** p<0.05, * p<0.1



Annex 3.5. Spatial distribution of analyzed smallholder and commercial farms

4. Chapter Four: Paper III - Demand elasticities of animal source food consumption in Ethiopia

Jonse Bane Boka

Economics Department

Addis Ababa University (Ethiopia)

jonseboka@yahoo.com; jonse.bane@aau.edu.et

Abstract

This paper examines consumption patterns of animal source foods (ASFs) and estimates their prices and expenditure elasticities by locations, expenditure quintiles and literacy. It applies censored Quadratic Almost Ideal Demand System (QUAIDS) to nationally representative Ethiopian household consumption expenditure (HCE) survey data of 2015/16. The findings indicate that ASFs consumption habits of Ethiopian households are limited to a few ASFs mainly dairy products. On average, rural household consumed higher quantity of dairy products, beef and goat and sheep meats compared to urban households per year but expenditures on meats are higher for urban dwellers may be due to higher meat prices in urban areas and urban households consumed better quality meats. Elasticity estimates reveal that consumption of ASFs is more sensitive to expenditure and price changes compared to staple foods. The results also indicate that meat groups are luxury while dairy products are necessity for all Ethiopian households. The findings also indicate that poor households benefit more from an increase in income level in terms of improving consumption of ASFs and at the same time higher prices of ASFs more severely affect poor households, which may exacerbate malnutrition among poor households. The findings also indicate that households substitute one ASF for the other. The paper suggests that tailored price and income policies could improve consumption of ASFs among poor households.

Keywords: consumption pattern of ASFs; censored QUAIDS; elasticity estimates; Ethiopia

JEL classification: D12, Q18

4.1. Introduction

Ethiopia is an agrarian society whose agricultural sector accounts for about 37 percent of GDP, generates 70 percent of export earnings, and employs about 75 percent of the country's workforce (National Planning Commission, 2016). Ethiopia's livestock is the one of the important among the agricultural sectors, generating about a quarter of agricultural GDP. Thus, in terms of growth, livestock has a strong influence on overall economic growth in Ethiopia, as in most nations in sub-Saharan Africa (SSA). The livestock sector has also a significant nutritional value in the rural areas of developing economies, including Ethiopia, as livestock products account for a significant proportion of nutritional intake (Hoddinott et al., 2015). This implies that there are strong links between the consumption of livestock products and improved nutritional outcomes. As in other economies, Ethiopian households have also started to experience a decline in the share of food expenditure on cereals coupled with an increase in the share of expenditure on high-protein foods like ASFs (Worku et al., 2017). This indicates a shift in consumption behavior from starchy foods to more protein-rich food items including ASFs. Changes in patterns of household consumption and responsiveness to changes in income and prices are bases for designing appropriate food, nutrition, and price policies by location and income groups, which is the focus of the present paper.

To this point, a number of empirical studies have estimated expenditure and price elasticities for food in general and ASFs in particular by focusing on transitional and developing economies, including SSA (see, for instance, Ecker et al., 2010; Chen & Abler, 2014). Country-specific studies in transitional economies such as China use censored QUAIDS and/or linear almost ideal demand systems (AIDS) to measure responsiveness of households to price and income changes (Yen et al., 2004; Jiang & Davis 2007; Zhuang & Abbott 2007; Zheng & Henneberry, 2009; Chen et al., 2016). Several studies in India also estimated household level price and income elasticities for various food items including ASFs using censored QUAIDS or linear AIDS (Gandhi & Zhou, 2010; Kumar et al., 2011; Chengappa et al., 2016). In Brazil, Coelho et al. (2010) estimated demand elasticities for foods using censored QUAIDS. Bilgic & Yen (2013) estimated price and income elasticities for Turkish households for sixteen food items using linear AIDS.

There are similar studies in the context of SSA including Ethiopia, Kenya, Malawi and South Africa (see Agbola, 2003; Abdulai & Aubert, 2004; Tafere et al., 2010; Ecker & Qaim, 2011; Hassen & Tafere, 2012; Ogundari & Abdulai, 2013; Cornelsen et al., 2016; Delport et al., 2017; Worku et al., 2017; Abegaz et al., 2018; Colen et al., 2018). However, except few, these and other African-specific previous studies tend to focus on estimating elasticities at aggregate level by merging different ASFs as single goods and hence ignore details of important ASFs (such as dairy products, beef, mutton and goat meats). Moreover, previous studies in Africa did not estimate demand elasticities by location (urban vs. rural) except few studies (Hassen & Tafere, 2012; Worku et al., 2017; Abegaz et al., 2018). More importantly, to the knowledge of the author, no earlier studies in Africa have considered that elasticities could be affected by differences in expenditure quintile and literacy (literate vs. illiterate).

Thus, the contribution of this paper to the current literature is that it estimates elasticities by expenditure quintile and literacy, which to the author's knowledge has not been done before in Ethiopia. Moreover, this paper utilizes a nationally representative unique Ethiopian household survey dataset from 2015/16 that has not been used in previous studies with a similar focus. Hence, this paper can provide new knowledge about changes in food preferences in response to changes in income, urbanization, and education of households and provide comparative elasticities across location (urban vs. rural), literacy level, and expenditure quintiles.

The rest of this paper is organized as follows: section 4.2 provides a brief summary of the literature, section 4.3 details the methodology applied, and section 4.4 presents descriptive and estimation results. The paper ends with some concluding remarks and policy implications.

4.2. Literature review

4.2.1. Theoretical framework

In estimating responsiveness of households' consumption to changes in income, prices and socio-economic characteristics (age, education, household size, etc.), economic theory has proposed two approaches. The first approach is the single equation demand model (partial analysis), which has its root in the goods characterization model by Lancaster (1971). The basic tenet of the model is that consumers derive utility from the characteristics of goods (or a bundle of goods) such as color, shape, size, taste, etc., not from the good itself. This method of demand estimation is simple to apply. However, it has a drawback as it does not capture interdependencies among commodities consumed by households, which are constrained by households' budgets and exogenous prices of commodities. Consequently, the second estimation approach – the demand system approach – was developed by Deaton and Muellbauer (1980), who called it AIDS. This demand system has two desirable properties; first, it simultaneously estimates a system of demand equations and hence takes care of interdependencies among goods in household consumption. Second, since it is derived from a utility maximization problem, it satisfies some properties: adding-up, homogeneity, and symmetry. Due to these properties and its flexibility, several authors applied AIDS (Green & Alston, 1990; Hayes et al., 1990; Cornelsen et al., 2016; Delport et al., 2017).

The original AIDS model was extended by Banks et al. (1997) to QUAIDS, which captures the idea of the Engel curve. In addition, both the linear and quadratic AIDS models were modified by Heien and Wessells (1990) and Shonkwiler and Yen (1999) in the context of two-step estimation procedures to deal with the data-censoring problem. The two-step modification of QUAIDS has dominated demand system estimations over the last two decades (Piggott & Marsh 2004;

Thompson, 2004; Coelho et al., 2010; Ecker & Qaim, 2011). Having rich evidences of the advantages of QUAIDS over linear AIDS, this paper applies QUAIDS to estimate expenditure- and price-elasticity parameters in the ten equations demand system for ten food items (five are ASFs and the remaining five are foods outside ASFs)[32].

4.2.2. Empirical review

Over the last two decades, several studies have estimated income/expenditure and price elasticities of AIDS and QUAIDS for foods including ASFs with a focus on transitional and developing countries as well as SSA (e.g., Abdulai & Aubert, 2004; Ecker et al., 2010; Ecker & Qaim, 2011; Ogundari & Abdulai, 2013). There are also some studies that have estimated prices and income elasticities for ASFs focusing on transitional economies. A meta-analysis by Chen and Abler (2014) for BRIIC countries (Brazil, Russia, India, Indonesia, and China) find that demand for animal products is more sensitive to price but less sensitive to income. Similarly, a meta-analysis in China by Chen et al. (2016) reveal that as income increases, the demand for food and livestock products has been declining, however, less for animal products. The authors also find that food items including ASFs become more sensitive to changes in prices indicating that economic development in China brings improved supply chains that provide consumers with better choices of food items. ASFs had higher income elasticity in rural China (Jiang & Davis 2007). In Turkey, Akbay et al. (2007) find higher expenditure elasticity for meat and meat products compared with other foods. Empirical results from India indicate that cereals have lower income elasticity while animal products have higher income elasticity with an increasing trend in consumption of livestock products indicating that as income increases, households shift their consumption to protein-rich food items (see for instance, Kumar et al., 2011; Gandhi & Zhou, 2010). Using the 2002/03 Brazilian household budget survey, Coelho et al. (2010) estimate the QUAIDS in the context of censored two-step estimation procedure and reported that high-quality beef, powdered milk, and cheese are income-elastic indicating that these products are luxury goods in Brazil while fluid milk, low-quality beef, butter, and pork are income-inelastic suggesting that fluid milk, butter, and pork are normal goods.

In Africa, using a meta-analysis, Colen et al. (2018) indicate a variation in income elasticities among different food groups, where staple foods such as cereals and legumes have lower income elasticities whereas foods with higher nutritional values such as ASFs (meat, eggs, fish, and dairy products) have higher income elasticities indicating that an increase in income of African countries encourages consumption of high-protein foods. Using linear AIDS, Cornelsen et al. (2016) analyze consumption of ASFs in Nairobi, Kenya, finding that beef is income-elastic whereas dairy products

[32] Five ASFs: beef; mutton and goat meat; dairy products; eggs and chickens; and other ASFs (pig, camel meats, all types of fish, internal organs, etc.), and non-ASFs also divided into five groups: cereals; oil and pulses, fruits and vegetables, spices and stimulants, and other foods including all processed food consumed outside and salt).

are income-inelastic. They also indicated that beef and dairy products are less price-sensitive as own price elasticities for these products are less than unity. In Malawi, Ecker and Qaim (2011) estimate income and price elasticities of food, calorie, and micronutrient with the censored demand system using disaggregated household-level data and find that eggs, red meat, and milk and dairy products are price-elastic while white meat and fish are price-inelastic. Applying linear AIDS to the 1993 national household survey in South Africa, Agbola (2003) analyzes price and income elasticities of various food items and found that animal products (meat, fish, and dairy products) and grains are price-elastic and expenditure elasticities are greater than unity for ASFs indicating that livestock products are luxury goods in South Africa. After nearly fifteen years, using linear AIDS, Delport et al. (2017) find that meat groups such as poultry and mutton and goat meats are income-elastic indicating that ASFs are still luxury goods in most African countries.

In Ethiopia, using nationally representative household level datasets, Kedir (2005), Ulimwengu et al. (2009), and Tafere et al. (2010) estimate price elasticities for livestock products at aggregate level and hence these studies ignored the breakdown of livestock products. Using the same dataset from 2004/05, Hassen and Tafere (2012) make a detailed analysis of consumption patterns and elasticities of livestock products in Ethiopia. Worku et al. (2017) estimated the censored demand system based on the 2010/11 HCE (Household Consumption Expenditure) survey of CSA and they point out that households have shifted their consumption from cereals to high-value products such as ASFs. Similarly, Abegaz et al. (2018) examined patterns and changes of ASFs over the last fifteen years and estimated expenditure and price elasticities for the year 2010/11 using the censored demand system and conclude that prices and income are major contributors to changes in the consumption of ASFs. However, their studies do not analyze elasticities by expenditure quintiles and literacy level.

4.3. Methods and data

4.3.1. Econometric models

Based on the theory of utility maximization by the consumer and applying Roy's identity to an indirect utility function (see Banks et al., 1997 for details), the quadratic demand function for expenditure share of commodity i and household h (w_{ih}) can be specified as

$$w_{ih} = a_{\mathrm{i}} + \sum_{j=1}^{k} \gamma_{ij} \ln p_j + \beta_{\mathrm{i}} \ln\left[\frac{y_h}{a(p)}\right] + \frac{\lambda_i}{b(p)}\left\{\ln\left[\frac{y_h}{a(p)}\right]\right\}^2 \qquad (1)$$

where y_h is household h budget; p_i and p_j refer to prices of commodity i and j, respectively; $\ln a(p)$ is the transcendental log function, which takes the form

$\ln a(p) = \alpha_0 + \sum_{i=1}^{k} \alpha_i \ln p_i + \frac{1}{2} \sum_{i=1}^{k} \sum_{j=1}^{k} \gamma_{\mathrm{ij}} \ln p_i \ln p_j$; $b(p)$ is the Cobb-Douglas price aggregator, which is defined as $b(p) = \prod_{i=1}^{k} p_i^{\beta_i}$, and the price aggregator lambda is given as $\lambda(p) = \sum_{i=1}^{k} \lambda_i \ln p_i$

Except α_0, all the symbols alphas, betas, gammas, and lambdas are parameters to be estimated.

The demand function in equation (1), which is derived from a well-behaved utility function, has some desirable properties such as adding-up to unity (for expenditure share) or adding-up to total expenditure in monetary value, homogeneity of degree zero (only in prices for compensated or Hicksian demand function or both in prices and income for uncompensated or Marshallian demand function), and symmetry in responses to cross-prices. The expression in equation (1) is the QUAIDS, which was proposed by Banks *et al.* (1997) by extending the original AIDS introduced by Deaton and Muellbauer (1980). The quadratic term in equation (1) captures the Engel curve, which indicates that, depending on income level and time, a commodity can be a luxury good at one point in time and become a normal good at another point. For instance, in Ethiopia beef is luxury among poor households but it is normal food for better-off households. Finally, if lambda is equal to zero, the QUAIDS boils down to the original AIDS without the quadratic term. Thus, by testing the hypothesis that $\lambda_i = 0 \forall i$, one can easily choose between original and quadratic AIDS models.

The QUAIDS equation initially proposed by Banks et al. (1997) did not, however, include socio-demographic variables. Following previous studies (Gao et al., 1997; Lazaridis, 2003; Ecker & Qaim, 2011), socio-demographic and other relevant variables linearly enter the QUAIDS via the intercept term, which becomes

$$a_i = \alpha_i + \sum_{HD} \theta_{iHD} HD_h \qquad (2)$$

where HD_h is household socio-demographic characteristics (age, sex, household size, and literacy), and the alpha and thetas are parameters to be estimated.

By substituting equation (2) into equation (1), the original QUAIDS can be modified as

$$w_{ih} = \alpha_{\mathrm{i}} + \sum_{j=1}^{k} \gamma_{ij} \ln p_j + \beta_{\mathrm{i}} \ln\left[\frac{y_h}{a(p)}\right] + \frac{\lambda_i}{b(p)} \left\{\ln\left[\frac{y_h}{a(p)}\right]\right\}^2$$
$$+ \sum_{HD} \theta_{iHD} HD_{hh} \qquad (3)$$

The adding-up property requires that all the thetas for HD vectors of variables sum to zero for all ten equations for ten foods groups[33].

Data censoring

However, since household survey data have a plethora of zeros, estimating equation (3) without considering these zeros leads to biased and inconsistent parameter estimates of QUAIDS and hence elasticity estimates are biased and inconsistent (Maddala, 1986). The zeros on consumption of one or more commodities can occur for a number of reasons including imperfect recall about specific commodities consumed during the survey period, permanent zero consumption owing to preferences or tastes (e.g., health- and/or religious-related reasons), short survey period, and corner solution as a result of high price of a commodity and/or lower income of a consumer.

In the presence of numerous zeros in the dependent variables, how to correctly estimate the parameters is a matter of continuing debate in applied economics. Over the last decades, seminal papers have proposed a two-step estimation technique to address problems arising from data censorship in a household survey dataset (Heien & Roheim, 1990; Shonkwiler & Yen, 1999). In the world of i commodities (i=1, 2, 3, …, k) and h consumers/households, the latent dependent variable for the selection equation (d_{ih}^*) and result equation (w_{ih}^*) is governed by the following two stochastic equations:

$$\begin{aligned} d_{ih}^* &= Z_{ih}^{'} \theta_i + v_{ih} \\ w_{ih}^* &= x_{ih}^{'} \mu_i + u_{ih} \end{aligned} \quad , \qquad (4)$$

where x_{ih} and z_{ih} are explanatory variables, μ_{i} *and* θ_{i} are vectors of parameters to be estimated and v_{ih} and u_{ih} are identically and independently distributed error terms of selection and result

[33] ASFs are: beef; mutton and goat meat; dairy products; eggs and chickens; and other ASFs (pig, camel meats, all types of fish, internal organs, etc.), and non-ASFs also divided into five groups: cereals; oil and pulses, fruits and vegetables, spices and stimulants, and other foods including all processed food consumed outside and salt).

equations, respectively. The observable dependent variables for the selection equation (d_{ih}) and result equation (w_{ih}) are given by the following equations:

$$d_{ih} = \begin{cases} 1 \ if \ d_{ih}^{*} > 0 \\ 0 \ if \ d_{ih}^{*} \leq 0 \end{cases} \qquad (5)$$
$$w_{ih} = d_{ih} w_{ih}^{*}$$

The idea of the two-step estimation procedure is that in the first step the probit model is estimated and the correction factor, which is used in the second step procedure, is derived from the first-step estimation procedure. Specifically, in the first step, the approach by Heien and Roheim (1990), HW hereinafter, generated the inverse Mills ratio, ($\frac{\phi(Z_{ih}\alpha_i)}{\Phi(Z_{ih}\alpha_i)}$), where $\phi(Z_{ih}\alpha_i)$ is a normal density function (pdf) and $\Phi(Z_{ih}\alpha_i)$ is a normal cumulative distribution function (cdf). The pdf and cdf are generated from the first step probit model[34]. The HW estimation procedure used the inverse Mills ratio in the second step as the correction factor for censored dependent variable, which is similar to the Heckman sample selection model. However, as indicated by Shonkwiler and Yen (1999), SY hereinafter, there is internal inconsistency in the HW approach and hence it lacks theoretical and statistical foundations. By assuming that the cross-equation error terms are bivariate normal distribution with $\text{cov}(u_{ih}, v_{ih}) = \sigma_i$, SY proposed an alternative two-step procedure that solved the internal inconsistency of HW. According to SY, the unconditional expectation of w_{ih} is given by:

$$E(w_{ih} / x_{ih}, Z_{ih}) = \Phi(x_{ih}, Z_{ih}) x_{ih}^{'} \mu_i + \delta_i \phi(x_{ih}, Z_{ih}) \qquad (6)$$

By substituting equation (6) into the system of equations in (5), the result/expenditure share equation can be written as:

$$w_{ih} = \Phi(x_{ih}, Z_{ih}) x_{ih}^{'} \mu_i + \delta_i \phi(x_{ih}, Z_{ih}) + \varepsilon_{ih} \qquad (7)$$

Similar to that of HW, the first-step estimation procedure of SY estimates a simple probit model by regressing d_{ih} on a set of regressors x_{ih} and generates the pdf or $\phi(Z_{ih}\alpha_i)$ and cdf or $\Phi(Z_{ih}\alpha_i)$ for each household. Specifically, the estimated model in the first step is:

[34] Results of first stage probit models are reported in annexes 4.3 to 4.10

$$d_{ih} = \beta_0 + \sum_j \beta_{ij}\, ln\, p_j + \beta_i\, ln\, y_h + \sum_{HD} \theta_{iHD}\, HD_h + \sum_{Dr} \beta_{iD}\, D_r + \varepsilon_{ih} \qquad (8)$$

where d_{ih} takes the outcome of one if household h consumes an ASF under consideration and zero otherwise, p_j denotes prices of commodities considered, y_h is household total food expenditure, HD_h is vector of household socio-demographic characteristics (age, sex, household size, literacy, assets ownership), and D_r represents regional dummies (regional states of the country, where one region serves as reference category). Equation (8) is estimated for all 10 commodities in the demand systems and the pdf and cdf are computed, which are utilized as correction terms to address censoring in the dependent variable in the second-step estimation procedure. Specifically, the pdf and cdf are incorporated in the budget share system as in equation (7), and the system is finally estimated in the seemingly unrelated regression (SUR) framework. The parameter estimates obtained by SUR are consistent, but since the error term in equation (7) is heteroscedastic, these second-step estimates are inefficient. This paper employs the robust standard error to address problems of heteroscedasticity.

In addition, since food expenditure is jointly determined within the system, there is an endogeneity problem, which leads to bias and inconsistent estimates of elasticity parameters. Applying Blundell and Robin's (1999) two-step approach, this paper corrects the endogeneity problem by regressing the total food expenditure on prices (p), demographic variables (HD), and dummy variables for regions. The residual from this regression (e_y) is used as an additional regressor in the second-step estimation procedure of the QUAIDS. Thus, in QUAIDS with demographic variables, correction terms for data censoring, and adjustment for the endogeneity problem, the SY second-step estimable models become

$$w_{ih} = \Phi(x_{ih}, Z_{ih}) \left(\begin{array}{l} \alpha_i + \sum_{j=1}^{k} \gamma_{ij} \ln p_j + \beta_i \ln\left[\frac{y_h}{a(p)}\right] + \frac{\lambda_i}{b(p)} \left\{ \ln\left[\frac{y_h}{a(p)}\right] \right\}^2 \\ + \sum_{HD} \theta_{iHD} HD_h + \theta_i e_{iy} \end{array} \right) + \delta_i \phi(x_{ih}, Z_{ih}) + \varepsilon_{ih} \qquad (9)$$

where $\phi(x_{ih}, Z_{ih})$ and $\Phi(x_{ih}, Z_{ih})$ are pdf and cdf obtained from the first-step probit estimates.

The other issues are lack of market prices for all goods in the HCE survey dataset. One possible solution to the lack of market prices in the dataset is employing a unit value that is defined as ratio of total expenditure on a specific good to quantity of that good consumed/purchased. This can easily be done as the HCE survey dataset has both total values and volumes of goods consumed by a household. Using unit value as proxy for market prices has both merits and demerits. The advantages of employing unit value in estimating QUAIDS are first that it provides detailed information at disaggregated geographical locations whereas actual market price gives information at aggregate levels or at large market centers. Second, unit value deals with household-level information and hence it takes into account heterogeneity in household preferences.

Using unit value as proxy for actual market price, however, has two major demerits: the quality effects related to aggregating commodities of different qualities into one subgroup and measurement errors in unit value due to the fact that either quantity or expenditure or both could be measured with errors. As unit value does not consider quality of different commodities in a group and the implication is that if the price of a good increases, consumers do not only reduce their consumption of this good but also look for a low-quality version of the good (substitution for lower quality of the good), a rise in the price of the good produces a less than proportional rise in unit value. This is when the price increases, but we employ a unit value as the market price is unobservable; the same change in quantity will induce a smaller change in unit value due to substitution effects among various qualities of the good. Consequently, price elasticity is overstated. Using weak separability assumption in utility function, Deaton (1988) proposed the solution for such a quality problem based on the assumption of weak separability of preferences. However, recent studies strongly reject the Deaton method (McKelvey, 2011) and hence it is no more valid to use this method to correct for the quality problem. Following Cox and Wohlgenant (1986), several studies (e.g., Lazaridis 2003; Cornelsen et al., 2016) proposed a quality-corrected unit value, which is defined as the residual plus the average regional or local unit value. The residual is obtained by regressing natural logarithmic of unit value on natural logarithmic of total food expenditure, household characteristics, assets of the households, and regional dummies, etc.

The second problem in utilizing a unit value as proxy for market price is that the unit value, which is the ratio of expenditure to quantity, could be contaminated by measurement errors in both quantity and total expenditure. Consequently, it might be spuriously negatively related to budget share as it overestimates actual market prices (Capéau & Dercon, 2006). However, several previous studies have reported that measurement errors are not a serious problem (Kedir, 2005; Lazaridis, 2003; McKelvey, 2011). Finally, since households in the same areas likely face the same price, the missing unit values was replaced by average unit value of the woreda or region.

4.3.2. The data and characterization of sampled households

This paper uses data from the 2015/16 Ethiopian HCE survey. The survey has been conducted every four years since 1995/96 and was known as the household income consumption expenditure survey during the first three rounds (1995/96, 1999/2000, 2004/2005). The last two surveys (2010/11 and 2015/16), however, have omitted the income component (which normally underestimates the income of households) and focused on household consumption expenditure, which measures the living standard of households and monitors trends of poverty in the country.

The unique feature of the 2015/16 survey is that, unlike the previous four surveys where data were collected via paper-based questionnaires, the 2015/16 HCE survey data were collected using computer-assisted personal interview (CAPI) methods, which have several advantages over paper-based methods of data collection. The 2015/16 survey also covered all rural and urban areas of Ethiopia including non-sedentary zones of the Afar and Somali regions, which were excluded from all previous four surveys. A total of 30,229 households (10, 368 HHs from rural areas and 19,861 HHs from urban areas) were included in the 2015/16 HCE survey, which were selected from 2,106 enumeration areas (EAs)[35] (864 and 1,242 EAs from rural and urban areas, respectively). Additionally, unlike previous surveys, in the 2015/16 HCE survey, the data collection was administered for HCE and household welfare monitoring surveys simultaneously.

Similar to previous surveys, for the 2015/16 HCE survey, CSA divided the country into three broad categories: 'rural', 'major urban centers', and 'other urban centers'.[36] The 'rural' category includes the rural areas of all nine regional states of the country and rural areas of Dire Dawa City Administration indicating that for the 2015/16 HCE survey samples were taken from all rural parts of the country. 'Major urban centers' mainly comprise 31 major urban centers: all nine regional capitals, 10 sub-cities in Addis Ababa and twelve other major urban centers with more dwellers than other urban centers. 'Other urban centers'[37] comprise all urban areas from eight regional states that are not included in the 'major urban centers' category. This category does not select samples from Harari Regional State and Addis Ababa and Dire Dawa City Administrations as they fall under the category of 'major urban centers', while rural areas of the Harari region and Dire Dawa City are included in the 'rural' category.

The HCE survey adopted stratified two- and three-stage cluster sampling techniques along with probability proportional to size (PPS) and systematic techniques. Specifically, in the 'rural' and 'major urban centers' categories, the survey applied stratified two-stage cluster sampling where these categories are clustered into enumeration areas. For 'other urban centers', stratified three-stage cluster sampling techniques were employed to select towns, enumeration areas, and households. In all three categories ('rural', 'major urban centers', and 'other urban centers'), EAs were selected using probability proportional to size sampling technique where 'size' refers to number of households reported in the 2007 Population and Housing Census of the country. Households were systematically selected from sampled EAs using new lists of households prepared by CSA for this purpose at the beginning of the survey.

[35]Enumeration area is a specific location/land demarcated to enumerate housing units and population without omitting and duplicating the housing unit and population. One EA usually consists of 150 to 200 households both in rural and urban areas.
[36]Urban centers are defined (at least for the HCE survey) as, regardless of their residents, (i) all administrative capitals (regions, zones, and woredas), (ii) residential areas with urban dwellers' kebele, which is not in (i) above, and (iii) localities with 1,000 or more residences not included in (i) and (ii) above.
[37] In the demand system and all analyses, urban area includes both 'major urban centers', and 'other urban centers' in the country

The data collection covered one year, 8 July 2015 to 7 July 2016, deploying 89 supervisors and 267 enumerators organized into 89 data collection teams indicating that one data collection team consisted of one supervisor and three enumerators (two enumerators for the HCE survey and one for the household welfare monitoring survey).[38] Two enumerators were assigned to each EA and an enumerator visited six and eight households in rural and urban areas, respectively. An enumerator completed data collection in an EA within one week collecting data from two to three households per day, hence visiting the household twice in the survey week. Data collection techniques were interviews and objective methods where in the former enumerators collected information from households while in the latter data were generated by measuring consumption of foods and beverages. Depending on the nature and types of expenditure, different reference periods were applied when generating expenditure data such as twice a week (food, beverage, and tobacco consumption; consumption of pharmaceutical products and drugs; communication; water and electricity; etc.), during last month (furnishings, household equipment and maintenance; housing, water, electricity, fuel and power; transport service; communication; education; etc.), during the last 12 months (renting of durable goods and less frequent services; medical treatment; purchase of communication and transportation facilities and equipment; clothing and footwear; etc.).

Unlike the early HICE surveys, those from 2010/11 and 2015/16 took a large proportion of households from urban centers. Accordingly, nearly two thirds of households included in the 2015/16 HCE survey were sampled from urban areas. Gender wise, about 66 percent of the sampled households are male-headed while the remaining 34 percent are female-headed. The education level of heads of the households indicates that over three fourths of males are literate while only 56 percent of females are literate implying that male heads are relatively better educated than female heads. The average age of male heads is about 41 years and that of female heads nearly 43 years indicating that, on average, female-headed households are led by older people compared to male-headed households. Male-headed households have a larger family size compared to female-headed households. Similarly, there are more adults in male-headed households (3.8 adults) than in female-headed households (2.8 adults), see Table 4.1.

Table 4.1: Some descriptive statistics of survey households

Items	Male-headed	Female-headed	Total
Urban (%)	60.7	75.6	65.7
Rural (%)	39.3	24.4	34.3
Male-headed HHs (%)			66.3
Female-headed HHs (%)			33.7
Literate (%)	75.6	55.6	68.9

[38]As indicated above, the 2015/16 HCE survey and HWMS were conducted simultaneously to ensure consistency between the two surveys.

Illiterate (%)	24.4	44.4	31.1
Average age (years)	41.1	42.6	41.6
Average HH size (number)	4.5	3.4	4.1
Average adult equivalent (number)	3.8	2.8	3.4

Source: Author's computations based on the 2015/16 HCE Survey data

4.4. Results and discussions

4.4.1. Overall households' consumption expenditure

Table 4.2 presents descriptive statistics on food and non-food expenditure by location, gender, expenditure quintiles and education levels. Ethiopian households allocated 54.5 percent of their total budget to food expenditure while the remaining 45.5 percent were allocated to non-food expenditure indicating that food consumption took the lion's share of total household budget.[39] The same trends were observed in other countries such as Uganda, where rural households allocated a greater share of their total budget to food baskets than non-food items (Maltsoglou, 2007). Low-income countries generally also spent nearly 50 percent of their income on food while an average individual in a rich country spent only 20 percent of their income on food (Muhammad et al., 2011; Murcott et al., 2013). This implies that an average household in poor countries spent a significant share of its income on foods while households in advanced countries spent a lion's share of their budget on non-food items.

In Ethiopia, the share of food expenditure in a total household budget varies by location, expenditure quintiles, and education levels. Specifically, households in urban areas as well as better-off households and those with more educated heads spent a larger proportion of their budget on non-food items whereas households in rural areas, worse-off households, and households led by illiterate or less educated heads spent a significant proportion of their income on food (see Table 4.2).

Nationally, nearly 16 percent of total food budget is allocated to ASFs, which is by far less than that of food budget allotted to ASFs in low-income countries. For instance, in urban areas of Nairobi, Kenya, even poor households allocated 38 percent of their food budget to consumption of ASFs (Cornelsen et al., 2016). Households in urban centers apportioned an average of close to 21 percent of their total food budget to ASF consumption, whereas households in rural areas allocated a smaller share of their total food budget to ASFs (an average of 14 percent); they rather allocated a significant share of their food budget to starchy foods like cereals and tubers. For

[39]This contradicts the share of non-food expenditure reported by Worku et al. (2017) using the 2010/11 HCE survey. The basic reason is that this paper left out un-incorporated household expenditure where few households purchased houses and cars, and weighting these expenditures according to the total households in rural and urban centers of the country overestimated total and non-food household consumption expenditure.

instance, households in the poorest quintile allocated about 34 percent of their food budget to cereals. This is related to lifestyles of households where individuals in urban centers are sedentary and hence require fewer calories but individuals in rural areas are engaged in laborious activities that require more energy. Consequently, rural households spent a larger share of their food budget on consumption of calorie-rich crops such as cereals and tubers. Besides, rural households depend on subsistence agriculture, which produces limited crops (mainly cereals) and hence cannot diversify their consumption to protein-rich foods (Regmi and Dyck, 2001).

Table 4.2: Descriptive statistics; overall consumption expenditure by location, literacy and gender

Levels	Average expenditure in ETB (per HH/year)				Share (%) of HH expenditure on ASFs	
Classification	Total	Food	Non-food	ASFs	Total	Food
Location						
Urban	59,827.3	27,522.9	32,309.5	5,651.2	9.4	20.5
Rural	39,507.7	23,110.9	16,396.7	3,146.2	8.0	13.6
Gender						
Male-headed	46,781.4	25,556.9	21,225.6	3,985.7	8.5	15.6
Female-headed	37,871.6	20,392.3	17,479.3	3,100.5	8.2	15.2
Education level						
Primary	46,724.4	25,970.7	20,754.8	3,917.2	8.4	15.1
Secondary	58,337.8	28,036.6	30,301.2	5,904.0	10.1	21.1
Tertiary	74,416.5	31,369.9	43,058.3	7,749.3	10.4	24.7
Other	40,796.5	22,777.4	18,019.1	3,590.8	8.8	15.8
Illiterate	36,580.4	21,473.0	15,107.4	2,707.6	7.4	12.6
Expenditure quintile						
First quintile	22,765.7	14,052.5	8,714.3	1,008.2	4.4	7.2
Second quintile	34,008.0	19,399.9	14,608.1	1,772.6	5.2	9.1
Third quintile	44,489.6	25,312.7	19,178.1	2,922.8	6.6	11.5
Fourth quintile	48,571.4	28,030.5	20,540.8	4,372.6	9.0	15.6
Fifth quintile	72,123.6	34,063.1	38,060.5	8,665.2	12.0	25.4
National level	44,391.6	24,171.2	20,220.4	3,817.5	8.6	15.8

Source: Author's computations based on the 2015/16 HCE Survey data

Food and non-food expenditure by expenditure quintiles reveal some interesting facts in the sense that for the first four quintiles, total food expenditure is greater than non-food expenditure. However, for the richest section of the households (fifth quintile), which covers 20 percent of the total households surveyed, total non-food expenditure is greater than food expenditure. The amount of expenditure on ASFs for the richest section of households is nearly 9 times larger than that of households in the poorest expenditure quintile. Similarly, households in the highest expenditure quintile spent over 25 percent of their food budget on ASFs, while the poorest households spent only 7 percent of their food expenditure on ASFs indicating that richer households spend more on high-protein foods (see Table 4.2). Thus, as income increases, households generally tend to spend more on high-quality and protein-rich foods such as ASFs. Similarly, households headed by a college or university graduate spent nearly 25 percent of their food expenditure on ASFs while those led by illiterate heads spent a smaller proportion of their total food budget on ASFs (13 percent).

A comparison of expenditure on ASFs and cereals reveals that as income increases, the share of the food budget spent on cereals has declined while that allocated to ASFs has increased (see Figure 2). Using the previous HCE survey dataset and welfare monitoring surveys, previous studies in Ethiopia generally reported the same relationship between consumption of ASFs and income levels (Worku et al., 2017; Workicho et al., 2016; Abegaz et al., 2018). The same trends were also found in other poor countries such as Peru (Humphries et al., 2014).

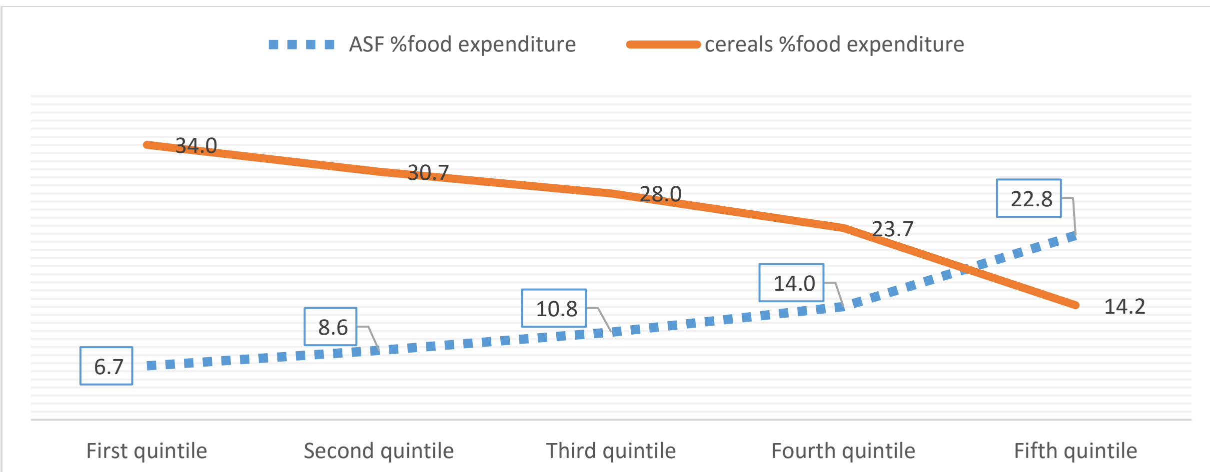


Figure 2: Share (in %) of expenditure on cereals and ASFs in food expenditure by income quintiles

4.4.2. ASFs consumption expenditure, quantity consumed, and consumption seasonality

4.4.2.1. Consumption expenditure on ASFs

In Ethiopia, different types of ASFs such as beef, mutton and goat meats, and dairy products, chicken and eggs, fish and fish products, other meats (camel, pig, etc.), and honey are commonly consumed. However, consumption of ASFs in the country is dominated by three major ASFs: dairy products, beef, and mutton and goat meats, which together constitute over 90 percent of total expenditure on ASFs. Thus, ASFs consumption habits of Ethiopian households are limited to certain livestock products. In pastoral areas of Afar and Somali (eastern and north-eastern parts of the country), dairy products take the lion's share of expenditure on ASFs, while expenditure on beef is higher in urban centers like Addis Ababa and Dire Dawa indicating an uneven distribution of ASF consumption in the country.

Table 4.3: Average HH ASF expenditure by location, literacy, sex of head, and income quintile (in ETB)

Classification	Beef	Mutton and goat meat	Dairy products	Poultry	Egg	Fish	Other meats	Honey
Location								
Urban	1,997.5	1,423.0	1,071.5	392.8	259.7	26.9	454.0	25.9
Rural	693.1	310.8	1,762.1	84.4	47.0	9.1	230.6	9.1
Gender								
Male-headed	1,042.6	603.2	1,747.3	160.1	103.7	13.2	301.4	14.3
Female-headed	908.2	509.5	1,184.1	154.0	82.9	13.8	237.8	10.1
Education level								
Primary	1,030.0	502.7	1,835.1	170.5	86.4	12.3	268.3	11.9
Secondary	2,009.0	1,290.7	1,457.5	362.2	273.0	27.0	443.8	42.8
Tertiary	2,826.2	1,618.7	1,726.4	466.3	457.0	42.8	553.5	47.9
Other	1,035.3	656.5	1,129.8	144.9	56.5	1.4	558.9	7.5
Illiterate	550.3	345.4	1,508.6	73.5	29.6	7.9	187.3	4.9
Income Quintile								
First quintile	124.0	67.0	698.6	10.2	10.7	6.6	88.8	2.3
Second quintile	265.8	142.1	1,151.5	48.6	27.6	12.5	123.3	1.0
Third quintile	542.2	190.6	1,900.2	74.1	36.9	10.2	161.3	7.3
Fourth quintile	1,099.0	477.3	2,149.4	181.5	103.1	11.2	338.8	12.3
Fifth quintile	3,001.7	2,013.2	2,081.5	478.1	312.1	26.3	709.4	42.9
Total	1,304.3	583.2	1,587.9	154.4	98.1	15.2	61.3	13.1

Source: Author's computations based on the 2015/16 HCE Survey data

There are considerable differences in household consumption expenditure on various ASFs by location, expenditure quintiles, and education levels. Specifically, households in urban centers spent a larger share of their budget on beef, mutton and goat meats, poultry, and eggs and fish compared with households in rural areas. However, rural households spent a higher share of their ASF budget on dairy products such as milk, cottage cheese, and butter milk (or *arera*) compared with their urban peers. This is due to the fact that dairy products are supplementary diets to cereals in nearly all rural settings of the country. Similarly, households headed by high-school or college/university graduates spent a greater share of their ASF budget on meat groups such as beef, mutton and goat meats, chicken and eggs, fish, and other meats compared with households led by heads who are illiterate or primary school graduates. However, households led by primary school graduates or illiterate heads spent more on dairy products (see Table 4.3). Average households in the highest expenditure quintile spent nearly 24, 30 and 3 times more on beef, mutton and goat meats, and dairy products, respectively, than average households in the lowest expenditure quintile. Thus, consumption of better-quality beef and sheep and goat meats is an indicator of income status in the country; poor households in rural areas consume relatively more dairy products than meats.

4.4.2.2. Quantity of ASFs consumed

Table 4.4 presents annual quantity of ASFs consumed per household. At the national level, the average per capita quantity of ASFs consumed was 20.6 kg per annum in 2010/11 and 28.3 kg in 2015/16 indicating a growth rate of about 37.4 percent between 2010/11 and 2015/16, which is less than the growth rate of expenditure on ASFs. At a country level, average meat consumption (beef, mutton and goat meats, and other meats) per adult was about 7.8 kg per year in 2015/16. Meat consumption has been dominated by beef in Ethiopia where it took the lion's share of total meat consumption per capita. In Kenya, the average meat consumption per capita was about 12 kg in 2015 (Shibia et al., 2017). This indicates that meat consumption in Ethiopia is low even by the standard of East African countries.

Table 4.4: Quantity of ASFs consumed per HH per year (in kg)

Classification	Beef	Mutton and goat meat	Dairy products	Poultry	Egg	Fish	Other meats	Honey
Location								
Urban	130.0	168.6	109.5	69.5	4.9	0.6	7.9	0.5
Rural	226.5	182.9	229.0	59.0	0.9	0.4	3.9	0.5
Gender								
Male-headed	195.9	182.5	210.9	66.6	2.0	0.4	5.1	0.6
Female-headed	155.5	155.3	181.4	57.1	1.5	0.4	4.2	0.3
Education level								
Primary	183.0	174.7	204.2	66.1	1.7	0.5	4.9	0.5
Secondary	131.4	212.2	141.1	69.6	5.1	0.7	7.9	2.2
Tertiary	141.6	188.9	136.6	65.2	8.9	1.1	8.6	1.1
Other	247.1	170.0	184.7	60.1	1.1	0.0	7.7	0.3
Illiterate	222.0	158.8	230.9	59.2	0.6	0.3	3.5	0.2
Income quintile								
First quintile	90.6	94.6	196.7	46.5	0.2	0.4	1.5	0.1
Second quintile	94.0	83.9	205.3	56.4	0.5	0.5	2.3	0.1
Third quintile	127.9	87.3	232.1	67.8	0.8	0.4	3.3	0.2
Fifth quintile	210.2	167.2	226.0	64.3	2.1	0.3	6.1	0.3

Source: Author's computations based on the 2015/16 HCE Survey data

Household consumption of ASFs varies by location (urban vs. rural), education levels, and expenditure quintiles. Specifically, the quantity of total ASFs consumed by households in rural areas is greater than that of households in urban centers (contrary to expenditure on ASFs). This could be due to the fact that urban households consume better-quality ASFs from modern shops and butcheries, which can be purchased at higher prices per unit. For instance, the average price of beef per kg is about 130 ETB in urban centers but it is 80 ETB in rural areas. Beef price variation is the highest in urban centers due to quality differences by location of butcheries and origin and type of animals slaughtered. Consequently, expenditure on meats is higher in urban centers even if the quantity consumed in these areas is smaller than that in rural areas. However, a larger quantity of chicken, eggs, and fish was consumed by urban households compared to rural households.

In rural areas, the quantity of dairy products consumed was more than double the quantity of these products consumed in urban centers. A larger quantity of beef and dairy products was consumed among households with illiterate heads or heads with basic or primary education compared with households with literate heads. Similarly, households in the lowest expenditure quintile consumed a larger quantity of dairy products compared with their counterparts in the highest expenditure quintiles. In short, educated, better-off, and urban households consumed better-quality ASFs, mainly meats and packaged dairy products such as yoghurt, whereas worse-off, illiterate, and rural households consumed raw milks and low-quality ASFs (as indicated by low expenditure but larger quantity consumed).

4.4.2.3. Seasonality in animal source food consumption

In developing countries such as Ethiopia, agricultural production and consumption are characterized by some seasonality based on rainfall patterns and holy days. Ethiopia has two major rainfall patterns, where central, western and northern parts of the country have a uni-modal rainfall pattern with the rainy season running from June to September whereas the eastern and south-eastern parts of the country have bi-modal rainy seasons. The main rainy season of the country is during June to September. During these months, there is better availability of livestock feeds and hence higher production of livestock products, mainly dairy products, and there is better-quality livestock: bulls, oxen, sheep, and goats. Consequently, consumption of ASFs increases during the rainy season but reaches its lowest level during the dry seasons (January to March). Furthermore, consumption of ASFs also depends on Orthodox Christian fasting (such as two months' Easter fasting), when consumption of livestock products is at its lowest level.

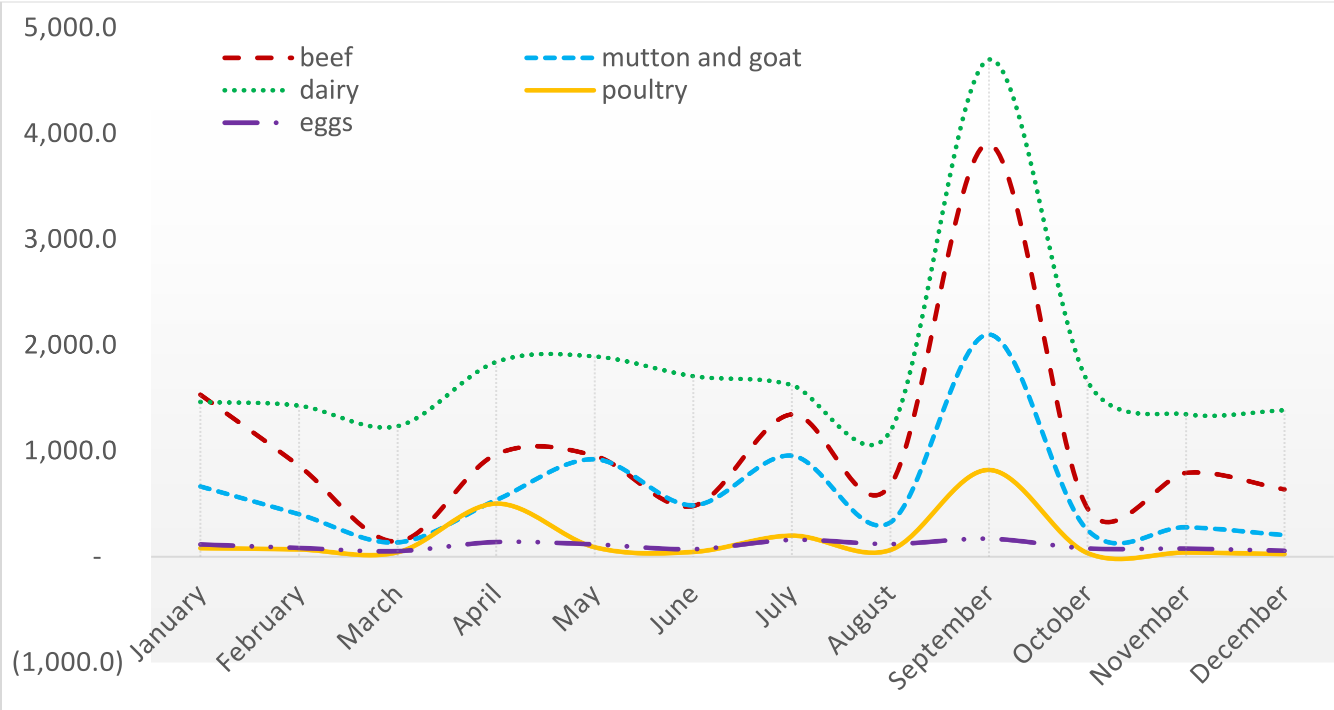


Figure 3: Seasonality in consumption expenditure on major components of ASFs (2015/16).

4.4.3. Estimation results

In estimating QUAIDS, this paper takes into account a number of requirements: adding-up properties and symmetry and homogeneity properties. The adding-up restriction requires dropping the n^{th} equation and estimating only n-1 equations (i.e., ASFs divided into five groups: beef; mutton and goat meat; dairy products; eggs and chickens; and other ASFs (pig, camel meats, all types of fish, internal organs, etc.), and non-ASFs also divided into five groups: cereals; oil and pulses, fruits and vegetables, spices and stimulants, and other foods including all processed food consumed outside and salt), and summing up several parameters to zero. Homogeneity property is imposed by adding the betas to zero. The other point is that since the terms in the budget share equation (9) are non-linear such as the quadratic term of the total food expenditure and the non-linear formulas for a(p) and b(p), we estimated the non-linear system of seemingly unrelated regression equations using iterated feasible generalized non-linear least squares (IFGNLS). This estimation procedure is applied to nine equations; one equation (for other foods outside ASFs) was dropped to address the problem of adding-up. The estimates for the n^{th} equation were retrieved using STATA software. Estimation results of structural parameters are given in annexes 4.11 to 4.18 for country level, urban, rural, income quintiles (first, third and fifth quintiles) and by literacy level.

Various statistical measures indicate that the QUAIDS models for both rural and urban areas perform well. For instance, root mean square errors (RMSE) are small for all the ten demand equations ranging from 0.04 for poultry and eggs to 0.12 for cereals for urban areas and from 0.03 to 0.13 for poultry and eggs and cereals, respectively, in rural areas. Similarly, the values of R^2, which has a maximum value of up to 80 percent in urban areas and 83 percent in rural areas, reveal that the estimated QUAIDS better fit the data. In line with the overall measures of the significance of the model, most of the parameter estimates (alphas, betas, lambdas, and coefficients for socio-demographic variables like age, sex, household size and literacy) are statistically significant. The significance of lambdas implies that the QUAIDS is preferred to original AIDS in both rural and urban areas. In addition, the coefficients of pdf in all the ten equations are statistically significant implying that correction for data censorship is a key to getting unbiased and consistent parameter estimates.

In the censored QUAIDS for all groups, in most cases, expenditure and price are with expected signs and statistically significant in explaining demand for foods including ASFs. The square term of total food expenditure is also statistically different from zero for most equations in the system indicating that the Engel curve is in action, which means that food expenditure increases at a decreasing rate. Socio-demographic variables of heads of the households such as age, family size, education, and sex are also important in explaining demand for foods.

Following previous studies (e.g., Colchero et al., 2015) on similar issues but with different focuses, sections 4.4.3.1 and 4.4.3.2 of this paper compare expenditure and price elasticity estimates by location (urban vs. rural), expenditure quintiles (poorest vs. richest) and literacy (illiterate vs. literate) without conducting tests for statistical significance for the differences in elasticities across these groups. Thus, even if the difference in magnitude of these elasticity estimates is high across groups, such difference may be statistically insignificant.

4.4.3.1. Expenditure elasticity estimates

Table 4.5 presents expenditure elasticities by location. In both urban and rural areas, meat products such as beef, mutton and goat meats, and poultry and eggs are income-elastic. Mutton and goat meats are the most responsive to expenditure changes, where a one percent increase in expenditure results in 2.4 and 1.2 percent increase in quantity demanded for mutton and goat meats in urban and rural areas, respectively. Similarly, if expenditure goes up by one percent, the quantity demanded for beef rises by about 1.1 and 1.5 percent in urban and rural areas, respectively. The implication is that meat groups (excluding other meats) are considered as luxury goods across the country. Beef was also income-elastic in other developing countries such as Brazil (Coelho et al. 2010) in Latin America, India (Gandhi & Zhou 2010) and China (Jiang & Davis 2007) in Asia; and Kenya (Cornelsen et al., 2016); Malawi (Ecker & Qaim, 2011); and South Africa (Delport et al., 2017) in Africa. Other ASFs including internal organs, camel meats, and canned meat products are income-inelastic in urban areas indicating that as income increases, households allocate a smaller proportion of their ASF budget to such food groups. In rural areas, however, other ASFs, mainly internal organs and camel meat, are income-elastic with an elasticity of 1.6 percent for one percent change in expenditure of rural households. This could be due to the fact that some meats in this group such as camel meats are luxury in north-eastern and southern parts of the country mainly among pastoral communities of Somali, Afar, and Oromia. This finding is contrary to results reported by Worku et al. (2017) and Abegaz et al. (2018) with both studies indicating that other ASFs are inferior in rural areas, which is not supported by previous studies.

In both rural and urban areas, dairy products, which are dominated by milk, are income-inelastic revealing that these products are among basic food items mainly for children and pregnant and lactating women. Moreover, dairy products are essential supplementary food items consumed with staple foods in all corridors of the country, mainly rural areas. Cereals, which are the most staple foods throughout the country, comprise teff, wheat, maize, sorghum, millet, etc. Expenditure elasticity for cereals indicates that these foods are income-inelastic in both rural and urban areas implying that cereals are a necessity for households in the country. Similarly, pulses and oils as well as fruits and vegetables are less income-sensitive.

In summary, beef and mutton and goat meats are luxury whereas dairy products are necessities in all parts of the country indicating that not all ASFs are luxury among Ethiopian households. Staple foods are income elastic indicating that they are necessities in the country.

Table 4.5: Expenditure share and estimated expenditure elasticities of demand for ASFs and other foods

Items	Share (%) in total food expenditure			Expenditure elasticity		
	National	Urban	Rural	National	Urban	Rural
Beef	4.05	6.96	2.93	1.139***	1.123***	1.473***
Mutton and goat meats	2.33	4.96	1.32	2.404***	2.437***	1.159***
Dairy products	6.42	3.74	7.46	0.640***	0.620***	0.934**
Poultry and eggs	1.03	2.27	0.56	0.697***	1.163***	1.930***
Other ASFs	1.25	1.77	1.05	0.920***	0.366***	1.633***
Cereals	24.59	17.70	27.24	0.505***	0.674***	0.727***
Pulses and oils	13.14	12.34	13.45	0.384***	0.549***	0.533***
Fruits and vegetables	13.44	11.41	14.21	0.402***	0.769***	0.466***
Spices and stimulants	15.04	12.08	16.18	0.847***	1.199***	1.006***
Other foods	18.70	26.76	15.61	1.525***	0.654***	1.268**

*** p<0.01, ** p<0.05

Source: Author’s computations based on the 2015/16 HCE Survey data

Table 4.6 displays expenditure elasticity estimates by expenditure quintiles and education level of households. Expenditure elasticity estimates indicate that beef is expenditure elastic among poorest households with a one percent increase in expenditure leading to 7.7 percent increases in demand for beef. However, beef is income inelastic among households in the highest income quintile. Thus, beef is luxury for poor households but normal for richer households as richer households afford to buy beef compared with poor households. Mutton and goat meats are expenditure elastic both for poorer and richer households with higher responses to income changes among poor households. Dairy products are income elastic for households in the poorest expenditure quintile but it is income inelastic for richer households indicating that dairy products are luxury for households in poorest income quintiles but normal for richer households. Expenditure elasticity estimates for cereals and pulses are stable across income quintiles indicating that expenditure elasticity for basic foods does not vary by income level.

Meat groups (beef, poultry and mutton and goat meats) are income elastic among illiterate while beef and dairy products are income inelastic among literate households. Thus, ASFs are luxury for the illiterate households but normal goods for literate ones. Mutton and goat meats are income-elastic for both literate and illiterate heads with higher expenditure elasticity among literate households indicating that consumption of mutton and goat meats is an indicator of wealth and considered as healthy ASFs. Staple foods including cereals and pulses have comparable income elasticity estimates across households led by literate and illiterate heads.

In a nutshell, beef is income-inelastic across better-off and better educated households whereas it is income-elastic for worse-off and illiterate households. Thus, beef is normal for richer and educated households but it is luxury for poor and illiterate households. Mutton and goat meats are luxury goods for all households regardless of their income and education levels. Cereals are normal goods for Ethiopian households regardless of their income, education, and location.

Table 4.6: Expenditure elasticity estimates by income quintiles and literacy

Food items	expenditure quintiles			Literacy	
	QI	QIII	QV	Literate	Illiterate
Beef	7.71***	1.32***	0.93***	0.56***	1.51***
Mutton and goat meats	4.14**	1.51***	2.60***	2.33***	1.60***
Dairy products	1.34***	0.76***	0.51***	0.31**	0.44***
Poultry and eggs	-2.13	0.73	1.10***	0.132	1.68***
Other ASFs	1.37***	1.41***	0.28**	0.89***	1.40***
Cereals	0.72***	0.57***	0.83***	0.43***	0.53***
Pulses and oils	0.76***	0.62***	0.46***	0.45***	0.48***
Fruits and vegetables	0.95***	0.82***	0.81***	0.57***	0.90***
Spices and stimulants	1.09***	1.22***	0.90***	0.73***	1.07***
Other foods	-8.72***	1.34**	0.69***	2.15***	0.96*

*** $p<0.01$; ** $p<0.05$; *$p<0.10$

Source: Author's computations based on the 2015/16 HCE Survey data

4.4.3.2. Own price elasticity estimates

Table 4.7 shows both uncompensated and compensated price elasticities of ASFs and other foods by location (urban vs. rural). In line with demand theory, both uncompensated or Marshallian and compensated or Hicksian town price elasticity estimates are negatively related to quantity demanded, and these associations are statistically significant at the usual level of significance. This indicates that a higher own price is associated with a smaller quantity demanded for each commodity in the demand system. Price elasticity estimates for meat groups such as beef, mutton and goat meats, and poultry are greater than unity in both urban and rural areas. The level of price sensitiveness for all meat groups is higher among rural households compared to households in urban areas. For instance, demand for beef is less price-sensitive in urban centers with a one percent increase in its own price resulting in a 1.3 percent reduction in quantity demanded while in rural areas a one percent rise in the price of beef leads to a 2.5 percent decline in quantity demanded (see Table 4.7). On the other hand, dairy products are less price-sensitive in rural areas due to the fact that they are integral components of daily foods of rural households as they supplement staple foods, mostly as sauces (Colen et al., 2018). Households in urban centers are more sensitive to changes in prices of dairy products as there are more choices of these products (mainly milk) in urban centers due to the availability of supermarkets and several small shops that sell packaged milk. Compensated own price elasticity estimates for ASF consumption are consistent with uncompensated price elasticities.

Table 4.7: Estimated own price elasticities of demand for ASFs and other foods by location

Items	Uncompensated own-price elasticity			Compensated own-price elasticity		
	National	Urban	Rural	National	Urban	Rural
Beef	-1.448***	-1.260***	-2.482***	-1.400***	-1.180***	-2.383***
Mutton and goat meats	-2.371***	-2.675***	-4.602***	-2.091***	-2.373***	-4.569***
Dairy products	-0.870***	-1.171***	-0.720***	-0.868***	-1.173***	-0.666***
Poultry and eggs	-2.060***	-2.003***	-5.602***	-2.071***	-1.976***	-5.535***
Other ASFs	-0.819***	-0.774***	-0.504***	-0.809***	-0.797***	-0.452***
Cereals	-0.616***	-0.595***	-0.631***	-0.514***	-0.474***	-0.420***
Pulses and oils	-0.658***	-0.364***	-0.921***	-0.612***	-0.292***	-0.854***
Fruits and vegetables	-0.905***	-0.990***	-0.873***	-0.860***	-0.894***	-0.816***
Spices and stimulants	-0.770***	-0.803***	-0.827***	-0.661***	-0.657***	-0.674***
Other foods	-0.227***	-0.199***	0.023	0.140***	-0.017	0.229

*** $p<0.01$

Source: Author's computations based on the 2015/16 HCE Survey data

Table 4.8 presents both uncompensated and compensated own price elasticities by expenditure quintiles and literacy level. Demands for ASFs among households in the poorest income quintiles are highly sensitive to changes in own prices of all ASFs compared to households in the richest income quintile. For instance, a one percent increase in own prices of beef, mutton and goat meats, and poultry leads to a reduction in quantity demand by about 8, 9 and 9.2 percent, respectively, for the households in the lowest income quintile. However, the response of quantity demand to own price changes is least among households in the highest income quintile. Similarly, households in the lowest income quintile are more responsive to changes in the prices of staple foods such as cereals compared to households in the highest income quintile. This implies that households in the poorest income quintile are severely hit by hiked prices of both ASFs and staple foods in both rural and urban areas. This is in line with findings by Alem and Söderbom (2012) for urban settings in Ethiopia. The same effects are observed using compensated own price elasticity estimates among households in the poorest and richest income quintiles.

The responsiveness of demand for beef, mutton and goat meats, and poultry for households in the lowest income quintiles is higher (about 1.6, 2.4, and 2.2 percent, respectively) compared to households in urban centers, which is 1.4, 2.0, and 2.1 percent for the respective meat groups. Compensated own price elasticity estimates have the same trend as that of uncompensated elasticities. Quantity demand for cereals is more responsive to own price changes among households with literate heads than households with illiterate heads indicating that literates are more price-sensitive towards staple foods as they look for alternative foods such as processed foods like pastas and others.

Table 4.8: Estimated own price elasticities of demand for ASFs and other foods by income quintile and literacy

	Uncompensated price elasticity				Compensated price elasticity			
Food Items	Expenditure quintiles		Literacy		Expenditure quintiles		Literacy	
	QI	QV	Illiterate	Literate	QI	QV	Illiterate	Literate
Beef	-7.85***	-1.19***	-1.74***	-1.36***	-6.57***	-1.13***	-1.62***	-1.41***
Mutton and goat meats	-8.95***	-2.96***	-2.49***	-2.33***	-8.43***	-2.64***	-2.36***	-2.07***
Dairy products	-1.17***	-1.11***	-0.98***	-0.87***	-1.07***	-1.06***	-1.01***	-0.90***
Poultry and eggs	-9.17***	-1.31***	-2.25***	-2.06***	-9.36***	-1.29***	-2.18***	-2.10***
Other ASFs	-1.49***	-0.60***	-0.71***	-2.23***	-1.44***	-0.62***	-0.68***	-2.11***
Cereals	-0.79***	-0.59***	-0.63***	-0.63***	-0.54***	-0.48***	-0.49***	-0.56***
Pulses and oils	-0.96***	-0.27***	-0.81***	-0.57***	-0.85***	-0.23***	-0.76***	-0.51***
Fruits and vegetables	-1.04***	-1.03***	-0.92***	-0.95***	-0.90***	-0.94***	-0.80***	-0.88***
Spices and stimulants	-0.91***	-0.78***	-0.80***	-0.75***	-0.77***	-0.68***	-0.65***	-0.67***
Other foods	-4.40*	-0.35***	0.33	-0.43***	-5.82**	-0.12***	0.52***	0.13***

*** p<0.01; *p<0.10

Source: Author's computations based on the 2015/16 HCE Survey data

Table 4.9 presents cross-price elasticities of ASFs by location. In both rural and urban areas ASFs such as beef, mutton and goat meats, and poultry and dairy products (mainly milk) are substitute foods as households exchange one for the other. Thus, there are evidences of substitution of consumption of ASFs among Ethiopian households. However, most ASFs supplement the consumption of staple foods (Colen et al., 2018).

Table 4.9: Cross-price elasticities of ASFs by location

Location	Types of ASFs	Beef	Mutton and goat	Dairy products	Poultry	Other ASFs
Urban	Beef	-1.26***	0.05	0.03	0.00	-0.08
	Mutton and goat	0.97**	-2.68***	0.18	0.61	0.18
	Dairy products	0.65**	-0.04	-1.17***	0.09	-0.01
	Poultry	1.16	0.41**	0.22	-2.00**	-0.09
	Other ASFs	0.84	-0.10	0.01	-0.04	-0.77
Rural	Beef	-2.48	0.80	2.11	0.11	-0.01
	Mutton and goat	2.45	-4.60***	3.74	1.93***	-0.21
	Dairy products	0.09	0.05	-0.72***	0.02	-0.03
	Poultry	0.62**	3.65***	5.44	-5.60***	0.58
	Other ASFs	0.00	0.02	1.00	0.08	-0.50

*** p<0.01, ** p<0.05

Source: Author's computations based on the 2015/16 HCE Survey data

4.5. Conclusions and policy implications

In developing economies such as Ethiopia, demand for ASFs has been increasing due to rapid urbanization and rising income. Understanding the relationship between demand for ASFs and income and how this relation changes with income level helps in designing an appropriate food and nutrition policy that plays a key role in curbing malnutrition in the country. This paper examines consumption patterns of ASFs and estimates their expenditure and price elasticities by applying censored QUAIDS by location (urban vs. rural), expenditure quintiles, and literacy (literate vs. illiterate), using recently collected nationally representative Ethiopian household consumption expenditure survey data.

The major conclusions drawn from the paper are: first, consumption of ASFs is dominated by a few products such as dairy products, beef, and mutton and goat meats, which account for over 90 percent of total expenditure on ASFs. Second, even if average expenditure on meat groups is higher among urban households, a larger quantity of meat is consumed among rural households per annum indicating that urban households consume better-quality meats. Similarly, a larger quantity of dairy products was consumed in rural areas as dairy products are an integral part of foods in rural areas in supplementing staple foods (Colen et al., 2018). Third, share of income spent on ASFs increases with income and education levels while that spent on cereals declines as richer and better educated consumers shift their consumption from starchy foods to more protein-rich foods including ASFs. Fourth, ASFs are more income- and price-sensitive than staple foods such as cereals. Fifth, the poorest households in both urban and rural areas are highly sensitive to hiked prices of foods including ASFs (Alem & Söderbom, 2012). Finally, beef, poultry, and dairy products are more income-elastic in rural areas than in urban areas while dairy products are more price-responsive in urban areas due to better availability of dairy products in urban centers. However, cereals have similar price and income elasticities in both urban and rural areas as well as among literates and illiterates. The policy implication is to design a food policy that differs in urban and rural areas and between poor and non-poor. Future research area could be in depth analysis of interdependency of prices of livestock products and non-livestock products.

References

Abdulai, A & Aubert, D. (2004). A cross-section analysis of household demand for food and nutrients in Tanzania. *Agricultural Economics*, 31(1), 67–79.

Abegaz, GA, Hassen, IW & Minten, B, (2018). Consumption of animal-source foods in Ethiopia: Patterns, changes, and determinants. ESSP Working Papers 113. International Food Policy Research Institute (IFPRI).

Agbola, FW, (2003). Estimation of food demand patterns in South Africa based on a survey of households. *Journal of Agricultural and Applied Economics*, 35(3), 663–670.

Akbay, C, Boz, I & Chern, WS, (2007). Household food consumption in Turkey. *European Review of Agricultural Economics*, 34(2), 209–231.

Alem, Y., & Söderbom, M. (2012). Household-level consumption in urban Ethiopia: the effects of a large food price shock. *World development*, *40*(1), 146-162.

Banks, J, Blundell, R & Lewbel, A (1997). Quadratic Engel curves and consumer demand. *Review of Economics and Statistics*, 79(4), 527–539.

Bilgic, A & Yen, ST (2013). Household food demand in Turkey: A two-step demand system approach. *Food Policy*, 43, 267–277.

Blundell, R & Robin, JM (1999). Estimation in large and disaggregated demand systems: an estimator for conditionally linear systems. *Journal of Applied Econometrics*, 14(3): 209–232.

Capéau, B., & Dercon, S. (2006). Prices, unit values and local measurement units in rural surveys: an econometric approach with an application to poverty measurement in Ethiopia. *Journal of African Economies*, *15*(2), 181-211.

Chen, D & Abler, D (2014). Demand growth for animal products in the BRIIC countries. *Agribusiness*, 30(1), 85–97.

Chen, D., Abler, D., Zhou, D., Yu, X., & Thompson, W. (2016). A meta-analysis of food demand elasticities for China. *Applied Economic Perspectives and Policy*, *38*(1), 50-72.

Chengappa PG, Umanath, M, Vijayasarathy, K, Babu, P & Manjunatha, AV (2016). Changing demand for livestock food products: An evidence from Indian households. *Indian Journal of Animal Sciences*, 86(9), 1055–1060.

Coelho, AB, de Aguiar, DRD & Eales, JS (2010). Food demand in Brazil: an application of Shonkwiler & Yen Two-Step estimation method. *Estudos Econômicos*, 40(1), 186–211.

Colchero, MA., Salgado, J.C., Unar-Mungu, M., Herna´ndez-Avila, M., Rivera-Dommarco, J.A. (2015). Price elasticity of the demand for sugar sweetened beverages and soft drinks in Mexico. *Economics and Human Biology*, 19, 129–137.

Colen, L, Melo, PC, Abdul-Salam, Y, Roberts, D, Mary, S, Gomez, S & Paloma, Y (2018). Income elasticities for food, calories and nutrients across Africa: A meta-analysis. *Food Policy*, 77, 116–132.

Cornelsen, L, Alarcon, P, Häsler, B, Amendah, DD, Ferguson, E, Fèvre, EM, Grace, D, Domingues-Salas, P & Rushton, J (2016). Cross-sectional study of drivers of animal-source food consumption in low-income urban areas of Nairobi, Kenya. *BMC Nutrition*, 2(1), 70.

Cox, TL & Wohlgenant, MK (1986). Prices and quality effects in cross-sectional demand analysis. *American Journal of Agricultural Economics*, 68(4), 908–919.

Deaton, A & Muellbauer, J (1980). An almost ideal demand system. *American Economic Review*, 70(3), 312–326.

Deaton, AS (1988). Quality, quantity, and spatial variation of price. *American Economic Review*, 78(3), 418–430.

Delport, M, Louw, M, Davids, T, Vermeulen, H & Meyer, F (2017). Evaluating the demand for meat in South Africa: an econometric estimation of short term demand elasticities. *Agrekon*, 56(1), 13–27.

Ecker, O & Qaim, M (2011). Analyzing nutritional impacts of policies: an empirical study for Malawi. *World Development*, 39(3), 412–428.

Ecker, O, Weinberger, K & Qaim, M (2010). Patterns and determinants of dietary micronutrient deficiencies in rural areas of East Africa. *African Journal of Agricultural and Resource Economics*, 4(2), 1–20.

Gandhi, VP & Zhou, Z-Y (2010). Rising demand for livestock products in India: nature, patterns and implications. *Australasian Agribusiness Review*, 18(1), 103–135.

Gao, XM, Wailes, EJ & Cramer, GL (1997). A microeconometric analysis of consumer taste determination and taste change for beef. *American Journal of Agricultural Economics*, 79(2), 573–582.

Green, R & Alston, JM (1990). Elasticities in AIDS Models. *American Journal of Agricultural Economics*, 72(2), 442–445.

Hassen, IW & Tafere, K (2012). Consumption patterns of livestock products in Ethiopia: Elasticity estimates using HICES (2004/05) data. ESSP Working Paper 38, International Food Policy Research Institute (IFPRI).

Worku, I. H., Dereje, M., Minten, B., & Hirvonen, K. (2017). Diet transformation in Africa: The case of Ethiopia. *Agricultural economics*, *48*(S1), 73-86.

Hayes, DJ, Wahl, TI, and Williams, GW (1990). Testing Restrictions on a model of Japanese meat demand. *American Journal of Agricultural Economics*, 72(3), 556–566.

Heien, D & Roheim Wessells, C (1990). Demand systems estimation with microdata: a censored regression approach. *Journal of Business & Economic Statistics*, 8(3), 365–371.

Hoddinott, J, Headey, D & Dereje, M (2015). Cows, missing milk markets, and nutrition in rural Ethiopia. *Journal of Development Studies*, 51(8), 958–975.

Humphries, DL, Behrman, JR, Crookston, BT, Dearden, KA, Schott, W & Penny, ME *et al*. (2014). Households across all income quintiles, especially the poorest, increased animal source food expenditures substantially during recent Peruvian economic growth. *PLoS ONE*, 9(11), e110961.

Jiang, B & Davis, J (2007). Household food demand in rural China. *Applied Economics*, 39(3), 373–380.

Kedir, AM (2005). Estimation of own- and cross-price elasticities using unit values: econometric issues and evidence from urban Ethiopia. *Journal of African Economies*, 14(1), 1–20.

Kumar, P, Kumar, A, Parappurathu, S & Raju, SS (2011). Estimation of demand elasticity for food commodities in India. *Agricultural Economics Research Review*, 24(1).

Kumar, P, Kumar, A, Parappurathu, S & Raju, SS (2011). Estimation of demand elasticity for food commodities in India. *Agricultural Economics Research Review*, 24(1): 1–14.

Lancaster, KJ (1971). Consumer theory: A new approach. Columbia, NY. Columbia University Press.

Lazaridis, P (2003). Household meat demand in Greece: A demand systems approach using microdata. Agribusiness: *An International Journal*, 19(1), 43–59.

Maddala, GS (1986). Limited-dependent and qualitative variables in econometrics. Cambridge, UK. Cambridge University Press.

Maltsoglou, I (2007). Household expenditure on food of animal origin: A comparison of Uganda, Vietnam and Peru. PPLPI Working Paper No. 43. Food and Agriculture Organization of the United Nations.

McKelvey, C (2011). Price, unit value, and quality demanded. *Journal of Development Economics*, 95(2), 157–169.

Muhammad, A, Seale, JL, Saager Meade, BG & Regmi, A (2011). International evidence on food consumption patterns: an update using 2005 international comparison program data. USDA-ERS Technical Bulletin No. 1929.

Murcott, A, Belasco, W & Jackson, P (eds.) (2013). The handbook of food research. London, UK, Bloomsbury Publishing.

National Planning Commission (2016). Database of the National Planning Commission, Addis Ababa, Ethiopia

Ogundari, K & Abdulai, A (2013). Examining the heterogeneity in calorie–income elasticities: A meta-analysis. *Food Policy*, 40(6): 119–128.

Piggott, NE & Marsh, TL (2004). Does food safety information impact U.S. meat demand? *American Journal of Agricultural Economics*, 86(1): 154–174.

Regmi, A & Dyck, J (2001). Effects of urbanization on global food demand. In Regmi, A (ed.) Changing structure of global food consumption and trade. Agriculture and Trade Report WRS-01-1. US Department of Agriculture, Washington, DC. 23–30.

Shibia, M., Rahman, S., & Chidmi, B. (2017). *Consumer demand for meat in Kenya: an examination of the linear approximate almost ideal demand system* (No. 1377-2016-109929).

Shonkwiler, JS & Yen, ST (1999). Two-step estimation of a censored system of equations. American Journal of Agricultural Economics. 81(4): 972–982.

Tafere, K, Taffesse, AS, Tamiru, S, Tefera, N & Paulos, Z (2010). Food demand elasticities in Ethiopia: Estimates using household income consumption expenditure (HICE) survey data. Discussion Paper No. ESSP2 011. Ethiopia Strategy Support Program 2.

Thompson, W. (2004). Using elasticities from an almost ideal demand system? Watch out for group expenditure!. *American Journal of Agricultural Economics*, *86*(4), 1108-1116.

Ulimwengu, JM, Workneh, S & Paulos, Z (2009). Impact of soaring food price in Ethiopia: Does location matter? IFPRI Discussion Paper 00846. International Food Policy Research Institute (IFPRI).

Workicho, A, Belachew, T, Feyissa, GT, Wondafrash, B, Lachat, C, Verstraeten, R & Kolsteren, P (2016). Household dietary diversity and animal source food consumption in Ethiopia: evidence from the 2011 Welfare Monitoring Survey. *BMC Public Health*, 16(1), 1192.

Yen, ST, Fang, C & Su, SJ (2004). Household food demand in urban China: a censored system approach. *Journal of Comparative Economics*, 32(3), 564–585.

Zheng, Z & Henneberry, SR (2009). An analysis of food demand in China: A case study of urban households in Jiangsu province. *Review of Agricultural Economics*, 31(4), 873–893.

Zhuang, R & Abbott, P (2007). Price elasticities of key agricultural commodities in China. *China Economic Review*, 18(2), 155–169.

Annex for chapter four

Annex 4.1: derivation of elasticities

Expenditure elasticity and uncompensated and compensated price elasticities can be derived as

Expenditure/income elasticity:

$$\mu_i = \left[\beta_i + \frac{2\lambda_i}{b(p)} \ln\left\{ \frac{y_h}{a(p)} \right\} \right] * \frac{1}{w_i} + 1$$

Uncompensated/Marshallian price elasticity:

$$\varepsilon_{ij} = \frac{1}{w_i} * \left[\gamma_{ij} - \left[\beta_i + \frac{2\lambda_i}{b(p)} \ln\left\{ \frac{y_h}{a(p)} \right\} \right] \right] \times$$

$$\left(\alpha_j + \sum_l \gamma_{jl} \ln p_l \right) - \frac{(\beta_i + \eta_j^{'} z)\lambda_i}{b(p)} \ln\left[\left\{ \frac{y_h}{a(p)} \right\} \right]^2 - \delta_{ij},$$

where Kronecker delta ($\delta_{ij} = 1$ if $i = j$ and $\delta_{ij} = 0$ if $i \neq j$).

Compensated price elasticity:

$\varepsilon_{ij}^{c} = \varepsilon_{ij} + \mu_i w_j$, which is the Slutsky equation.

Annex 4.2: Share of households consumed a group of goods included into the QUAIDS

food items	total	urban	rural	QI	QIII	QV	illiterate	literate
Beef	19.45	25.17	8.43	3.13	12.68	37.73	9.17	24.10
Mutton and goat meats	12.47	16.25	5.17	2.79	8.19	23.87	8.78	14.14
Dairy products	37.70	36.22	40.50	13.94	32.12	59.10	35.25	38.81
Poultry and eggs	16.81	22.62	5.62	2.97	11.02	32.49	5.37	21.99
Other ASFs	24.00	27.46	17.32	18.99	23.68	27.72	16.33	27.48
Cereals	88.37	83.93	96.87	87.00	86.75	91.44	94.66	85.53
Pulses and oils	92.26	92.68	91.44	84.89	93.12	95.36	91.32	92.69
Fruits and vegetables	90.68	92.58	87.04	80.90	91.46	95.01	87.39	92.17
Spices and stimulants	93.38	92.94	94.22	86.51	93.67	96.55	94.52	92.86
Other foods	98.73	99.16	97.89	94.95	99.14	99.84	97.66	99.21

Annex 4.3: First stage regression results of probit model: national

Variables	Eq.1	Eq.2	Eq.3	Eq.4	Eq. 5	Eq.6	Eq.7	Eq.8	Eq.9	Eq.10
Ln (food exp.)	1.074***	1.323***	0.989***	0.994***	1.064***	-0.181***	0.283***	0.189***	0.245***	0.743***
	(0.0338)	(0.0388)	(0.0293)	(0.0328)	(0.0328)	(0.0368)	(0.0356)	(0.0306)	(0.0347)	(0.0587)
lnp1	-0.747***	0.105*	0.0849	0.102	0.125**	-0.160*	0.0425	-0.126	-0.173	0.181
	(0.0724)	(0.0560)	(0.0626)	(0.0690)	(0.0626)	(0.0826)	(0.0912)	(0.0777)	(0.117)	(0.111)
lnp2	0.755***	-0.529***	0.398***	0.455***	0.633***	-0.968***	0.315*	0.250*	-0.580***	-0.680*
	(0.121)	(0.166)	(0.109)	(0.122)	(0.147)	(0.144)	(0.183)	(0.143)	(0.193)	(0.361)
lnp3	0.0914***	0.0828***	-0.782***	0.0211	0.0533**	0.000579	0.000185	0.0498	-0.0109	0.0175
	(0.0248)	(0.0313)	(0.0328)	(0.0280)	(0.0272)	(0.0284)	(0.0291)	(0.0303)	(0.0475)	(0.0567)
lnp4	-0.193	0.259**	-0.501***	-1.057***	-0.730***	-0.582***	-0.0793	0.405***	0.424**	-0.798***
	(0.120)	(0.117)	(0.108)	(0.162)	(0.122)	(0.157)	(0.121)	(0.110)	(0.166)	(0.290)
lnp5	0.239***	-0.0151	0.177***	0.0813*	-0.992***	0.444***	0.457***	0.315***	0.236***	-0.535***
	(0.0561)	(0.0526)	(0.0502)	(0.0456)	(0.0574)	(0.0504)	(0.0522)	(0.0556)	(0.0599)	(0.0998)
lnp6	-0.108*	-0.111**	-0.179***	-0.00279	-0.355***	-0.377***	0.250***	0.198***	0.250***	-0.155
	(0.0562)	(0.0533)	(0.0416)	(0.0526)	(0.0485)	(0.0371)	(0.0596)	(0.0510)	(0.0632)	(0.109)

lnp7	-0.164***	0.00895	-0.112***	-0.103**	-0.212***	0.0986**	-0.474***	0.0845*	0.241***	0.0725
	(0.0496)	(0.0582)	(0.0379)	(0.0479)	(0.0466)	(0.0492)	(0.0331)	(0.0510)	(0.0555)	(0.0726)
lnp8	-0.00381	0.0785*	-0.0648*	0.105***	-0.0317	0.311***	0.319***	-0.488***	0.219***	-0.0541
	(0.0391)	(0.0469)	(0.0337)	(0.0401)	(0.0360)	(0.0428)	(0.0449)	(0.0293)	(0.0485)	(0.0687)
lnp9	-0.118***	-0.119***	0.0595**	0.114***	0.0159	0.0617	0.240***	0.0546	-0.415***	-0.221***
	(0.0300)	(0.0403)	(0.0250)	(0.0353)	(0.0332)	(0.0387)	(0.0315)	(0.0339)	(0.0256)	(0.0618)
lnp10	-0.102***	0.155***	-0.0305	-0.0643**	0.309***	0.184***	-0.0625*	-0.131***	-0.228***	-0.366***
	(0.0251)	(0.0319)	(0.0238)	(0.0314)	(0.0233)	(0.0355)	(0.0333)	(0.0281)	(0.0323)	(0.0225)
Ln (HH size)	-0.284***	-0.609***	0.00587	-0.291***	-0.957***	1.209***	0.801***	0.633***	0.839***	-0.226***
	(0.0312)	(0.0334)	(0.0272)	(0.0286)	(0.0302)	(0.0414)	(0.0388)	(0.0349)	(0.0424)	(0.0813)
Ln (age)	-0.178***	0.0134	-0.150***	-0.251***	-0.134***	0.321***	0.0789	-0.00655	0.277***	-0.131
	(0.0549)	(0.0585)	(0.0454)	(0.0519)	(0.0485)	(0.0574)	(0.0568)	(0.0523)	(0.0636)	(0.107)
Sex dummy (F=1)	-0.0767**	0.0130	0.0150	-0.100***	0.0817**	-0.441***	-0.461***	-0.523***	-0.607***	-0.00223
	(0.0354)	(0.0397)	(0.0318)	(0.0354)	(0.0329)	(0.0456)	(0.0495)	(0.0449)	(0.0546)	(0.105)
Education dummy										
Primary=1	0.112**	0.125**	0.0466	0.170***	0.0320	-0.0866	0.301***	0.297***	0.202***	0.217**
	(0.0475)	(0.0529)	(0.0375)	(0.0500)	(0.0454)	(0.0562)	(0.0540)	(0.0498)	(0.0611)	(0.0991)
Secondary=1	0.220***	0.0960	0.0486	0.464***	0.0241	-0.0960	0.317***	0.358***	0.119*	0.0517
	(0.0559)	(0.0616)	(0.0468)	(0.0559)	(0.0545)	(0.0630)	(0.0627)	(0.0575)	(0.0697)	(0.149)
Graduates=1	0.308***	0.174***	0.273***	0.680***	0.0233	-0.106*	0.273***	0.377***	0.159**	0.252*
	(0.0501)	(0.0576)	(0.0453)	(0.0523)	(0.0523)	(0.0590)	(0.0626)	(0.0600)	(0.0671)	(0.136)
Other education=1	0.0616	0.0405	0.0855	0.0855	0.127*	-0.214*	0.215**	0.205***	-0.162*	0.135
	(0.0736)	(0.0800)	(0.0668)	(0.0810)	(0.0656)	(0.114)	(0.100)	(0.0700)	(0.0857)	(0.125)
Capacity to 300 ETB=1	-0.167***	-0.0250	0.0401	0.0403	-0.000608	0.175***	-0.241***	-0.00338	-0.131**	-0.0452
	(0.0407)	(0.0465)	(0.0346)	(0.0407)	(0.0395)	(0.0496)	(0.0484)	(0.0463)	(0.0566)	(0.0890)
Livestock own=1	-0.0769*	-0.0137	0.161***	-0.0526	0.00611	0.170***	-0.0287	-0.0511	0.00679	-0.0511
	(0.0403)	(0.0441)	(0.0354)	(0.0415)	(0.0400)	(0.0436)	(0.0509)	(0.0461)	(0.0559)	(0.0874)
Land own=1	-0.151***	-0.0220	0.00748	-0.0732**	0.0282	0.110***	0.0922*	-0.113**	0.0646	0.0189
	(0.0372)	(0.0384)	(0.0349)	(0.0369)	(0.0370)	(0.0385)	(0.0500)	(0.0464)	(0.0534)	(0.0934)
Mobile own=1	-0.0326	0.0548	-0.0535	-0.00153	0.0133	-0.236***	0.126***	0.0874**	0.0171	-0.182**
	(0.0418)	(0.0448)	(0.0336)	(0.0429)	(0.0380)	(0.0529)	(0.0436)	(0.0402)	(0.0511)	(0.0834)
refrigerator own=1	0.117***	0.0678	-0.0472	0.116***	-0.0914**	-0.0660*	0.119**	0.145**	0.0293	-0.00210
	(0.0379)	(0.0447)	(0.0375)	(0.0369)	(0.0372)	(0.0398)	(0.0596)	(0.0641)	(0.0562)	(0.153)
Regional dummy										
Afar=1	-1.373***	0.206***	1.222***	-0.798***	-0.439***	-0.443***	-1.270***	-0.517***	-0.172*	0.403*
	(0.148)	(0.0681)	(0.0663)	(0.0780)	(0.0674)	(0.120)	(0.0848)	(0.0668)	(0.101)	(0.239)
Amhara=1	0.114**	-0.163***	0.0938*	-0.472***	0.191***	-0.161**	0.153**	0.130**	-0.286***	0.0978
	(0.0565)	(0.0556)	(0.0485)	(0.0538)	(0.0442)	(0.0747)	(0.0730)	(0.0507)	(0.0660)	(0.0930)
Oromia=1	-0.0913	-0.791***	0.808***	-0.368***	-0.768***	-0.609***	-0.407***	0.229***	0.164**	0.298**
	(0.0602)	(0.0648)	(0.0539)	(0.0630)	(0.0601)	(0.0757)	(0.0782)	(0.0602)	(0.0755)	(0.124)
Somali=1	-1.448***	-0.603***	1.685***	-1.926***	-2.341***	0.000437	-1.078***	-1.107***	0.203	-
	(0.0902)	(0.0712)	(0.0700)	(0.120)	(0.107)	(0.125)	(0.0912)	(0.0673)	(0.139)	
Benishangul=1	0.503***	-0.765***	0.196***	-0.490***	-0.139**	-0.193**	0.405***	0.805***	0.313***	0.422**
	(0.0681)	(0.0934)	(0.0616)	(0.0734)	(0.0614)	(0.0975)	(0.0965)	(0.0824)	(0.102)	(0.164)
SNNP=1	0.0753	-1.307***	0.447***	-0.796***	-1.307***	-1.079***	-0.498***	1.088***	0.250***	0.322***
	(0.0555)	(0.0739)	(0.0473)	(0.0560)	(0.0552)	(0.0790)	(0.0726)	(0.0601)	(0.0742)	(0.120)
Gambella=1	-0.0410	-0.987***	0.264***	-0.877***	-0.00770	-0.755***	-0.810***	0.404***	-1.191***	0.461*
	(0.0638)	(0.0724)	(0.0573)	(0.0697)	(0.0568)	(0.0862)	(0.0867)	(0.0774)	(0.0791)	(0.240)
Harari=1	0.387***	-1.816***	0.630***	-0.400***	-0.884***	-1.176***	-0.600***	0.115	-0.217**	0.707*
	(0.0744)	(0.153)	(0.0735)	(0.0757)	(0.0747)	(0.0975)	(0.102)	(0.0889)	(0.108)	(0.395)
Addis Ababa=1	0.115**	-0.955***	0.310***	-0.396***	-0.629***	-0.997***	-0.177**	0.464***	0.107	0.560***
	(0.0542)	(0.0624)	(0.0511)	(0.0524)	(0.0500)	(0.0755)	(0.0801)	(0.0647)	(0.0781)	(0.168)
Dire Dawa=1	-0.0387	-0.791***	0.445***	-0.603***	-0.660***	-0.921***	-0.225**	0.180**	-0.0256	-0.543***
	(0.0775)	(0.0963)	(0.0736)	(0.0846)	(0.0743)	(0.102)	(0.110)	(0.0799)	(0.114)	(0.119)
Constant	-10.69***	-13.56***	-10.33***	-9.555***	-9.429***	1.794***	-1.917***	-1.261***	-2.219***	-4.048***
	(0.362)	(0.427)	(0.322)	(0.353)	(0.360)	(0.415)	(0.417)	(0.355)	(0.419)	(0.663)
Obs.	27,957	27,957	27,957	27,957	27,957	27,957	27,957	27,957	27,957	26,230

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Equations 1-10 and lnp1-lnp10 refer to ten groups of goods in the demand system: 1=beef, 2=mutton and goat meat, 3=dairy products, 4=poultry and eggs, 5=other livestock products, 6=cereals, 7=pulses and oils, 8=fruits and vegetables, 9= spices and stimulants and 10=other non-livestock food items

Annex 4.4: First stage regression results of probit model: urban

Variables	Eq.1	Eq.2	Eq.3	Eq.4	Eq. 5	Eq.6	Eq.7	Eq.8	Eq.9	Eq.10
Ln food exp.)	1.308***	1.449***	1.103***	1.035***	1.032***	-0.221***	-0.0233	0.0874**	0.0569	1.081***
	(0.0306)	(0.0345)	(0.0299)	(0.0309)	(0.0295)	(0.0364)	(0.0548)	(0.0441)	(0.0490)	(0.0713)
lnp1	-1.263***	0.150**	-0.0982	0.0310	0.0221	0.0787	0.164	0.0882	0.128	0.0559
	(0.0867)	(0.0698)	(0.0671)	(0.0630)	(0.0690)	(0.0953)	(0.114)	(0.0995)	(0.114)	(0.0861)
lnp2	0.483***	-1.006***	0.314***	0.261**	0.471***	-0.235	0.0838	0.0603	-0.0343	-0.836
	(0.115)	(0.135)	(0.112)	(0.115)	(0.138)	(0.151)	(0.106)	(0.0944)	(0.102)	(0.718)
lnp3	0.00485	-0.00967	-0.730***	-0.0423**	-0.0129	0.0152	0.0104	0.000385	-0.0173	-0.0797
	(0.0202)	(0.0241)	(0.0224)	(0.0205)	(0.0229)	(0.0285)	(0.0320)	(0.0355)	(0.0363)	(0.119)
lnp4	0.0918	-0.618***	-0.356**	-1.173***	-0.539***	0.121	0.0826	0.0297	0.0341	0.505
	(0.142)	(0.134)	(0.153)	(0.159)	(0.154)	(0.217)	(0.250)	(0.211)	(0.228)	(0.327)
lnp5	0.307***	-0.149***	0.188***	0.173***	-1.018***	0.470***	0.628***	0.529***	0.533***	-0.582***
	(0.0426)	(0.0442)	(0.0425)	(0.0424)	(0.0478)	(0.0425)	(0.0522)	(0.0506)	(0.0518)	(0.0954)
lnp6	-0.136***	-0.166***	0.0758*	0.110**	-0.306***	-0.407***	0.107	0.190**	0.296***	-0.481***
	(0.0490)	(0.0620)	(0.0458)	(0.0476)	(0.0559)	(0.0529)	(0.0892)	(0.0739)	(0.0792)	(0.139)
lnp7	-0.345***	-0.0877	-0.113**	-0.138***	-0.277***	0.202***	-0.182***	0.109	0.302***	-0.0226
	(0.0483)	(0.0564)	(0.0473)	(0.0480)	(0.0505)	(0.0622)	(0.0600)	(0.0686)	(0.0674)	(0.138)
lnp8	-0.0564	0.216***	0.146***	0.0866**	-0.129***	0.205***	-0.0666	-0.371***	-0.0692	0.139
	(0.0411)	(0.0498)	(0.0389)	(0.0406)	(0.0409)	(0.0537)	(0.0718)	(0.0410)	(0.0603)	(0.0981)
lnp9	0.108***	-0.165***	0.0959***	0.0402	-0.110***	0.105***	0.187***	0.178***	-0.308***	-0.0853
	(0.0315)	(0.0375)	(0.0311)	(0.0339)	(0.0337)	(0.0402)	(0.0509)	(0.0421)	(0.0348)	(0.123)
lnp10	-0.255***	0.184***	-0.131***	-0.154***	0.806***	0.235***	-0.402***	-0.440***	-0.502***	-0.795***
	(0.0290)	(0.0318)	(0.0280)	(0.0289)	(0.0348)	(0.0364)	(0.0785)	(0.0620)	(0.0717)	(0.0592)
Ln (HH size)	-0.384***	-0.619***	0.0468*	-0.290***	-0.977***	1.404***	1.397***	1.230***	1.194***	-0.250***
	(0.0260)	(0.0317)	(0.0249)	(0.0259)	(0.0290)	(0.0376)	(0.0520)	(0.0449)	(0.0491)	(0.0934)
Ln (age)	-0.0785*	-0.0424	-0.113***	-0.274***	-0.111**	0.513***	0.189***	0.230***	0.373***	-0.0105
	(0.0443)	(0.0535)	(0.0427)	(0.0459)	(0.0437)	(0.0508)	(0.0671)	(0.0648)	(0.0676)	(0.131)
Sex dummy (F=1)	-0.106***	0.0402	-0.0173	-0.0647**	0.0843***	-0.628***	-1.041***	-1.018***	-0.932***	-0.264**
	(0.0299)	(0.0356)	(0.0293)	(0.0303)	(0.0317)	(0.0404)	(0.0642)	(0.0584)	(0.0581)	(0.104)
Education dummy										
Primary=1	0.0630	-0.0502	0.0725*	0.215***	0.00298	-0.00516	0.149*	0.259***	0.0739	0.200
	(0.0471)	(0.0541)	(0.0423)	(0.0496)	(0.0457)	(0.0607)	(0.0782)	(0.0716)	(0.0825)	(0.129)
Secondary=1	0.0893*	-0.160***	0.148***	0.428***	-0.112**	0.166**	0.261***	0.370***	0.120	0.332*
	(0.0534)	(0.0619)	(0.0494)	(0.0546)	(0.0538)	(0.0670)	(0.0904)	(0.0815)	(0.0923)	(0.172)
Graduates=1	0.153***	-0.148**	0.356***	0.602***	-0.0840	0.194***	0.405***	0.557***	0.305***	0.264
	(0.0529)	(0.0594)	(0.0498)	(0.0540)	(0.0533)	(0.0662)	(0.0910)	(0.0816)	(0.0903)	(0.186)
Other education=1	0.0728	0.0780	0.0418	0.275***	-0.0380	0.0275	0.116	0.235	-0.147	-0.1000
	(0.0804)	(0.0824)	(0.0752)	(0.0877)	(0.0810)	(0.108)	(0.167)	(0.145)	(0.150)	(0.169)
Capacity to 300 ETB=1	0.0150	-0.0151	-0.0387	-0.0512	-0.0602	0.00289	0.0247	0.0353	-0.0445	-0.140
	(0.0363)	(0.0421)	(0.0351)	(0.0360)	(0.0373)	(0.0432)	(0.0570)	(0.0539)	(0.0564)	(0.118)
Livestock own=1	0.0222	0.129***	0.180***	-0.0180	-0.0297	0.170***	0.00239	-0.0149	0.0271	-0.147
	(0.0384)	(0.0435)	(0.0358)	(0.0383)	(0.0398)	(0.0458)	(0.0566)	(0.0531)	(0.0570)	(0.122)
Land own=1	-0.0549*	0.0972***	0.116***	0.00695	0.0443	0.0216	-0.114**	-0.199***	-0.105**	0.0269
	(0.0321)	(0.0372)	(0.0308)	(0.0320)	(0.0341)	(0.0401)	(0.0498)	(0.0465)	(0.0505)	(0.122)
Mobile own=1	-0.0195	-0.0142	-0.0324	0.0166	-0.0351	-0.0147	0.0186	0.0529	-0.0370	0.0961
	(0.0456)	(0.0514)	(0.0429)	(0.0458)	(0.0465)	(0.0541)	(0.0722)	(0.0634)	(0.0684)	(0.124)
refrigerator own=1	0.0257	-0.0400	-0.0472	0.0969***	-0.0915***	0.00216	0.128**	0.211***	0.0950	-0.0459
	(0.0344)	(0.0419)	(0.0345)	(0.0350)	(0.0353)	(0.0430)	(0.0584)	(0.0569)	(0.0587)	(0.142)
Regional dummy										
Afar=1	-1.847***	1.839***	0.313**	-0.0239	0.395***	-0.854***	-0.599***	-0.476***	-0.334*	-
	(0.180)	(0.125)	(0.134)	(0.133)	(0.138)	(0.159)	(0.195)	(0.169)	(0.189)	-
Amhara=1	-0.359***	-0.232***	-0.417***	-0.419***	-0.123*	-0.212***	-0.0491	0.0894	-0.260***	-0.0587
	(0.0669)	(0.0651)	(0.0605)	(0.0613)	(0.0628)	(0.0792)	(0.1000)	(0.0918)	(0.0881)	(0.144)
Oromia=1	-0.231***	-0.712***	0.424***	-0.462***	-0.826***	-0.585***	-0.181*	0.127	0.107	0.662***
	(0.0689)	(0.0715)	(0.0625)	(0.0656)	(0.0694)	(0.0880)	(0.105)	(0.0976)	(0.0960)	(0.208)
Somali=1	-1.670***	0.347***	0.877***	-1.653***	-1.456***	-0.332**	-0.799***	-0.685***	-0.0641	-
	(0.108)	(0.0944)	(0.0923)	(0.107)	(0.113)	(0.140)	(0.163)	(0.146)	(0.178)	

Benishangul	0.135	-0.701***	0.290***	-0.520***	-0.0717	-0.114	-0.0675	0.235*	0.00278	0.743**
	(0.0943)	(0.117)	(0.0890)	(0.0954)	(0.0938)	(0.119)	(0.149)	(0.135)	(0.138)	(0.320)
SNNP	0.163**	-1.237***	0.305***	-0.387***	-1.091***	-0.857***	-0.140	0.602***	0.311***	1.357***
	(0.0795)	(0.0897)	(0.0747)	(0.0789)	(0.0809)	(0.102)	(0.124)	(0.115)	(0.116)	(0.302)
Gambella	-0.300***	-0.744***	-0.271***	-0.982***	-0.00578	-0.906***	-0.730***	-0.00806	-0.990***	0.955**
	(0.0870)	(0.0952)	(0.0840)	(0.0874)	(0.0866)	(0.108)	(0.138)	(0.128)	(0.125)	(0.424)
Harari	0.497***	-1.832***	0.321***	-0.0972	-0.691***	-0.869***	-0.342**	0.0193	0.241	0.275
	(0.100)	(0.187)	(0.0997)	(0.0985)	(0.0990)	(0.125)	(0.163)	(0.160)	(0.169)	(0.308)
Addis Ababa	-0.166**	-0.945***	-0.0487	-0.359***	-0.700***	-0.895***	0.0737	0.437***	0.256**	0.570***
	(0.0679)	(0.0718)	(0.0617)	(0.0635)	(0.0651)	(0.0862)	(0.108)	(0.101)	(0.101)	(0.213)
Dire Dawa	-0.288***	-0.789***	-0.0563	-0.509***	-0.361***	-0.792***	-0.165	0.121	0.313	-
	(0.0988)	(0.113)	(0.105)	(0.102)	(0.0994)	(0.126)	(0.169)	(0.147)	(0.196)	
Constant	-13.12***	-14.43***	-11.36***	-9.907***	-8.958***	1.096***	0.619	-1.019**	-0.695	-7.693***
	(0.341)	(0.396)	(0.325)	(0.332)	(0.322)	(0.399)	(0.593)	(0.491)	(0.531)	(0.868)
Observations	19,860	19,860	19,860	19,860	19,860	19,860	19,860	19,860	19,860	17,557

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Annex 4.5: First stage regression results of probit model: rural

Variables	Eq.1	Eq.2	Eq.3	Eq.4	Eq. 5	Eq.6	Eq.7	Eq.8	Eq.9	Eq.10
Ln (food exp.)	1.004***	1.259***	0.885***	0.907***	1.147***	-0.0121	0.537***	0.369***	0.406***	0.764***
	(0.0528)	(0.0667)	(0.0383)	(0.0567)	(0.0508)	(0.0687)	(0.0544)	(0.0461)	(0.0551)	(0.0707)
lnp1	-0.737***	0.242**	-0.0366	0.0205	0.131	-0.376**	0.272***	0.0297	-0.165	0.0933
	(0.0912)	(0.0997)	(0.0835)	(0.103)	(0.0956)	(0.160)	(0.0846)	(0.0796)	(0.173)	(0.129)
lnp2	0.577**	-0.835***	0.369*	0.329	0.652**	-0.658**	0.568**	0.358	-0.450	0.220
	(0.263)	(0.320)	(0.217)	(0.273)	(0.328)	(0.276)	(0.255)	(0.219)	(0.371)	(0.859)
lnp3	0.179***	0.0786	-0.757***	0.0731	0.0931**	0.00539	0.155***	0.235***	0.0448	0.177***
	(0.0369)	(0.0512)	(0.0370)	(0.0481)	(0.0370)	(0.0431)	(0.0429)	(0.0377)	(0.0572)	(0.0530)
lnp4	0.535	0.170	-0.408	-1.550***	-0.0523	-0.568	-0.275	-0.899***	0.442	-0.868
	(0.410)	(0.351)	(0.350)	(0.416)	(0.310)	(0.523)	(0.471)	(0.344)	(0.514)	(0.881)
lnp5	0.200**	-0.0671	0.174**	0.0181	-1.065***	0.516***	0.371***	0.128	0.0719	-0.510***
	(0.0853)	(0.0816)	(0.0693)	(0.0817)	(0.0866)	(0.108)	(0.0982)	(0.0873)	(0.102)	(0.106)
lnp6	-0.0342	-0.23***	-0.400***	-0.241***	-0.507***	-0.27***	0.154**	-0.00107	0.0972	-0.259***
	(0.0689)	(0.0792)	(0.0474)	(0.0734)	(0.0618)	(0.0503)	(0.0715)	(0.0609)	(0.0852)	(0.0927)
lnp7	-0.0715	0.00753	-0.0192	-0.153**	-0.211***	-0.149*	-0.53***	0.154***	0.343***	-0.0883
	(0.0546)	(0.0786)	(0.0385)	(0.0604)	(0.0536)	(0.0869)	(0.0337)	(0.0540)	(0.0648)	(0.0666)
lnp8	-0.108***	0.0338	-0.0633**	0.101**	-0.000671	0.413***	0.248***	-0.430***	0.229***	-0.126**
	(0.0401)	(0.0561)	(0.0323)	(0.0487)	(0.0387)	(0.0514)	(0.0427)	(0.0260)	(0.0493)	(0.0591)
lnp9	-0.379***	-0.0958	0.0879***	0.0584	-0.0372	0.0811*	0.181***	-0.0574	-0.470***	-0.256***
	(0.0370)	(0.0610)	(0.0267)	(0.0488)	(0.0429)	(0.0443)	(0.0334)	(0.0374)	(0.0323)	(0.0645)
lnp10	-0.0494*	0.154***	-0.0501**	-0.00354	0.291***	0.156***	-0.0397	-0.0870***	-0.148***	-0.324***
	(0.0297)	(0.0422)	(0.0244)	(0.0398)	(0.0273)	(0.0438)	(0.0349)	(0.0277)	(0.0353)	(0.0211)
Ln (HH size)	-0.272***	-0.60***	0.0511	-0.30***	-1.00***	0.778***	0.420***	0.325***	0.677***	-0.30***
	(0.0531)	(0.0614)	(0.0390)	(0.0548)	(0.0485)	(0.0744)	(0.0572)	(0.0512)	(0.0664)	(0.0880)
Ln (age)	-0.260***	-0.0695	-0.166***	-0.34***	-0.18***	0.0167	-0.0378	-0.158**	0.177**	-0.218*
	(0.0795)	(0.0931)	(0.0547)	(0.0870)	(0.0663)	(0.0961)	(0.0727)	(0.0647)	(0.0810)	(0.112)
Sex dummy (F=1)	-0.0360	0.129	0.0353	-0.0593	0.0406	-0.139	-0.22***	-0.254***	-0.45***	-0.00506
	(0.0660)	(0.0786)	(0.0453)	(0.0740)	(0.0547)	(0.0912)	(0.0607)	(0.0548)	(0.0785)	(0.103)
Education dummy										
Primary=1	0.0590	0.0534	0.000146	0.134**	0.0495	-0.0958	0.381***	0.311***	0.248***	0.200**
	(0.0585)	(0.0760)	(0.0425)	(0.0658)	(0.0568)	(0.0855)	(0.0666)	(0.0578)	(0.0776)	(0.102)
Secondary=1	0.333***	0.00722	-0.126	0.523***	0.0885	-0.197	0.645***	0.512***	0.262	-0.249
	(0.126)	(0.163)	(0.0975)	(0.125)	(0.114)	(0.160)	(0.191)	(0.167)	(0.195)	(0.215)
Graduates=1	0.291**	0.223	-0.143	0.977***	0.112	-0.399**	0.443**	0.367*	-0.0155	0.214
	(0.142)	(0.154)	(0.123)	(0.129)	(0.140)	(0.165)	(0.181)	(0.202)	(0.187)	(0.361)
Other education=1	-0.0216	-0.0168	-0.00200	0.0257	0.178**	-0.268*	0.204*	0.221***	-0.154*	0.174
	(0.0874)	(0.0989)	(0.0724)	(0.105)	(0.0761)	(0.139)	(0.109)	(0.0730)	(0.0906)	(0.145)
Capacity to 300 ETB=1	-0.311***	-0.0108	0.0370	-0.0236	-0.00539	0.246***	-0.264***	-0.0106	-0.0941	-0.0230
	(0.0530)	(0.0730)	(0.0415)	(0.0666)	(0.0535)	(0.0728)	(0.0665)	(0.0551)	(0.0742)	(0.0914)
Livestock own=1	-0.119*	0.0308	0.216***	0.0596	0.0335	0.107	-0.115	0.00181	-0.00834	0.144
	(0.0669)	(0.0760)	(0.0500)	(0.0799)	(0.0619)	(0.0955)	(0.0786)	(0.0621)	(0.0868)	(0.107)
Land own=1	-0.208**	0.170*	-0.0693	-0.0186	-0.123	0.0913	0.0648	-0.0831	0.209**	-0.0270
	(0.0836)	(0.0992)	(0.0663)	(0.0999)	(0.0774)	(0.119)	(0.0855)	(0.0782)	(0.103)	(0.129)
Mobile own=1	-0.106**	0.0169	-0.0824**	-0.00613	0.0363	-0.158**	0.131***	0.0641	0.0506	-0.0781

	(0.0492)	(0.0591)	(0.0364)	(0.0555)	(0.0443)	(0.0688)	(0.0507)	(0.0445)	(0.0604)	(0.0812)
refrigerator own=1	0.116	-0.0404	-0.212	-0.0517	-0.211	-0.0720	0.178	-0.157	-0.0456	0.0616
	(0.243)	(0.217)	(0.156)	(0.260)	(0.176)	(0.274)	(0.228)	(0.198)	(0.230)	(0.376)
Regional dummy										
Afar=1	-1.158***	-0.414***	1.434***	-1.681***	-0.585***	-0.676***	-1.424***	-0.663***	-0.147	0.116
	(0.249)	(0.125)	(0.101)	(0.193)	(0.107)	(0.208)	(0.134)	(0.0962)	(0.160)	(0.265)
Amhara=1	0.228***	-0.191**	0.237***	-0.513***	0.278***	-0.0294	0.131	0.172***	-0.282***	0.111
	(0.0853)	(0.0762)	(0.0628)	(0.0768)	(0.0606)	(0.158)	(0.0998)	(0.0611)	(0.0917)	(0.121)
Oromia=1	-0.282***	-1.569***	1.039***	-0.733***	-1.071***	-0.671***	-0.273**	0.673***	0.202*	-0.494***
	(0.0934)	(0.112)	(0.0699)	(0.0856)	(0.0752)	(0.159)	(0.111)	(0.0735)	(0.116)	(0.142)
Somali=1	-2.004***	-1.087***	1.913***	-2.177***	-3.219***	0.243	-1.252***	-1.117***	0.162	-
	(0.389)	(0.126)	(0.0954)	(0.304)	(0.427)	(0.299)	(0.122)	(0.0856)	(0.176)	
Benishangul	0.598***	-0.838***	0.176**	-0.473***	-0.192**	-0.110	0.789***	1.148***	0.390**	0.469**
	(0.108)	(0.132)	(0.0887)	(0.112)	(0.0892)	(0.207)	(0.224)	(0.130)	(0.169)	(0.238)
SNNP	-0.0644	-1.532***	0.512***	-1.005***	-1.571***	-0.974***	-0.537***	1.421***	0.304***	0.300*
	(0.0925)	(0.119)	(0.0707)	(0.0998)	(0.0954)	(0.154)	(0.106)	(0.101)	(0.117)	(0.173)
Gambella	-0.105	-1.272***	0.486***	-0.771***	-0.0781	-0.335*	-0.927***	0.621***	-1.440***	0.384
	(0.119)	(0.135)	(0.0867)	(0.119)	(0.0927)	(0.195)	(0.129)	(0.118)	(0.129)	(0.303)
Harari	-1.251***	-2.228***	0.678***	-1.581***	-2.251***	-1.166***	-0.670***	0.238*	-0.744***	1.719**
	(0.198)	(0.308)	(0.129)	(0.222)	(0.202)	(0.200)	(0.168)	(0.137)	(0.174)	(0.700)
Addis Ababa	-1.658***	-1.320***	0.773***	-1.312***	-2.254***	-0.0639	0.0374	0.319**	-0.443**	-0.993***
	(0.360)	(0.236)	(0.132)	(0.231)	(0.222)	(0.275)	(0.198)	(0.135)	(0.200)	(0.280)
Constant	-9.503***	-12.81***	-9.382***	-8.490***	-9.853***	1.502**	-3.463***	-2.382***	-3.487***	-3.975***
	(0.562)	(0.701)	(0.412)	(0.620)	(0.512)	(0.730)	(0.580)	(0.485)	(0.607)	(0.731)
Obs.	10,367	10,367	10,367	10,367	10,367	10,367	10,367	10,367	10,367	9,792

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Annex 4.6: First stage regression results of probit model: first quintile

Variables	Eq.1	Eq.2	Eq.3	Eq.4	Eq. 5	Eq.6	Eq.7	Eq.8	Eq.9	Eq.10
Ln (food exp.)	1.096***	1.403***	0.748***	0.715***	1.313***	0.0600	0.640***	0.194***	0.264***	0.790***
	(0.265)	(0.267)	(0.134)	(0.181)	(0.143)	(0.0907)	(0.0752)	(0.0681)	(0.0732)	(0.0865)
lnp1	-0.903***	0.246	0.518	1.001*	0.473	0.0353	0.293*	0.295*	0.128	0.394*
	(0.231)	(0.269)	(0.390)	(0.579)	(0.378)	(0.264)	(0.167)	(0.154)	(0.202)	(0.202)
lnp2	0.0415	0.106	0.703	1.282	-0.0850	-2.60***	-0.687	-0.635	-1.111*	-2.66***
	(0.553)	(1.271)	(0.524)	(0.965)	(0.635)	(0.643)	(0.453)	(0.678)	(0.599)	(0.972)
lnp3	0.0103	-0.140	-1.18***	-0.131	0.110	0.0789	0.0281	0.0711	0.0913	-0.110
	(0.140)	(0.150)	(0.137)	(0.149)	(0.138)	(0.0969)	(0.0671)	(0.0785)	(0.110)	(0.119)
lnp4	0.544	0.0900	-0.715*	-2.111*	-0.645	0.219	0.785***	0.606	0.458	-0.353
	(0.533)	(0.853)	(0.400)	(1.261)	(0.476)	(0.410)	(0.302)	(0.392)	(0.410)	(0.660)
lnp5	0.306	0.108	0.839***	0.0499	-1.61***	0.890***	0.729***	0.443***	0.322***	-0.49***
	(0.239)	(0.173)	(0.213)	(0.157)	(0.175)	(0.133)	(0.117)	(0.105)	(0.120)	(0.0955)
lnp6	-0.827***	-0.415**	-0.186	0.0790	-0.61***	-1.04***	0.133	-0.0564	0.119	-0.0331
	(0.193)	(0.193)	(0.119)	(0.197)	(0.128)	(0.0978)	(0.0980)	(0.100)	(0.111)	(0.168)
lnp7	-0.203	-0.112	-0.0940	-0.198	-0.163	-0.0220	-0.80***	-0.0200	0.0175	0.0635
	(0.179)	(0.153)	(0.0910)	(0.148)	(0.110)	(0.0809)	(0.0690)	(0.0865)	(0.0807)	(0.122)
lnp8	0.0388	0.0710	-0.167*	-0.0602	0.0184	0.211***	0.346***	-0.69***	0.245***	-0.0431
	(0.113)	(0.138)	(0.0877)	(0.116)	(0.0793)	(0.0756)	(0.0715)	(0.0569)	(0.0730)	(0.0893)
lnp9	0.208	0.0542	0.0148	0.509***	0.157**	0.214***	0.228***	0.118*	-0.60***	-0.0681
	(0.135)	(0.174)	(0.0651)	(0.165)	(0.0790)	(0.0716)	(0.0507)	(0.0611)	(0.0574)	(0.120)
lnp10	-0.0565	0.135	-0.0199	-0.0477	0.160***	0.430***	0.0525	-0.084**	-0.15***	-0.45***
	(0.0615)	(0.105)	(0.0577)	(0.0967)	(0.0495)	(0.0587)	(0.0484)	(0.0406)	(0.0441)	(0.0371)
Ln (HH size)	-0.399***	-0.558***	-0.0975	-0.36***	-0.98***	0.999***	0.374***	0.295***	0.577***	-0.293**
	(0.106)	(0.124)	(0.0732)	(0.0935)	(0.0736)	(0.0997)	(0.0759)	(0.0642)	(0.0738)	(0.114)
Ln (age)	-0.0192	0.0710	-0.187	-0.191	-0.143	0.0215	-0.00433	-0.177*	0.196*	-0.124
	(0.161)	(0.163)	(0.127)	(0.150)	(0.108)	(0.129)	(0.103)	(0.0955)	(0.103)	(0.158)
Sex dummy (F=1)	-0.0614	-0.101	0.0694	-0.0251	0.0113	-0.68***	-0.33***	-0.37***	-0.41***	-0.103
	(0.152)	(0.157)	(0.0917)	(0.119)	(0.0832)	(0.114)	(0.0925)	(0.0806)	(0.0893)	(0.138)

Education dummy										
Primary=1	0.0766	0.0741	-0.0281	0.109	0.129	-0.139	0.230**	0.181*	0.114	0.265*
	(0.164)	(0.168)	(0.119)	(0.170)	(0.119)	(0.106)	(0.103)	(0.0943)	(0.104)	(0.150)
Secondary=1	0.114	0.0687	-0.118	0.350	0.129	-0.362**	0.270*	0.167	0.0110	-0.184
	(0.258)	(0.312)	(0.155)	(0.240)	(0.168)	(0.159)	(0.154)	(0.129)	(0.146)	(0.208)
Graduates=1	-0.402	-0.496	-0.00679	0.647**	0.0503	-0.54***	0.461**	0.422**	0.135	-0.144
	(0.296)	(0.305)	(0.208)	(0.321)	(0.192)	(0.186)	(0.186)	(0.196)	(0.208)	(0.254)
Other education=1	-0.108	0.0732	0.249	0.414*	0.138	-0.224	0.112	0.231*	-0.275**	0.375**
	(0.221)	(0.253)	(0.174)	(0.224)	(0.159)	(0.224)	(0.161)	(0.127)	(0.134)	(0.182)
Capacity to 300 ETB=1	-0.198	-0.277*	0.142	0.278*	0.246**	-0.131	-0.286***	-0.142	-0.179*	-0.0737
	(0.149)	(0.167)	(0.0998)	(0.162)	(0.104)	(0.114)	(0.0997)	(0.0904)	(0.106)	(0.149)
Livestock own=1	0.326*	-0.0151	0.107	-0.248	0.0835	0.337***	-0.0445	0.0794	-0.0129	-0.0211
	(0.166)	(0.161)	(0.108)	(0.156)	(0.108)	(0.111)	(0.0989)	(0.0867)	(0.102)	(0.132)
Land own=1	-0.444**	0.0875	0.0218	0.172	0.0552	0.0813	0.174	-0.102	0.119	0.153
	(0.202)	(0.164)	(0.122)	(0.149)	(0.115)	(0.115)	(0.111)	(0.101)	(0.110)	(0.150)
Mobile own=1	-0.109	0.265**	-0.182*	0.326**	0.0575	-0.221*	0.135*	0.137*	0.105	-0.171
	(0.135)	(0.135)	(0.0929)	(0.136)	(0.0904)	(0.116)	(0.0816)	(0.0755)	(0.0820)	(0.126)
refrigerator own=1	-0.132	-0.609**	-0.0670	0.164	-0.145	-0.0420	0.0346	0.0362	-0.0692	-0.276
	(0.247)	(0.286)	(0.206)	(0.208)	(0.155)	(0.131)	(0.211)	(0.179)	(0.159)	(0.244)
Regional dummy										
Afar=1	-1.051**	0.234	1.730***	-0.78***	-0.72***	-0.77***	-1.20***	-0.42***	-0.51***	0.263
	(0.420)	(0.230)	(0.182)	(0.285)	(0.201)	(0.283)	(0.173)	(0.139)	(0.196)	(0.418)
Amhara=1	-0.0314	-0.162	0.0440	-0.46***	0.0878	-0.317*	-0.00076	0.258***	-0.61***	-0.0477
	(0.147)	(0.161)	(0.114)	(0.139)	(0.106)	(0.169)	(0.126)	(0.0889)	(0.121)	(0.138)
Oromia=1	-0.174	-1.068***	0.655***	-1.14***	-0.61***	-0.78***	-0.45***	0.477***	-0.0798	0.562**
	(0.232)	(0.339)	(0.165)	(0.293)	(0.179)	(0.210)	(0.165)	(0.166)	(0.175)	(0.253)
Somali=1	-	-0.801***	1.516***	-1.63***	-2.18***	-0.210	-1.13***	-1.06***	-0.564**	-
		(0.271)	(0.221)	(0.382)	(0.352)	(0.292)	(0.219)	(0.209)	(0.267)	
Benishangul=1	0.165	-0.347	0.0362	-1.02***	-0.235	0.250	0.700***	1.122***	0.399*	0.241
	(0.206)	(0.264)	(0.178)	(0.322)	(0.150)	(0.228)	(0.216)	(0.166)	(0.222)	(0.245)
SNNP=1	-0.352	-1.430***	0.284**	-1.48***	-1.39***	-0.95***	-0.70***	1.268***	-0.0397	1.190***
	(0.227)	(0.268)	(0.123)	(0.287)	(0.151)	(0.187)	(0.131)	(0.118)	(0.140)	(0.209)
Gambella=1	-0.524	-1.274***	0.226	-1.11***	-0.393*	-0.425	-1.01***	1.310***	-1.76***	0.228
	(0.336)	(0.440)	(0.202)	(0.424)	(0.201)	(0.275)	(0.192)	(0.244)	(0.184)	(0.449)
Harari=1	0.365		0.583*	-0.569	-0.74***	-1.91***	-0.82***	0.193	-1.36***	0.721
	(0.336)		(0.313)	(0.399)	(0.267)	(0.235)	(0.237)	(0.204)	(0.210)	(0.568)
Addis Ababa=1	-0.599**	-0.626**	-0.262	-1.71***	-0.79***	-1.37***	0.204	1.267***	0.257	0.368
	(0.286)	(0.299)	(0.262)	(0.392)	(0.186)	(0.216)	(0.229)	(0.219)	(0.221)	(0.345)
Dire Dawa=1	-	-0.816*	0.746***	-0.910*	-0.74***	-1.01***	-0.719**	0.254	-0.82***	-0.427
		(0.492)	(0.254)	(0.509)	(0.258)	(0.335)	(0.300)	(0.257)	(0.277)	(0.303)
Constant	-11.22***	-14.44***	-7.78***	-7.57***	-11.8***	1.491	-4.47***	-0.629	-1.719**	-4.47***
	(2.521)	(2.530)	(1.339)	(1.819)	(1.378)	(0.958)	(0.811)	(0.725)	(0.807)	(0.944)
Obs.	3,990	4,073	4,130	4,130	4,130	4,130	4,130	4,130	4,130	4,031

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Annex 4.7: First stage regression results of probit model: third quintile

Variables	Eq.1	Eq.2	Eq.3	Eq.4	Eq. 5	Eq.6	Eq.7	Eq.8	Eq.9	Eq.10
Ln (food exp.)	1.848***	1.94***	0.982***	1.032***	2.184***	-0.52***	-0.0078	-0.369*	0.0630	0.87***
	(0.160)	(0.182)	(0.126)	(0.142)	(0.158)	(0.203)	(0.200)	(0.215)	(0.210)	(0.250)
lnp1	-0.92***	0.212*	-0.0191	0.00767	-0.00289	0.0819	-0.0363	-0.467**	-0.349*	0.0963
	(0.207)	(0.125)	(0.189)	(0.242)	(0.162)	(0.222)	(0.203)	(0.208)	(0.196)	(0.148)
lnp2	0.469	-0.951*	0.708*	0.988**	0.611	-0.942**	-0.300	-0.403	-1.71***	-1.090
	(0.465)	(0.504)	(0.377)	(0.424)	(0.414)	(0.470)	(0.348)	(0.268)	(0.563)	(0.767)
lnp3	0.234***	-0.0580	-0.75***	0.0906	0.147**	-0.0432	0.111	0.0135	-0.0647	0.00355
	(0.0705)	(0.088)	(0.0777)	(0.0832)	(0.0672)	(0.0589)	(0.071)	(0.0731)	(0.114)	(0.093)
lnp4	0.0136	0.813**	-0.437	-1.37***	-0.705**	-1.003*	0.127	0.602**	1.076***	-0.216
	(0.353)	(0.329)	(0.270)	(0.431)	(0.297)	(0.517)	(0.267)	(0.259)	(0.397)	(0.843)
lnp5	0.381***	-0.154	0.0510	0.181*	-1.06***	0.360***	0.57***	0.272**	0.137	-1.36***
	(0.141)	(0.125)	(0.115)	(0.102)	(0.129)	(0.0955)	(0.118)	(0.131)	(0.167)	(0.395)
lnp6	-0.0561	-0.110	-0.0910	-0.0885	-0.37***	-0.51***	0.197	0.0819	0.389**	-0.0739

	(0.156)	(0.137)	(0.0939)	(0.136)	(0.117)	(0.0869)	(0.139)	(0.133)	(0.164)	(0.204)
lnp7	-0.111	-0.0869	-0.139*	-0.192	-0.0720	0.263**	-0.22***	-0.0724	0.383**	-0.0559
	(0.113)	(0.126)	(0.0796)	(0.122)	(0.109)	(0.125)	(0.0681)	(0.133)	(0.166)	(0.159)
lnp8	0.0387	0.171	-0.0178	0.141	-0.114	0.399***	-0.128	-0.35***	0.260**	0.0590
	(0.0908)	(0.106)	(0.0709)	(0.0961)	(0.0825)	(0.0947)	(0.0941)	(0.0583)	(0.122)	(0.154)
lnp9	-0.188**	-0.151*	0.0708	0.264***	-0.0109	-0.107	0.188**	-0.0281	-0.350***	-0.466***
	(0.0736)	(0.088)	(0.0533)	(0.0852)	(0.0769)	(0.0716)	(0.0862)	(0.0924)	(0.0619)	(0.178)
lnp10	-0.141**	0.25***	0.00791	-0.111	0.321***	0.0883	-0.136	-0.34***	-0.30***	-0.27***
	(0.0612)	(0.073)	(0.0551)	(0.0738)	(0.0559)	(0.0786)	(0.0843)	(0.0775)	(0.0911)	(0.0685)
Ln (HH size)	-0.25***	-0.64***	-0.0435	-0.47***	-0.90***	1.196***	1.020***	0.541***	0.923***	0.0777
	(0.0722)	(0.0831)	(0.0611)	(0.0734)	(0.0787)	(0.0866)	(0.0926)	(0.0830)	(0.103)	(0.197)
Ln (age)	-0.230*	-0.0163	-0.0447	-0.305**	-0.227*	0.214	0.0876	-0.179	0.277*	0.0403
	(0.120)	(0.142)	(0.1000)	(0.125)	(0.119)	(0.133)	(0.145)	(0.127)	(0.152)	(0.255)
Sex dummy (F=1)	0.0590	0.148	0.0997	-0.134	0.0437	-0.35***	-0.53***	-0.59***	-0.81***	-0.517**
	(0.0828)	(0.0962)	(0.0732)	(0.0903)	(0.0747)	(0.103)	(0.122)	(0.0969)	(0.102)	(0.249)
Education dummy										
Primary =1	0.137	0.0751	0.212***	0.0489	-0.0332	-0.0142	0.457***	0.152	0.419***	0.126
	(0.111)	(0.123)	(0.0819)	(0.118)	(0.0953)	(0.117)	(0.131)	(0.118)	(0.128)	(0.204)
Secondary=1	0.155	0.129	0.0507	0.329***	0.116	-0.0144	0.398***	-0.0748	0.214	-
	(0.136)	(0.147)	(0.112)	(0.124)	(0.133)	(0.133)	(0.142)	(0.129)	(0.137)	
Graduates=1	0.347***	0.103	0.422***	0.620***	0.0936	-0.258**	0.367**	-0.100	0.203	0.439
	(0.130)	(0.156)	(0.113)	(0.130)	(0.128)	(0.122)	(0.145)	(0.143)	(0.145)	(0.341)
Other education=1	-0.0835	-0.128	0.234	0.0563	0.144	0.169	0.854**	0.0321	-0.179	-0.329
	(0.153)	(0.171)	(0.146)	(0.183)	(0.160)	(0.276)	(0.410)	(0.182)	(0.212)	(0.261)
Capacity to 300 ETB=1	-0.124	-0.0309	0.111	-0.0910	0.112	0.310***	-0.189*	0.107	-0.201	0.529***
	(0.0952)	(0.106)	(0.0732)	(0.0969)	(0.0935)	(0.104)	(0.107)	(0.0994)	(0.132)	(0.163)
Livestock own=1	-0.151	0.118	0.346***	-0.00056	-0.135	0.121	-0.219*	0.0202	0.0676	-0.0320
	(0.0964)	(0.107)	(0.0770)	(0.0958)	(0.0991)	(0.105)	(0.113)	(0.108)	(0.140)	(0.272)
Land own=1	-0.176*	-0.0713	-0.109	-0.0229	0.103	0.139	0.279**	-0.182*	0.144	0.0403
	(0.0942)	(0.102)	(0.0781)	(0.0921)	(0.0894)	(0.0897)	(0.121)	(0.0951)	(0.131)	(0.296)
Mobile own=1	-0.0658	-0.0538	-0.0686	-0.0175	0.00340	-0.284**	-0.0348	0.0535	-0.0258	0.0177
	(0.0931)	(0.100)	(0.0730)	(0.0963)	(0.0880)	(0.111)	(0.108)	(0.0933)	(0.121)	(0.174)
refrigerator own=1	0.150	-0.114	-0.0849	0.0696	-0.0675	-0.112	-0.0450	-0.0152	-0.0179	-
	(0.0953)	(0.134)	(0.0943)	(0.0916)	(0.0908)	(0.0891)	(0.141)	(0.149)	(0.124)	
Regional dummy										
Afar=1	-0.95***	-0.115	1.455***	-1.05***	-0.68***	0.142	-1.36***	-0.52***	-0.151	-
	(0.313)	(0.148)	(0.140)	(0.170)	(0.152)	(0.357)	(0.202)	(0.146)	(0.219)	
Amhara =1	0.196	-0.441***	0.181	-0.495***	0.0585	-0.0465	0.215	0.309**	0.00705	0.471**
	(0.128)	(0.130)	(0.115)	(0.121)	(0.103)	(0.172)	(0.193)	(0.126)	(0.148)	(0.238)
Oromia =1	-0.0334	-0.87***	0.756***	-0.542***	-0.949***	-0.530***	-0.321*	0.432***	0.534***	0.606**
	(0.150)	(0.160)	(0.135)	(0.168)	(0.134)	(0.183)	(0.191)	(0.134)	(0.174)	(0.305)
Somali=1	-1.62***	-1.10***	1.950***	-2.00***	-2.70***	0.341	-0.84***	-1.15***	0.574	-
	(0.196)	(0.203)	(0.156)	(0.205)	(0.209)	(0.243)	(0.243)	(0.157)	(0.379)	
Benishangul=1	0.606***	-1.20***	0.356***	-0.490***	-0.386***	-0.329	-0.0263	0.487***	0.184	-
	(0.151)	(0.213)	(0.135)	(0.159)	(0.147)	(0.218)	(0.218)	(0.166)	(0.205)	
SNNP=1	0.201	-1.58***	0.555***	-0.86***	-1.58***	-1.16***	-0.334*	1.314***	0.625***	0.614**
	(0.125)	(0.138)	(0.112)	(0.129)	(0.120)	(0.182)	(0.189)	(0.143)	(0.174)	(0.296)
Gambella=1	-0.0617	-1.60***	0.238*	-0.53***	-0.170	-0.82***	-0.99***	0.384**	-1.17***	-
	(0.161)	(0.203)	(0.136)	(0.154)	(0.133)	(0.200)	(0.212)	(0.160)	(0.186)	

Harari=1	0.668***		0.893***	-0.500**	-0.99***	-0.84***	-0.421	0.222	0.410	0.233
	(0.202)		(0.177)	(0.215)	(0.204)	(0.242)	(0.276)	(0.205)	(0.322)	(0.420)
Addis Ababa=1	-0.0136	-1.124***	0.259**	-0.56***	-0.66***	-0.99***	-0.0807	0.513***	0.461***	0.695
	(0.136)	(0.177)	(0.130)	(0.128)	(0.117)	(0.175)	(0.197)	(0.144)	(0.177)	(0.439)
Dire Dawa=1	-0.636**	-1.54***	0.660***	-0.85***	-0.78***	-1.092***	-0.245	0.0876	0.200	-0.924***
	(0.267)	(0.296)	(0.166)	(0.258)	(0.162)	(0.238)	(0.305)	(0.200)	(0.274)	(0.278)
Constant	-18.4***	-19.4***	-10.9***	-9.41***	-20.2***	5.368***	0.851	5.270**	-0.536	-6.415**
	(1.683)	(1.843)	(1.318)	(1.450)	(1.610)	(2.083)	(2.084)	(2.213)	(2.132)	(2.677)
Obs.	5,103	5,012	5,103	5,103	5,103	5,103	5,103	5,103	5,103	2,866

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Annex 3-8: First stage regression results of probit model: fifth quintile

Variables	Eq.1	Eq.2	Eq.3	Eq.4	Eq. 5	Eq.6	Eq.7	Eq.8	Eq.9	Eq.10
Ln (food exp.)	0.82***	1.287***	1.07***	0.807***	0.932***	-0.33***	-0.289	-0.133	0.0673	0.599***
	(0.0565)	(0.0628)	(0.0647)	(0.0533)	(0.0611)	(0.120)	(0.208)	(0.182)	(0.184)	(0.185)
lnp1	-0.6***	0.139	-0.0349	0.0551	0.0777	-0.23**	-0.0052	-0.653***	-0.83***	0.254
	(0.0964)	(0.0865)	(0.0866)	(0.0867)	(0.0899)	(0.116)	(0.122)	(0.166)	(0.271)	(0.200)
lnp2	0.87***	-0.793***	0.141	0.386***	0.373**	-1.18***	0.611**	0.428**	-0.229	0.988**
	(0.145)	(0.150)	(0.129)	(0.127)	(0.160)	(0.235)	(0.242)	(0.177)	(0.223)	(0.389)
lnp3	0.0515*	0.0836**	-0.49***	-0.0146	0.0245	0.0653	0.0310	0.0891*	-0.0304	0.225*
	(0.0295)	(0.0371)	(0.0357)	(0.0347)	(0.0348)	(0.0483)	(0.0489)	(0.0520)	(0.0819)	(0.134)
lnp4	-0.199	-0.0532	-0.283	-0.660***	-0.585***	-0.468*	-0.53**	-0.178	-0.112	-1.613***
	(0.191)	(0.159)	(0.173)	(0.188)	(0.180)	(0.241)	(0.233)	(0.235)	(0.260)	(0.353)
lnp5	0.0942	-0.0739	-0.0707	0.0596	-0.159*	0.266***	0.39***	0.372***	0.223*	-0.148
	(0.0773)	(0.0714)	(0.0761)	(0.0696)	(0.0840)	(0.0901)	(0.108)	(0.138)	(0.122)	(0.189)
lnp6	0.0447	0.182**	-0.0424	0.0394	-0.331***	0.455***	0.405**	0.972***	0.210	-0.893***
	(0.0855)	(0.0869)	(0.0848)	(0.0885)	(0.0952)	(0.0905)	(0.205)	(0.132)	(0.147)	(0.227)
lnp7	-0.23***	0.0759	-0.0388	0.0379	-0.155*	0.0340	-0.126	0.335**	0.672***	0.00622
	(0.0797)	(0.0821)	(0.0813)	(0.0728)	(0.0848)	(0.129)	(0.1000)	(0.145)	(0.146)	(0.220)
lnp8	-0.16**	0.0627	0.0882	0.178**	-0.0294	0.406***	0.28***	-0.117	0.278**	-0.437
	(0.0683)	(0.0731)	(0.0690)	(0.0692)	(0.0731)	(0.0972)	(0.100)	(0.0923)	(0.126)	(0.282)
lnp9	-0.0285	-0.193***	-0.0243	0.0217	-0.286***	0.106	0.0761	-0.0579	-0.181**	0.109
	(0.0549)	(0.0557)	(0.0563)	(0.0582)	(0.0652)	(0.0812)	(0.0773)	(0.0827)	(0.0830)	(0.167)
lnp10	-0.19***	0.111**	-0.14***	-0.158***	0.737***	0.0319	-0.40**	-0.406***	-0.546***	-0.0451
	(0.0441)	(0.0478)	(0.0456)	(0.0433)	(0.0481)	(0.0844)	(0.169)	(0.148)	(0.155)	(0.103)
Ln (HH size)	-0.322***	-0.599***	0.0640	-0.299***	-0.779***	1.343***	1.27***	1.145***	1.256***	0.124
	(0.0475)	(0.0525)	(0.0522)	(0.0467)	(0.0523)	(0.0841)	(0.0976)	(0.0924)	(0.104)	(0.276)
Ln (age)	-0.187**	0.0315	-0.33***	-0.338***	-0.174*	0.805***	0.244*	0.220	1.166***	-0.887
	(0.0835)	(0.0879)	(0.0918)	(0.0813)	(0.0906)	(0.110)	(0.143)	(0.156)	(0.207)	(0.557)
Sex dummy (F=1)	-0.100*	-0.0421	-0.0207	-0.00326	0.0149	-0.425***	-0.85***	-0.646***	-0.982***	-0.0505
	(0.0518)	(0.0545)	(0.0564)	(0.0528)	(0.0568)	(0.0830)	(0.137)	(0.122)	(0.135)	(0.463)
Education dummy										
Primary=1	0.165*	0.161*	0.0536	0.326***	0.131	-0.0112	0.398**	0.129	0.329*	0.360
	(0.0842)	(0.0915)	(0.0815)	(0.0905)	(0.0910)	(0.150)	(0.181)	(0.152)	(0.186)	(0.385)
Secondary=1	0.336***	0.0823	0.135	0.531***	0.0974	0.181	0.531***	0.253	0.308	0.266
	(0.0905)	(0.0951)	(0.0858)	(0.0909)	(0.0948)	(0.150)	(0.191)	(0.170)	(0.222)	(0.391)
Graduates=1	0.401***	0.182**	0.28***	0.649***	0.228**	0.259*	0.549***	0.377**	0.365*	1.313**
	(0.0845)	(0.0921)	(0.0821)	(0.0867)	(0.0906)	(0.140)	(0.171)	(0.149)	(0.191)	(0.637)
Other education=1	0.466***	0.140	0.124	0.238*	0.254*	-0.559**	0.0525	0.223	-0.676***	0.0196
	(0.140)	(0.130)	(0.131)	(0.135)	(0.134)	(0.254)	(0.259)	(0.214)	(0.258)	(0.328)
Capacity to 300 ETB=1	-0.198***	-0.0193	-0.127*	0.0436	-0.252***	0.186*	-0.158	0.255**	0.163	-0.238
	(0.0689)	(0.0644)	(0.0659)	(0.0655)	(0.0702)	(0.0979)	(0.128)	(0.120)	(0.135)	(0.308)
Livestock own=1	-0.159**	-0.0568	0.0186	-0.0847	0.00686	0.253***	0.0450	-0.206*	0.0454	-0.648***
	(0.0652)	(0.0629)	(0.0634)	(0.0596)	(0.0680)	(0.0913)	(0.153)	(0.115)	(0.120)	(0.223)
Land own=1	-0.152***	-0.0498	0.114**	-0.105**	-0.0333	0.107	0.0114	-0.0603	0.0514	0.474**
	(0.0507)	(0.0507)	(0.0501)	(0.0493)	(0.0530)	(0.0762)	(0.112)	(0.104)	(0.0962)	(0.231)

Mobile own=1	0.113	0.231***	0.109	-0.0833	-0.0846	-0.173	0.241*	0.0969	-0.235	-0.876***
	(0.0732)	(0.0772)	(0.0719)	(0.0731)	(0.0771)	(0.115)	(0.131)	(0.112)	(0.155)	(0.268)
refrigerator own=1	0.0943*	0.0161	-0.0563	0.104**	0.00608	-0.0214	0.221**	0.265**	-0.0618	0.380
	(0.0518)	(0.0560)	(0.0538)	(0.0500)	(0.0529)	(0.0785)	(0.106)	(0.127)	(0.116)	(0.279)
Regional dummy										
Afar=1	-1.573***	0.570***	0.340**	-0.528***	-0.164	-1.015***	-1.075***	-0.826***	-0.339	-
	(0.236)	(0.148)	(0.142)	(0.145)	(0.159)	(0.229)	(0.234)	(0.240)	(0.240)	
Amhara=1	0.0197	-0.137	-0.0849	-0.409***	0.0493	-0.332**	-0.198	-0.0521	-0.613***	0.175
	(0.107)	(0.102)	(0.102)	(0.0975)	(0.0985)	(0.133)	(0.156)	(0.188)	(0.177)	(0.467)
Oromia=1	0.0929	-0.798***	0.83***	-0.114	-0.801***	-0.471***	-0.226	0.130	0.0665	-0.500
	(0.101)	(0.102)	(0.0931)	(0.0980)	(0.103)	(0.138)	(0.181)	(0.170)	(0.175)	(0.379)
Somali=1	-1.343***	-0.438***	1.55***	-1.775***	-2.082***	0.445**	-1.556***	-1.777***	0.617**	-
	(0.106)	(0.111)	(0.130)	(0.149)	(0.159)	(0.213)	(0.183)	(0.204)	(0.272)	
Benishangul =1	0.427***	-1.023***	0.328**	-0.409***	-0.139	-0.267	-0.196	0.207	-0.411	-
	(0.143)	(0.159)	(0.142)	(0.148)	(0.155)	(0.229)	(0.216)	(0.253)	(0.363)	
SNNP=1	0.223**	-1.247***	0.59***	-0.577***	-1.153***	-1.047***	-0.492**	0.735***	0.0327	-1.203***
	(0.109)	(0.128)	(0.0998)	(0.0997)	(0.109)	(0.162)	(0.202)	(0.200)	(0.194)	(0.373)
Gambella=1	0.223**	-0.841***	0.204*	-0.794***	-0.0789	-1.047***	-0.805***	-0.333	-1.504***	-
	(0.112)	(0.116)	(0.109)	(0.110)	(0.107)	(0.155)	(0.207)	(0.207)	(0.221)	
Harari=1	0.477***	-1.741***	0.48***	-0.346***	-0.803***	-1.027***	-0.557**	-0.106	-0.225	-
	(0.115)	(0.179)	(0.116)	(0.110)	(0.118)	(0.173)	(0.227)	(0.245)	(0.268)	
Addis Ababa=1	0.243***	-0.879***	0.36***	-0.190**	-0.613***	-0.788***	-0.349**	0.0648	-0.446***	-0.209
	(0.0923)	(0.0964)	(0.0883)	(0.0865)	(0.0881)	(0.136)	(0.171)	(0.176)	(0.171)	(0.408)
Dire Dawa=1	0.283**	-0.801***	0.208*	-0.394***	-0.667***	-0.772***	-0.0409	0.0242	-0.250	-1.089**
	(0.121)	(0.139)	(0.122)	(0.123)	(0.130)	(0.191)	(0.245)	(0.238)	(0.329)	(0.431)
Constant	-8.109***	-13.39***	-10.5***	-7.364***	-8.070***	1.226	3.073	1.159	-3.231	1.266
	(0.686)	(0.757)	(0.787)	(0.625)	(0.746)	(1.367)	(2.376)	(2.078)	(2.058)	(2.774)
Obs.	8,371	8,371	8,371	8,371	8,371	8,371	8,371	8,371	8,371	6,460

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Annex 4.9: First stage regression results of probit model: illiterate

Variables	Eq.1	Eq.2	Eq.3	Eq.4	Eq. 5	Eq.6	Eq.7	Eq.8	Eq.9	Eq.10
Ln (food exp.)	0.95***	1.28***	0.890***	0.820***	1.170***	-0.136*	0.616***	0.416***	0.40***	0.86***
	(0.0616)	(0.0721)	(0.0474)	(0.0671)	(0.0602)	(0.0695)	(0.0583)	(0.0493)	(0.0628)	(0.0751)
lnp1	-0.90***	0.00343	0.0339	0.0422	0.256**	-0.288	0.207*	-0.0732	-0.0488	0.117
	(0.121)	(0.108)	(0.103)	(0.130)	(0.115)	(0.179)	(0.107)	(0.0904)	(0.150)	(0.154)
lnp2	0.411*	-0.284	0.624***	0.692**	0.711**	-0.611**	0.666***	0.659***	-0.130	0.783*
	(0.235)	(0.317)	(0.181)	(0.279)	(0.281)	(0.244)	(0.215)	(0.213)	(0.307)	(0.470)
lnp3	0.18***	0.0699	-0.88***	0.102	0.00463	0.00903	0.189***	0.272***	0.145**	0.153**
	(0.0497)	(0.0620)	(0.0498)	(0.0645)	(0.0461)	(0.0524)	(0.0488)	(0.0414)	(0.0641)	(0.0611)
lnp4	0.0343	0.589**	-0.229	-1.23***	-0.91***	-0.401*	0.150	0.206	0.539	-1.38***
	(0.319)	(0.246)	(0.220)	(0.391)	(0.224)	(0.241)	(0.221)	(0.182)	(0.331)	(0.408)
lnp5	0.377***	0.0533	0.126	0.0671	-1.340***	0.606***	0.399***	0.245***	0.0651	-0.433***
	(0.127)	(0.105)	(0.0864)	(0.114)	(0.114)	(0.103)	(0.0947)	(0.0881)	(0.119)	(0.0671)
lnp6	-0.00115	-0.107	-0.37***	0.00399	-0.347***	-0.514***	0.119	0.0528	0.0437	-0.176
	(0.0936)	(0.0917)	(0.0602)	(0.0873)	(0.0752)	(0.0618)	(0.0823)	(0.0694)	(0.102)	(0.109)
lnp7	-0.177**	0.0500	-0.00866	-0.160**	-0.276***	-0.00387	-0.531***	0.174***	0.37***	-0.0653
	(0.0714)	(0.0896)	(0.0489)	(0.0776)	(0.0626)	(0.104)	(0.0404)	(0.0632)	(0.0746)	(0.0783)
lnp8	-0.0593	0.0200	-0.0247	0.122*	-0.0146	0.379***	0.231***	-0.481***	0.21***	-0.159**
	(0.0516)	(0.0629)	(0.0418)	(0.0637)	(0.0485)	(0.0597)	(0.0492)	(0.0327)	(0.0571)	(0.0647)
lnp9	-0.351***	-0.16***	0.0483	0.00934	-0.0656	0.139***	0.179***	-0.0455	-0.51***	-0.285***
	(0.0483)	(0.0612)	(0.0346)	(0.0655)	(0.0543)	(0.0527)	(0.0405)	(0.0435)	(0.0380)	(0.0707)
lnp10	-0.0631*	0.19***	-0.064**	-0.0688	0.310***	0.198***	-0.0434	-0.103***	-0.11***	-0.342***
	(0.0377)	(0.0521)	(0.0314)	(0.0524)	(0.0333)	(0.0458)	(0.0406)	(0.0336)	(0.0418)	(0.0253)
Ln (HH size)	-0.244***	-0.49***	0.00256	-0.206***	-1.091***	0.875***	0.372***	0.254***	0.58***	-0.419***
	(0.0615)	(0.0654)	(0.0478)	(0.0621)	(0.0586)	(0.0789)	(0.0615)	(0.0549)	(0.0738)	(0.0894)
Ln (age)	-0.231**	-0.0196	-0.149**	-0.128	-0.230***	0.0429	-0.0511	-0.185***	0.0300	-0.310**
	(0.0918)	(0.0976)	(0.0648)	(0.102)	(0.0777)	(0.0909)	(0.0754)	(0.0701)	(0.0884)	(0.130)
Sex	-0.0518	-0.0457	0.0821*	-0.0697	0.0636	-0.128	-0.250***	-0.253***	-0.37***	0.0379

dummy (F=1)										
	(0.0656)	(0.0706)	(0.0483)	(0.0729)	(0.0584)	(0.0871)	(0.0625)	(0.0566)	(0.0818)	(0.102)
Capacity to 300 ETB=1	-0.215***	-0.0778	0.134**	-0.0340	0.0205	0.150*	-0.224***	0.0358	-0.0628	0.104
	(0.0699)	(0.0825)	(0.0540)	(0.0807)	(0.0671)	(0.0885)	(0.0767)	(0.0645)	(0.0841)	(0.102)
Livestock own=1	-0.192**	-0.108	0.246***	-0.0495	0.0386	0.117	-0.105	-0.0610	0.00608	-0.0369
	(0.0802)	(0.0774)	(0.0589)	(0.0943)	(0.0697)	(0.0923)	(0.0785)	(0.0642)	(0.0931)	(0.109)
Land own=1	-0.200**	0.0175	-0.0275	-0.147	-0.175**	0.168*	0.114	-0.149**	0.0492	-0.125
	(0.0844)	(0.0796)	(0.0699)	(0.100)	(0.0775)	(0.0951)	(0.0829)	(0.0751)	(0.106)	(0.128)
Mobile own=1	-0.0729	0.0729	-0.109**	0.118	-0.00251	-0.192**	0.124**	0.0974*	0.0846	-0.0695
	(0.0615)	(0.0682)	(0.0463)	(0.0721)	(0.0551)	(0.0796)	(0.0570)	(0.0507)	(0.0682)	(0.0876)
refrigerator own=1	0.194	0.178	-0.0941	0.152	0.0404	0.0260	0.177	-0.00909	0.0337	-0.115
	(0.147)	(0.121)	(0.120)	(0.131)	(0.116)	(0.119)	(0.197)	(0.174)	(0.210)	(0.299)
Regional dummy										
Afar=1	-1.569***	-0.121	1.596***	-1.236***	-0.724***	-0.566***	-1.525***	-0.605***	-0.237	0.0964
	(0.320)	(0.110)	(0.101)	(0.153)	(0.107)	(0.199)	(0.131)	(0.0915)	(0.149)	(0.232)
Amhara=1	0.152	-0.0910	0.112	-0.436***	0.183**	-0.132	0.0338	0.0625	-0.28***	-0.0712
	(0.0985)	(0.0892)	(0.0799)	(0.0922)	(0.0764)	(0.168)	(0.118)	(0.0722)	(0.109)	(0.139)
Oromia=1	-0.200**	-1.33***	1.011***	-0.860***	-1.046***	-0.700***	-0.418***	0.505***	0.171	-0.525***
	(0.0957)	(0.119)	(0.0756)	(0.0974)	(0.0846)	(0.162)	(0.118)	(0.0772)	(0.122)	(0.135)
Somali=1	-1.403***	-0.68***	1.775***	-2.107***	-2.664***	0.0210	-1.365***	-1.125***	0.0505	
	(0.155)	(0.105)	(0.0969)	(0.262)	(0.203)	(0.215)	(0.132)	(0.0879)	(0.172)	
Benishangul=1	0.636***	-0.92***	0.128	-0.659***	-0.328***	0.259	0.724***	0.993***	0.263	0.152
	(0.126)	(0.208)	(0.110)	(0.156)	(0.119)	(0.218)	(0.228)	(0.151)	(0.191)	(0.219)
SNNP=1	-0.00656	-1.38***	0.465***	-0.913***	-1.540***	-0.981***	-0.651***	1.285***	0.259**	0.276
	(0.102)	(0.153)	(0.0807)	(0.114)	(0.121)	(0.163)	(0.115)	(0.108)	(0.129)	(0.174)
Gambella=1	0.0603	-1.06***	0.724***	-0.708***	-0.00390	-0.478**	-1.216***	0.585***	-1.57***	0.213
	(0.142)	(0.182)	(0.102)	(0.163)	(0.116)	(0.212)	(0.144)	(0.147)	(0.138)	(0.317)
Harari=1	0.0295		0.666***	-0.652***	-1.570***	-1.272***	-0.621***	0.102	-0.46***	1.626*
	(0.162)		(0.133)	(0.185)	(0.165)	(0.192)	(0.179)	(0.141)	(0.170)	(0.931)
Addis Ababa=1	-0.00347	-0.92***	0.453***	-0.529***	-0.852***	-0.987***	-0.0638	0.933***	0.426**	0.130
	(0.128)	(0.152)	(0.114)	(0.125)	(0.116)	(0.183)	(0.201)	(0.171)	(0.207)	(0.289)
Dire Dawa=1	-0.317*	-0.71***	0.567***	-0.853***	-1.221***	-0.978***	-0.227	0.285**	-0.419**	-0.849***
	(0.174)	(0.174)	(0.120)	(0.211)	(0.145)	(0.199)	(0.201)	(0.122)	(0.167)	(0.178)
Constant	-9.126***	-13.0***	-9.52***	-8.358***	-9.733***	2.538***	-4.046***	-2.430***	-2.67***	-4.115***
	(0.656)	(0.808)	(0.514)	(0.768)	(0.616)	(0.754)	(0.633)	(0.524)	(0.708)	(0.830)
Obs.	9,414	9,203	9,414	9,414	9,414	9,414	9,414	9,414	9,414	8,378

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Annex 4.10: First stage regression results of probit model: literate

Variables	Eq.1	Eq.2	Eq.3	Eq.4	Eq. 5	Eq.6	Eq.7	Eq.8	Eq.9	Eq.10
Ln (food exp.)	1.115***	1.355***	0.995***	1.032***	1.043***	-0.114***	0.0921*	0.132***	0.186***	0.749***
	(0.0401)	(0.0479)	(0.0368)	(0.0373)	(0.0387)	(0.0440)	(0.0532)	(0.0474)	(0.0465)	(0.0749)
lnp1	-0.630***	0.379***	0.0561	0.158*	0.0391	-0.194*	0.0179	-0.105	-0.143	0.307***
	(0.0831)	(0.0771)	(0.0739)	(0.0828)	(0.0799)	(0.100)	(0.119)	(0.108)	(0.147)	(0.0981)
lnp2	0.923***	-0.391**	0.283**	0.769***	0.808***	-1.090***	-0.604*	-0.383*	-0.88***	1.138***
	(0.135)	(0.191)	(0.127)	(0.129)	(0.159)	(0.192)	(0.317)	(0.211)	(0.267)	(0.286)
lnp3	0.117***	0.101***	-0.629***	0.0264	0.118***	-0.00426	0.0309	0.101**	-0.0862	0.204***
	(0.0268)	(0.0306)	(0.0325)	(0.0303)	(0.0296)	(0.0327)	(0.0456)	(0.0460)	(0.0560)	(0.0745)
lnp4	-0.339**	-0.186	-0.531***	-1.12***	-0.680***	-0.668***	-0.267	0.350**	0.370*	-2.246***
	(0.137)	(0.131)	(0.129)	(0.169)	(0.142)	(0.210)	(0.189)	(0.146)	(0.205)	(0.517)
lnp5	0.179***	0.0167	0.168***	0.108**	-0.868***	0.390***	0.492***	0.362***	0.370***	-0.452***
	(0.0574)	(0.0567)	(0.0560)	(0.0531)	(0.0683)	(0.0541)	(0.0615)	(0.0699)	(0.0707)	(0.157)
lnp6	-0.0423	-0.133*	-0.278***	-0.104	-0.510***	-0.248***	0.138	-0.0413	0.246***	-0.441***
	(0.0620)	(0.0706)	(0.0529)	(0.0637)	(0.0601)	(0.0493)	(0.0858)	(0.0752)	(0.0814)	(0.109)
lnp7	-0.123**	-0.178***	-0.0829*	-0.210***	-0.217***	-0.0988	-0.409***	0.112	0.285***	-0.153

	(0.0541)	(0.0684)	(0.0474)	(0.0525)	(0.0572)	(0.0942)	(0.0418)	(0.0762)	(0.0837)	(0.0968)
lnp8	-0.122***	0.0690	-0.0192	0.115**	-0.0106	0.363***	0.225***	-0.351***	0.165**	-0.0459
	(0.0427)	(0.0586)	(0.0395)	(0.0447)	(0.0443)	(0.0547)	(0.0614)	(0.0324)	(0.0662)	(0.0987)
lnp9	-0.195***	0.00493	0.144***	0.105***	0.0230	0.0579	0.230***	-0.0251	-0.362***	-0.0812
	(0.0369)	(0.0486)	(0.0311)	(0.0379)	(0.0384)	(0.0509)	(0.0486)	(0.0506)	(0.0369)	(0.0913)
lnp10	-0.0949***	0.118***	-0.0538*	-0.0456	0.446***	0.153***	-0.155***	-0.195***	-0.374***	-0.409***
	(0.0314)	(0.0363)	(0.0293)	(0.0336)	(0.0322)	(0.0448)	(0.0503)	(0.0410)	(0.0497)	(0.0386)
Ln (HH size)	-0.323***	-0.703***	0.0979***	-0.344***	-0.947***	1.167***	1.055***	0.876***	1.047***	-0.166
	(0.0355)	(0.0400)	(0.0325)	(0.0341)	(0.0364)	(0.0555)	(0.0540)	(0.0496)	(0.0595)	(0.108)
Ln (age)	-0.169***	-0.0237	-0.196***	-0.372***	-0.154**	0.410***	0.0893	0.103	0.515***	0.00502
	(0.0638)	(0.0772)	(0.0585)	(0.0640)	(0.0618)	(0.0742)	(0.0934)	(0.0839)	(0.0970)	(0.152)
Sex dummy (F=1)	-0.0692*	0.0793*	-0.0294	-0.119***	0.123***	-0.518***	-0.746***	-0.882***	-0.994***	-0.203
	(0.0404)	(0.0463)	(0.0402)	(0.0410)	(0.0401)	(0.0595)	(0.0812)	(0.0752)	(0.0706)	(0.155)
Education dummy										
Primary=1	0.0149	-0.00246	0.0337	0.0178	-0.147**	0.138	0.141	0.254***	0.498***	0.166
	(0.0756)	(0.0822)	(0.0658)	(0.0797)	(0.0704)	(0.121)	(0.118)	(0.0871)	(0.109)	(0.151)
Secondary=1	0.192**	0.0348	0.0194	0.370***	-0.155**	0.134	0.207	0.350***	0.492***	0.0410
	(0.0848)	(0.0898)	(0.0748)	(0.0860)	(0.0783)	(0.125)	(0.130)	(0.0984)	(0.120)	(0.195)
Graduates=1	0.275***	0.109	0.223***	0.627***	-0.130*	0.100	0.256**	0.444***	0.522***	0.466**
	(0.0795)	(0.0856)	(0.0726)	(0.0831)	(0.0761)	(0.121)	(0.122)	(0.0964)	(0.115)	(0.190)
Capacity to 300 ETB=1	-0.204***	0.0319	-0.0547	-0.0101	-0.0472	0.158**	-0.190***	-0.0829	-0.142*	-0.260*
	(0.0471)	(0.0530)	(0.0421)	(0.0488)	(0.0471)	(0.0629)	(0.0698)	(0.0628)	(0.0781)	(0.133)
Livestock own=1	-0.102**	-0.00263	0.122***	-0.0603	0.00112	0.243***	0.0164	-0.0120	0.00912	0.204
	(0.0462)	(0.0498)	(0.0423)	(0.0445)	(0.0483)	(0.0611)	(0.0671)	(0.0628)	(0.0706)	(0.128)
Land own=1	-0.153***	-0.0831**	0.0206	-0.0822**	-0.0107	0.145***	0.0236	-0.0508	0.157**	-0.0239
	(0.0415)	(0.0419)	(0.0408)	(0.0398)	(0.0422)	(0.0521)	(0.0590)	(0.0597)	(0.0652)	(0.122)
Mobile own=1	-0.0888*	0.0557	-0.0144	0.0101	0.0415	-0.137**	0.0677	0.0377	-0.00853	0.00577
	(0.0485)	(0.0552)	(0.0415)	(0.0494)	(0.0469)	(0.0675)	(0.0646)	(0.0580)	(0.0730)	(0.120)
refrigerator own=1	0.156***	0.0982**	-0.0270	0.159***	-0.0817*	-0.114**	0.0550	0.103	-0.0219	0.383***
	(0.0452)	(0.0488)	(0.0439)	(0.0421)	(0.0417)	(0.0548)	(0.0625)	(0.0738)	(0.0646)	(0.146)
Regional dummy										
Afar=1	-1.362***	0.564***	0.710***	-0.595***	-0.258***	-0.407***	-0.563***	-0.119	0.0713	-
	(0.179)	(0.0953)	(0.0934)	(0.107)	(0.0991)	(0.147)	(0.146)	(0.115)	(0.164)	
Amhara=1	0.0904	-0.202***	0.0803	-0.506***	0.189***	-0.164**	0.192**	0.256***	-0.298***	0.354***
	(0.0711)	(0.0732)	(0.0614)	(0.0668)	(0.0570)	(0.0749)	(0.0976)	(0.0766)	(0.0901)	(0.130)
Oromia=1	-0.202***	-1.178***	0.752***	-0.592***	-0.899***	-0.608***	0.00368	0.557***	0.352***	-0.259**
	(0.0671)	(0.0732)	(0.0570)	(0.0621)	(0.0579)	(0.0820)	(0.1000)	(0.0767)	(0.0970)	(0.129)
Somali=1	-1.490***	-0.422***	1.591***	-1.754***	-2.133***	-0.163	-0.921***	-1.236***	0.432*	-
	(0.0977)	(0.105)	(0.112)	(0.145)	(0.114)	(0.144)	(0.162)	(0.113)	(0.261)	
Benishangul=1	0.430***	-0.690***	0.229***	-0.428***	-0.0550	-0.273**	0.368***	0.798***	0.389***	0.910***
	(0.0840)	(0.112)	(0.0745)	(0.0894)	(0.0748)	(0.108)	(0.123)	(0.101)	(0.123)	(0.280)
SNNP=1	0.118*	-1.352***	0.386***	-0.751***	-1.242***	-1.050***	-0.362***	1.039***	0.368***	0.412**
	(0.0700)	(0.0944)	(0.0593)	(0.0677)	(0.0662)	(0.0908)	(0.103)	(0.0813)	(0.101)	(0.197)
Gambella=1	-0.0591	-0.995***	0.0400	-0.951***	-0.0264	-0.822***	-0.556***	0.392***	-1.075***	0.823**
	(0.0759)	(0.0872)	(0.0690)	(0.0815)	(0.0684)	(0.0915)	(0.117)	(0.100)	(0.110)	(0.355)
Harari=1	0.517***	-1.828***	0.551***	-0.336***	-0.739***	-1.161***	-0.541***	0.190	-0.0774	0.501
	(0.0898)	(0.169)	(0.0885)	(0.0890)	(0.0883)	(0.110)	(0.131)	(0.122)	(0.152)	(0.418)
Addis Ababa=1	0.102	-1.003***	0.240***	-0.423***	-0.625***	-0.975***	-0.00354	0.589***	0.194**	0.699***
	(0.0649)	(0.0743)	(0.0595)	(0.0619)	(0.0578)	(0.0798)	(0.0977)	(0.0814)	(0.0989)	(0.208)

Dire Dawa=1	0.0417	-0.895***	0.290***	-0.552***	-0.506***	-0.898***	-0.147	0.224**	0.270	-0.256
	(0.0933)	(0.119)	(0.0944)	(0.101)	(0.0909)	(0.115)	(0.141)	(0.112)	(0.182)	(0.191)
Constant	-10.96***	-13.62***	-10.18***	-9.291***	-9.006***	0.575	-0.0634	-1.020*	-2.674***	-4.653***
	(0.452)	(0.501)	(0.420)	(0.422)	(0.419)	(0.512)	(0.645)	(0.560)	(0.583)	(0.808)
Obs.	20,813	20,813	20,813	20,813	20,813	20,813	20,813	20,813	20,813	19,414

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Structural parameters

Annex 4.11: Structural parameters of QUAIDS-national

Variables	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10
Lnp1	-0.116***	0.128***	0.0258***	0.00942	-0.0099***	-0.0102***	-0.00458*	0.000131	0.0379***	-0.060***
	(0.0102)	(0.0108)	(0.00414)	(0.00779)	(0.00312)	(0.00391)	(0.00235)	(0.00322)	(0.00255)	(0.00594)
Lnp2	0.128***	-0.222***	0.0283***	0.091***	0.0194***	0.0240***	-0.00481	0.00703	-0.00736*	-0.063***
	(0.0108)	(0.0221)	(0.00573)	(0.0100)	(0.00449)	(0.00607)	(0.00404)	(0.00483)	(0.00400)	(0.00729)
Lnp3	0.0258***	0.028***	-0.0078***	0.013***	0.00116	-0.0348***	-0.00336***	-0.00934***	-0.0053***	-0.00712*
	(0.00414)	(0.00573)	(0.00233)	(0.00282)	(0.00145)	(0.00171)	(0.000942)	(0.00127)	(0.000999)	(0.00380)
Lnp4	0.00942	0.091***	0.0125***	-0.077***	-0.00229	-0.0309***	-0.00615*	0.00867***	0.0163***	-0.021***
	(0.00779)	(0.0100)	(0.00282)	(0.0112)	(0.00238)	(0.00424)	(0.00318)	(0.00335)	(0.00259)	(0.00329)
Lnp5	-0.0099***	0.019***	0.00116	-0.00229	0.0115***	-0.0287***	-0.00495***	0.00119	0.0082***	0.0044**
	(0.00312)	(0.00449)	(0.00145)	(0.00238)	(0.00264)	(0.00225)	(0.00163)	(0.00170)	(0.00154)	(0.00175)
Lnp6	-0.0102***	0.024***	-0.0348***	-0.031***	-0.0287***	0.112***	-0.00376**	-0.00289	-0.0263***	0.00112
	(0.00391)	(0.00607)	(0.00171)	(0.00424)	(0.00225)	(0.00331)	(0.00153)	(0.00181)	(0.00150)	(0.00210)
Lnp7	-0.00458*	-0.00481	-0.0034***	-0.00615*	-0.0049***	-0.00376**	0.0486***	0.0122***	-0.0105***	-0.023***
	(0.00235)	(0.00404)	(0.000942)	(0.00318)	(0.00163)	(0.00153)	(0.00178)	(0.00133)	(0.00096)	(0.00139)
Lnp8	0.000131	0.00703	-0.0093***	0.009***	0.00119	-0.00289	0.0122***	-0.00139	-0.0083***	-0.007***
	(0.00322)	(0.00483)	(0.00127)	(0.0033)	(0.00170)	(0.00181)	(0.00133)	(0.00207)	(0.0014)	(0.0016)
Lnp9	0.0379***	-0.00736*	-0.0053***	0.016***	0.0082***	-0.0263***	-0.0105***	-0.00830***	0.0277***	-0.032***
	(0.00255)	(0.00400)	(0.0010)	(0.0026)	(0.00154)	(0.00150)	(0.00096)	(0.00139)	(0.00177)	(0.00132)
Lnp10	-0.0599***	-0.063***	-0.00712*	-0.021***	0.00442**	0.00112	-0.0227***	-0.00728***	-0.0322***	0.208***
	(0.00594)	(0.00729)	(0.00380)	(0.0033)	(0.00175)	(0.00210)	(0.00139)	(0.00155)	(0.00132)	(0.00769)
Ln(food exp.)	0.108***	0.061***	0.125***	0.0136	0.0213***	-0.0628***	-0.0415***	-0.0386***	0.00347	0.060***
	(0.0129)	(0.0144)	(0.00662)	(0.00838)	(0.00316)	(0.00303)	(0.00192)	(0.00248)	(0.00237)	(0.0158)
Ln(food exp.)^2	-0.0299***	0.00620	0.0313***	0.00285	-0.0307***	-0.0525***	-0.0240***	-0.0283***	-0.0149***	0.140***
	(0.0115)	(0.0175)	(0.00514)	(0.00695)	(0.00466)	(0.0035)	(0.00211)	(0.00271)	(0.00246)	(0.0177)
Exp. residual	-0.0258***	0.027***	0.0153***	-0.011***	0.00123	-0.0118***	-0.00771***	-0.00592***	-0.00166**	0.0206*
	(0.00620)	(0.00869)	(0.00315)	(0.00256)	(0.00144)	(0.00094)	(0.00051)	(0.000526)	(0.000748)	(0.0109)
Ln(HH size)	0.0125	-0.00374	0.0124***	-0.000587	-0.0185***	0.00642***	0.0241***	-	0.0180**	-0.262***
	(0.00827)	(0.00776)	(0.00380)	(0.00223)	(0.00161)	(0.00151)	(0.00163)		(0.00822)	(0.00538)
Ln(age of head)	-0.000523	0.044***	0.00446	0.007***	-0.0099***	0.00612***	-0.00698***	0.0763***	0.0132***	-0.047***
	(0.00620)	(0.00293)	(0.00478)	(0.0018)	(0.00123)	(0.00188)	(0.00118)	(0.0115)	(0.00390)	(0.00638)
Sex of head (M=1)	0.0117	-0.010***	0.00155	0.039***	0.0175***	-0.00147	-	0.0821***	-0.164***	-
	(0.00774)	(0.00362)	(0.00317)	(0.00219)	(0.00140)	(0.00131)		(0.0130)	(0.00654)	
Literate =1	-0.0237*	-0.030***	-0.0184***	-0.045***	0.0108***	-0.0111***	-0.0171***	-0.158***	0.133***	0.310***
	(0.0135)	(0.00836)	(0.00495)	(0.00325)	(0.00197)	(0.00127)	(0.00159)	(0.0168)	(0.0112)	(0.00858)
Constant	0.0830***	-0.0573**	0.223***	0.0298**	0.0581***	0.228***	0.129***	0.169***	0.0832***	0.0538**
	(0.0232)	(0.0292)	(0.00997)	(0.0135)	(0.00767)	(0.00569)	(0.00341)	(0.00460)	(0.00403)	(0.0269)

RMSE	.0947005	.0694684	.063273	.041303	.0392758	.1190776	.0796386	.0993229	.09411	-
R-sq	0.3598*	0.3300*	0.3858*	0.1921*	0.2749*	0.7893*	0.7709*	0.6772*	0.6482*	-
Obs.	30,227	30,227	30,227	30,227	30,227	30,227	30,227	30,227	30,227	30,227

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
R-squared is uncentered

Where Wi and lnpi (i=1,2,3…10) indicates share of food expenditure and unit price for 1=beef, 2=mutton and goat meat, 3=dairy products, 4=poultry and eggs, 5=other livestock products, 6=cereals, 7=pulses and oils, 8=fruits and vegetables, 9= spices and stimulants and 10=other non-livestock food items

Annex 4.12: Structural parameters of QUAIDS-urban

Variables	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10
Lnp1	-0.039***	0.102***	-0.00386	0.00730	-0.0159***	-0.0209***	-0.0075***	0.0154***	0.0242***	-0.0617***
	(0.0101)	(0.0103)	(0.00308)	(0.00731)	(0.00310)	(0.00467)	(0.00268)	(0.00247)	(0.00273)	(0.00594)
Lnp2	0.102***	-0.229***	0.0234***	0.0811***	0.0291***	0.0436***	-0.00505	0.0196***	-0.00342	-0.0609***
	(0.0103)	(0.0195)	(0.00447)	(0.00900)	(0.00430)	(0.00623)	(0.00395)	(0.00390)	(0.00391)	(0.00689)
Lnp3	-0.00386	0.023***	-0.00624***	0.00614***	-0.000991	-0.0110***	-0.0055***	0.00164*	0.0036***	-0.00715***
	(0.00308)	(0.00447)	(0.00177)	(0.00227)	(0.00135)	(0.00160)	(0.000921)	(0.000959)	(0.00102)	(0.00243)
Lnp4	0.00730	0.081***	0.00614***	-0.0336***	-0.0080***	-0.0322***	0.00120	-0.0275***	0.0198***	-0.0142***
	(0.00731)	(0.00900)	(0.00227)	(0.0103)	(0.00261)	(0.00441)	(0.00298)	(0.00296)	(0.00257)	(0.00337)
Lnp5	-0.016***	0.029***	-0.000991	-0.00799***	0.0181***	-0.0226***	-0.0105***	-0.00441**	0.0069***	0.00831***
	(0.00310)	(0.00430)	(0.00135)	(0.00261)	(0.00270)	(0.00256)	(0.00177)	(0.00174)	(0.00161)	(0.00229)
Lnp6	-0.021***	0.044***	-0.0110***	-0.0322***	-0.0226***	0.0810***	-0.0123***	-0.0173***	-0.0197***	0.0113***
	(0.00467)	(0.00623)	(0.00160)	(0.00441)	(0.00256)	(0.00450)	(0.00206)	(0.00211)	(0.00194)	(0.00289)
Lnp7	-0.008***	-0.00505	-0.00550***	0.00120	-0.0105***	-0.0123***	0.0839***	-0.00240	-0.0211***	-0.0208***
	(0.00268)	(0.00395)	(0.000921)	(0.00298)	(0.00177)	(0.00206)	(0.00226)	(0.00152)	(0.00124)	(0.00184)
Lnp8	0.015***	0.020***	0.00164*	-0.0275***	-0.00441**	-0.0173***	-0.00240	0.0314***	-0.00338**	-0.0129***
	(0.00247)	(0.00390)	(0.00096)	(0.00296)	(0.00174)	(0.00211)	(0.00152)	(0.00231)	(0.00144)	(0.00147)
Lnp9	0.024***	-0.00342	0.00357***	0.0198***	0.0069***	-0.0197***	-0.0211***	-0.00338**	0.0250***	-0.0320***
	(0.00273)	(0.00391)	(0.0010)	(0.00257)	(0.00161)	(0.00194)	(0.00124)	(0.00144)	(0.00270)	(0.00173)
Lnp10	-0.062***	-0.061***	-0.00715***	-0.0142***	0.0083***	0.0113***	-0.0208***	-0.0129***	-0.0320***	0.190***
	(0.00594)	(0.00689)	(0.00243)	(0.00337)	(0.00229)	(0.00289)	(0.00184)	(0.00147)	(0.00173)	(0.00845)
Ln(food exp.)	0.048***	0.103***	0.0409***	0.0148*	-0.00489	-0.0713***	-0.0491***	-0.0153***	-0.0099***	0.0550***
	(0.0159)	(0.0124)	(0.00459)	(0.00837)	(0.00334)	(0.00330)	(0.00202)	(0.00217)	(0.00235)	(0.0209)
Ln(food exp.)^2	-0.034***	0.0143**	-3.23e-05	-0.0109***	-0.000223	-0.0107***	-0.0091***	-0.0064***	-0.000900	0.0574***
	(0.00615)	(0.00704)	(0.00200)	(0.00256)	(0.00145)	(0.00168)	(0.000765)	(0.000959)	(0.00169)	(0.00953)
Exp. residual	-0.052***	-0.015***	0.000467	0.0241***	-0.0127***	-0.0438***	-0.0219***	-0.0324***	-0.00344	0.157***
	(0.0100)	(0.0032)	(0.00338)	(0.00583)	(0.00459)	(0.00373)	(0.00218)	(0.00226)	(0.00250)	(0.0138)
Ln(HH size)	0.046***	-0.00397	0.0232***	-0.00357	-0.0176***	0.00106	0.0196***	-	-0.0164**	-0.119***
	(0.00826)	(0.00708)	(0.00382)	(0.00257)	(0.00192)	(0.00150)	(0.00180)		(0.00791)	(0.00584)
Ln(age of head)	-0.00707	0.023***	0.0154***	0.00366*	-0.0092***	-0.0060***	-0.0050***	-0.0543***	-0.000864	-0.0849***
	(0.00605)	(0.00228)	(0.00490)	(0.00202)	(0.00150)	(0.00166)	(0.00130)	(0.0132)	(0.00479)	(0.00695)
Sex of head (M=1)	-0.0143*	-0.010***	0.00578*	0.0184***	0.0221***	-0.000998	-	0.0756***	-0.185***	-
	(0.00751)	(0.00289)	(0.00332)	(0.00288)	(0.00158)	(0.00119)		(0.0109)	(0.00684)	
Literate=1	-0.0243*	-0.00906	-0.0444***	-0.0185***	0.00471**	0.0059***	-0.0146***	-0.0212	0.202***	0.204***
	(0.0132)	(0.00749)	(0.00558)	(0.00403)	(0.00231)	(0.00121)	(0.00184)	(0.0168)	(0.0116)	(0.00930)
Constant	0.159***	-0.099***	0.160***	0.0419***	0.0779***	0.219***	0.125***	0.173***	0.0864***	0.0576*
	(0.0259)	(0.0291)	(0.00803)	(0.0147)	(0.00924)	(0.00677)	(0.00391)	(0.00417)	(0.00454)	(0.0318)
RMSE	0.0948	0.0710	0.0481	0.0424	0.0355	0.1168	0.0751	0.0794	0.0904	

R-sq	0.3758*	0.3561*	0.4258*	0.1915*	0.3221*	0.7812*	0.7987*	0.7425*	0.6545*	
Obs.	19,860	19,860	19,860	19,860	19,860	19,860	19,860	19,860	19,860	19,860

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
R-squared is uncentered

Annex 4.13: Structural parameters of QUAIDS-rural

Variables	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10
Lnp1	-0.260***	0.262***	0.0384***	0.00776	0.00428	-0.0124	0.00500	-0.025***	0.032***	-0.052***
	(0.0207)	(0.0285)	(0.0131)	(0.0151)	(0.00697)	(0.00820)	(0.00551)	(0.00843)	(0.00571)	(0.0114)
Lnp2	0.262***	-0.551***	0.0266	0.252***	-0.0104	-0.0009	0.0135	-0.00045	-0.00044	0.00872
	(0.0285)	(0.0765)	(0.0169)	(0.0360)	(0.0118)	(0.0134)	(0.0109)	(0.0115)	(0.0107)	(0.0214)
Lnp3	0.0384***	0.0266	0.00360	0.00660	-0.00292	-0.042***	-0.0109***	-0.00170	-0.006***	-0.0112
	(0.0131)	(0.0169)	(0.00688)	(0.0111)	(0.00410)	(0.00344)	(0.00261)	(0.00324)	(0.0024)	(0.00878)
Lnp4	0.00776	0.252***	0.00660	-0.222***	0.0133*	-0.057***	-0.00908	0.00872	0.00565	-0.00604
	(0.0151)	(0.0360)	(0.0111)	(0.0380)	(0.00769)	(0.00978)	(0.00850)	(0.00752)	(0.00735)	(0.00723)
Lnp5	0.00428	-0.0104	-0.00292	0.0133*	0.0240***	-0.019***	0.00200	0.00415	0.0083**	-0.024***
	(0.00697)	(0.0118)	(0.00410)	(0.00769)	(0.00759)	(0.00378)	(0.00377)	(0.00338)	(0.00382)	(0.0037)
Lnp6	-0.0124	-0.0009	-0.0422***	-0.057***	-0.0188***	0.137***	-0.0103***	0.028***	-0.025***	0.00171
	(0.00820)	(0.0134)	(0.00344)	(0.00978)	(0.00378)	(0.00415)	(0.00236)	(0.00283)	(0.00220)	(0.00261)
Lnp7	0.00500	0.0135	-0.0109***	-0.00908	0.00200	-0.010***	0.000927	0.021***	-0.00201	-0.0101**
	(0.00551)	(0.0109)	(0.00261)	(0.00850)	(0.00377)	(0.00236)	(0.00268)	(0.00206)	(0.00158)	(0.00415)
Lnp8	-0.0249***	-0.00045	-0.00170	0.00872	0.00415	0.028***	0.0210***	-0.021***	-0.010***	-0.00424*
	(0.00843)	(0.0115)	(0.00324)	(0.00752)	(0.00338)	(0.00283)	(0.00206)	(0.00351)	(0.0022)	(0.00252)
Lnp9	0.0321***	-0.000442	-0.0063***	0.00565	0.00825**	-0.025***	-0.00201	-0.010***	0.028***	-0.031***
	(0.00571)	(0.0107)	(0.00243)	(0.00735)	(0.00382)	(0.0022)	(0.00158)	(0.00215)	(0.00201)	(0.00223)
Lnp10	-0.0520***	0.00872	-0.0112	-0.00604	-0.0239***	0.00171	-0.0101**	-0.00424*	-0.031***	0.128***
	(0.0114)	(0.0214)	(0.00878)	(0.00723)	(0.00373)	(0.00261)	(0.00415)	(0.00252)	(0.00223)	(0.0194)
Ln(food exp.)	0.0512*	0.0741*	0.139***	-0.0111	0.0260***	-0.030***	-0.0669***	-0.018***	0.021***	0.19***
	(0.0303)	(0.0385)	(0.0140)	(0.0232)	(0.00839)	(0.00552)	(0.0041)	(0.00578)	(0.00492)	(0.0387)
Ln(food exp.)^2	0.0103	-0.0297*	0.0158**	0.00039	0.0103***	-0.008***	-0.00432***	-0.004***	-0.0008**	0.0107
	(0.0167)	(0.0177)	(0.00616)	(0.0054)	(0.00387)	(0.0014)	(0.0007)	(0.00076)	(0.000307)	(0.0261)
Exp. residual	0.139***	0.0569	0.00635	0.00383	-0.0487***	-0.087***	0.0371***	-0.068***	-0.00756	-0.0327
	(0.0307)	(0.0443)	(0.0116)	(0.0204)	(0.0105)	(0.00673)	(0.00481)	(0.00707)	(0.00551)	(0.0457)
Ln(HH size)	-0.0348*	-0.0175	-0.00730	0.000445	-0.0144***	-0.034***	0.0216***	-	0.082***	-0.409***
	(0.0208)	(0.0233)	(0.0102)	(0.00513)	(0.00309)	(0.00374)	(0.00348)		(0.0141)	(0.00920)
Ln(age of head)	0.0266	0.029***	-0.0174	0.00437	0.00301	0.031***	-0.00944***	0.121***	-0.00484	0.00419
	(0.0179)	(0.00614)	(0.0111)	(0.00392)	(0.00262)	(0.00456)	(0.00254)	(0.0256)	(0.00789)	(0.0128)
Sex of head (M=1)	-0.00192	-0.032***	-0.00319	0.060***	0.0076***	0.0083**	-	0.0642**	0.122***	-
	(0.0190)	(0.00789)	(0.00819)	(0.00367)	(0.00288)	(0.00331)		(0.0318)	(0.0224)	
Literate =1	0.0102	0.0206	0.0278***	-0.065***	0.00381	-0.00457	-0.0121***	-0.185***	-0.200***	0.405***
	(0.0299)	(0.0246)	(0.00791)	(0.00649)	(0.00398)	(0.00285)	(0.00324)	(0.0385)	(0.0270)	(0.0160)
Constant	0.0378	-0.0722	0.373***	-0.0039	0.0691***	0.240***	0.141***	0.170***	0.114***	-0.0683
	(0.0559)	(0.0734)	(0.0215)	(0.0349)	(0.0177)	(0.0101)	(0.00701)	(0.0113)	(0.00867)	(0.0557)
RMSE	0.0597	0.0489	0.10802	0.0276	0.0401	0.1428	0.0973	0.1418	0.1228	-
R-sq	0.3614*	0.2263*	0.4073*	0.0496*	0.1782*	0.8242*	0.6835*	0.6011*	0.6200*	-
Obs.	10,367	10,367	10,367	10,367	10,367	10,367	10,367	10,367	10,367	10,367

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
R-squared is uncentered

Annex 4.14: Structural parameters of QUAIDS-Q1

Variables	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10
Lnp1	-0.171***	0.0123	0.088***	-0.0653	-0.00184	0.00454	0.0103	0.042***	0.0412***	0.0394

	(0.0587)	(0.0946)	(0.0308)	(0.0504)	(0.0134)	(0.0255)	(0.0099)	(0.0129)	(0.00826)	(0.0719)
Lnp2	0.0123	-0.466*	0.0242	0.156**	-0.00729	0.0161	-0.0514***	-0.0360	0.0344**	0.317***
	(0.0946)	(0.271)	(0.0417)	(0.0787)	(0.0159)	(0.0386)	(0.0198)	(0.0272)	(0.0163)	(0.0824)
Lnp3	0.088***	0.0242	-0.00976	0.0367	-0.0128*	-0.0559***	0.0230***	0.00795	-0.0142***	-0.0875**
	(0.0308)	(0.0417)	(0.0143)	(0.0286)	(0.00710)	(0.0115)	(0.00502)	(0.00595)	(0.00508)	(0.0350)
Lnp4	-0.0653	0.156**	0.0367	-0.546***	-0.0126	0.0429	0.0584***	0.00958	0.0266***	0.294***
	(0.0504)	(0.0787)	(0.0286)	(0.127)	(0.0114)	(0.0276)	(0.0162)	(0.0172)	(0.0101)	(0.0948)
Lnp5	-0.00184	-0.00729	-0.0128*	-0.0126	-0.00726	0.0168**	0.0153**	7.86e-05	0.0132***	-0.00357
	(0.0134)	(0.0159)	(0.00710)	(0.0114)	(0.00743)	(0.00746)	(0.00595)	(0.00443)	(0.00512)	(0.0101)
Lnp6	0.00454	0.0161	-0.056***	0.0429	0.0168**	0.0912***	-0.0225***	0.000803	-0.0269***	-0.067***
	(0.0255)	(0.0386)	(0.0115)	(0.0276)	(0.00746)	(0.0116)	(0.00433)	(0.00498)	(0.00375)	(0.0205)
Lnp7	0.0103	-0.051***	0.023***	0.058***	0.0153**	-0.0225***	0.0210***	0.029***	-0.0246***	-0.058***
	(0.00992)	(0.0198)	(0.00502)	(0.0162)	(0.00595)	(0.00433)	(0.00478)	(0.00329)	(0.00262)	(0.00933)
Lnp8	0.042***	-0.0360	0.00795	0.00958	7.86e-05	0.000803	0.0286***	-0.041***	-0.0160***	0.00446
	(0.0129)	(0.0272)	(0.00595)	(0.0172)	(0.00443)	(0.0050)	(0.00329)	(0.00555)	(0.00302)	(0.00874)
Lnp9	0.041***	0.0344**	-0.014***	0.027***	0.013***	-0.0269***	-0.0246***	-0.016***	0.0213***	-0.055***
	(0.00826)	(0.0163)	(0.00508)	(0.0101)	(0.00512)	(0.00375)	(0.00262)	(0.00302)	(0.00299)	(0.00860)
Lnp10	0.0394	0.317***	-0.0875**	0.294***	-0.00357	-0.0671***	-0.0582***	0.00446	-0.0550***	-0.384***
	(0.0719)	(0.0824)	(0.0350)	(0.0948)	(0.0101)	(0.0205)	(0.00933)	(0.00874)	(0.00860)	(0.0678)
Ln(food exp.)	0.210***	0.313***	-0.0158	0.267***	0.0179	-0.0874***	-0.0391***	-0.000679	-0.0279***	-0.637***
	(0.0728)	(0.0828)	(0.0379)	(0.0683)	(0.0128)	(0.0146)	(0.00640)	(0.00812)	(0.00555)	(0.0914)
Ln(food exp.)^2	0.089***	-0.00964	0.025***	-0.0280**	-0.00179	0.00106	0.00242**	0.000858	0.0051***	-0.084***
	(0.0219)	(0.0113)	(0.00636)	(0.0116)	(0.00115)	(0.00292)	(0.00096)	(0.00102)	(0.00136)	(0.0241)
Exp. residual	-0.234***	-0.246***	-0.0425	-0.0443	-0.062***	0.0219	0.0469***	-0.0225**	0.0366***	0.546***
	(0.0875)	(0.0744)	(0.0597)	(0.0322)	(0.0175)	(0.0175)	(0.00629)	(0.00885)	(0.00652)	(0.129)
Ln(HH size)	0.0974**	0.0398*	-0.0518*	0.020***	-0.026***	-0.0200***	0.0184***	-	0.145**	-0.315***
	(0.0444)	(0.0240)	(0.0265)	(0.00476)	(0.00486)	(0.00419)	(0.00366)		(0.0571)	(0.0134)
Ln(age of head)	0.0659**	0.0152	0.069***	0.00234	-0.016***	0.0334***	-0.0123***	0.0747	-0.00457	-0.074***
	(0.0282)	(0.0191)	(0.0203)	(0.00424)	(0.00341)	(0.00506)	(0.00286)	(0.0536)	(0.00991)	(0.0135)
Sex of head (M=1)	-0.121***	0.0275	0.0125	0.058***	0.00562	-0.00840**	-	0.0585	-0.105***	-
	(0.0303)	(0.0183)	(0.0117)	(0.00727)	(0.00378)	(0.00391)		(0.0501)	(0.0187)	
Literate =1	-0.0424	-0.083***	-0.0295	-0.081***	0.037***	-0.00500	-0.00615*	-0.133*	-0.0350	0.389***
	(0.0534)	(0.0296)	(0.0281)	(0.0095)	(0.00581)	(0.00343)	(0.00346)	(0.0770)	(0.0642)	(0.0192)
Constant	-0.395***	-0.269***	0.181***	-0.225**	-0.00440	0.308***	0.193***	0.147***	0.115***	0.948***
	(0.111)	(0.0923)	(0.0614)	(0.0884)	(0.0157)	(0.0215)	(0.00974)	(0.0130)	(0.00934)	(0.162)
RMSE	0.0366	0.0195	0.0581	0.0194	0.0282	0.1659	0.1098	0.1317	0.1023	-
R-sq	0.2271*	0.0717*	0.4458*	0.1764*	0.2055*	0.7691*	0.7122*	0.6262*	0.6521*	-
Obs.	6,046	6,046	6,046	6,046	6,046	6,046	6,046	6,046	6,046	6,046

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
R-squared is uncentered

Annex 4.15: Structural parameters of QUAIDS-Q3

Variables	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10
Lnp1	-0.0730***	0.0597*	0.066***	0.0334*	-0.0108	0.00234	0.00105	0.00859	0.0385***	-0.125***
	(0.0230)	(0.0318)	(0.0125)	(0.0175)	(0.00750)	(0.00926)	(0.00516)	(0.00765)	(0.00589)	(0.0147)
Lnp2	0.0597*	-0.0423	-0.0277	0.132***	0.00411	-0.0155	-0.0587***	-0.0458***	-0.0117	0.00559
	(0.0318)	(0.0954)	(0.0212)	(0.0322)	(0.0126)	(0.0165)	(0.00877)	(0.0123)	(0.00941)	(0.0179)
Lnp3	0.0657***	-0.0277	0.00879	-0.00395	0.0094**	-0.0478***	0.00207	0.00832**	-0.00387	-0.0108**
	(0.0125)	(0.0212)	(0.00697)	(0.00973)	(0.00454)	(0.00509)	(0.00273)	(0.00397)	(0.00290)	(0.00545)
Lnp4	0.0334*	0.132***	-0.00395	-0.143***	0.00349	-0.0134	0.00817	-0.00634	0.0118**	-0.0228**
	(0.0175)	(0.0322)	(0.00973)	(0.0238)	(0.00612)	(0.00982)	(0.00673)	(0.00758)	(0.00586)	(0.0093)
Lnp5	-0.0108	0.00411	0.0092**	0.00349	0.00508	-0.0215***	0.00341	0.00256	0.0092***	-0.00481

	(0.00750)	(0.0126)	(0.00454)	(0.00612)	(0.00594)	(0.00494)	(0.00366)	(0.00361)	(0.0034)	(0.00456)
Lnp6	0.00234	-0.0155	-0.048***	-0.0134	-0.022***	0.113***	0.00424	0.00141	-0.0330***	0.0102**
	(0.00926)	(0.0165)	(0.00509)	(0.00982)	(0.00494)	(0.00632)	(0.00314)	(0.00373)	(0.00319)	(0.00471)
Lnp7	0.00105	-0.059***	0.00207	0.00817	0.00341	0.00424	0.0576***	0.0104***	-0.00493**	-0.023***
	(0.00516)	(0.00877)	(0.00273)	(0.00673)	(0.00366)	(0.00314)	(0.00377)	(0.00285)	(0.00215)	(0.00225)
Lnp8	0.00859	-0.046***	0.0083**	-0.00634	0.00256	0.00141	0.0104***	0.0302***	-0.00277	-0.0066**
	(0.00765)	(0.0123)	(0.00397)	(0.00758)	(0.00361)	(0.00373)	(0.00285)	(0.00458)	(0.00301)	(0.00315)
Lnp9	0.0385***	-0.0117	-0.00387	0.0118**	0.009***	-0.0330***	-0.00493**	-0.00277	0.0225***	-0.026***
	(0.00589)	(0.00941)	(0.00290)	(0.00586)	(0.0034)	(0.0032)	(0.00215)	(0.00301)	(0.00279)	(0.00257)
Lnp10	-0.125***	0.00559	-0.0108**	-0.0228**	-0.00481	0.0102**	-0.0234***	-0.00662**	-0.0259***	0.204***
	(0.0147)	(0.0179)	(0.00545)	(0.00930)	(0.00456)	(0.00471)	(0.00225)	(0.00315)	(0.00257)	(0.0204)
Ln(food exp.)	0.154***	-0.114**	-0.0287*	0.00476	0.0120	-0.105***	-0.0119*	0.0274***	0.00424	0.0573
	(0.0338)	(0.0529)	(0.0147)	(0.0254)	(0.0109)	(0.0105)	(0.00708)	(0.0098)	(0.00818)	(0.0370)
Ln(food exp.)^2	-0.00182	0.156***	-0.064***	-0.00202	-0.0312**	-0.0379***	-0.000562	0.0106	0.0199**	-0.0488
	(0.0483)	(0.0520)	(0.0166)	(0.0226)	(0.0155)	(0.0104)	(0.00620)	(0.00852)	(0.00894)	(0.0637)
Exp. residual	-0.0437	0.070***	0.075***	0.0262*	-0.072***	-0.113***	-0.0370***	0.00416	-0.00616	0.0961*
	(0.0307)	(0.0049)	(0.0155)	(0.0147)	(0.0160)	(0.00780)	(0.00523)	(0.00717)	(0.00576)	(0.0538)
Ln(HH size)	0.0560***	-0.00637	0.028***	0.00320	-0.011***	0.0124***	0.0170***	-	-0.0285*	-0.318***
	(0.0194)	(0.0143)	(0.00931)	(0.00526)	(0.00354)	(0.00355)	(0.00354)		(0.0170)	(0.0130)
Ln(age of head)	-0.00576	0.058***	7.36e-05	0.0171***	-0.009***	0.0140***	-0.0120***	0.0286	-0.000895	-0.086***
	(0.0131)	(0.00728)	(0.00992)	(0.00420)	(0.0028)	(0.00445)	(0.00242)	(0.0261)	(0.0107)	(0.0131)
Sex of head (M=1)	0.0268	-0.036***	0.00256	0.0183***	0.027***	-0.0125***	-	0.0875***	-0.179***	-
	(0.0168)	(0.00874)	(0.00612)	(0.00491)	(0.00307)	(0.00311)		(0.0220)	(0.0134)	
Literate =1	-0.0771***	-0.0151	-0.031***	-0.0385***	-0.00692	-0.0138***	-0.00500	-0.116***	0.208***	0.404***
	(0.0286)	(0.0162)	(0.00913)	(0.00755)	(0.00427)	(0.00288)	(0.00337)	(0.0325)	(0.0237)	(0.0184)
Constant	0.00923	-0.0298	0.306***	0.0845***	0.071***	0.201***	0.109***	0.158***	0.104***	-0.0134
	(0.0480)	(0.0527)	(0.0253)	(0.0264)	(0.0172)	(0.0122)	(0.0075)	(0.0110)	(0.0087)	(0.0412)
RMSE	0.0745	0.0428	0.0729	0.0299	0.0365	0.1235	0.0810	0.1111	0.0924	-
R-sq	0.2344*	0.1852*	0.4012*	0.1338*	0.2771*	0.8093*	0.7801*	0.6563*	0.6860*	-
Obs.	6,045	6,045	6,045	6,045	6,045	6,045	6,045	6,045	6,045	6,045

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

R-squared is uncentered

Annex 4.16: Structural parameters of QUAIDS-Q5

Variables	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10
Lnp1	-0.0727***	0.119***	-0.00065	0.0126*	-0.0092**	-0.0128***	-0.0104***	-0.0101***	0.0303***	-0.0457***
	(0.0108)	(0.0110)	(0.0039)	(0.00739)	(0.00400)	(0.00428)	(0.00293)	(0.00313)	(0.00351)	(0.00622)
Lnp2	0.119***	-0.258***	0.0312***	0.0619***	0.019***	0.0415***	0.0137***	0.0151***	0.00359	-0.0471***
	(0.0110)	(0.0215)	(0.00549)	(0.00888)	(0.00501)	(0.00593)	(0.00390)	(0.00427)	(0.00476)	(0.00867)
Lnp3	-0.000646	0.0312***	0.00338	0.0102***	-0.0039**	-0.0148***	-0.0085***	-0.0083***	0.000642	-0.00931**
	(0.00390)	(0.00549)	(0.00238)	(0.00268)	(0.00184)	(0.00186)	(0.0012)	(0.00136)	(0.00137)	(0.00425)
Lnp4	0.0126*	0.0619***	0.0102***	-0.0452***	-1.16e-05	-0.0319***	-0.00210	-0.00226	0.0190***	-0.0222***
	(0.00739)	(0.00888)	(0.00268)	(0.0113)	(0.00330)	(0.00454)	(0.00319)	(0.00344)	(0.00326)	(0.00381)
Lnp5	-0.00920**	0.0194***	-0.00391**	-1.16e-05	0.029***	-0.0306***	-0.0182***	-0.0066***	0.00299	0.0166***
	(0.00400)	(0.00501)	(0.00184)	(0.00330)	(0.00429)	(0.00371)	(0.00212)	(0.00241)	(0.00274)	(0.00300)
Lnp6	-0.0128***	0.0415***	-0.0148***	-0.0319***	-0.031***	0.0837***	-0.0071***	0.00355	-0.0279***	-0.00347
	(0.00428)	(0.00593)	(0.00186)	(0.00454)	(0.00371)	(0.00497)	(0.00246)	(0.00265)	(0.00264)	(0.00356)
Lnp7	-0.0104***	0.0137***	-0.0085***	-0.00210	-0.018***	-0.0071***	0.0771***	-0.00439**	-0.0168***	-0.0233***
	(0.00293)	(0.00390)	(0.00122)	(0.00319)	(0.00212)	(0.00246)	(0.00254)	(0.00192)	(0.00142)	(0.00291)
Lnp8	-0.0101***	0.0151***	-0.0083***	-0.00226	-0.007***	0.00355	-0.00439**	0.0285***	-0.00430**	-0.0111***
	(0.00313)	(0.00427)	(0.00136)	(0.00344)	(0.00241)	(0.00265)	(0.00192)	(0.00283)	(0.00170)	(0.00267)
Lnp9	0.0303***	0.00359	0.000642	0.0190***	0.00299	-0.0279***	-0.0168***	-0.00430**	0.0390***	-0.0465***
	(0.00351)	(0.00476)	(0.00137)	(0.00326)	(0.00274)	(0.00264)	(0.00142)	(0.00170)	(0.00304)	(0.00230)
Lnp10	-0.0457***	-0.0471***	-0.00931**	-0.0222***	0.017***	-0.00347	-0.0233***	-0.0111***	-0.0465***	0.192***
	(0.00622)	(0.00867)	(0.00425)	(0.00381)	(0.00300)	(0.00356)	(0.00291)	(0.00267)	(0.00230)	(0.0105)
Ln(food	-0.0322	0.0854***	0.0649***	0.00524	0.0110*	-0.0661***	-0.0544***	-0.0381***	0.00559	0.148***

exp.)										
	(0.0208)	(0.0261)	(0.00864)	(0.0104)	(0.00566)	(0.00414)	(0.00285)	(0.00351)	(0.00387)	(0.0290)
Ln(food exp.)^2	0.0146*	0.0242*	-0.00258	-0.00939***	-0.0060**	-0.0042***	-0.0044***	-0.0032***	-0.0014***	-0.00769
	(0.00871)	(0.0130)	(0.00333)	(0.00330)	(0.00295)	(0.00108)	(0.000778)	(0.000564)	(0.00033)	(0.0150)
Exp. residual	-0.0602***	0.00933	0.0212***	0.00924	-0.00126	-0.0532***	-0.0248***	-0.0189***	0.00422	0.114***
	(0.0120)	(0.0152)	(0.00527)	(0.00642)	(0.00581)	(0.00416)	(0.00254)	(0.00329)	(0.00369)	(0.0153)
Ln(HH size)	0.0367***	-0.0121	0.0103**	-0.00977**	-0.018***	0.0061***	0.0086***	-	0.0126	-0.140***
	(0.0101)	(0.00894)	(0.00446)	(0.00429)	(0.00239)	(0.00229)	(0.00331)		(0.00935)	(0.00796)
Ln(age of head)	0.00389	0.0320***	0.0104*	0.00268	-0.008***	0.000688	0.000943	-0.0260	0.0137**	0.0109
	(0.00772)	(0.00335)	(0.00600)	(0.00300)	(0.00188)	(0.00249)	(0.00233)	(0.0160)	(0.00666)	(0.0168)
Sex of head (M=1)	-0.0377***	-0.0129***	0.000996	0.0462***	0.021***	-0.0051***	-	0.126***	-0.118***	-
	(0.00897)	(0.00432)	(0.00416)	(0.00365)	(0.00213)	(0.00175)		(0.0143)	(0.00989)	
Literate =1	-0.00290	-0.00703	-0.0217***	-0.0391***	0.00493*	-0.00175	-0.0096***	-0.100***	0.0919***	0.129***
	(0.0159)	(0.00972)	(0.00645)	(0.00637)	(0.00294)	(0.00187)	(0.00351)	(0.0223)	(0.0150)	(0.0188)
Constant	0.191***	-0.222***	0.198***	0.0254	0.0609***	0.198***	0.134***	0.167***	0.0942***	0.152***
	(0.0330)	(0.0378)	(0.0126)	(0.0182)	(0.0136)	(0.00912)	(0.00539)	(0.00644)	(0.00875)	(0.0427)
RMSE	0.13318	0.11641	0.08867	0.05945	0.04364	0.09640	0.05779	0.07411	0.12580	-
R-sq	0.4133*	0.3759*	0.4057*	0.2207*	0.3085*	0.7927*	0.7513*	0.6788*	0.5495*	-
Obs.	8,371	8,371	8,371	8,371	8,371	8,371	8,371	8,371	8,371	8,371

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

R-squared is uncentered

Annex 4.17: Structural parameters of QUAIDS-literate

Variables	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10
Lnp1	-0.113***	0.106***	0.0208***	0.00571	-0.0082***	0.00495	-0.00226	0.0091***	0.0287***	-0.0514***
	(0.0113)	(0.0111)	(0.00389)	(0.00794)	(0.00312)	(0.00431)	(0.00253)	(0.00312)	(0.00270)	(0.00631)
Lnp2	0.106***	-0.222***	0.0262***	0.0780***	0.0200***	0.0211***	-0.0103**	0.0158***	0.0160***	-0.0512***
	(0.0111)	(0.0239)	(0.00567)	(0.0100)	(0.00460)	(0.00675)	(0.00426)	(0.00499)	(0.00425)	(0.00774)
Lnp3	0.0208***	0.0262***	6.78e-05	0.0135***	0.000288	-0.0211***	-0.0033***	-0.0092***	-0.0065***	-0.0207***
	(0.00389)	(0.00567)	(0.00221)	(0.00257)	(0.00146)	(0.00187)	(0.00098)	(0.00129)	(0.00105)	(0.00378)
Lnp4	0.00571	0.0780***	0.0135***	-0.0740***	-0.00246	-0.0167***	-0.00273	0.00576*	0.0136***	-0.0208***
	(0.00794)	(0.0100)	(0.00257)	(0.0114)	(0.00241)	(0.00432)	(0.00318)	(0.00346)	(0.00264)	(0.00357)
Lnp5	-0.00819***	0.0200***	0.000288	-0.00246	0.0110***	-0.0354***	-0.00337*	-0.00284	0.0084***	0.0125***
	(0.00312)	(0.00460)	(0.00146)	(0.00241)	(0.00276)	(0.00254)	(0.00179)	(0.00184)	(0.00167)	(0.00187)
Lnp6	0.00495	0.0211***	-0.0211***	-0.0167***	-0.0354***	0.0945***	-0.00324*	-0.0133***	-0.0254***	-0.00540*
	(0.00431)	(0.00675)	(0.00187)	(0.00432)	(0.00254)	(0.00394)	(0.00181)	(0.00212)	(0.00172)	(0.00304)
Lnp7	-0.00226	-0.0103**	-0.0033***	-0.00273	-0.00337*	-0.00324*	0.0612***	0.0060***	-0.0129***	-0.0292***
	(0.00253)	(0.00426)	(0.000981)	(0.00318)	(0.00179)	(0.00181)	(0.00211)	(0.00161)	(0.0012)	(0.00158)
Lnp8	0.00913***	0.0158***	-0.0092***	0.00576*	-0.00284	-0.0133***	0.0060***	0.0162***	-0.0126***	-0.0151***
	(0.00312)	(0.00499)	(0.00129)	(0.00346)	(0.00184)	(0.00212)	(0.00161)	(0.00242)	(0.00168)	(0.00174)
Lnp9	0.0287***	0.0160***	-0.0065***	0.0136***	0.00839***	-0.0254***	-0.0129***	-0.0126***	0.0244***	-0.0336***
	(0.00270)	(0.00425)	(0.00105)	(0.00264)	(0.00167)	(0.00172)	(0.00120)	(0.00168)	(0.00179)	(0.00144)
Lnp10	-0.0514***	-0.0512***	-0.0207***	-0.0208***	0.0125***	-0.00540*	-0.0292***	-0.0151***	-0.0336***	0.215***
	(0.00631)	(0.00774)	(0.00378)	(0.00357)	(0.00187)	(0.00304)	(0.00158)	(0.00174)	(0.00144)	(0.00859)
Ln(food exp.)	0.105***	0.0454***	0.0986***	0.0134	0.00858***	-0.0767***	-0.0337***	-0.0317***	-0.0178***	0.0861***
	(0.0141)	(0.0158)	(0.00697)	(0.00866)	(0.00329)	(0.00343)	(0.00205)	(0.0026)	(0.00240)	(0.0179)
Ln(food exp.)^2	-0.0331***	0.0278***	0.00592*	-0.0129***	-0.00125	-0.0101***	-0.00728***	-0.0056***	-0.0029***	0.0393***
	(0.00652)	(0.00971)	(0.00318)	(0.00220)	(0.00157)	(0.00114)	(0.000695)	(0.00057)	(0.00046)	(0.0115)
Exp. residual	0.000223	0.0139**	0.0324***	0.0188***	-0.0168***	-0.0396***	-0.0392***	-0.0367***	-8.19e-05	0.0670***
	(0.0111)	(0.0062)	(0.00446)	(0.00625)	(0.00448)	(0.00382)	(0.00230)	(0.00280)	(0.00261)	(0.0158)
Ln(HH size)	0.0491***	0.0187*	0.0152***	-0.00985***	-0.00408*	0.0057***	0.00887***	-	0.0251***	-0.283***

	(0.00939)	(0.0104)	(0.00394)	(0.00305)	(0.00225)	(0.0019)	(0.00219)		(0.00683)	(0.00869)
Ln(age of head)	0.0287***	0.0471***	0.00582	0.00279	-0.00521***	-0.0200***	-0.0192***	0.0932***	0.0154***	-0.116***
	(0.00722)	(0.00264)	(0.00527)	(0.00241)	(0.00173)	(0.00233)	(0.00162)	(0.0116)	(0.00439)	(0.00778)
Sex of head (M=1)	0.0164*	-0.00405	0.00693**	0.0479***	0.0163***	-0.0117***	-	0.0673***	-0.155***	-
	(0.00859)	(0.00425)	(0.00338)	(0.00354)	(0.00189)	(0.00174)		(0.0137)	(0.00839)	
Literate =1	-0.0942***	-0.0618***	-0.0279***	-0.0408***	-0.00705**	0.0260***	0.0104***	-0.161***	0.114***	0.399***
	(0.0161)	(0.0111)	(0.00671)	(0.00534)	(0.00321)	(0.00328)	(0.00285)	(0.0170)	(0.0118)	(0.0118)
Constant	-0.0445	-0.128***	0.191***	0.0136	0.0775***	0.172***	0.128***	0.239***	0.132***	0.219***
	(0.0271)	(0.0382)	(0.0116)	(0.0150)	(0.00926)	(0.00864)	(0.00508)	(0.00632)	(0.00606)	(0.0333)
RMSE	0.0947	0.0695	0.0633	0.0413	0.0393	0.1191	0.0796	0.0993	0.0941	-
R-sq	0.3598*	0.3300*	0.3858*	0.1921*	0.2749*	0.7893*	0.7709*	0.6772*	0.6482*	-
Obs.	20,813	20,813	20,813	20,813	20,813	20,813	20,813	20,813	20,813	20,813

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
R-squared is uncentered

Annex 4.18: Structural parameters of QUAIDS-illiterate

Variables	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10
Lnp1	-0.144***	0.0827***	0.0650***	0.0358**	-0.0160*	-0.0287***	0.00846	-0.0165**	0.066***	-0.0536***
	(0.0227)	(0.0257)	(0.0122)	(0.0164)	(0.00862)	(0.0101)	(0.00596)	(0.00837)	(0.00582)	(0.0141)
Lnp2	0.0827***	-0.307***	0.0737***	0.157***	0.0120	0.0348***	0.0201*	-0.0125	-0.0268***	-0.0339**
	(0.0257)	(0.0643)	(0.0158)	(0.0348)	(0.0129)	(0.0129)	(0.0105)	(0.0118)	(0.0103)	(0.0157)
Lnp3	0.0650***	0.0737***	-0.0197***	-0.0114	-0.00614	-0.0639***	-0.00313	-0.00073	-0.0112***	-0.0224**
	(0.0122)	(0.0158)	(0.00648)	(0.0135)	(0.00418)	(0.00432)	(0.00281)	(0.00327)	(0.00264)	(0.00907)
Lnp4	0.0358**	0.157***	-0.0114	-0.131***	0.00264	-0.0423***	-0.0178*	0.0147	0.0173**	-0.0246*
	(0.0164)	(0.0348)	(0.0135)	(0.0438)	(0.00847)	(0.0110)	(0.0102)	(0.00970)	(0.00836)	(0.0133)
Lnp5	-0.0160*	0.0120	-0.00614	0.00264	0.0185***	-0.00172	-0.00903**	0.00878**	0.00527	-0.0143***
	(0.00862)	(0.0129)	(0.00418)	(0.00847)	(0.00668)	(0.00435)	(0.00362)	(0.00375)	(0.00366)	(0.00414)
Lnp6	-0.0287***	0.0348***	-0.0639***	-0.0423***	-0.00172	0.140***	0.00289	0.0117***	-0.0381***	-0.0151***
	(0.0101)	(0.0129)	(0.00432)	(0.0110)	(0.00435)	(0.00519)	(0.00276)	(0.00347)	(0.00310)	(0.00462)
Lnp7	0.00846	0.0201*	-0.00313	-0.0178*	-0.00903**	0.00289	0.0211***	0.0186***	-0.0136***	-0.0276***
	(0.00596)	(0.0105)	(0.00281)	(0.0102)	(0.00362)	(0.00276)	(0.00309)	(0.00251)	(0.00195)	(0.00311)
Lnp8	-0.0165**	-0.0125	-0.000732	0.0147	0.00878**	0.0117***	0.0186***	-0.0199***	-0.00579**	0.00178
	(0.00837)	(0.0118)	(0.00327)	(0.0097)	(0.00375)	(0.00347)	(0.00251)	(0.00399)	(0.00256)	(0.00248)
Lnp9	0.0663***	-0.0268***	-0.0112***	0.0173**	0.00527	-0.0381***	-0.0136***	-0.00579**	0.0347***	-0.0280***
	(0.00582)	(0.0103)	(0.00264)	(0.00836)	(0.00366)	(0.00310)	(0.00195)	(0.00256)	(0.00365)	(0.00249)
Lnp10	-0.0536***	-0.0339**	-0.0224**	-0.0246*	-0.0143***	-0.0151***	-0.0276***	0.00178	-0.0280***	0.218***
	(0.0141)	(0.0157)	(0.00907)	(0.0133)	(0.00414)	(0.00462)	(0.00311)	(0.00248)	(0.00249)	(0.0213)
Ln(food exp.)	0.0195	0.0636**	0.106***	0.0596**	0.0184***	-0.0737***	-0.0458***	0.00498	0.00889*	0.170***
	(0.0262)	(0.0293)	(0.0123)	(0.0286)	(0.00671)	(0.00555)	(0.00423)	(0.00511)	(0.00463)	(0.0308)
Ln(food exp.)^2	0.0142***	0.0105**	0.00417	0.0213**	0.00118	-0.0116***	-0.0060***	-0.00361***	0.000304	-0.0304
	(0.0027)	(0.0045)	(0.00432)	(0.0107)	(0.00321)	(0.00176)	(0.00078)	(0.00071)	(0.00090)	(0.0192)
Exp. residual	-0.0106***	-0.0118***	0.0109	0.00738	-0.0347***	-0.0476***	0.00409	-0.0757***	0.00217	0.156***
	(0.0022)	(0.0024)	(0.0119)	(0.0386)	(0.00959)	(0.00682)	(0.00506)	(0.00638)	(0.00544)	(0.0541)
Ln(HH size)	0.0171	0.0561**	0.0244	0.0108**	0.000285	-0.0494***	-0.00178	-	0.0305	-0.314***
	(0.0217)	(0.0223)	(0.0173)	(0.00450)	(0.00342)	(0.00392)	(0.00379)		(0.0242)	(0.00919)
Ln(age of head)	0.0395**	0.00954	0.0581***	0.00679	-0.0172***	0.00713*	-0.0301***	0.0295	-0.00434	-0.0494***
	(0.0194)	(0.00696)	(0.0176)	(0.00447)	(0.00349)	(0.00424)	(0.00299)	(0.0275)	(0.00824)	(0.0163)
Sex of head	0.0510***	-0.0428***	0.0259*	0.0756***	0.0103***	-0.0296***	-	0.0888**	-0.0763***	-

(M=1)										
	(0.0183)	(0.00837)	(0.0150)	(0.00480)	(0.00307)	(0.00348)		(0.0361)	(0.0196)	
Literate =1	-0.108***	-0.0228	-0.108***	-0.0931***	0.00664	0.0718***	0.0319***	-0.118***	0.0501	0.363***
	(0.0328)	(0.0240)	(0.0267)	(0.00786)	(0.00576)	(0.00691)	(0.00490)	(0.0443)	(0.0309)	(0.0189)
Constant	0.0601	-0.339***	0.434***	-0.255***	0.0343*	0.129***	0.173***	0.312***	0.254***	0.197***
	(0.0749)	(0.0830)	(0.0325)	(0.0695)	(0.0194)	(0.0213)	(0.0148)	(0.0182)	(0.0181)	(0.0609)
RMSE	0.0622	0.0538	0.0968	0.02829	0.03322	0.1429	0.09544	0.12644	0.1203	-
R-sq	0.3029*	0.2768*	0.4051*	0.1104*	0.2003*	0.8154*	0.7043*	0.5961*	0.6181*	-
Obs.	9,414	9,414	9,414	9,414	9,414	9,414	9,414	9,414	9,414	9,414

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

R-squared is uncentered

5. Chapter Five: Overall conclusion, policy implications and areas for future research

5.1. Overall conclusion and policy implications

Diets of Ethiopian households are dominated by limited staple foods where consumption of cereals account for significant share of total food expenditure. This indicates that diets of households in Ethiopia is least diversified with high level of child malnutrition. The dissertation concludes that livestock diversification could play a key role in improving dietary diversity and quality of farm households. Even if Ethiopia is known for large number of livestock, productivity of the sector is one of the lowest in SSA. One of the reasons for low yield is limited supply of improved livestock technologies and poor livestock management in terms of feeds and improving health of livestock. The dissertation also concludes that adoption of improved livestock technologies coupled with improved livestock management plays a key role in increasing milk productivity of farm households. It is also concluded that smallholder livestock owners learn from their peer farmers in adopting high-yielding livestock technology and practicing improved livestock management indicating that strengthen existing farmer networks can achieve more widespread livestock technology diffusion and improved livestock management in the Ethiopian livestock sector. However, there is no or limited knowledge spillover effects from commercial farm establishments to smallholder livestock owners. Low yield is manifested in low level of consumption of ASFs. The country is also known for consuming only few livestock products mainly dairy products. Expenditure and price elasticities are higher for ASFs compared to cereals. Demand elasticities vary by location (urban vs. rural), income quintiles and literacy level. This lies foundation for tailored price and food policies.

5.2. Possible areas for future research

The dissertation suggests some areas for further research in the future. These are:

I. Roles of Livestock diversification in consumption smoothing and reducing vulnerability to shocks
II. Does market access substitute livestock diversification in influencing households' dietary diversity?
III. Livestock diversification and its roles in reducing multidimensional poverty
IV. Roles of research centers in facilitating diffusion of livestock technologies and improved livestock management
V. Analysis of interdependency of prices of livestock products and non-livestock products.