Production Efficiency, Commercialization of Cereal Crops and Multidimensional Poverty among Farm Households in Major *'Teff'* Growing Areas of Ethiopia

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DISSERTATION APPROVAL

This is to certify that the thesis prepared by Fisseha Zegeye Birhanu, entitled: *“Production Efficiency, Commercialization of Cereal Crops and Multidimensional Poverty among Farm Households in Major ‘Teff’ Growing Areas of Ethiopia”* and submitted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy (Development Studies) complies with the regulations of the university and meets the accepted standards with respect to originality and quality.

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DECLARATION

I, Fisseha Zegeye, hereby declare that this PhD dissertation is my own original research work. The materials in this research work, neither the whole nor any part of it, were not submitted for the attainment of any academic degree elsewhere. All reference materials form other authors have been fully acknowledged and the reporting procedures do comply with the expected standards and regulation of the university.

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During the Ph.D. studies, the following papers were published and under review.

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Fisseha Zegeye

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ACRONYMS

ADLI	Agricultural Development Led Industrialization
AF	Alkire Foster
CMP	Conditional Mixed Process
CSA	Central Statistical Agency
DOI	Digital Object Identifier
EEA	Ethiopian Economic Association
EIAR	Ethiopian Institute of Agricultural Research
FAO	Food and Agriculture Organization
FGDs	Focus Group Discussions
GDP	Gross Domestic Product
GOs	Governmental Organizations
GTP-I	Growth and Transformation Plan-I
GTP-II	Growth and Transformation Plan-II
Ha	Hectare
HDI	Human Development Index
IV	Instrumental Variable
ILRI	International Livestock Research Institute
KIIs	Key Informant Interviews
m.a.s.l.	Meter Above Sea Level
MoFED	Ministry of Finance and Economic Development
MPI	Multidimensional Poverty Index
VMP	Vulnerability to Multidimensional Poverty
NGOs	Non-Governmental Organizations
OLS	Ordinary Least Square
OPHI	Oxford Poverty and Human Development Initiative
PASDEP	Plan for Accelerated and Sustainable Development to End Poverty
SDPRP	Sustainable Development and Poverty Reduction Program
SSA	Sub-Saharan African
TLU	Tropical Livestock Units

UN	United Nations
UNDP	United Nations Development Program
VEP	Vulnerability as Expected Poverty
VIFs	Variance Inflation Factors
WHO	World Health Organizations

ABSTRACT

The majority population in SSA including Ethiopia is multidimensional poor, resides in rural areas, and depends on smallholder agriculture for their livelihood. Hence, poverty alleviation and agricultural productivity growth remain the primary policy agenda for many developing countries in SSA. In Ethiopia, cereals are the principal staple crops strategic for poverty alleviation, suggesting that the prospect of increasing cereal outputs has crucial policy importance to design anti-poverty strategies and thereby improve smallholder welfare. This dissertation, therefore, examined the effect of technical efficiency and commercialization of cereal crops on household multidimensional poverty in rural Ethiopia. The study followed a mixed-method research design in which more emphasis was given for quantitative research design with an embedded qualitative research approach. Primary data was generated from randomly selected 392 sample farm households in the year 2019/2020 from major teff-growing areas of Ethiopia using structured questionnaire, key informant interviews (KIIs), and focus group discussions (FGDs). Descriptive and inferential statics was applied to explain farm households' characteristics. The study also used a wide range of analytical and econometric models: Stochastic Meta-Frontier, Tobit Model, Multidimensional Poverty Index (MPI), Vulnerability Analysis, Fractional Logit Model, IV Tobit Model, CMP, Dose-Response Function, and 3SLS Model to address the objectives of the study. Thematic analysis was applied to analyze qualitative data. The result of the study indicated that the average technical efficiency score of farm households was found to be 58%, inferring that about 36% of cereal output is lost due to inefficiency. The results showed that the adoption of high-yielding varieties together with production methods improves production efficiency. Moreover, sex of the household head, age of the household head, mobile phone ownership, cooperative membership, access to modern inputs, and stress incidence were found the major determinants for efficiency. The study, hence, asserts that the cereal output can be improved with the current input mix and technology. The results revealed that, on average, about 38% of cereal crops produced were commercialized, suggesting a semi-commercialized production system. The simultaneous model estimates coffered that cereal commercialization significantly improves the use of production inputs and cereal yield at 1% level. Bi-directional causality between commercialization and technical efficiency was also confirmed at 1% level. This means that enhancing commercialization among cereal farmers helps to improve land and labor productivity and thereby brings an upward shift in the production technology. Moreover, the results showed that the extent of cereal commercialization positively determined by sex of the household head, land size, credit service, mobile phone ownership, improved seed, and agricultural assets, while negatively influenced by family size, dependency ratio, and non-farm employment. The incidence of poverty, the mean deprivation scores, and MPI were found to be 57.9%, 44.1%, and 31.2%, respectively, implying a higher proportion of farm households were classified as multidimensional poor. The study showed that improving technical efficiency and commercialization of farm households significantly decreases MPI. Overall, information asymmetry, cooperatives, input and output market integration, modern technologies, incidence of crop stresses, land reform and land rent in/out practices, improved livestock breeds, rural infrastructure, and services were among key areas of policy recommendations.

Keywords: Cereal crops, Input use, Production methods, Production efficiency, Commercialization, Multidimensional poverty, Ethiopia

CHAPTER ONE: GENERAL INTRODUCTION

1.1. Background of the study

1.1.1. Poverty and growth in agriculture

In sub-Saharan Africa (SSA), when estimated at the extreme poverty line (US$1.90), 413 million people live in extreme poverty in 2015 (World Bank, 2018; FAO, 2020) and many of them have barely escaped from extreme poverty and are at the risk of failing back (World Bank, 2020). The poverty situation is also more of a rural phenomenon where the majority of the population primarily depends on agriculture for a living. In a developing country, as explained by Johnston & Mellor (1961); Udemezue & Osegbue (2018), agriculture contributes to a higher proportion of the national income, employs a large proportion of the rural labor force, and utilizes a large number of resources chiefly land and labor. Therefore, the poverty reduction strategy adopted by many developing countries seeks to achieve economic development through growth in agricultural productivity. Because, growth in agriculture is much more responsive to poverty reduction than the growth in other sectors (Janvry & Sadoulet, 2009). The multiple pathways through which increases in agricultural productivity can reduce poverty are including but are not limited to real income changes, employment generation, rural non-farm multiplier effects, and food price effects (Schneider & Gugerty, 2011). Therefore, for agriculture to be the fundamental instrument for poverty reduction, developing countries require a significant productivity shift in smallholder farming.

Achieving growth of agricultural productivity requires continuous improvement in total factor productivity (Sarris, 2001) through technological innovation and efficient utilization of inputs, so that, producers can obtain higher income and be able to escape from poverty. During the green revolution, as evidenced in Asia and Latin America, packages of inputs and more efficient use of production technologies had enormous positive effects on the agricultural productivity of many countries. For instance, Pakistan could make possible the wheat yield nearly double from 4.6 million tons in 1965 to 7.3 million tons in 1970, become self-sufficient in wheat production by 1968, and produced over 21 million tons by 2000 (Nene, 2012). Similarly, as the same source indicated, in India, yields increased from 12.3 million tons in 1965 to 20.1 million tons in 1970. By 1974 India turn out to be self-sufficient within the production of all cereals and by 2000, India was reaping a record of 76.4 million tons of wheat (Nene, 2012). Much of the success was caused by the combination of high rates of investment in crop research, infrastructure, and market development, and appropriate policy support (Pingali, 2012) implying producers were able to harness the technologies and packages of inputs. The successful history of Asia since 1965 depends on the green revolution in food staples output, mainly on subsistence and near subsistence smallholdings into rapid growth with massive poverty reduction (Lipton, 2013).

Commercialization of smallholder agriculture is equally important for the substantial impact of agricultural productivity growth on poverty. It leads to a diversified market-oriented production system, progressive substitution out of non-traded inputs in favor of purchased inputs, and the gradual decline of integrated farming systems and their replacement by specialized enterprises (Pingali & Rosegrant, 1995). Market-oriented production enables smallholders to achieve rapid income growth, respond to remunerative opportunities, and improve productivity through increased use of capital inputs, better agricultural practices, and the most efficient use of resources (von Braun & Kennedy, 1994; Kirimi, et al., 2013; Poulton, 2017). However, the likely effect of commercialization on agricultural productivity depends on the availability of new technologies, such as improved seeds and agronomic practices, greater utility obtained from market participation, investment in infrastructure, diversification in food demand patterns, and policies for market creation, among other as noted by (von Braun, 1995; Pingali & Rosegrant, 1995).

In addition to this, the impact of growth in the agricultural sector cannot be tangible on poverty until growing nations like Ethiopia is capable of managing factors related to market failure. Market failure that is due to excessive transaction cost and credit constraints restrict households not only to take part in the market but also lesson the sales volume of the producer surplus (Renkow, et al., 2004; Goetz, 1992; De Janvry, et al., 1991). Hence, the adoption of technological packages, production efficiency, market access, and commercial transformation of producers are the key areas of the agricultural policy followed to realize the real effect of agriculture on poverty.

1.1.2. Ethiopian agriculture and cereal production

The Ethiopian economy primarily depends on agriculture. The sector contributes 33% to the GDP, one of the highest shares in sub-Saharan Africa, employs around 72% of the total population, accounts for 83.9 % of export, and is the major source of capital for investment and market (FAO, 2018; NBE, 2020). The share of agriculture and allied activities in GDP declined from 42% in 2010 to nearly 39% by 2015 (NPC, 2016), inferring a bit of structural shift from agriculture to industry and service sectors. During 2010/11-1014/15 (GTP I), the agricultural sector, on average, grew by 6.6%. Within agriculture, the crop production subsector was most important representing 28% of GDP and growing at an average annual growth rate of 8.8% (World Bank, 2016). In the 2018/19 Meher season, the smallholder farmer produced a total volume of about 32 million metric tons of major crops from 12.7 million hectares covered by grain crops (CSA, 2019). This amount increased from 18 million metric tons in 2009/10 (CSA, 2010). When these amounts are compared, it shows 14 million metric tons of additional production of major crops. The average productivity of major crops by smallholder farmers for the main season is also increased from 15.7 quintals per hectare in 2009/10 to 21.5 quintals per hectare in 2014/15 (NPC, 2016). This means that the major crops are the most important contributor to the overall growth in agriculture and allied activities.

Ethiopia is one of the eight centers of diversity and origin for cereal crops in the world. The heterogeneity[1] in topography, climatic conditions, and soil types enable the country to grow a wide variety of tropical and temperate crops (Legesse, et al., 2019; Melese, et al., 2019). Vavilov has made an expedition to Ethiopia from December 1926 to April l927 (Fentahun, et al., 2017), and as per his note Ethiopia, (Abyssinia Center) is distinguished by its diversity of forms of hulled barley, violet-grained wheat, original races of peas, peculiar races of oats, and by a series of cultivated endemic plants (Vavilov, 1926; quoted in Harlan (1969). He identified *'teff'*, millet, and some subspecies of wheat and barley that were domesticated in Ethiopia. *Teff* (*Eragrostis tef*) and finger millet (*Eleusine coracana*) were domesticated in northern Ethiopia (Ofcansky & Berry, 1991; D'Andrea, 2008; Marshall & Weissbrod, 2011). However, Asian cultivars such as

[1] The large variation in altitude as documented in the country report by Plant Genetic Resources Center (PGRC, 1996) ranging from 110 m.a.s.l in some areas of Kobar Sink, to 4,620 m.a.s.l at Ras Dashen, makes Ethiopia be the origin for a wide variety of landraces.

emmer (*Triticum dicoccum*) and bread wheat (*Triticum aestivum*), barley (*Hordeum vulgare*) were later brought to the region from Asia (D'Andrea, et al., 1999; Ofcansky & Berry, 1991). The major landrace cereal crops of Ethiopia include barley (*Hordeum vulgare*), wheat (*Triticum spp*.), sorghum (*Sorghum bicolor*), *Teff* (*Eragrostis tef*), finger millet (*Eleusine coracanaa*), oats (*Avena sap.*), and rice (Oryza sap.) (PGRC, 1996).

Cereals are the major staple crops that dominate Ethiopian crop production. It accounts for roughly 60 % of rural employment, 81 % of total cultivated land, and 30% of GDP (Rashid, 2010; CSA, 2019). Cereals are also the source of 62 % of average Ethiopians' daily calorie intake and account for about close to half of consumer food expenditure for an average household (Rashid, 2010; Diao, 2010; World Bank, 2018). According to the 2018/19 Agricultural Sample survey of the CSA of Ethiopia, cereals comprise about 81.39% of the crop area under cultivation and 87.97% of total crop output (CSA, 2019). From the total cultivated farmland under cereals, *'teff'*, maize, sorghum, wheat, and barley, which are the heart of the country's agriculture and food economy (Seyoum, et al., 2011) occupied 24.17%, 18.60%, 14.38%, 13.73% and 6.42% of the crop area, respectively. Cereal production is the single largest sub-sector within Ethiopia's agriculture, far exceeding all others in terms of its share in rural employment, agricultural land use, calorie intake, and contribution to national income (Rashid, 2010). An outsized proportion of cereal is produced by small-scale producers, where 94% of Ethiopian farmers rely on less than 5 hectares of land, of which 55% cultivate less than 2 hectares (Mitik, et al., 2016). Hence, the prospect of productivity growth of cereal crops has a crucial policy and welfare implication in the agriculture sector of the country.

Ever since 1992, Agricultural Development-Led Industrialization (ADLI) has been serving as a foundation of the government economic policy of Ethiopia. Since then, a series of interrelated development programs (such as SDPRP, PASDEP, GTP I, and GTP II) were formulated and adopted in the country. In all of the development programs, agriculture and particularly smallholder agriculture remains the single most important source of economic growth and the main drivers to achieve food security and poverty reduction. To this end, an agricultural-centered rural development program has been developed and implemented to realize the country's rural and agricultural development objectives (MoFED, 2003). In the programs, it has emphasized the building of a healthy, industrious, and sufficiently educated and trained agricultural labor force, and a continuous supply of demand and market-oriented improved agricultural technologies (MoFED, 2003). Moreover, in second development plan of the country (GTP: 2014/15-2019/20), much stress has been given to boost the productivity of smallholders and thereby realizing the agricultural transformation objective of the country (NPC, 2016). In the recent Ten Years Perspective Development Plan (2021 – 2030) of the country, agriculture is considered as one of the major pillars of economic growth and poverty reduction, and prosperity (NPC, 2021). This shows that for achieving rapid productivity growth in the sector, smallholder farmers require to adopt improved technologies and produce significant marketable surplus through efficient use of production inputs. Hence, enhancing the capacity of smallholder farmers to reach the production possibility frontier is among the major priority in the country. Moreover, the commercial transformation of smallholder farmers has also been considered as a guiding principle and basis to transform the agricultural sector of Ethiopia (MoFED, 2003). Because commercial oriented production system can trigger rapid income growth, increase labor productivity and generate employment through an efficient resource utilization over subsistence production system (von Braun, 1995; Pingali, 1997; Kirimi, et al., 2013)

1.2. Statement of the problem

In Ethiopia, great attention has been given to achieving food security, poverty reduction, and improved smallholder welfare through productivity growth and progressive transition from subsistence to the market-oriented production system (MoFED, 2003; NPC, 2016). The Government has envisaged a marked shift in crop productivity by rising the productivity level of the majority of farmers to the level attained by the model farmers and agricultural research centers. The main assumption of improving agricultural sector productivity is to help smallholder farmers to link with the market with surplus production and fetch an income that induces real changes in household welfare. Foremost among crops grown in the country, the major focus has been given to improve cereal productivity and efficiency by focusing on the adoption of improved crop varieties along with their production package (NPC, 2016). This is because major cereals, including *'teff'*, wheat, maize, barely, maize and sorghum are the major contributor to the country's economy.

The government has been pursuing holistic measures as part of the country's intensification efforts aimed at addressing constraints and challenges related to the supply and use of agricultural inputs. The government, for example, has been working to increase the availability of certified seed from 1887,000 tons (2015) to 365,000 tons by 2020, which amounts to about 8% annual average growth rate (Alemu & Berhanu, 2018). In addition to this, the same source noted that the availability of fertilizer was targeted to reach 2.06 million metric tons, by increasing 15% every year. As a result of which, the share of smallholder farmers using agricultural inputs in the sector has increased over the last decades. For example, the share of cereal producers using improved seed[2] has increased from 10% in 2004/05 to 21% in 2013/14; while chemical fertilizer imports have increased by 124% and fertilizer use by smallholders increased by 144% between 2004/05 and 2013/14 (World Bank, 2016). However, during the GTP I period the performance improved input supply sill falls short of the target set. The quantity of fertilizer distributed in 2014/15 was 1.201 million quintals, but this was only 72.2% of the target planned for the year. The delivery of improved seeds was only 1.514 million quintals, which represents about 42% of the target planned for 2014/15 (NPC, 2016).

However, despite the efforts, crop production in general and the cereal sub-sector, in particular, is still characterized by a subsistence production system on account of its low productivity. Many factors contribute to the low levels of productivity in the country. These encompass, among others, limited access, utilization, and inefficiency in the use of production inputs (Yu, et al., 2011; Tilahun, 2014; Urgessa, 2015; Merga & Haji, 2019), the weak introduction of technologies, rain-dependent agriculture, poor utilization of fertilizer, improved seeds, pesticides, landholding, weather, climate change (MoFED,2014), land shortage in the Ethiopian highlands, limited potential for irrigation, inadequate marketing infrastructure, and a weak seed sector (Dorosh & Rashid, 2012). As a result of which, the country's import of cereals (wheat, rice, and barley), edible oil, and lint cotton, continues to rise dramatically, now costing over a billion dollars every year (Diriba, 2020). Hence, it is very challenging to supply adequate food for the rapidly growing population of the country. This reminds raising the productivity and efficiency

[2] This was driven by the rapid increase of improved maize seed adoption which increased from 12 to 28 percent over the decade (World Bank, 2016).

of smallholders are essential aspects of agricultural policy interventions aimed at improving food security and reducing the levels of poverty in rural areas.

Under the ADLI strategy, the Ethiopian Government has been also exerted concentrated efforts to build an efficient agricultural marketing system[3], expanding rural infrastructures such as road, electricity, and telecommunication in rural areas and thereby reducing marketing costs for smallholder farmers. Moreover, among the various initiatives useful to enhance the process of agricultural commercialization, the government has been working to expand the agricultural commercialization cluster (ACC) approach in different areas of the country. The primary aim of the initiatives was to provide a strategic platform important to drive diversification, commercialization, and specialization for priority commodity value chains (Alemu & Berhanu, 2018). On top of these, health, education, water supply, sanitation, finance, and other social services have been also increasingly extended to the rural areas of the country (MoFED, 2002; MoFED, 2006; MoFED, 2010; NPC, 2016).

On account of the effort by the government and other international development partners, the share of the population in Ethiopia below the poverty line, in monetary terms, markedly decline from 45.5 % in 1995/96 and 29.6 % in 2010/11 to 23.5 % in 2015/16 (NPC, 2017). Between 2010/11 and 2015/16 about 5.3 million people have been lifted out of poverty, implying the economic and social performance helped to reduce the level of poverty in the country. However, the poverty reduction was strong in urban areas as compared to rural areas, on account of many factors partly caused by the drought (World Bank, 2019). Overall, despite the impressive reductions in poverty rates between 2005 and 2015, yet rapid population growth counters the gain in Ethiopia, resulting in higher absolute numbers of poor people (World Bank, 2020). On top of this, tremendous achievements in access to social services, such as education, health, water and sanitation, and infrastructure have been realized over the past decades. Access to universal primary education reached 100 %, health coverage 98 %, access to potable water 65 %, life expectancy reached 64.6 years, and others (UNDP, 2018). Ethiopia's HDI value for 2019 and the values on the key indicators show progress in the country. Ethiopia's HDI value for 2019 is

[3] The Ethiopian Government has envisaged to develop the efficiency of agricultural marketing system through grading agricultural produce, provision of market information, promoting and strengthening cooperatives, strengthening the participation of private capital in marketing, and improving rural finance (MoFED, 2003).

0.337, which decreased from the HDI value of 0.47 for 2018, and between 1990 and 2018 the HDI indicators, such as life expectancy at birth, mean years of schooling, expected years of schooling, and GNI per capita increased by 19.1 years, 1.3 years, 5.6 years and 173.7 %, receptively (UNDP, 2019).

However, despite an unprecedented decline in the incidence of poverty, poverty is projected to decrease with a slow rate to 22% by 2020 due to weak transmission between overall GDP growth and poverty reduction in Ethiopia (World Bank, 2019). HDI value also put the country in the low human development category, positioning it at 173 out of 189 countries and territories. Moreover, although the multi-dimensional poverty index (MPI) reduced from 0.545 to 0.489 between 2011 and 2016, the percentage of multi-dimensionally poor people fell from 88.4 % to 83.5 % with the intensity of deprivation dropped from 61.6 % to 58.5 % (UNDP & OPHI, 2019), implying trivial change both in the intensity of proportion and deprivation. The same source also revealed that 93.3% of multi-dimensional poor people in Ethiopia live in rural areas. The facts on the poverty situation of the country evoke the requirement of empirical studies using a multitude of measurements to poverty and hence, sufficient evidence will be generated useful to understand the causes of poverty and develop holistic and integrated anti-poverty strategies.

Although, higher productivity growth through the adoption of improved technologies, efficiency, and market access are believed to ensure food security and reduce poverty in countries, as Schneider, and Gugerty (2011) noted that the importance of productivity to agricultural sector growth and poverty reduction is complex and depends on a variety of contextual factors including the initial distribution of poverty, asset endowments, the strength of market linkages, etc. Moreover, barriers to technology adoption, (such as education, health, initial asset endowments, infrastructure, and other social services, among others), low level of production efficiency, and constraints to market access also impend the ability of the smallholders to participate in the gains from productivity growth (Thirtle, et al., 2001; Irz, et al., 2001; Schneider & Gugerty, 2011). Supporting this, Lipton (2013) argued the importance of location-specific studies in addition to macro-level analysis to inform the policymaking process with trustworthy and dependable empirical shreds of evidence. Added to this, the reality of Ethiopia's agriculture varies across space within Ethiopia as well as over time due to changes in policies, weather shocks, and other factors (Dorosh & Rashid, 2012). Hence, widening the scope of understanding by geography and farming system assists to provide greater information for locally targeted policy options (Chamberlin & Schmidt, 2012). Therefore, creating an empirical understanding of crop technologies adoption, production efficiency, the commercialization of smallholders, and multi-dimensional poverty offers insights on key variables useful for policy-making and anti-poverty strategies in rural areas in general and that of major *'teff'* growing areas in particular. The major *'teff'* production area is one of the highland mixed farming areas of the major agricultural systems[4] found in Ethiopia. The areas are well known for their potential to grow major cereal such as *'teff'*, wheat, maize, sorghum, and barely, in that order.

Previous empirical studies in Ethiopia and elsewhere around the world investigated the poverty reduction effects of improving productivity (for example, Ahmad,2003; Abro, et al., 2014; Dzanku, 2015; Darko, et al., 2018; Islam & Haider, 2018) and the effects of commercialization on household poverty (for example, Awotide, et al., 2016; Boka, 2017; Ouedraogo, 2019). However, to the best of the researcher's knowledge, none of them addressed the link between production efficiency, commercialization, and household multidimensional poverty. This thesis hence made multiple contributions to the literature. First, the study examines the effects of research recommended production practices on the production efficiency of smallholder cereal farmers using a Meta frontier approach. Second, the study offers an insight into the effects of smallholders' commercialization on input utilization and yield using different econometric models. Third, the study provides an empirical understanding of the relationship between production efficiency and the scale of commercialization of smallholder farmers. Forth, the study offers an insight on the effect of production efficiency and commercialization on the welfare situation of the smallholder cereal farmers using multi-dimensional welfare indicators, which empirical evidence is lacking. Finally, the proposed study by filling the existing knowledge gap enables planners to design and implement integrated agricultural development policies and strategies based on the latest empirical evidence and important variables.

[4] Ethiopia is characterized mainly by three major agricultural systems, such as the highland mixed farming system, the low plateaux and valley mixed agriculture and the pastoral livestock production of the arid and semi-arid zones (PGRC, 1996).

1.3. Objectives and research questions

General objective

The general objective of this study is to examine the poverty reduction effects of improving technical efficiency and commercialization of smallholder cereal farm households in major *'teff'* growing areas of Ethiopia.

Specific objectives

The study aimed at addressing the following specific objectives and associated research questions.

1) To assess the effects of extension recommendationcereal production practices on the efficiency of smallholder farmers in the study areas;
   a) What is the adoption status of high-yielding cereal varieties and research recommended production practices among farm households?
   b) What is the level of technical efficiency of smallholder farm households?
   c) How do improved cereal crop varieties and production methods affect farm households' efficiency scores?
2) To assess the scale of cereal commercialization among smallholder farm households in the study areas;
   a) To what extent do smallholder farmers commercialize cereal output?
   b) How does cereal commercialization affect the utilization of production inputs, efficiency, and productivity?
   c) Is there a bi-causal relationship between technical efficiency and commercialization?
   d) What are the factors that affect the degree of cereal crop commercialization of farm households?
3) To examine the technical efficiency effects on multidimensional poverty among farm households;
   a) What effects does the farm households' efficiency have on the multidimensional poverty of farm households?
   b) Are there any two-way relationships between farm households' technical efficiency and multidimensional poverty?

c) Does the effect of technical efficiency on the multidimensional poverty of farm households differ in crop diversification status?

4) To investigate the effects of cereal commercialization on multidimensional poverty among farm households?

a) How cereal crop commercialization does affect farm households' multidimensional poverty?

b) What are the channels through which cereal crop commercialization affects multidimensional poverty?

1.4. Significances of the Study

The current study is supposed to possess several significances. First, the study by analyzing production efficiency, and commercialization with multidimensional poverty situation of smallholder cereal farmers provide empirical knowledge and household level micro-data. So that policy makers and practitioners be able to design policies and anti-poverty strategies using up-to-date empirical evidence and the latest data. The study can also serve as a springboard to conduct further analysis by using the conceptual and methodological approaches used in this study. Furthermore, the interpretation of the findings provides conceptual, regulatory, managerial, operational benefits for academia, researchers and research organizations, federal and regional agricultural offices, non-government organizations, private agricultural operators, subject matter specialists, and development agents.

1.5. Scope and Delimitation of the Study

Thematically, the study focused on analyzing improved crop varieties, production methods, production efficiency, commercialization of smallholder cereal farmers with household multidimensional poverty situations in the study area. The current study employed representative sample size, appropriate quantitative and qualitative data collection and analysis methods and tools, and relevant measurement techniques. Stochastic meta-frontier approach, commercialization index, and multidimensional poverty measures, and appropriate specification and econometric modeling were applied. In terms of geographical scope, the present study was conducted in major *'teff'*-producing areas of Ethiopia. The data collection for the study covered two '*Weradas'* (such as Adea and Enemay) in the two major *'teff'*-growing zones in Oromia and Amhara regional states. The '*Weradas'* are known for their potential for *'teff'* and other major cereal crops. The study collected primary data from 392 smallholder farm households randomly chosen from two '*Weradas'* and six *'Kebeles'*.

1.6. Theoretical and Empirical Literature Review

Growth in agriculture: Concepts and Theories

The fundamental questions under the agricultural development theories have been included as stated by Sarris (2001) include: 'What is the role of agriculture in economic growth?', 'Can agriculture be a leading sector to induce foster growth?', 'How does agriculture grow?' and 'What the determinants of agricultural supply?' One of the arguments to this end, agricultural growth can contribute to the overall economic growth is linked with its potential in releasing surplus and abundant labor resources to other important and highly productive sectors. Regards to this, many development analysts (Rosenstein-Rodan, 1943; Lewis, 1954; Fei & Ranis, 1961; Jorgenson, 1961) considered agriculture as a stimulant for the commencement of structural transformation by which poor nations be able to transform the overall economic structure from traditional subsistence agriculture to more diversified industrial economy. The role of agriculture as per these scholars was seen as a source of surplus labor and ancillary to the main strategy of growth, which was accelerating industrialization (Sarris, 2001). This means that agriculture plays merely a passive and supportive role. The primary role of agriculture, as per these theorists, is only to provide sufficient low-priced food and manpower to the expanding industrial economy (Todaro & Smith, 2010), which they thought to be a dynamic or leading sector in the overall economy. However, contrasting to this view, growth in agricultural productivity is an indispensable base of modern economic growth (Kuznets,1968; cited in Sarris, 2001) in developing countries by contributing beyond surplus labor and primary products.

Such view that agriculture plays the leading role in the economy of developing nations has been re-emphasized by scholars (Kuznets, 1961; Johnston & Mellor, 1961; Kuznets, 1965; Timmer, 1988; Delgado, et al., 1998; Timmer, 2002), particularly since the 1970s. These scholars put forth the contribution of agriculture to the economic development of poor nations in several ways, such as providing food and raw materials for non-agricultural sectors of the economy, creating demand for industrial outputs, providing labor and investable surplus in the form of savings and taxes to be invested in non-agricultural sectors, provide earnings through the export of agricultural products. Moreover, growth in agricultural productivity encourages entrepreneurial activities in rural areas and stimulates new economic opportunities, such as the production of new products, the creation of rural services, and the establishment of new agro-processing firms (World Bank, 2008). Faster agricultural growth rises farm incomes and demand for industrial goods; lowers food prices, curbs inflation and induces non-farm growth, and creates an additional demand for workers (Salami, et al., 2010).

The next important question could be linked with ‘how does agriculture grow?’. To this end, there have been two important intellectual development views that have arisen since World War II. The first view as explained by Johnson (1997), quoted by Timmer (2002), was the scientific revolution in agriculture that should take place to transforming the potential productivity of land and rural people from subsistence levels to the levels that produce substantial market surplus; and second, as Timmer (2002) added, the fundamental role of the market and key aspects of public intervention to foster its role in the overall agricultural and rural development. For realizing the role of agriculture in the rest of the economy, the major issue that stands out from these two perspectives is the need of adopting a market-oriented strategy, which is accompanied by a technological change to achieve rapid growth in the agricultural sector. In addition to technological change in the production of the agricultural sector, it is substantially important to enhance the productivity of the production factor. On this line, the basic ingredients that make up for total factor productivity include agricultural research and development, extension, rural infrastructure, physical capital, the use of modern inputs, and human capital such as education, and health (Sarris, 2001).

Increasing agricultural productivity per worker is the first stage that should be well succeeded particularly at the early stage of agricultural growth (Timmer, 1988). Apart from increasing productivity, expansion of improved infrastructure and establishment of market linkage is among the indispensable factors required to achieve growth in agriculture. The gradual integration of the agricultural sector into the macroeconomy through the improvement of infrastructure and market-equilibrium linkages, is among the key step to ensure growth in agriculture (Timmer, 1988). This is to say that without the integration of the agricultural sector to the whole economy, growth in agriculture cannot be realized no matter how fast its productivity per worker/hectare is on the rise.

Concerning this view, the commercial transformation of smallholder agriculture is one of the undeniable paths to increase income and improve standards of living in rural areas of developing countries (von Braun & Kennedy, 1986; von Braun, 1995; Moti, et al., 2009). Pingali (2010) also argues the requirement of smallholder lead productivity growth as vector of poverty reduction in the developing countries, in particular those of sub-Saharan Africa. Increasing the productivity of smallholder agriculture can lead to achieving food security, poverty reduction, and overall economic growth by raising the income of smallholders, transferring surplus to another important sector, reducing food expenditure, and thus reducing income inequality. Smallholders produce a wide range of foods, often wider than large commercialized farms (Rapsomanikis, 2015). An increased smallholders' food production can lead to failing real prices of food, especially for staples (Wiggins & Keats, 2013).

In the literature (Ruttan, 1977; Udemezue & Osegbue, 2018; Welteji, 2018), there are five general models for agricultural development, such as the frontier, conservation, urban-industrial impact, diffusion, and the high pay of input models. The frontier model, also known as the 'resource exploitation model', put the expansion of cultivation areas as an approach to agricultural development. Conservation model involves the execution of complicated land and labor-exhaustive farming system, the application of organic manures, and labor-intensive capital creation through the use of intensive labor, and facilities effective utilization of land and water resources. The urban-industrial impact model suggests the more effective performance of the factor and product market linkage of agricultural and non-agricultural sectors for areas where there is rapid urban-industrial development. From the perspective of the dissemination model, successful diffusion of technical knowledge and decline of productivity gaps between farmers and regions are the main path to agricultural development. The high pay of input model, which is also termed as 'transformation approach' or 'the quick-fix approach', assumed the requirement of an investment, which is designed to expand the diffusion and the adoption of the high-yielding varieties.

Production efficiency: Concepts and Measurements

Definitions and concepts: The concept of production in economics is beyond an activity of making something material like the growing of wheat, maize, *'teff'*, or any other crops or livestock products by the farmers. It is the transformation of factors of production (land, capital, labor, and entrepreneurship) into products (also term as outputs) (Rasmussen, 2011) through the production process to satisfy human wants. In its wider concept, production involves the process of utilizing resources to satisfy human wants through the creation or addition of utility. Creating or adding utility to the resources in the production process follows the process of changing resources into form, time, place, service utility. Hence the entire process of production is creating or adding form, place, time, and/or personal utility.

In microeconomics theory, the concept of productivity and efficiency is seen from two different but related concepts. The productivity of a firm can be briefly defined as the ratio of output (s) to its input(s) (Coelli, et al., 2005; Fried, et al., 2008; Rasmussen, 2011). The productivity of a firm could be measured using partial productivity, such as yield per hectare, output per labor, or total factor productivity (TFP) (ratio of aggregate output to aggregate input). Efficiency can be briefly defined as "the achieved compared to what can be achieved" (Rasmussen, 2011, p. 61). More comprehensively, Fried, *et al.* (2008, p.8) defined the efficiency of the production unit as "observed output to maximum potential output attainable from the input, or evaluating observed input to minimum potential input needed to produce the output or some blend of the two." The definition of efficiency advanced by Fried and his colleagues involves two important concepts, the first efficiency is the relation between the observed and the optimal value of its inputs and outputs; the second efficiency has both output (output-oriented efficiency) and input side (input-oriented efficiency) of the production process.

A firm's productivity is greatly determined by the type and quality of inputs and how well these inputs are combined in the production process. The type and quality of inputs represent the production technology while the way inputs are combined in the production process refers to the technical efficiency of the production process (FAO, 2017). A firm's productivity can be, therefore, enhanced by either advancing the state of technology that can shift the production frontier upward or improving efficiency on the use of the existing frontier. Changes in the efficiency of a firm can be seen from the change of the firm's position relative to the current technological frontier (Rasmussen, 2011), suggesting that it is important to address efficiency gaps in addition to production technology and environment in which the production occurs.

Using a simple definition, the production function is the functional relationship between inputs and output. However, the definition goes beyond the input and output relationship. According to Debertin (1966, p. 14), "a production function designates the technical connection that converts inputs into outputs." The theoretical description of a production function as forwarded by Aigner, *et al.* (1977, pp. 1) is "the maximum amount of output obtainable from given input bundles with fixed technology." Similarly, Battese (1992, p. 185) defined production function in terms of "the maximum output that can be produced from a specified set of inputs, given the exiting technology available to the firm involved." According to Todaro & Smith (2010), "production function is defined as technological or engineering relationship between the quantity of a good produced and the quantity of input required to produce it." Concerning this, the output takes the form of the volume of goods and services; whereas the inputs are different factors of production such as land, labor, capital, and enterprise/organization.

Measurement of efficiency: In theoretical literature, Koopmans (1951), Debreu (1951), and Shephard (1953) are regarded as a pioneer in starting frontier efficiency measures on production efficiency in the early 1950s. The methodology behind the measurement of productivity and efficiency extended by the seminal work of Farrell (1957) who was inspired by the work of Debreu (1951) and Koopmans (1951) to define a simple measure of firm efficiency that could represent several inputs. Econometricians have been estimating average/response production functions using traditional least-square methods up until the late 1960s (Aigner, et al., 1977 ; Battese, 1992). However, Farrell (1957) in his work presents the possibility of estimating the so-called frontier production functions. He proposed the notion of relative efficiency in which the efficiency of a particular production technology may be compared with another one within a given group. He identified the efficiency of a firm into three types of efficiency, such as technical efficiency, allocative efficiency (termed by Farrell as price efficiency), and economic efficiency (termed by Farrell as overall efficiency).

Technical efficiency (TE), as per Farrell's (1957) explanation, reflects the ability of a firm to obtain maximal feasible output from a given set of inputs (output-oriented TE) or produce a given level of output using the minimum feasible amounts of inputs (input-oriented TE). Though both ways of measuring technical efficiency prevail in efficiency literature, the output-oriented measure of technical efficiency is routinely used in the literature on the stochastic frontier approach (Kumbhakara & Tsionas, 2006). Allocative efficiency (AE) reflects the capacity of a firm to use up the inputs in optimum sizes (minimize production costs), given their corresponding prices and the production technology. Economic efficiency is also known as cost efficiency obtained from the combination or the product of both TE and AE.

There are four most commonly used methods of measuring efficiency, including (1) Least-squares economistic production models, (2) Total factor productivity (TFP) indices, (3) Data envelopment analysis (DEA), and (4) Stochastic Frontiers Analysis (SFA). The first two methods of measuring efficiency are most often applied to aggregate time-series data and provide measures of technical change and/or TFP (Coelli, et al., 2005). Whereas, DEA and SFA provide measures of relative efficiency among sample unit data at one point in time (Coelli, et al., 2005). DEA is a non-parametric approach proposed by Charnes, et al. (1978), and SFA is a parametric method developed by Aigner, et al. (1977) and Meeusen & van Den Broeck (1977). DEA uses a linear programming technique to estimate technical efficiencies, whereas SFA uses an econometric method to estimate efficient frontiers with statistical noise in the data (Coelli, et al., 2005; Toma et al., 2015; Mardani & Salarpour, 2015).

As discussed in Coelli (1995), SFA imposes specific restriction assumptions on the functional form of the frontier and the distribution of stochastic error terms, which is considered as one of the weaknesses of SFA. In contrast, DEA uses linear programming methods to construct a piecewise frontier of the data, and hence, no assumption about the production function and the distribution of the error terms is required. However, the DEA does not take account of the sort of statistical errors, e.g., errors of measurement (Kalirajan & Shand, 1999), therefore less convenient for agricultural-related studies in developing countries (Coelli, 1995). In contrast, SAF can measure efficiency, while simultaneously considering the presence of statistical noise by assuming a production function and specific distributions for the error term (Andor & Hesse, 2011).

The introduction of a stochastic meta-frontier approach in efficiency literature is also another methodological progress in the measurement of production efficiency. The traditional approach, which is dominantly applied to measure efficiency scores uses a single production function based on the assumption that underlying technology is the same for all the sample observations, irrespective of differences in working conditions and surroundings (Alem, et al., 2018). Differently, however, this approach provides methodological rigor in estimating technical inefficiencies by simultaneously accommodating the heterogeneity across different groups, such as farms, firms, regions, and countries in terms of production technologies used. Comparing the efficiency scores of different farms located in different geographical regions using a single estimate is likely to produce misleading results (Orea & Kumbhakar, 2004; Kumbhakar, et al., 2015; Chen, et al., 2016).

The approach was the extension of the meta-production function, which was first introduced by Hayami (1969); Hayami & Ruttan (1970, 1971) as envelop of commonly conceived neoclassical production functions. Battese & Rao (2002) proposed a stochastic meta-frontier function to operationalize the standard meta-production function approach and Battese, et al. (2004) further developed a modified model that encompasses the deterministic components of the stochastic frontier production functions for the firms that operate under the different technologies. The Battese, Rao, and O’Donnell model estimated the stochastic frontier analysis in two steps, where a stochastic frontier estimation for the homogeneous group frontier is estimated in the first step and the meta-frontier is estimated using linear programming in the second step.

After some years, O’Donnell, et al. (2008) provided an essential analytical framework important for the definition of a meta-frontier and how a meta-frontier can be assessed using non-parametric and parametric methods. Huang, et al. (2014) further improved the approach by proposing a new two-step stochastic frontier approach that estimates the group-specific frontier and the meta-frontiers, respectively. Different from Battese, et al. (2004) and O'Donnell, et al. (2008), the estimation strategy is based on a stochastic frontier framework rather than a mathematical programming technique, which allows separating the random shocks from the technology gaps.

Agricultural commercialization: Definitions, Concepts, and Measurements

Definitions and concepts: The commercialization of agriculture is a key element for achieving agricultural growth and poverty reduction in developing countries. Several accounts (for example, Rostow, 1960; Timmer, 1988) have put commercialization as a stimulant of economic growth that releases resources from the agricultural sector to the non-farm sector. In respect to this, Leavy & Poulton (2006) documented the potential contribution of commercialization as including stimulating rural growth, creating employment opportunities, increasing productivity, direct income benefits for employees and employers, expanding food supply, and potentially improving nutritional status. While, Von Braun & Kennedy (1994) put forth the benefits of commercialization concerning the so-called multiplier effects, supposing increasing demand for food and services in rural areas.

Carletto, *et al.* (2017) states agricultural commercialization enhances trade and efficiency, leading to economic growth and welfare improvement at the national level. This is further expected to initiate a virtuous cycle that raises household income, thus improving consumption, food security, and nutritional outcomes inside rural households (Carletto, et al., 2017). Overall, as Von Braun & Kennedy (1986) noted that increasing market integration of smallholders in developing countries appears unavoidable because as discussed by Pingali & Rosegrant (1995); and Pingali (1997) it is driven by major forces, such as economic growth, population growth, urbanization, expansion of the non-agricultural sector, technological change, etc.

In much of available literature (Nakajima, 1965; Fisk, 1975; Von Braun & Kennedy, 1986; Makhura, 1994; Pingali & Rosegrant, 1995; Pingali, 1997; Govereh, et al., 1999; Pingali, et al., 2005; Sokoni, 2008; Moti, et al., 2009), authors have defined commercialization of smallholder agriculture from different perspectives. The perspectives are including commercial orientation, outputs with an increased marketed surplus, the use of increased purchased input, the proportion of area planted with marketable crops, the volume of produce and household resource that enter into the exchange economy and earning from the sale of crops of small family farms. Commercialization of agriculture at the output side is defined as the value of agricultural sales in markets per agricultural production value; whereas, commercialization of agricultural at the input side is defined as the value of inputs acquired from the market per agricultural production value (Von Braun & Kennedy, 1994). Mahaliyanaarachchi & Bandara (2006) explained commercialization of agriculture as farmers' production that is aimed mainly for sales, oriented to profit maximization, aim at the satisfaction of different needs and interests of consumers, and leads to the entrepreneurial achievement of the farmers.

Commercial transformation of smallholder agriculture encompasses a transition from subsistence-oriented to progressively market-oriented forms of production and input use (Govereh, et al., 1999; Sokoni, 2008; Carletto, et al., 2017). Subsistence oriented production system is an economy in which production is mainly for personal consumption and the standard of living yields little more than necessities of life, such as food, shelter, and clothing (Todaro & Smith, 2010). On the other hand, a market-oriented production system is more than the marketing of agricultural output, it means the product choice and input use decisions are based on the principles of profit maximization (Pingali & Rosegrant, 1995).

The evolution of agricultural production in the smallholders' economy passes through three broad stages or sub-systems (Weitz, 1971; Pingali & Rosegrant, 1995). These stages are subsistence system, semi-commercial system, and commercial system (Table 2.1). This type of classification is mainly based on the level of smallholders' market orientation. The subsistence system is characterized by smallholder farms with low productivity, still prevalent in Africa. Whereas, a semi-commercial system can also be termed as diversified or mixed family agriculture, where a small part of the produce is grown for consumption and a significant part of the sale to the commercial sector, as in much of Asia. The commercial system, the final stage, is the stage at which the farms are exclusively engaged in high-productive specialized agriculture geared to the commercial market, as in developed countries and often found in the highly urbanized developing countries. At the specialized stage of commercialization, the production unit starts rapidly responding to market price and quality inputs (Pingali & Rosegrant, 1995).

Table 1.1: Characteristics of food production systems with increasing commercialization

Level of market orientation	*Farmer's objective*	*Sources of inputs*	*Product mix*	*Household income sources*
Subsistence systems	*Food self-sufficiency*	*Household generated (non-traded)*	*Wide range*	*Predominantly agricultural*
Semi-commercial systems	*Surplus generation*	*A mix of traded and non-traded inputs*	*Moderately specialized*	*Agricultural and non-agricultural*
Commercial systems	*Profit maximization*	*Predominantly traded inputs*	*Highly specialized*	*Predominantly non-agricultural*

Source: Pingali & Rosegrant (1995)

Commercialization in agriculture is also viewed as occurring only for high-value cash crops. However, commercialization is not only restricted to just cash crops but also occurs for the primary staple cereals (Von Braun & Kennedy, 1994; Von Braun, 1995; Pingali & Rosegrant, 1995; Pingali, 1997; Salau, et al., 2018). Apart from this, as Von Braun & Kennedy (1986, 1994) indicated, sometimes commercialization may influence national, community, and household level food availability. The situation may occur when cash crop production competes for a scarce resource. As the same sources notice there are a variety of mechanisms through which cash crop production can affect consumption and nutritional status. Cash crop production may reduce food availability at the household level which may increase food prices. High or increasing food prices again severely affects the poor and malnourished than the better of the consumer because the poor need to spend a large proportion of their total incomes on food to meet smallest wants.

Measurement of the degree of commercialization: The concept attached to commercialization in agriculture dictates its measurement. For example, “under the semi-commercial system, where both market and home consumption are playing a key role in production and marketing decision, all crops produced by a household may not be marketable in the identical proportion” (Berhanu & Moti, 2010, p 5). Under this system hence, measurement of commercialization is seen from either the proportion of household products to be marketed or the proportion of inputs used to produce the specific product in the production system. In this case, households could differ in their market orientation depending on their resource allocation (land, labor, and capital) to the more marketable commodities (Berhanu & Moti, 2010).

More broad measures of commercialization are proposed by Von Braun & Kennedy (1994). They propose a measure of commercialization concerning a household's integration into the cash economy. Von Braun & Kennedy specify the integration of the household into the cash economy from three different angles and measure the extent of their prevalence at the household level with the following ratios:

Commercialization of agriculture (output side) = Value of agricultural sales in markets/agricultural production value

Commercialization of agriculture (input side) = Value of inputs acquired from market/agricultural production value

Commercialization of rural economy = Value of goods and services acquired through market transaction/Total income

Measuring commercialization from the input side may disregard different input requirements of different crops, which may have implications for the need to purchase external inputs (Berhanu & Moti, 2010). Hence, the degree of commercialization can be computed as the proportion of the value of purchased inputs to the value of total input used instead of the total value of crop production. There are also studies (for example, Berhanu & Moti, 2010) that used the Market Orientation Index (MOI) to measure the level of household's degree of commercialization. Market Orientation Index (MOI) is a measure of a household's market orientation computed from the land allocation pattern of the household weighted by the marketability index of each crop. The marketability index for annual crops is calculated based on the proportion of the total amount of crop sold to the total production aggregated at the district level. Several studies used the household commercialization index and measures the extent to which household corp or livestock production oriented toward the market. The index is measured along the scale from zero to 100, such that zero would imply a total subsistence-oriented household, the closer the index is to 100, the higher degree of commercialization.

Poverty: Definition, Concept, and Measurement

Definition and concept: The development actors define poverty based on a set of perspectives, which are intermixed with the interest of the development actors themselves. The three dominant perspectives that have been used to define poverty are income perspective, basic needs perspectives, and capability perspectives. Following these main perspectives, the poverty definitions can be grouped into two categories: first traditional definitions of poverty that adopt uni-dimensional perspectives whereas modern definitions of poverty that use multi-dimensional perspectives (Seyoum, 2013).

Poverty is defined as "a pronounced deprivation of well-being" (World Bank, 2005, p. 9). This way of defining poverty encompasses only material deprivation of well-being, which is measured by the appropriate concept of income or consumption. In this case, if a person's income level is below the defined poverty line, he/she is considered poor or in poverty. However, the income or consumption-based approach to define poverty is not problem-free. This is because "it fails to apprehend key dimensions of poverty and that it every so often fails to reflect subjective observations of well-being" (Greeley, 1994).

The basic needs perspective goes beyond the lack of income of an individual from the defined threshold. It describes poverty in terms of specific types of consumer goods, including enough food, basic health, education, shelter, and other essential services that are fundamental to preventing people from falling into poverty. As pointed out by Chambers (2006), the basic need approach is linked to material lack or wants, besides income, this includes absent, limited, or low qualities of assets (such as shelter, clothing, furniture, personal means of transport, radio, etc.) and insufficient access to other basic services. In this case, poverty is measured by examining the status of every of the basic consumption goods against basic minimum requirements.

The capability approach, which is driven by Amartya Sen (1987), argues that well-being comes from a "capability" to function in society. It is a people-focused approach, which consists of two basic elements, such as functionings and freedom. Sen uttered poverty as capability denial that goes beyond material lack or wants to include the human capability. Hence, poverty ascends when people face absence of capabilities, and so have insufficient income or education, or poor health, or insecurity, or low self-confidence, or a sense of incapability, or the absence of rights such as freedom of speech. The capability approach to define poverty reflects that poverty is a complex multi-dimensional and contextual experience problem, such that it is impossible to amend with a simple common solution.

Poverty measurement approaches: There are four notable approaches to measure poverty. These approaches are the monetary approach, the capability approach, social exclusion, and participatory methods.

The monetary approach: The monetary approach is the most widely used instrument for measuring poverty. This approach to poverty measurement was pioneered by the seminal work by Booth and Rowntree, who studied poverty in London and New York, respectively, in the 19th and early 20th Centuries (Ruggeri-Laderchi, et al., 2003). It is a one-dimensional measure of poverty usually based on income or consumption, which are taken as a proxy for well-being or living standard (UNDP, 1996; UN, 2017; OPHI, 2019).

The monetary approach is compatible with the utility-maximizing behavior assumption that the objective of consumers is to maximize utility and that expenditures reflect the marginal value or utility people place on commodities (Ruggeri-Laderchi, et al., 2003). In this case, welfare can be measured as the total consumption enjoyed, proxied by either expenditure or income data, and poverty is defined as shortfall below the defined poverty line. The poverty line that identifies poor and non-poor is determined by either absolute or relative terms. With regards to this, absolute poverty lines represent the value of a set of levels of resources necessary to provide a given minimum standard of well-being; whereas, the relative poverty lines are set about the average situation within a society (UN, 2017). In this case, the valuation of the different components of income or consumption is done at market prices, which requires identification of the relevant market and the imputation of monetary values for those items that are not valued through the market (such as subsistence production and, in principle, public goods) (Grosh & Glewwe, 2000).

It is argued that monetary poverty is better measured by consumption data as it approximates welfare more closely than income (Deaton, 1997). Added to this, Seyoum (2013) noted the use of consumer data is more recommended due to two main reasons, first, there are no standard units and prices to monetize the products of the farmers in estimating their total income; second income data from rural households as unreliable as farmers tend to underestimate it due to tax reasons.

The capability approach: The capability approach as a poverty measure has emerged as an alternative framework to measure poverty in the 1980s. The approach considers development as an expansion of capability and freedom and argues against the more standard concentration on utility as in traditional welfare economic formulations (Sen, 1999). The capability to function is related to what a person can do or can be with real freedoms that people enjoy. However, there are unresolved issues regarding the definition and measurement of capabilities, outlining the poverty threshold and aggregating it across space and time (Laderich *et al.*, 2003; Nussbaum, 2000; UNDP, 1997, cited in Seyoum, 2013).

Multidimensional Poverty Index (MPI) based on Alkire and Foster (2011) is one of the most widely used methods of multiple poverty measurement. The tool was first developed in 2007 to allow the measurement of multidimensional poverty using the concept of the capability approach. The identification steps following Alkire and Foster (2011) employ two forms of cutoff: one within each dimension to determine whether a person is deprived in that dimension, and a second across dimensions that identifies the poor by 'counting' the dimensions with which a person is deprived. The methodology is flexible in that different indicators, cut-offs and weights can be used, including cardinal, ratio-scale, binary, ordinal, and categorical variables (Alkire, et al., 2014).

Social exclusion*:* The other measure of poverty that goes beyond monetary measures is the social exclusion approach. The term social exclusion was used for the first time by former French Secretary of State for Social Action, René Lenoir in 1974 to refer to the situation of certain groups of people. These people are "the psychologically and the physically handicapped, hopeless people, aged invalids, ill-treated children, drug addicts, criminals, single parents, multiproblem households, peripheral, antisocial persons, and other ‘social misfits’” (UN, 2016b, p. 18).

The concept of social exclusion is contested, and defined in different ways by different sources. Social exclusion is a multidimensional process that affects both the quality of life of individuals and the equality and cohesion of society as a whole, as defined by Levitas, *et al.* (2007). It involves the lack of denial of resources, rights, goods and services, and the inability to participate in normal relationships and activities. United Nations (2016b, p 18) defined social exclusion as “a state in which individuals are unable to participate fully in economic, social, political and cultural life, as well as the process ahead to and maintaining such a state.”

Perhaps it is not surprising that there is no single validated measure of social exclusion as multiple-meaning attaching to the concept of social exclusion (Mathieson, et al., 2008). Development agencies use social indicators differently. For example, the Social Protection Committee of the European Commission (2001) uses indicators that address social outcomes rather than how they are achieved based on predefined methodological principles. The social protection committee suggests three levels of social exclusion indicators. First, chief indicators be composed of a limited number of lead indicators that have been well-thought-out the most significant elements in leading to social exclusion. Second, secondary indicators that would support these lead indicators and describe other dimensions of the problem. Finally, the third level of indicators highlights specificities in some particular areas.

Similarly, Atkinson, *et al.* (2002) proposed a three-tier structure of indicators to measure social exclusion. The first level consists of a restricted number of lead indicators; the second level would support these lead indicators, providing greater detail, and describing other dimensions of the problem; the third level indicators would be added by the member state themselves to highlight specificities in particular areas, and to help interpret Level 1 and Level 2 indicators. Upon recent international work on social exclusion concepts and indicators, Scutella, *et al.* (2009) offer a framework for computing social exclusion in Australia. They differentiate seven dimensions or life domains for the estimation of social exclusion, such as (1) material resources;

(2) employment; (3) education and skills; (4) health and disability; (5) social; (6) community; and (7) personal safety.

Participatory methods: Conventional poverty estimates, including both monetary and capability estimates, have been planned for being *externally* imposed, and for not taking into consideration the opinions of poor people themselves (Ruggeri-Laderchi, et al., 2003). Due to the shift in thinking[5], the model of learning moves away from extractive survey questionnaires and toward new approaches and models for participatory appraisal and analysis (Chambers, 1994). In these alterations, Participatory Rural Appraisal (PRA) has established and extend fast in the 1990s. Chambers is the pioneer for participatory approach by his exceptional work, which is *"The origins and practice of PRA"* and *"Whose Reality Counts? Putting the First Last"* in 1994 and 1997, respectively. The approach aims to bring the poor people to the center of poverty assessment and analysis, by which they decide about what it means to be poor and the magnitude of poverty. The Participatory Rural Appraisal (PRA) is defined as "a flourishing family of approaches and methods to allow local people to share, enhance and analyze their familiarity of life and conditions, to plan and to act" (Chambers, 1994, p. 53). It is an approach by which researchers can learn about rural life from, with, and by rural people.

Cornwall (2000), cited in Ruggeri-Laderchi, *et al.* (2003) differentiates three types of PA: (i) those associated with self-determination and empowerment; (ii) those associated with increasing the efficiency of programs; (iii) those emphasizing mutual learning. Contextual methods of analysis are involved, i.e. data collection methods that "attempt to understand poverty dimensions within the social, cultural, economic and political environment of a locality" (Booth *et al.*, 1998, p. 52). The methods derive from and emphasize poor people's ability to understand and analyze their reality. A range of tools has been devised, including the use of participatory mapping and modeling, seasonal calendars, wealth, and well-being ranking. A large variety of methods can be used flexibly. This contrasts with the other approaches, where a more rigid framework and methodology are involved (Ruggeri-Laderchi, et al., 2003). There remain, however, some challenges in truly operationalizing PPAs (Seyoum, 2013).

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[5] The shift is away from top-down to bottom-up, from centralized standardization to local diversity, and from blueprint to learning process (Chambers, 1994).

Review of the empirical literature

In this section, the researcher reviewed the most pertinent earlier studies on production efficiency and commercialization of major crops and the welfare of smallholder farmers in Ethiopia. A large number of studies (for example, Asefa, 2011, Bizuayehu, 2014; Croppenstedt & Demeke, 2014; Weldegebriel, 2014; Geffersa et al. 2019); assessed the technical efficiency of major crops grown in Ethiopia. Except for Weldegebriel (2014), the rest of the studies revealed the possibility of improving the crop output produced by smallholders through removing inefficiencies that result from farm-specific factors. the finding of the study by Weldegebriel (2014) showed that the predicted level of technical inefficiency in crop production is inconsiderable, such that the deviation of actual output from the frontier output in crop production is the result of the stochastic factors beyond the control of the producers such as bad weather, drought, and the like.

There are also studies in Ethiopia that address the production efficiency of specific crops such as *'teff'*, wheat, and maize (for instance, Bekele, et al., 2009; Alemu, et al. (2009); Tesfaye & Beshir, 2014; Magnar & Alamrew, 2014; Nisrane, *et al.*, 2015; Leggesse, 2015; Hailu, *et al.*, 2015; Beshir, 2016; Dessale, *et al.*, 2018; Mersha, 2019). Similarly, these studies revealed the presence of technical inefficiency in crop production in Ethiopia due to farm-specific determinant factors. Studies by Nisrane, *et al.* (2015), Leggesse, (2015), Hailu, *et al.* (2015), and Dessale, *et al.* (2018) estimated the production efficiency of smallholder *'teff'* producers and investigated farm-specific attributes that affect smallholder *'teff'* producers production efficiency. The studies revealed the possibility of improving *'teff'* output (22% to 28%) produced by smallholders through removing inefficiencies that result from farm-specific factors.

The study by Alemu, et al. (2009) investigated efficiency variations across agro-ecological zones in Ethiopia and found a mean technical efficiency of 76% with a statistically significant difference among agro-ecological zones. The study also found that positive and significant elasticity for asset endowments including physical (land and draft power), financial (credit and market access), and human (labor and education). The study conducted by Oyetunde-Usman & Olagunju (2019) showed a mean technical efficiency of 52% for farm households in Nigeria. Similarly, the efficiency analysis by Wongnaa & Awunyo-Vitor (2018) revealed the mean technical efficiency of 58.1% for maize farmers in Ghana. This study also found that educational level, farming experience, extension contact, group membership, use of fertilizer, and improved seed enhance technical efficiency, whilst farm size and land fragmentation decrease technical efficiency among maize farmers.

Other empirical studies conducted in Ethiopia revealed the presence of technical inefficiency in crop production due to farm and household-specific determinant factors. For example, a study conducted by Bizuayehu (2014) found that education of the household head, the use of soil and water conservation, livestock ownership and access to improved seed have statistically significant and positive associations with the technical efficiency of farm households. Similarly, Tenaye (2020) found that age and education of the household head, farm size, cultivated land quality, access to extension service were positively associated with technical efficiency while family size, land fragmentation, access to credit service, and off-farm income were negatively affected the technical efficiency of farm households.

A study carried out by Geffersa, et al. (2019) showed that the sex of the household head, family size, off-farm income, saving, farmer group participation has a significant and positive association with technical efficiency while the age of the household head was negatively related to technical efficiency. Few studies have been conducted on the impact of improved technologies on technical efficiency scores in developing countries. A study conducted by Ahmed, et al. (2017) is a good example that estimates the impact of improved maize variety on the technical efficiency of farm households in East Hararghe Zone of Ethiopia using the propensity score matching method. They found that farm households who adopt improved maize varieties have 4.42% of technical efficiency gain compared with their non-adopted counterparts. (Chirwa, 2007) assessed sources of technical efficiency among smallholder maize farmers using plot-level data from Southern Malawi. The study found that the average efficiency score is 46.23%, indicating smallholder maize farmers in Malawi are inefficient. The model estimation showed that the use of hybrid seeds and club membership improves maize farmers' efficiency. Using a stochastic frontier approach, (Shanmugam & Venkataramani, 2006) showed that the mean technical efficiency is found to be 79%, which means the farmers could increase agricultural output without additional resources. The study also identified literacy, rural electrification, and road as some important drivers for technical efficiency in India.

The other most pertinent and recent studies that address merely the commercialization of smallholder farmers are including Gebre-Selassie & Sharp (2007), Pender & Alemu (2007), Gebremedhin & Dirk (2009); Berhanu & Moti (2010); Abafita, et al. (2016); Dessie & Raman (2017); Mirie & Zemedu (2018); Tadesa (2018). Except for Pender & Alemu (2007), Gebremedhin & Dirk (2009); Berhanu & Moti (2010); Hailu et al. (2015); Abafita, et al. (2016); Dessie & Raman (2017) the rest of them studied commercialization of smallholder *'teff'* producers in different locations. Pender & Alemu (2007) develop a theoretical farm household model of food crop production and marketing decisions, together with the determinants of these decisions using a nationally representative survey of a farm household in Ethiopia. They paid attention on production and marketing verdicts for *'teff'* and maize, two vital corps in Ethiopia. The study found out net buyers and autarkic households are poorer in many respects than net sellers. Added to this, the econometric analysis shows that increasing production of *'teff'* and maize is the most important factor contributing to increased sales, and increased smallholder access to roads, land, livestock, farm equipment, and traders are key to enabling increased smallholder production and commercialization of these crops. Studies by Berhanu & Moti (2010); Abafita, et al. (2016) identified a low level of smallholders' participation in the output market.

The study by Mirie & Zemedu (2018) used Heckman's two-stage econometric model to identify factors that affect market participation and intensity of market participation among *'teff'* producers in the Dera District of South Gondar Zone of Amhara region. They identified lagged price, family size, and credit access as factors that determine the decision to participate in *'teff'* marketing in the first stage of probit model estimation. On the other hand, on the second stage of the model estimation, amount of *'teff'* produced, family size, land size, livestock, and age were found statistically significant factors that determine the extent of *'teff'* marketed.

Similarly, Tadesa (2018) attempted to identify the determinants of *'teff'* commercialization in Abay Chomen Wereda, Horo Guduru Wallaga Zone of Oromia region. He used descriptive statistics and Hackman's two-stage econometric models to analyze cross-sectional data collected from *'teff'* growers. He found out the proportion of land allocated for *'teff'* production, oxen ownership and access to village town significantly and positively affect household *'teff'* market participation decision while family size and age of household head significantly and negatively affect household *'teff'* market participation decision. Whereas, landholding size, the proportion of land allocated for *'teff'* production, oxen and donkey ownership, and frequency of agricultural extension contact significantly and positively affect the level of *'teff'* commercialization; distance from market and livestock holding significantly and negatively determine the level of *'teff'* commercialization.

Different from other studies mentioned above, Gebre-Selassie & Sharp (2007), even though it is not a recent study, tried to address the level of *'teff'* commercialization, factors that affect smallholder *'teff'* market participation, and its welfare outcomes among smallholders against different output commercialization levels. They also attempted to identify the determinants of *'teff'* output using Cobb-Douglas (C-D) production function. They measured the degree of commercialization using the crop commercialization index in value terms. Their findings revealed that the level of commercialization in the study area is by far higher (farmers sold almost half /49.7%/ of their production in value terms) than the national average. However, the degree of commercialization differs across sampled households and the size of the market (per seller) was very thin because the volume of trade is constrained by low per capita production. Further, the study identified the total value of farm production and the proportion of land allocated to *'teff'* had a positive and significant effect on the household degree of market participation. Finally, the study confirmed that household commercialization appeared to be positively associated with a better standard of living including food consumption.

Some studies investigate the link between productivity and market participation (Strasberg, et al., 1999; Rios, et al., 2008; Bekele, et al., 2010). Strasberg, *et al.*, (1999) analyzed the effects of smallholder commercialization on food crop input use and productivity in rural Kenya using a two-equation econometric model. They found that a significant and positive effect of agricultural commercialization on food crop input use and productivity. Whereas Rios, *et al.*, (2008) analyzed the direction of causality between market participation and productivity using cross-country household data from Tanzania, Vietnam, and Guatemala. They applied a 2SLS method to predict the parameter of interest. Results indicate that households with higher productivity tend to participate in agricultural markets regardless of market access factors; whereas having better market access does not necessarily lead to higher productivity. The study by Bekele, *et al.* (2010) examined the trade-off between commercial orientation and crop productivity among smallholders in the central rift valley of the country. The study used a censored simultaneous model and found a unidirectional relationship between total factor productivity being influenced by endogenous commercial orientation factor.

Evidence from different countries also revealed that increased agricultural productivity reduces poverty in developing countries (Ahmad, 2003; Asogwa, et al., 2012; Mukami, et al., 2018; Islam & Haider, 2018). The studies showed an inverse relationship between poverty and technical efficiency estimates among the respondents, implying that as average productivity increases poverty decreases. Similarly, smallholders' commercialization is also associated with a reduced level of poverty in different counties (Mitiku, 2014; Muricho, et al., 2015; Wasseja, et al., 2016; Murichoa, et al., 2017; Bokaa, 2017; Abdullah, et al., 2019). Except for Mitiku (2014), all of the studies reviewed here showed agricultural commercialization significantly reduces poverty among commercialized when compared against non-commercialized households.

1.7. Conceptual framework of the study

A conceptual framework is a researcher's understanding of how the problem under study will best be explored (Grant & Osanloo, 2014). It shows the specific outline the study will have to take and the relationship between the different variables in the study. Commonly, a conceptual framework consists of concepts, important theories, and empirical findings, and a series of actions that the researcher applied to undertake the study. A conceptual framework of the present study is presented in Figure 1.1.

There are two important paths, among others, through which growth in agricultural productivity can be sustained, such as technological change and efficient use of available technologies. The efficiency of farm households, meaning the ability to produce feasible maximum output from available inputs, is determined by many factors, including the availability of production inputs and inefficiency factors. Therefore, addressing inefficiency gaps through optimum use of available technologies leads to surplus output, which in turn improves the annual income for the farm households. Moreover, a greater understanding of the determinants of production will enhance our understanding of the agricultural development process.

The effects of technical efficiency on poverty can be heterogeneous on account of a diversity of factors varied across farm households. Crop diversification is one of these factors, which may either deter or advance the possible effects of technical efficiency on poverty. In the literature, the concept of diversification conveys different meanings to different people at different levels (Joshi, et al., 2003). Crop diversification can be considered as the practice of growing more than one variety of crops in a given area in the form of rotations and or intercropping (Makate, et al., 2016). A diversified cropping system has many benefits for smallholders in developing countries. Just to mention a few of them include reducing crop production risks, increasing resilience, improving soil fertility, controlling for pests and diseases, suppressing weeds and volunteer crops, improving production stability, increasing yield per unit of area, nutrition diversity, and health, etc. (Lin, 2011; Makate, et al., 2016). Smallholder farmers minimize their exposure to risks, such as price and environmental shocks by growing many crops (Rapsomanikis, 2015). In addition to this, the same sources indicated that producing one or few crops may increase efficiency but smallholders diversify the crop they produce to spread risk over many crops. This shows that crop diversification is one of the livelihood strategies pursued by smallholders to maintain a sustainable and productive farming system and thus improve welfare.

Empirical evidence in Tanzania showed a positive association between crop diversification and that of crop productivity, crop income, food security, and nutrition (Makate, et al., 2016). Furthermore, the study by (Thapa, et al., 2017) in Nepal and (Birthal, et al., 2015) in India showed that diversification of crop production into high-value crops positively affects monthly per capita consumption expenditure and poverty outcomes. In this study, therefore, it is established that improving technical efficiency positively affects household multidimensional poverty and the effects are also hypothesized as heterogeneous by diversification of cropping system.

Promoting the commercialization of subsistence agriculture is important for achieving agricultural growth, poverty reduction, and economic growth in developing countries (von Braun & Kennedy, 1986; von Braun, 1995; Pingali, 1997). It is a part of the agricultural transformation process in which smallholders move from subsistence-oriented farming to increasingly market-oriented patterns of production and input use (Moti, et al., 2009), suggesting that agricultural development cannot be thought of without a market-oriented setting. In fact, given the heterogeneity of rural populations, there exist multiple pathways for using agriculture to help rural households move out of poverty, but with market-oriented smallholder farming appears to be the most effective one (de Janvry & Sadoulet, 2010).

Commercial oriented production system permits smallholders to attain rapid income growth, respond to lucrative opportunities, generate employments, and accumulate possessions (von Braun, 1995; Kirimi, et al., 2013; Poulton, 2017; Carletto, et al., 2017). Market-oriented farming households can leave the subsistence economy and become able to participate in the market and improve their well-being through increased income obtained out of selling agricultural produces on markets (de Janvry & Sadoulet, 2010). It leads to progressive substitution out of non-traded inputs in favor of purchased inputs (Pingali & Rosegrant, 1995) and attain the most efficient use of resources thereby improve productivity. Commercial reorientation of agricultural production occurs not only for high-value cash crops but also for the primary staple cereals (von Braun, 1995; Pingali, 1997), It also offers smallholders the possibility of diversification through producing non-staples (Pingali, et al., 2005), indicating the important role of food crop commercialization in alleviating poverty in rural areas.

Commercialization, through raising incomes, supports smallholders to acquire available technologies, such as improved seeds, chemical fertilizers, agro-chemicals, agronomic practices, and agricultural assets, etc. Doing so help leading towards more advanced production systems, which could be based on comparative advantages among smallholders (Abdullah, et al., 2019). Widespread adoption of the advanced production system, in turn, leads to increased land and labor productivity that generates more output and marketable surplus. Previous empirical studies, in developing countries, showed that integration into output markets significantly improved farm productivity (Tipraqsa & Schreinemachers, 2009; Bekele, et al., 2010). Increasing the productivity of farmworkers progressively causes an upward shift of the overall production function (von Braun, et al., 1994). The technological innovations in agricultural production once again facilitate the commercialization process (von Braun, et al., 1994), because the adoption of production technology fundamentally affects market participation by affecting productivity (Barrett, 2008). The agricultural productivity growth can then affect welfare and thus, poverty by lowering real food prices and increasing real wages (Minten & Barrett, 2008).

Moreover, the productivity of the farm sector contributes to generating higher incomes and stimulates linkage to the non-farm economy, consequently leads to economic growth and rapid poverty reduction (Hazell & Haggblade, 1993; Irz, et al., 2001; Timmer, et al., 2006). The higher income further allows investment in the non-farm sector and creates jobs and income in the other sectors (Irz, et al., 2001). The findings of the study by Mellor & Malik (2017) substantiated that poverty situations are doubtful to reduce without rapid productivity growth and increased spending of farm income from small commercial farmers on the rural non-farm sector, implying that commercialization of smallholder agriculture can improve the wellbeing of the whole rural populations by injecting farm income into the non-farm sector as well.

Commercialization may increase farm income that leads to greater demand for consumer goods and services (Hazell & Haggblade, 1993). Increased farm incomes allow for better nutrition, better health, and increased investment and education amongst the rural population, leading directly to improved welfare and indirectly to high labor productivity (Irz, et al., 2001). It may result in an income-induced transition of diets from grains to higher-valued foods, such as meat, fruit, and vegetables (Pingali, 1997). The evidence from Tanzania revealed that income improvement could lead to an increased demand for more diversified and nutritious diets (Abdulai & Aubert, 2004). Generating marketable surplus can also allow smallholders to create trust and social capital through increased interactions between farmers and other agents within the agricultural supply chain and related actors, and stimulate demand for infrastructure (Irz, et al., 2001). Moti, et al. (2009) also discussed the effect of commercialization on welfare and poverty by taking three orders. First, income and employment effects are directly reflected in household welfare. Second, health and nutrition aspects are usually contingent on the extent of income and attained through the prevailing level of commercialization. Finally, higher-order effects are the macro-economic and environmental effects that transcend beyond the household level. Overall, agricultural commercialization increases the availability of food production and income at the household level. On account of the income gain, farm households can accumulate assets and improve overall living standards. To this end, the crucial questions that this study aims to empirically address to understand the poverty reduction effect of commercialization include: how staple crop commercialization does affect multidimensional poverty and vulnerability to multidimensional poverty; and what are the possible transmission channels through which commercialization can reduce multidimensional poverty of farm households?

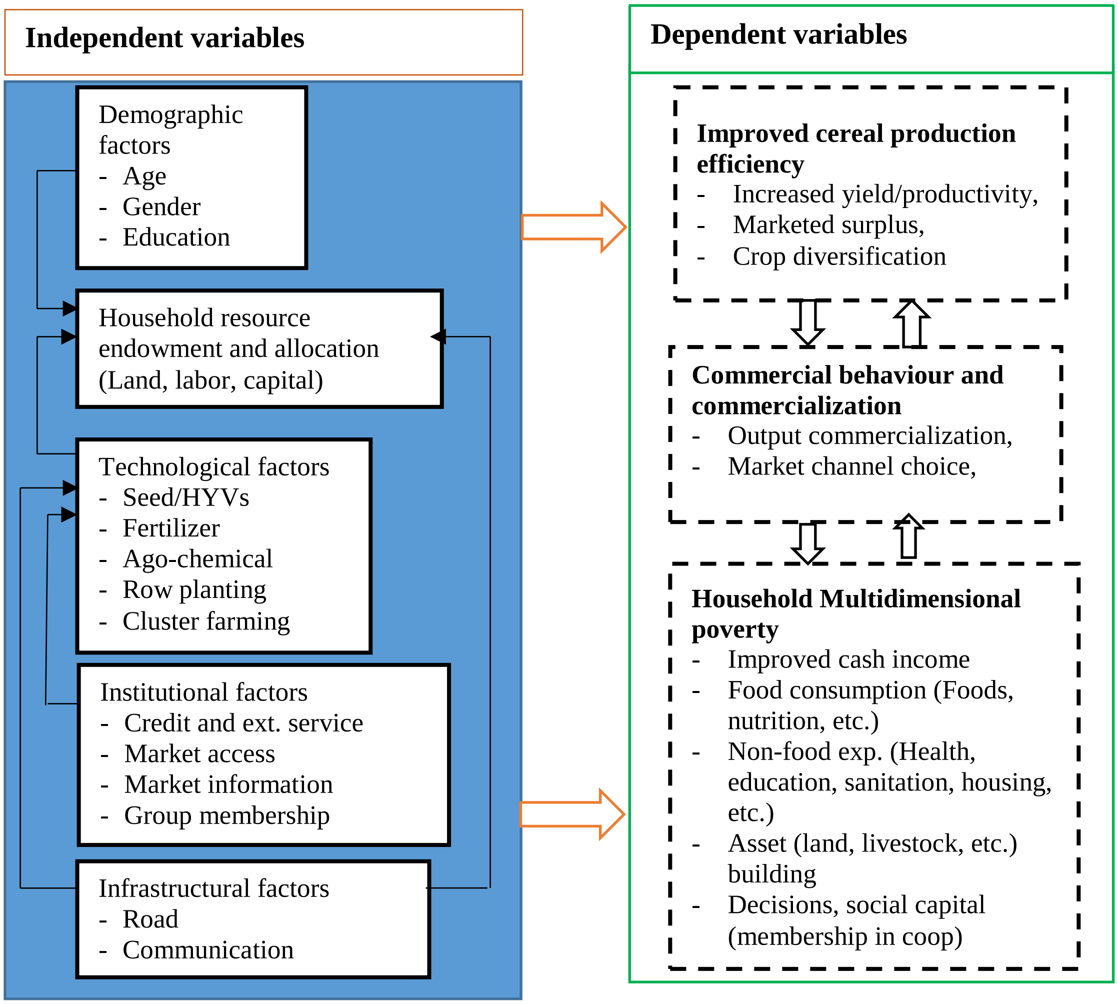

Figure 1.1: Conceptual framework of the study

Source: Authors' construction based on literature review and own understanding (2020)

1.8. Thesis Contributions

The contributions of the thesis are as indicated in Table 2 below.

Table 1.2: Research gap and contribution of the thesis by chapter

Chapter	Research gap	Contribution (Conceptual, Empirical, Methodological, Policy level)
Two	- Little emphasis in the use of technological variables accounting for the inefficiency of smallholders - Studies on the effects of cereal production practices, such as HYVs, seed rate, fertilizer rate, cluster farming, and row planting on technical efficiency is meager - Previous technical efficiency estimations giving less attention to geographical heterogeneity	- Effects of extension recommended cereal production practices on technical efficiency - Expand understanding on the application of the stochastic meta-frontier framework - Empirical evidence on technical efficiency estimates on cereal producing farm households - Significant variables and their implication for policy
Three	- All-inclusive study that systematically explores the input use (HYVs, UREA, NPS, agrochemical, and hired labor) effects the commercialization - Limited literature on bi-directional causality between market participation and technical efficiency using rigger and more efficient econometric model	- Commercialization effects on input use and cereal crop productivity - Demonstrates the application of the simultaneous CMP and dose-response function. - Understand the bi-directional causation between technical efficiency and commercialization - Application of CMP when one or more of the variables is binary - Expand understanding on the application 3SLS model - Significant variables and their implication for policy
Four	- Nexus between poverty and productivity were studied using yield, partial measure, as proxy to agricultural productivity - Poverty is measured in monetary terms and a multidimensional conception is stingy. - No prior knowledge of whether or not poverty reduction effects of technical efficiency is heterogeneous by crop diversification status - Lack of studies that apply an econometric model that takes the censored nature of technical efficiency and MPI	- Empirical evidence on multidimensional poverty using multidimensional poverty index - Expand understanding on the application of IV Tobit, and CMP analysis frameworks - Heterogeneous effects of technical efficiency on poverty by farm households' crop diversification status
Five	- Mixed estimate on the degree of cereal commercialization in major *'teff'*-growing areas - Absence of MPI and VMP estimate for major *'teff'* growing areas - Scant empirical research on the poverty reduction effects of cereal commercialization using multiple poverty indicators - Lack of evidence on the possible channels through	- Estimate CCI, MPI, and VMP for potential *'teff'*-producing areas. - Overall and dimensional effects of cereal commercialization on multidimensional deprivations - Channels through which commercialization of cereal farmers enhances MPI - Expand understanding on the application of IV

	which cereal commercialization affects the dimensions of multidimensional poverty - Lack of studies that apply an econometric model that takes the censored nature of commercialization and MPI	Tobit, CMP analysis frameworks - Significant variables and their implication for policy

1.9. Philosophy and Methodology of the Study

Context of the study area: Ethiopian regions are characterized by a wide range of agro-climatic conditions with diverse cultural and farming practices. The country is commonly characterized by three major agricultural systems, such as the highland mixed farming system, the low plateau and valley mixed agriculture and the pastoral livestock production of the arid and semi-arid zones (PGRC, 1996). The landscape defines certain agriculture production, potentials, access to input and output markets, and local population densities, which determine both labor availability and local demand for food (Chamberlin & Schmidt, 2012). Considering the importance of farming system for designing context sensitive policy and development interventions, the current study was conducted in major *'teff'* growing areas of the country. Major *'teff'* production area is one of the areas of the country characterized under a highland mixed farming system. The areas are known for their potential to grow major cereal such as *'teff'*, wheat, maize, sorghum, and barely, in that order.

This study was conducted in Oromia and Amhara regions, major *'teff'*-producing areas of Ethiopia. The regions collectively accounted for 81% of cereal cultivated land and 82% of total cereal production in the country (CSA, 2020). More specifically, 85% of *'teff'* cultivated land and 87% of total '*teff*' production belong to these regions. East Shewa Zone in the Oromia region and East Gojjam Zone in the Amhara region are particularly known as *'teff'*-based mixed farming areas in the country. East Shewa and East Gojjam zone are located at a distance of 100 km and 300 km from Addis Ababa, the capital of the country, to the southeast and northwest direction, respectively. East Shewa and East Gojjam zones receive an annual average rainfall ranging from 350 mm to 1150 mm and 900 to 1800 mm with uni-modal and bi-modal rainfall pattern, in that order (Senbeta, et al., 2020; Ferede, et al., 2020). The mean annual minimum and maximum temperature of the zones range from 12^{o}C and 39^{o}C and 7.5^{o}C and 27^{o}C, respectively. The altitude of East Shewa and East Gojjam zone ranges from 900 to 2300 and 800 to 4200 meters above sea level (m.a.s.l.), respectively. A mixed farming system dominated by the extensive type of management system is a feature of East Shewa and East Gojjam zone, where crop and livestock production is the main source of livelihood for the household. From these zones, two major *'teff'* producing *'Weredas'*, namely Adea and Enemay *Weredas*[6] was purposively selected for the study.

Adea *Wereda* is one of the 12 *Weredas* in the East Shewa Zone of Oromia Regional State. The *Wereda* administrative town is Bishoftu which is located 45 km away east of Addis Ababa. Whereas, Enemay *Wereda* is found in the East Gojjam Zone of the Amhara region at 265 km in the Northwest of Addis Ababa. Altitudes in Ada'a and Enemay *Wereda* range between 1500 to over 2000 meters and 1600 and 3200 m.a.s.l., respectively. The mean annual minimum and maximum temperature in Adea *Wereda* vary from 7.9^{o}C to 28^{o}C, respectively. Whilst the mean annual temperature of the Enemay *Wereda* is 21^{o}C. The mean annual rainfall is recoded as 839 mm for Adea *Wereda* and 1150 mm for Enemay *Wereda*. Black clay soil, light sandy soil, stony soil, and a mixture of black and red-light soil locally known as 'Koticha', 'Gombore, 'Abolse', and 'Cheri', in that order, are the dominant type of soil of the Adea *Wereda*. Whereas, black soil, red soil, and a mixture of black and red-light soil predominantly characterized the soil type of Enemay *Wereda*. '*Teff*', wheat, barley, maize, sorghum, and chickpea are the major crops grown in this *Wereda*s. Figure 1.2 below shows the map of the study areas in Oromia and Amhara regions.

[6] *'Wereda'* is an administration unit equivalent to district, whilst 'Kebele' is the lowest administration region in Ethiopia.

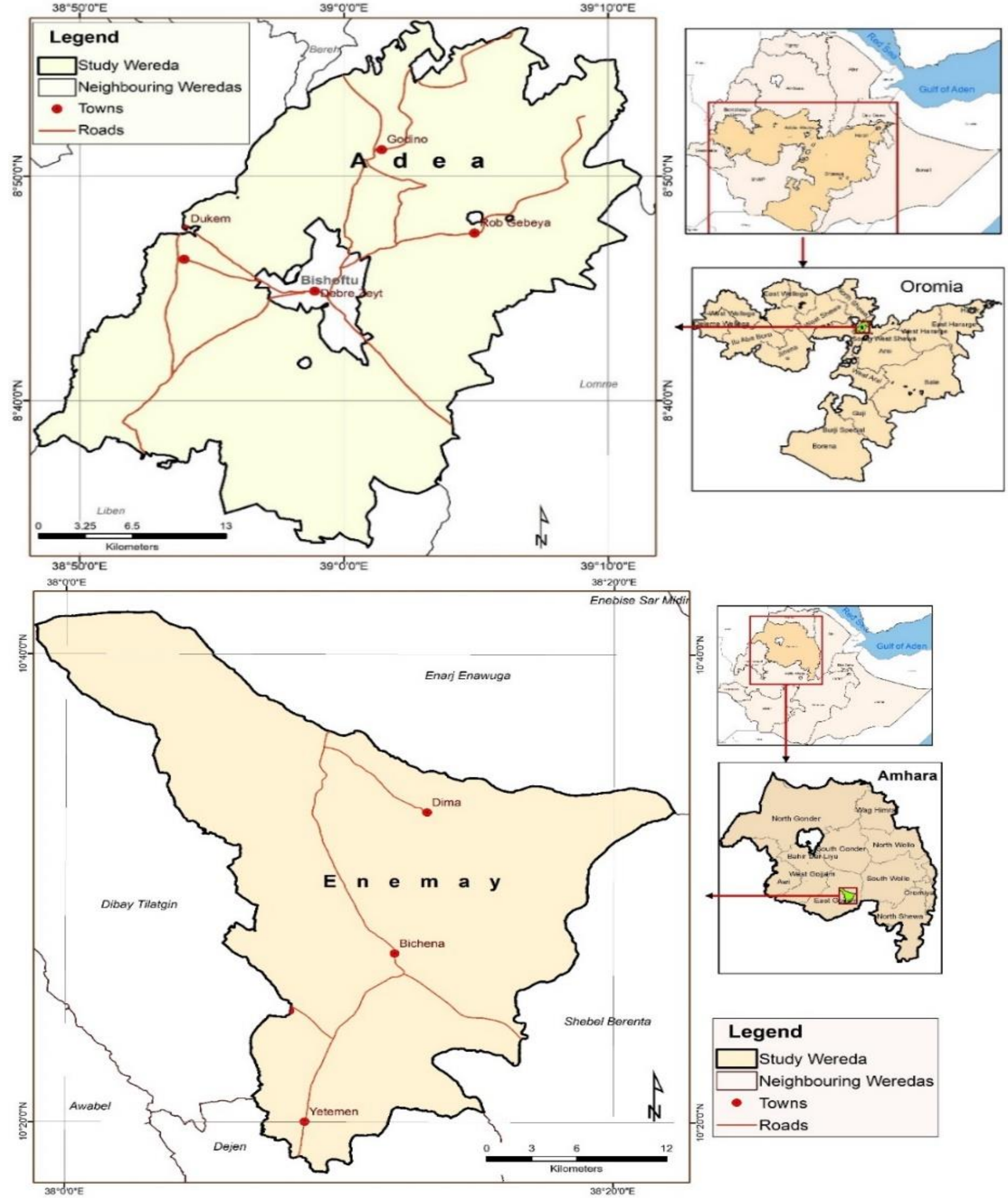

Figure 1.2: Map of the study areas.

Source: Ethio GIS and CSA (2007)

Philosophical worldview: the pragmatic research paradigm was adopted as a research philosophy of this study. The paradigm allows using meta-methodology and maximizes the rewards of using a combination of methodologies (Jackson, 2000, cited in Ormerod, 2006).

Research design: Concurrent embedded design, one of the major mixed method research designs, was selected following Creswell (2009) to be the research design of this study. In this design, both quantitative and qualitative data were collected at one data collection phase, in which qualitative methods were embedded within the quantitative design.

Population and sampling procedure: The target populations of the study are smallholder farming households, those institutions and actors who played key roles in cereal value chain and innovation system. Multistage stratified sampling procedure was applied to select the final sample of rural farm households for the study. In the first stage, major '*teff*' growing regions namely Oromia and Amhara regions were purposively selected given the growing importance of the crop worldwide. In the second stage, from Oromia and Amhara regions, major *'teff'* growing areas/Zones (East Shewa Zone of the Oromia region and East Gojam Zone of the Amhara region) are purposively selected for the study. In the third stage, Adea wereda and Enemay wereda were purposively selected from East Shewa and East Gojam, respectively, given the high potential and typical nature for '*teff*' production in the country. Both weredas are characterized by a mixed farming system where '*teff*', wheat, barley, maize, sorghum, and pulses, in that order, are the primary crops and sources of livelihood for farm households who live in the study areas. In fourth stage, given available time, resources, the prevailing similar production system, a total of six kebeles, three kebeles by wereda, were randomly selected from the total rural kebeles[7] of the study weredas, which is stratified based on their crop production potential as high potential and low potential. Hence, the study is considered four potentials and two non-potential rural kebeles following probability proportion to size (PPS) sampling techniques. The study employed sample size formula developed by Kothari (2004) as spesified below.

$$n = \frac{Z^2 pqN}{e^2(N-1) + Z^2 pq}$$

[7] Kebeles in the respective study weredas were stratified into high potential and low potential strata in consultation with experts assigned by wereda level agricultural offices.

where, n denotes the desired sample size, Z represents the standard cumulative distribution that corresponds to the level of confidence with the value of 1.96; e is the required degree of precision; p is the estimated proportion of an attribute that exist in the population with a value of 0.5 to get the desired minimum sample size of the household at 95% confidence level and ± 5% precision; q=1-p; and N is the size of the total population from which the sample is drawn.

Therefore, based on the formula developed by Kothari (2004), the sample size of 356 farm households was determined for the study. To account for the possible missing response values, the researcher assumed 10% contingency from the total sample to achieve the required accuracy (Naing, et al., 2006). Accordingly, a total sample of 392 farm households including 10% contingency were the sample size of the study. Out of 392, we excluded 14 observations due to missing information. Besides, the study was used key informant interview and FGD to complement the result of the quantitative study. Farm household is the unit of analysis and the cereal production process is the main focus area of this study. Cereal crops considered in this study were '*teff*', wheat, barley and maize, sorghum. Table 1.2 summarizes the distribution of the total sample size of the study by sample rural *'Kebeles'*.

Table 1.3: Distribution of sample size for the selected *'Kebeles'*.

S/N	Region	Zone	Woreda	Kebele	Total Household	Sample Proportion (%)	Sample size
1	Oromia	East Shewa	Adea	Denkaka**	937	17.9	70
				Gobosay*	797	8.9	35
				Wajitu**	649	12.2	48
2	Amhara	East Gojjam	Enemaye	Endshignet**	935	17.9	70
				Mankorkoria**	812	15.6	61
				Sekela*	814	27.6	108
Total				***6***	***4944***	***100***	***392***

Note that **, * refers to high and low potential categories for cereal production, respectively

Data sources and collection methods

Quantitative data: Primary data used in this study was collected from sample farm households in the year 2019/20 using a structured questionnaire administered by a cross-sectional survey in mixed farming areas of Ethiopia. Prior to administering the questionnaire, a pre-test was undertaken to check the cogency and clarity of the questionnaire.

Qualitative data: The study also used semi-structured checklists applied using 30 key informant interviews (KIIs) and two focus group discussions (FGDs). The collection of the data offered substantial emphasis for the various aspects of cereal production, technology, and institutional support services, biotic and abiotic stresses, climate change, and overall challenges of cereal production. Perceptions and reflections of farm households, development agents, agricultural experts, and researchers at different levels were taken into account for the study.

Secondary data: Secondary data were also gathered from zonal and *Wereda* level agricultural offices, Central Statistics Authority (CSA) cereal production and productivity data, CSA poverty interim report, other policy documents, and specific studies carried out in Ethiopia to address the objectives of the study.

Data reliability, validity and ethical consideration: From the conception to different stages of data analysis of the study, researchers used a variety of methods to verify data reliability and validity. These methods were preparing questions in a simple, clear and logical way, selecting cross-checked questions, pilot pre-testing, providing training for data enumerators, clarifying queries if any during the data collection, reviewing filled questionnaires on a daily basis and take correction measures, and assigning supervisors, using different data collection tools administered for different sources, etc. Moreover, the study paid utmost emphasis to ethical considerations, such as informed consent, anonymity, and confidentiality throughout the collection of both quantitative and qualitative data.

Analytical approaches: In addition to descriptive statistics, this study used a variety of econometric models, as shown in the Table 1.3 below. Before running the model, proper diagnostic post estimation tests, such as normality, multicollinearity, and homoscedasticity tests were assessed by applying Jarque–Bera (JB) test, Variance Inflation Factor and Pairwise ranking, and Breusch-Pagan / Cook-Weisberg test, respectively.

Table 1.4: Summary of analytical approach

Chapter	Econometric model	Specification	References	Justification
Two	Utility model	$U_i = X_i'\gamma + u_i \ with \ U_i = \begin{cases} 1 \ if \ U_i^* > 0 \\ 0 \ otherwise \end{cases}$	Asfaw, et. al. (2012)	- Adoption depends on the utility gained from the technology
	Stochastic meta-frontier framework	$f^k(x_i^k, \beta^k) = f^M(x_i^k, \beta)\ e^{(v_i^M - u_i^M)}$ $TE_i^k = \frac{f^k(x_i^k, \beta^k) e^{(-u_i^k)}}{f^k(x_i^k, \beta^k)} = e^{-u_i^k}$	Huang, et al. (2014).	- Differences between the sample study districts in terms of production technology
	Tobit model	$y_i^* = \beta_0 + \beta_1 Z_1 + \beta_1 Z_1 + \cdots + \beta_i Z_i + e_i, \quad (i = 1,2, \dots, n)$ $y_i = \begin{cases} 1 \ if \ y_i^* > 1 \\ y_i^* if \ 0 < y_i^* < 1 \\ 0 \ if \ y_i^* < 0 \end{cases}$	Tobin (1958)	- Handle the characteristics of the distribution of efficiency measures - Estimating by regression may make the predication to fail outside the interval
Three	Commercialization Index (CCI)	$CCI_{ij} = \frac{\sum_{k=1}^{K} S_{ik}\bar{P}_k}{\sum_{k=1}^{K} Q_{ik}\bar{P}_k} = \begin{cases} = non - seller \\ > 0 \ seller \end{cases}$	von Braun & Kennedy (1994)	- Permits to go beyond the traditional dichotomies of sellers versus non-sellers
	Simultaneous equation model and estimated using Conditional Mixed Process (CMP) approach	$Y_i^* = X_1'\beta_1 + \varepsilon_{1i},$ $S_i^* = X_2'\beta_2 + \varepsilon_{2i},$ $U_i^* = X_3'\beta_3 + \varepsilon_{3i},$ $N_i^* = X_4'\beta_4 + \varepsilon_{4i},$ $C_i^* = X_5'\beta_5 + \varepsilon_{5i},$ $L_i^* = X_6'\beta_6 + \varepsilon_{6i},$	Roodman, (2011); Wooldridge (2012)	- Account for the simultaneity, interdependency, and nature of the exogenous variables - Applied to estimate several interdependent binary and continuous outcomes simultaneously
	Dose-response function with the Generalized Propensity Score (GPS)	$r(t, x) = f_{T\|X}(t\|x)$ R=r(T,X) $T_i\|X_i \sim N(\beta_0 + \beta_1' X_i, \sigma^2$ $\hat{R}_i = \frac{1}{\sqrt{2\pi\{\sigma^2}} \exp\left(-\frac{1}{2\hat{\sigma}^2}\left(T_i - \hat{\beta}_0 - \hat{\beta}_1' X_i\right)^2\right)$ $\beta(t, r) = E(Y\|T = t, R = r)$ $E[Y_i\|T_i, R_i] = \alpha_0 + \alpha_1 T_i + \alpha_2 T_i^2 + \alpha_3 R_i + \alpha_4 R_i^2 + \alpha_5 T_i R_i$ $\mu(t) = E[\beta\{t, r(t, X)\}]$	Hirano & Imbens, (2004); Jochen, et al., (2012); Imbens, (2000)	- Observe the dynamic effects of the treatment on outcome variables at different doses/treatment levels.

		$E(Y\|t) = \frac{1}{N}\sum_{i=1}^{N} \hat{\alpha}_0 + \hat{\alpha}_1 t + \hat{\alpha}_2 t^2 + \hat{\alpha}_3 \hat{r}(t, X_i) + \hat{\alpha}_4 \hat{r}^2(t, X_i) + \hat{\alpha}_5 t\hat{r}(t, X_i)$		
	Three-stage simultaneous model (3SLS)	$y_1 = \gamma_1 y_2 + \beta_{11}x_1 + \beta_{12}x_2 + \cdots + \beta_{1i}X_i + \varepsilon_1$ $y_2 = \gamma_2 y_1 + \beta_{21}x_1 + \beta_{22}x_2 + \cdots + \beta_{2i}X_i + \varepsilon_1$	Zellner & Theil (1962); Greene (2012); Wooldridge, (2012); Gujarati (2004)	- Capture bi-directional causality if exists.
	Tobit model and Fractional logit model	$y_i^* = \beta_0 + \beta_1 x_1 + \beta_1 x_1 + \ldots + \beta_i x_i + e = x\beta + e$ $y_i = \begin{cases} 1 \ if \ y_i^* > 1 \\ y_i^* if \ 0 < y_i^* < 1 \\ 0 \ if \ y_i^* < 0 \end{cases}$	Tobin (1958); Dorta (2016); Papke and Wooldridge, 1996); Papke and Wooldridge, (2008)	- Handle the characteristics of the distribution of CCI - Estimating by regression may make the predication to fail outside the interval - Statistical validity and correct non-linear relationship if any due to repeated zeros/one
Four	Multidimensional household poverty	$p(y_i z) = \begin{cases} 1 \ multidimensional \ poor \ (c_i \geq k), \\ 0 \ \ otherwise \ (c_i < k), \end{cases}$ $H = q/n$ $A = \sum_{i=1}^{n} c_i(k)/q$ $M_0 = \mathrm{HxA}$	Alkire & Foster (2011); Alkire & Santos (2014); UN (2016)	- Expediency, obvious normative presumption, data availability and empirical literature
	Crop diversification Herfindahl Index (HI)	$\mathrm{CDI} = \sum_{\mathrm{i-1}}^{\mathrm{i-n}} \mathrm{S_i^2}$ $\mathrm{S_i} = \frac{a_i}{\mathrm{A}}$	Rahman, 2009	- Accounts for available land at the household level
	Instrumental variable Tobit framework	$y_{1i}^* = y_{2i}\beta + x_{1i}\gamma + u_i$ $y_{2i} = x_{1i}\prod_1 + x_{2i}\prod_2 + v_i$--- (15)	Wooldridge (2012);	- Values of the outcome variables and endogenous covariate are censored at 0 and 1 - Circumvent the endogeneity

		$y_{1i} = \begin{cases} 1 & if\ \ y_i^* > 1 \\ y_{1i}^* & if\ \ 0 \le y_i^* \le 1 \\ 0 & if\ \ y_i^* < 0 \end{cases}$		
Five	Multidimensional household poverty	$p(y_i z) = \begin{cases} 1\ multidimensional\ poor\ (c_i \ge k), \\ 0\ \ otherwise\ (c_i < k), \end{cases}$ $H = q/n$ $A = \sum_{i=1}^{n} c_i(k)\ /q$ $M_0 = \text{HxA}$	Alkire & Foster (2011); Alkire & Santos (2014); UN (2016)	- Expediency, obvious normative presumption, data availability and empirical literature
	Vulnerability to multidimensional poverty	$d_i = X_i\beta + e_i$ $\delta_{OLS,i}^2 = X_i\theta + u_i$ $\frac{\delta_{OLS,i}^2}{X_i\hat{\theta}_{OLS}} = \left(\frac{X_i}{X_i\hat{\theta}_{OLS}}\right)\theta + \frac{u_i}{X_i\hat{\theta}_{OLS}}$ $\hat{\sigma}_i = \sqrt{X_i\hat{\theta}_{FGLS}}$ $\frac{d_i}{\hat{\sigma}_i} = \left(\frac{X_i}{\hat{\sigma}_i}\right)\beta + \frac{e_i}{\hat{\sigma}_i}$ $V_{i,t} = P_r\left(d_{i,\ t+1} > Z \mid X_i\right) = \phi\left(\frac{X_i\hat{\beta}_{FGLS} - Z}{\hat{\sigma}_{i,t+1}}\right)$	Chaudhuri, et al. (2002)	- Cross-sectional study, hence, this study applied the Vulnerability to Expected Poverty (VEP)
	Instrumental variable Tobit framework	$y_{1i}^* = y_{2i}\beta + x_{1i}\gamma + u_i$ $y_{2i} = x_{1i}\prod_1 + x_{2i}\prod_2 + v_i$--- (15) $y_{1i} = \begin{cases} 1 & if\ \ y_i^* > 1 \\ y_{1i}^* & if\ \ 0 \le y_i^* \le 1 \\ 0 & if\ \ y_i^* < 0 \end{cases}$	Wooldridge (2012);	- Values of the outcome variables and endogenous covariate are censored at 0 and 1 - Circumvent the endogeneity
	Seemingly Unrelated Regressions (SUR) model estimated by using CMP	$E_i = X_1\beta_1 + C_i\gamma_{1i} + e_{1i}$ $H_i = X_2\beta_2 + C_i\gamma_{2i} + e_{2i}$ $L_i = X_3\beta_3 + C_i\gamma_{3i} + e_{3i}$ $W_i = X_4\beta_4 + C_i\gamma_{4i} + e_{4i}$ $M_i = X_5\beta_5 + C_i\gamma_{5i} + e_{5i}$	Zellner (1962); Roodman, 2011	- SUR estimator of the individual equations predicts the classical regressions with a continuous dependent variable. - CMP: flexibility in estimating the parameters of interest while keeping the nature of the dependent variables

1.10. Thesis Organization

The dissertation is organized in six chapters. The first chapter is about the general introduction, which consists of background, problem statement, objective, theoretical and empirical literature review, conceptual framework, and finally briefly presents the philosophical and methodological orientation employed in the study. The second chapter analyses the adoption of crop varieties and production methods and their independent effects on technical efficiency of cereal farmers. The third chapter focuses on commercialization of cereal producing farm households and the level of association with utilization of production inputs, efficiency, and productivity. The result of multidimensional poverty reduction effects of technical efficiency and commercialization of smallholder cereal farmers are presented in the fourth and fifth chapter. Finally, chapter six summarizes the key findings and conclusion, and draws important policy implications from the results of the study.

CHAPTER TWO: CEREAL PRODUCTION PRACTICES AND TECHNICAL EFFICIENCY AMONG FARM HOUSEHOLDS IN MAJOR '*Teff*' GROWING AREAS OF ETHIOPIA: A STOCHASTIC META-FRONTIER APPROACH

ABSTRACT: *In Ethiopia, cereal productivity remains very low relative to its potential yields. To this end, the use of high yielding varieties (HYVs) along with the packages of production practices has been recommended as a means to improve the productivity over the past years. This study, therefore, examined the effects of HYVs and cereal production practices on the technical efficiency of farm households based on household-level data generated from questionnaire surveys, focus group discussions, and key informant interviews. The technical efficiency scores were estimated using the stochastic meta-frontier approach because it allows addressing the expected differences in production technologies. Tobit regression framework was applied to identify factors related to farm inefficiency. Results showed mean technical efficiency of 58%, implying that the farm households can improve cereal output by about 36% with the current level of input mix and technologies. The T-test results revealed farm households who adopted high-yielding varieties with research-based recommended production practices were technically more efficient than their counterpart. Our econometric model results also indicated that the use of high-yielding varieties and research-based recommended seed rate affects the technical efficiency of farm households positively and significantly. In addition, we find gender, age, mobile telephone ownership, cooperative membership, access to input market, and crop damage as significant factors affecting the efficiency of farm households. Our findings highlight the importance of addressing technology adoption gaps and gender-based disparities, expanding access to information and modern inputs, strengthening social capital, and adopting climate change adaptation practices to improve the efficiency of farm households.*

Keywords: Research recommended production practices, Technical Efficiency, Meta-frontier, Cereal production, Ethiopia

2.1. INTRODUCTION

Cereal crops are important sources of income for a majority of Ethiopia's population. Mainly, the major cereals such as *'teff'*, wheat, maize, barely, and sorghum are the core of the country's agriculture and food economy and dominate the Ethiopian smallholder agriculture (Seyoum, et al., 2011; Chamberlin & Schmidt, 2012). Cereals contributed 87.97% of the grain production, from which maize, *'teff'*, wheat, and sorghum made up 30.08%, 17.12%, 15.33%, and 15.92% of the grain production, in the same order (CSA, 2019). On the side of consumption, it is estimated that an average person in Ethiopia consumes about 150 kilos of cereals per annum, with slightly higher in rural areas (152 kg) as compared to urban ones (137 kg) (Minten, et al., 2012).

Cereal crop development and intensification have been at the center of the Ethiopian agricultural development policies and investments over the past two decades. Cereal intensification with high priority was headed when Participatory Demonstration and Training Extension System (PADETES) was started in 1994/95 to pilot technological package driven extension approach (Byerlee, et al., 2007; Yu, et al., 2011). The approach was implemented in moisture-reliant highland parts of the country by focusing on specific crops (*'teff'*, wheat, and maize) to scale up the approach and raise productivity in the country. Since then, new packages have been developed to support other crop and livestock enterprises (Spielman, et al., 2012). The core aim of most of the interventions was to sustainably improve cereal productivity through increased availability of improved seed, chemical fertilizer, better management practices (MoFED, 2003; NPC, 2016).

In addition to this, the government has been pursuing holistic measures as part of the country's intensification efforts to address constraints and challenges related to the supply and use of agricultural inputs. As a result of which, the share of farm households using agricultural inputs in the sector has increased over the last decades. For example, the share of cereal producers using improved seed has increased from 10% in 2004/05 to 21% in 2013/14; while chemical fertilizer imports have increased by 124% and fertilizer use by smallholders increased by 144 percent between 2004/05 and 2013/14 (World Bank, 2016). However, during the GTP I period the performance of improved input supply still falls short of the target set. The amount of fertilizer supplied in 2014/15 was a record 1.201 million quintals, but this was only 72.2% of the target set for the year. The supply of improved seeds was only 1.514 million quintals, which accounted for about 42% of the target set for 2014/15 (NPC, 2016). Moreover, since recently the Government has been promoting cluster-based crop production approaches as a way to encourage smallholder farmers to adopt new crop varieties along with its full improved management practices. The approach has been increasingly practiced in major crop-growing areas of the country. It is a method by which farmers merge their small and fragmented plots of farms into a big mother farm to produce the same type of crop and variety.

Because of the efforts, cereal production has grown significantly in the country, rising from 61.5 million quintals in 1994/95 to 296.7 million quintals in 2019/20 with an average annual growth rate of 6.6% (CSA 1994/95-2019/20). The growth in cereals production increased more rapidly by 7.2% particularly since 2004/05 than the previous years with an average growth rate of 3.97%, while the cultivated area under cereal increased only by 2.5% with a declining rate. This is perhaps a reflection of heavy policy emphasis on cereals (Rashid, 2010). Despite the significant shift in the volume of crop production, cereal productivity remains very low relative to its potential yields. Many factors contribute to the low levels of productivity in the country, among others, including limited access, utilization, and inefficiency in the use of production inputs (Yu, et al., 2011; Urgessa, 2015).

Besides, the domestic price for cereals is also growing from time to time due to the rapid increase in domestic demand, rapid population growth, income, and urbanization. The projected population of Ethiopia in 2015 that was 90.0 is expected to be 171.8 million in 2050 (UN, 2015; CSA, 2016; UN, 2019) with 2.6 percent of an annual growth rate. This shows that the population of the country is expected to increase by 81.8 million over 35 years. On the other hand, the country’s import of cereals (wheat, rice, and barley), edible oil, and lint cotton, continues to rise dramatically, now costing over a billion dollars every year (Diriba, 2020). The situation reminds raising the productivity and efficiency of smallholders is one of the essential aspects of agricultural policy interventions to address food supply gaps in the country.

Satisfying increased demand for food and agricultural products for developing countries like Ethiopia, requires technological packages, the more efficient use of production technologies, and a combination of both, among others (Dhungana, et al., 2004; World Bank , 2007; IFAD, 2013). The adoption of technological packages ranges from improved high-value varieties, farming equipment, natural resource management practices, to conservation agriculture practices (Ogundari & Bolarinwa, 2018). Whereas, production efficiency is a way to ensure that products are produced in the best and most profitable manner (Mardani & Salarpour, 2015). It is also related to how well a firm allocates scarce resources to meet production goals (Mardani & Salarpour, 2015; Wu, 2008) and produces maximum feasible output at a minimum average cost (Coelli, et al., 2005). Productivity gains through improved technology and efficiency are the main sources of growth in agriculture and the primary means to satisfy increased demand for food and agricultural products for developing countries like Ethiopia (World Bank, 2007). Empirical evidence also suggests that growth in agricultural productivity through intensification, adoption of improved technologies, and more efficient use of inputs become successful in Asia (Pingali & Heisey, 1999). This shows that the adoption of technological packages and improving production efficiency are two key strategies followed to increase the production and productivity of smallholder farmers. Therefore, technology adoption and efficiency analysis are crucial to generate evidence that guides intensification strategy.

Several empirical studies assess the technical efficiency of smallholders in Ethiopia using different methodologies. For example, studies (Alemu, et al., 2009; Nisrane, et al., 2015; Tiruneh & Geta, 2016) estimated the production efficiency of smallholders and identified factors contributing to the inefficiency of crop production in a different part of Ethiopia. Most of the previous studies, however, have given little emphasis in the use of technological variables that suggest HYVs along with packages of improved production methods. . Other studies, such as Ahmed, et al. (2017); Geffersa, et al. (2019), among others, are good examples of studies that examined the effect of maize variety adoption on-farm production. The studies found that the use of improved maize varieties has a positive and significant effect on-farm productivity. On top of high-yielding crop varieties, a range of location-specific recommended improved practices[8] has been also promoted to improve farm households’ productivity in the country.

[8] Research based recommended practices are mainly planting density/seed rate, fertilizer rate, cluster farming and row planting

To this end, the literature stated that the adoption of modern inputs should be blended with best management practices to increase the level of performance (Diao & Pratt, 2007). The use of modern inputs together with its recommended rate provides an opportunity for increasing resource use efficiency, attaining sustainability, and increase in agricultural food production (Leeuw & Vaessen, 2009). It is, therefore, assessing the use of both high-yielding varieties along with their recommended practices and their effect on production efficiency is crucial for providing intuitive policy options on how to improve smallholder agriculture in the country. Besides, earlier efficiency studies mentioned above assumed homogeneous production technology across locations while estimating the technical efficiency of farm households. However, overlooking differences among farm households in terms of geographical location, resources and knowledge may lead to predicting biased efficiency scores for the farm households (Orea & Kumbhakar, 2004; Chen, et al., 2016). Hence, unlike the previous studies in Ethiopia, this study used a meta-frontier framework because production technologies are expected to differ by location. In consideration of the above-mentioned research gaps, this study contributes to the empirical literature by analyzing the adoption of research-based recommended production practices and their effects on the level of farm households' technical efficiency.

The rest of the article is organized into three sections. The second section presents methodological frameworks and definitions of variables. Section three presents descriptive statistics and a discussion of empirical results. Finally, the study's main conclusions and policy implications are presented in the last section.

2.2. METHODOLOGY

2.2.1. Analytical approaches

Adoption of improved cereal production practices: The study considered packages of production technologies, such as the adoption of high yielding cereal crop varieties, recommended level of seed rate, and fertilizer rate, cluster farming and row planting. Farm household decision on the adoption of these technologies, which can be denoted as U_i^*, is depends on the difference between utility from adopting the technologies (U_{iA}) and the utility from not adopting the technologies (U_{iN}). This means that if the utility gained from adopting the technologies exceeds the utility from not adopting the technologies, $(U_i^* = U_{iA} - U_{iN} > 0)$. Following Asfaw, et. al. (2012), the adoption of the technologies can be specified as a function of observable variables in a random utility framework as follow:

$$U_i = X_i'\gamma + u_i \ with \ U_i = \begin{cases} 1 \ if \ U_i^* > 0 \\ 0 \ otherwise \end{cases} \quad \text{--- (2.1)}$$

where, U_i is a binary variable that takes 1 if a farm household adopts the technologies and 0 otherwise, in our case a binary variable that takes 1 if the farmers adopts high yielding cereal variety, or applied the recommended rate of seed, or fertilizer, row planting, or participate in cluster farming, considered for independently for each technology. $X_i'\gamma$ represents an estimate of the difference in utility from adopting the technologies $(U_{iA} - U_{iN})$ given household and farm level characteristics denoted by and explanatory variable X_i'. The term γ is the vector of parameters and u_i is the error term. The present study described and compares the adoption of the improved production techniques among smallholders using descriptive and inferential statistics.

Estimation of technical efficiency: In this study, SFA was chosen overDEA the fact that DEA does not take statistical errors in to account (Kalirajan & Shand, 1999), therefore less convenient for agricultural-related studies in developing countries (Coelli, 1995). Considering this, the farm households' efficiency score was estimated using a two-step estimation of stochastic meta-frontier framework following Huang, et al. (2014). Many studies (Ng'ombe, 2017; Alem, et al., 2018) employed this approach to estimate, and compare the efficiency scores for smallholders. The approach is used to account for the prevailing differences between the sample study districts in terms of production technology, study-specific characteristics, and agro-ecologic conditions. Such method of addressing variation across study districts is supported by literature (Orea & Kumbhakar, 2004), because estimating the conventional stochastic frontier in the presence of unobserved heterogeneity in technologies leads to biased TE scores

In this study, accordingly, three SFPs are estimated, two for *Wereda* level frontiers (Adea and Enemay *Weredas*) and one frontier based on the pooled sample following a two-step approach. In the first step, group-specific frontiers were estimated for Adea and Enemay *Wereda* and in the second step, a meta-frontier production function was estimated for pooled data. A stochastic group-specific production frontier is formulated as:

$$y_i^k = f^k\left(x_i^k; \beta^k\right) e^{\left(v_i^k - u_i^k\right)}, \quad i = 1, \ldots, n(k) \quad \text{--- (2.2)}$$

where, y_i^k represents the value of total cereal crops (*'teff'*, wheat, barely, maize and sorghum) of the *i-th* sample farm household in the k^{th} *Wereda*, x_i^k is a kx1 vector of direct inputs of the *i-th* farm household, β^k a vector of unknown parameters to be estimated. v_i^k denotes the random variation in output (y_i^k) due to factors outside the control of the firm (measurement errors and other noises), and u_i^k is a non-negative technical inefficiency component of the error term that captures factors under the control of the farm. v_i^k is assumed to be independently and identically distributed as $\mathrm{N}\left(0, \sigma_v^{k2}\right)$ and is independent of u_i^k. Whereas, u_i^k is assumed to follow truncated normal distribution at zero, *i.i.d.* $(u_i^k \sim N^+(\mu^k\left(Z_i^k\right), \sigma^{k2}))$, where Z_i^k denotes farm-specific or group-specific variables that may influence on-farm efficiency performance.

The estimation of the parameters in Eq. (1.1) and the farm household's technical efficiency can be obtained using the maximum likelihood estimation method. The TE of the i^{th} farm household relative to the group k^{th} frontier can be computed as:

$$TE^k = \frac{y_i^k}{f^k(x_i^k, \beta^k) e^{\left(v_i^k\right)}} = e^{-u_i^k} \quad \text{--- (2.3)}$$

In Eq. (1.2) the inefficiency component (u_i^k) of the error term is the log difference between the maximum (Y_i^k) and actual output (y_i^k) hence, $u_i^k \times 100\%$ is the percentage by which actual output can be increased using the same inputs if the production is fully efficient (Kumbhakar & Wang, 2015). This implies that $u_i^k \times 100\%$ gives the percentage of the output that is lost due to technical inefficiency. If the value of u_i^k close to zero, it shows full efficiency of the farm household.

Following Huang, et al. (2014), the stochastic meta-frontier that envelops all frontiers k^{th}groups is defined as:

$$f^k\left(x_i^k, \beta^k\right) = f^M(x_i^k, \beta)\, e^{\left(v_i^M - u_i^M\right)} \quad \text{---}\ (2.4)$$

where, $u_i^M \geq 0$, which implies that $f^M(.) \geq f^k(.)$ and the ratio of k^{th} group's production frontier to the meta-frontier can be defined as the technology gap ratio (TGR) expressed as:

$$TGR_i^k = \frac{f^k\left(x_i^k \beta^k\right)}{f^M(x_i^k \beta)} = e^{-u_{ki}^M} \leq 1 \qquad \text{---}\ (2.5)$$

Technology gap ratio (TGR) of the farm household equal to one is interpreted as the farm household adopted the most advanced technology to produce cereal outputs. The technology gap component u_{ki}^M in Eq. (2.5) is thus group, firm, and time-specific and depends on the accessibility and extent of adoption of the available meta-frontier production technology (Huang, et al., 2014). As it is stated in Huang, et al. (2014), at a given input level x_i^k, the farm household's observed output $y_i^k$of the i^{th} farm household relative to the meta-frontier consists of three components, that is:

$$\frac{y_i^k}{f^M(x_i^k)} = TGR_i^k \times TE_i^k \times e^{v_i^k} \quad \text{-----}\ (2.6)$$

where,

$TGR_i^k = \frac{f^k(x_i^k, \beta^k)}{f^M(x_i^k, \beta)}$, the farm household's technological gap ratio,

$TE_i^k = \frac{f^k(x_i^k, \beta^k) e^{(-u_i^k)}}{f^k(x_i^k, \beta^k)} = e^{-u_i^k}$, is the farm household's TE, and

$e^{v_i^M} = \frac{y_i^k}{f^k(x_i^k, \beta) e^{-u_i^k}} =$, the random noise component.

The two-step approach to estimate the meta-frontier has two stochastic frontier production functions as defined below:

$$lny_i^k = f^k\left(x_i^k, \beta^k\right) + v_i^k - u_i^k\,, \quad i = 1, \ldots, n(k) \ \text{----}(2.7)$$

$$ln\hat{f}^k\left(x_i^k, \beta^k\right) = f^M\left(x_i^k, \beta\right) + v_i^M - u_i^M \ \ldots\ldots(2.8)$$

where, $ln\hat{f}^k\left(x_i^k, \beta^k\right)$ is the estimate of the group-specific frontier from Eq.(2.7). Since the $ln\hat{f}^k\left(x_i^k, \beta^k\right)$ are group-specific, the SFA is estimated two times, one for each *Wereda*. The output estimates from the two *Wereda*s/groups are then pooled to estimate Eq. (2.8). The meta-frontier should be larger than or equal to the group-specific frontier that is, $f^k(x_i^k;\beta^k) < f^M(x_i^k,\beta^k)$. The estimated TGR must always be less than or equal to unity:

$$TGR_i^k = \hat{E}(e^{-u_i^M}|\hat{\varepsilon}_i^M) \leq 1, \ldots. \text{(2.9)}$$

where, $\hat{\varepsilon}_i^M$=$ln\hat{f}^k(x_i^k) - ln\hat{f}^m(x_i^k)$ are the estimated composite residual of Eq. (2.8). The TE of the i^{th} farm household to the meta-frontier is equal to the product of the estimate of the TGR in Eq.(2.8) and the individual farm household's estimated TE in Eq.(2.3), that is, $M\hat{T}E_i^k = T\hat{G}R_i^k \times \widehat{TE}_i^k$.

2.2.2. Empirical model and estimation strategy

Stochastic frontier model: The functional form of the Cobb-Douglas stochastic frontier model for the group-frontier with decomposed error terms at household level is specified as:

$$lny_i^k = \beta_0^k + \beta_1^k lnx_{1i} + \beta_2^k lnx_{2i} + \beta_3^k lnx_{3i} + \beta_4^k lnx_{4i} + \beta_5^k lnx_{5i} + v_i^k - u_i^k, \quad \ldots \text{(2.10)}$$
$$i = 1,2,\ldots,378$$

where, lny_i^k represents the natural logarithm of the aggregate value of cereals (*'teff'*, wheat, barely, maize and sorghum) expressed in Ethiopian Birr, β_i^k's unknown parameters of conventional inputs to be estimated, $x_{1i}..x_{5i}$ represents conventional inputs such as cereal cultivated land in ha, seed use in kg, fertilizer use in kg, labor in man days and draught power in ox-day, respectively. v_i^k is idiosyncratic error term distributed at *i,i,d* N(0,σ_v^2) and independent from u_i^k. u_i^k is a non-negative error component associated with technical inefficiency of smallholder households that that follows truncated normal distribution at zero ($u_i^k \sim N^+(\mu^k(Z_i^k), \sigma^{k2})$. $Z_1 - Z_{15}$ represents socio-economic, location and improved production techniques.

Effect of improved production techniques on technical efficiency: The effect of improved agricultural practices and farm-specific variables on the technical efficiency of households was assessed using the Tobit regression framework. Some authors support the use of the Tobit model in efficiency analysis as it can handle the characteristics of the distribution of efficiency measures and thus provide results that can guide policies to improve performance (Tipi, et al., 2009; Boubacar, et al., 2016).

Tobin (1958) applied to estimate consistent parameter estimates for censored and truncated data (Speelman, et al., 2008). The standard Tobit model is specified as follows.

$$y_i^* = x_i'\beta + e_i, \quad (i = 1,2,\dots,n) \quad \text{--- (2.11)}$$

$$y_i = \begin{cases} 1 \; if y_i^* \geq 1 \\ y_i^* \; if \; 0 < y_i^* < 1 \\ 0 \; if y_i^* \leq 0 \end{cases}$$

where, y_i^* is the latent variable and y_i is an observed dependent variable, x_i are vectors of explanatory variables related to attributes of households or farms within the sample, β are unknown parameters, and e_i is an error term that is independently and normally distributed with mean zero and variance $\sigma^2(e_i \sim N(0,\sigma^2))$ and independent of x_i.

Empirical Tobit model: The empirical Tobit model adopted for this study is therefore held the following functional form:

$$y_i^* = \beta_0 + \beta_1 Z_1 + \beta_2 Z_2 + \dots + \beta_i Z_i + e_i, \quad (i = 1,2,\dots,n) \text{ --- (2.12)}$$

Denoting y_i as the observed dependent (censored) variable is represented as:

$$y_i = \begin{cases} \text{U} \; if y_i^* \geq \text{U} \\ y_i^* \; if \; \text{L} < y_i^* < U \\ \text{L} \; if y_i^* \leq \text{L} \end{cases} \quad \text{--- (2.13)}$$

where, y_i^* is the latent variable, y_i is observed dependent variable, in our case the efficiency scores for household i, and Z_i are independent variables that consist of a range of variables (see Appendix A) that are hypothesized to affect the technical efficiency of the household. β_i are unknown parameters and e_i is the error term that is independently and normally distributed with mean zero and variance $\sigma^2(e_i \sim N(0,\sigma^2))$ and independent of Z_i.

2.2.3. Explanation of variables used in the empirical models

The study employed inputs and variables hypothesized to affect the level of technical efficiency. The variables are identified based on theoretical assumptions, empirical shreds of evidence, and the researcher's knowledge of the farming system. The output variable is measured by the aggregated value of cereals produced by the farm households in Ethiopia Birr (ETB). Inputs include cereal cultivated land measured in hectares, the quantity of seed measured in kilogram, the quantity of fertilizer measured in kilogram, labor used in man-days, and draught power in oxen-day, respectively.

The variables used in the inefficiency model were classified into three main groups, such as socio-economic, location-specific variables, and agricultural technologies (Table 2.1). We used these variables to estimate the first stage of group-specific frontiers. For the second stage of the meta-frontier, we employed variables that correspond to differences in terms of access to technology and other location-specific factors, between the study districts. These variables are including access to high-yielding cereal crop varieties, land quality and stress incidences. Furthermore, we used five interventions related to agricultural technologies such as high-yielding varieties, recommended seed and fertilizer rate, row planting, and participation in cluster farming. The technologies are selected because they have been receiving substantial emphasis to improve the production of smallholder farmers in rural Ethiopia. The study used recommended seed and fertilizer rates, which are standardized by the national research system on the basis of agro-ecologies. The rates for each cereal crop were decided using Crop Technology Packages and Crop Technology Guideline developed by the Ministry of Agriculture (MoA) and the Ethiopian Institute of Agricultural Research (EIAR) (see Appendix IIH). Moreover, we refined the recommended rates in consultation with agronomists and district agricultural experts to ensure the representativeness of the recommendations for the sample study districts. Soil type and planting method were also taken into account.

Table 2.1: Definition of variables

Variables	Definitions	Hypothesis associates with the inefficiency variables
Dependent variable: Cereal output: the natural logarithm of the aggregate value of cereal production in ETB[9]		
Conventional inputs for production		
Ln land	Continuous	The natural logarithm area planted in ha
Ln seed	Continuous	The natural logarithm seed use in kg
Ln fertilizer	Continuous	The natural logarithm of fertilizer use in kg
Ln labor	Continuous	The natural logarithm of labor use in man-days[10]
Ln draught power	Continuous	The natural logarithm in ox-days
Inefficiency variables		
Sex head	Dummy: 1= if household head is male, and zero if female.	Male-headed households has higher level of technical efficiency than their counterpart female-headed households.
Age head	Continuous: age of the household head in years.	Household with older head has lower technical efficiency as compared with households having younger heads
Family size	Continuous: total number of people living in house	Households with higher number of family size more likely to be technically efficient than households having less number of family size.
Farm size	Continuous: area of total cultivated land in hectare	Households having more cultivated cereal land tends to be less technically efficient when compared to those with smaller land holding.
Extension access	Dummy 1= if the household has access to extension services, 0 otherwise	Households who have access to extension services have higher technical efficiency
Membership in organization	Dummy: 1 if household belong to an association, 0 otherwise	Membership in organization tends to increase the technical efficiency of the households.
Mobile telephone ownership	Dummy: 1 if household has mobile telephone, 0 otherwise.	Mobile telephone ownership increase technical efficiency due to access to information on available technologies
Number of crops	Contentious: the number of crop grown by the HH	The higher number of crops the households cultivating tends to increase the technical efficiency of the households
Input center (km)	Location of HH relative to input center in km	The longer distance to input market tends to be technically inefficient.
Tropical livestock unit (TLU)	Continuous: total number of livestock in TLU	Households with higher herd size more likely to be technically efficient as compared to those with smaller herd holdings.
Stress incidence	Continuous: Proportion of area of cultivated land affected by stresses	Incidence of biotic and abiotic stress on the farm tends to decrease the technical efficiency of households
Use of improved seed	Dummy: 1 if household used improved variety on some proportion of farm land, 0 otherwise	Use of improved seed increase the technical efficiency of the households
Cluster farming	Dummy: 1 if household participated in cluster farming, 0 otherwise	Participating in cluster farming tends to increase the technical efficiency of households
Seed rate	Dummy: 1 if household applied	The use of seed as per recommended rate increase

[9] The total value of cereal crop is computed based on the volume of output and the price of the crops. The price for the crops were obtained from 2018/19 price data collected by CSA from the study areas.
[10] Man-day will be calculated based on regular and common working hours in the study areas, which is equivalent to 8 hours and converted into adult equivalent unit using appropriate conversion factors (See Annex III) to account for age and gender differences across family members of the farm household.

	as per recommended rate on some proportion of farm land, 0 otherwise	technical efficiency of households
Nitrogen fertilizer rate	Dummy: 1 if household applied as per recommended rate on some proportion of farm land, 0 otherwise	The use of fertilizer as per recommended rate increase technical efficiency of households
Row planting	Dummy: 1 if household planted in row on some proportion of farm land, 0 otherwise	Planting cereal crops with row expected to have higher level of technical efficiency
Land quality index[11]	Continuous: 1 if the soil has best land quality, 9 is lowest quality	Farm households having best land quality become more technical efficient than those who do not have.

Source: Authors' compilation (2020)

11 Land quality index is constructed based on multiplying the plots slope and the fertility indicators of the plots, implying a low index value indicates better land quality, while high index value would indicate the lowest quality evaluated at household level (Nisrane, et al., 2015).

2.3. RESULTS AND DISCUSSIONS

2.3.1. Descriptive statistics

From Table 2.2, about 95% of farm households were male-headed. Empirical studies (for example Zenga, et al., 2018; Haileyesus & Mekuriaw, 2021) reported comparable findings in Ethiopia. This may advance the adoption of improved technologies and thereby positively impacts the technical efficiency in the study area. This is largely because male-headed households are believed to have improved access to agricultural technologies as compared to female-headed households due to resource-related gender-based disparities. The age of farm households was ranged from 20 to 82 years with an average age of 45 years, which is comparable to the average age (46 years) reported by Kelemu (2016). This means that the majority of the farm households in the study area were middle-aged farmers, implying farm productivity seems to reach optimum and start to diminish with age.

Table 2.2: Background of the respondents

	Adea		**Enemay**		**Overall**	
Variable name	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
Sex head (Male Headed HH)	0.94	0.24	0.96	0.20	0.95	0.21
Age head	47	12.71	44	12.77	45	12.79
Family size	5.10	1.77	4.44	1.69	4.70	1.75
Farm size	1.50	1.02	1.02	0.67	1.21	0.86
Extension access (yes)	0.79	0.41	0.69	0.46	0.73	0.45
Membership in organization (yes)	0.61	0.49	0.83	0.38	0.74	0.44
Mobile telephone ownership (yes)	0.91	0.29	0.75	0.43	0.81	0.39
Number of crops	3	1.06	3	1.13	3	1.10
TLU	6.30	3.58	4.18	2.29	5.03	3.05
Input center (km)	2.35	1.96	1.92	1.71	2.08	1.82
Land quality	2.59	1.43	2.87	1.75	2.76	1.64

Source: Authors' analysis using primary data (2020)

Land is a basic asset for smallholders in Ethiopia. On average the farm household in the study area cultivated 1.21 ha of land to produce different crops, which is greater than the average farm size (0.96 hectares) estimated by (Headey, et al., 2014) for high-potential areas, and the national average farm size (0.9 hectares) of smallholders in Ethiopia (Rapsomanikis, 2015). Large landholding in the study area implies farm households appear to be surplus producers. Land quality index was used as an indicator for soil fertility, which takes soil fertility and plot slope into account. On average, farm households in the study area have 2.76, with a minimum of 1 and a maximum of 9. The average number of crops cultivated per farm household was found 3. To this end, literature underscores that growing a higher number of crops enables to improve soil fertility, reduce weeds, disease, and pests, and hereby enhance farm efficiency (Ogundari, 2013). Livestock ownership is also another important wealth indicator in rural Ethiopia. The average number of livestock measured in terms of TLU was found to be 5.3, which is by far greater than the national average estimated around 3.7 TLU (Bachewe, et al., 2008). As it was learned from the focus group discussion, despite the good size of TLU, the farm households reported the number of livestock per household is decreasing from time to time due to expansion of cultivated land and limited availability of feed. Extension access is a key supply-side policy instrument to influence agricultural productivity in developing countries (Wossen, et al., 2017). Concerning this, about 73% of the farm households had access to extension services during the cropping season. However, government sources showed that the number of full package beneficiaries is still very low (23%) due to mainly poor function of FTCs[12] and low motivation of DAs, among others (MoA, 2017). This connotes that, despite a higher proportion of extension service users, the number of technology beneficiaries reported to be very low, which is mainly due to the limited access to alternative technologies. The farm households were located on average 2.08 km away from a nearby input market, which is the distance that the farm households should walk to access modern inputs. This distance was by far lower than the distance to the input market reported by Kelemu (2016), 4.26 km. Among the sample farm households, 74% of them were members of the cooperative, whilst 81% used a mobile telephone.

Table 2.3 provides the means and standard deviations of output and input variables. The majority of farm households were producers of *'teff'* (99%) followed by wheat (60%) and maize (19%). A higher size of the land was allocated for '*teff*' (1.08ha) and wheat (0.5ha), implying the crops are important sources of income and food security in the study area. The average yields of *'teff'*,

[12] FTCs are farmers' training centers one of Ethiopia's strategies to support smallholders in Ethiopia. They were established throughout the country to train the farmers on the use of technological packages. Development agents (Das) who are assigned at each FTC facilitate the farmers' training centers.

wheat and maize were 1115 kg/ha, 1800 kg/ha, and 1349 kg/ha, respectively. The average yields in all of the cereal crops were found lower as compared to the national average reported in 2018/19 CSA reports, where the average productivity is 1700 kg/ha, 2700 kg/ha, and 3900 kg/ha, respectively (CSA, 2019). On average the farm households produce 49,535 ETB of cereal output, among which '*teff*' and wheat took the higher share, in ranking order.

Table 2.3: Mean values of the cereal output, input variables, and stress incidence by crop type

Variables	**'*Teff*'**		**Wheat**		**Barely**		**Maize**		**Sorghum**	
	Mean	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
Yield (kg/ha)	1115.32	531.69	1799.80	1022.53	1711.95	1166.18	1349.13	1785.89	2064.14	1108.41
Land (ha)	1.08	0.74	0.50	0.41	0.35	0.20	0.23	0.13	0.38	0.13
Seed (kg/ha)	35.03	22.39	140.09	66.81	97.75	49.84	31.76	37.10	14.85	5.40
UREA (kg/ha)	156.98	112.40	123.97	96.24	101.06	83.43	68.42	300.92	-	-
NPS (kg/ha)	142.19	93.90	128.36	92.12	82.28	85.67	23.12	44.88	-	-
Man days/ha	63.84	29.31	67.56	33.95	54.27	21.77	77.83	90.01	59.51	25.49
Oxen days/ha	16.21	9.84	17.91	12.36	14.17	7.50	24.71	47.04	13.54	7.58
Stress incidence	0.53	0.47	0.37	0.48	0.17	0.38	0.38	0.48	-	-

Source: Authors' analysis using primary data (2020)

On average, the farmers applied 35 kg/ha, 140 kg/ha, and 32 kg/ha of seed for *'teff'*, wheat, and maize, which is slightly higher than the recommended standard. Furthermore, farm households were used more quantities of chemical fertilizer in '*teff*' production as compared to the other crops. It appears to be due to *teff* and wheat has been produced for both food and cash in the study area. Nitrogen fertilizer was progressively used because of higher immediate returns perceived by the farm households. Overall, the farm household used 62 man-days and 15 oxen-days per hectare to produce cereal crops in the study area. On-farm stress incidence is measured by the proportion of the size of cereal cultivated land affected by stresses, such as floods, pests, and diseases, climatic conditions, etc. Accordingly, about a higher proportion of the area of farmland is affected by stress incidences, where *'teff'*, maize, and wheat account for 53%, 38%, and 37%, in ranking order. The incidences of stress reported by this study are higher than the incidence estimated by Nisrane, et al. (2015) for *'teff',* 11%. The surveyed farm households reported the incidence of stress is dynamic and unpredictable.

2.3.2. Adoption of improved inputs and production practices

Table 2.4 presents the spread of the adoption of high-yielding varieties and production practices by crop type. It was computed in terms of the proportion of farm households adopting improved technologies. The data show that 35% of the surveyed farm households have adopted improved cereal crop varieties. Most of them used the improved varieties for '*teff*', maize and wheat. From the total farm households who produced '*teff*', maize, and wheat, only 30%, 28%, and 22% of them used high-yielding varieties, respectively. About 26% of the farm households reported they followed the recommended seed rate. Of the farm households who produced '*teff*', close to 19% of them applied the recommended seed rate, while a relatively lower proportion of farm households (10%) who grew wheat used the recommended seed rate. The adoption studies in Ethiopia revealed mixed results. For example, a study by Gebru, et al. (2021) in semiarid northern Ethiopia showed that the adoption rate for improved *teff* and wheat was estimated at 16%, and 13.8%, respectively. The study further reported that, on average, about 3% and 5% of their farm area with improved teff and wheat, in that order. A similar study in Ethiopian Arisi Zone revealed a 56% of rate of adoption for wheat crop (Tesfaye, et al., 2016). The national-level study by Shiferawa, et al. (2014) on improved wheat adoption showed that about 70% of households grew improved wheat varieties with, on average, 83% of total wheat area. A study by Ahmed, et al. (2017) in East Hararghe Zone of Ethiopia found a 59.4% of adoption rate for maize.

Table 2.4: Improved technologies adoption by crop type

	'*Teff*' (N=374)		**Wheat (N=225)**		**Barely (N=66)**		**Maize (N=71)**		**Sorghum (N=15)**		**Overall (N=378)**	
Practices	***No***	***%age***	***No***	***%age***	***No***	***%age***	***No***	***%age***	***No***	***%age***	***No***	***%age***
Improved seed/HYV (yes)	114	30.48	49	21.78	-	-	20	28.17	-	-	134	35.45
Seed rate (yes)	71	18.98	23	10.22	-	-	2	2.82	6	40	97	25.66
Fertilizer rate/UREA (yes)	126	33.69	87	38.67	18	27.27	6	8.45	-	-	139	36.77
Fertilizer rate/NPS (yes)	165	44.12	90	40	14	21.21	1	4.1	-	-	207	54.76
Row planting (yes)	42	11.23	10	4.4	2	3.03	32	45.07	-	-	75	19.84

Source: Authors' analysis using primary data (2020)

Moreover, the result revealed that 37% and 55% of the farm households adopted the recommended rate of UREA and NPS, in that order. Crop-wise, a large proportion of farm households practiced the recommended rate of fertilizer for *'teff'* and wheat. Overall, limited practice of raw planting was also confirmed among the surveyed farm households. The result may suggest that still a large proportion of farm households have not used high yielding varieties and most of them practiced sub-optimal seed and fertilizer rate, which is lower and higher than the recommended standard. This is the reflection of many farmers in developing countries and it is mainly due to limited access to modern inputs and relevant information (Amare, et al., 2012; Stewart, et al., 2015; Verkaart, et al., 2017). Cluster farming is an intervention in which farmers consolidate their farmland to produce the same crops. Governments, NGOs, and private sectors promote cluster-based farming, however, only 25% of the farm households participated in cluster farming. A lower level of participation appears to be due to limiting factors related to institutional services, farmers' organizations, and individual and biophysical differences. The approach has been promoted without implementation guidelines, proper institutional structure, and trained staff on farmers' organizations.

The result of the intensity of adoption is summarized in Table 2.5 below, which is measured by the proportion of the total area under improved technologies to the total area of cereal farms in the cropping year. The result shows that the overall intensity of adoption of high-yielding varieties for cereals was 23% with a statistically significant mean difference between the sampled study districts.[13] About 24% (0.32ha), 22% (0.15ha), and 29.58% (0.07 ha) of the total area under *'teff'*, wheat and maize were covered by improved varieties, respectively. Whereas, about 24% (0.25ha), and 36 % (0.17ha) of the total area under *'teff'* and wheat were cropped with the recommended rate of UREA, in that order. With a slightly higher proportion of area, about 34% (0.35ha) and 39% (0.17ha) of area planted with *'teff'* and wheat were cropped with the required standard of NPS fertilizer rate. Except for maize, the farm households planted a significant proportion of their farmland with a broadcasting method of sawing and a small proportion of farm area covered with recommended seed rate. As per the qualitative responses,

[13] A higher proportion of cereal farmland is covered by improved seed in Adaa wereda than Enemay wereda with a statistically significant mean difference at less than 1 percent significant level.

low level of adoption of improved technologies might be attributed to poor access to improved inputs, lack of awareness, higher price and low quality of improved seed, absence of alternative improved varieties that substitute old varieties, low level of participation in package training, a variation of extension service across areas.

Table 2.5: Intensity of adoption by crop type

	'Teff' **(N=374)**	**Wheat (N=225)**	**Barely (N=66)**	**Maize (N=71)**	**Sorghum (N=15)**	**Overall (N=378)**
Practices	**(%age/Mean)**	**(%age/Mean)**	**(%age/Mean)**	**(%age/Mean)**	**(%age/Mean)**	**(%age/Mean)**
Improved seed/HYV (ha)	24.37 (0.32)	22 (0.15)	-	29.58 (0.07)	-	22.62 (0.41)
Seed rate (ha)	11.13 (0.11)	10 (0.06)	-	2.81 (0.01)	40 (0.125)	10.72 (0.15)
Fertilizer rate/UREA (ha)	24.16 (0.25)	36.41(0.17)	27.27 (0.10)	0.8 (0.02)	-	19.73 (0.27)
Fertilizer rate/NPS (ha)	33.62 (0.35)	38.6 (0.19)	21.21 (0.08)	1.4 (0.004)	-	32.3 (0.48)
Row planting (ha)	8 (0.09)	4.44 (0.02)	3.03 (0.02)	44.6 (0.11)	-	10.11 (0.12)

Source: Authors' analysis using primary data (2020)

2.3.3. Stochastic meta-frontier estimation

Before the estimation of the stochastic production frontier, we conducted various hypothesis tests. The first test is testing whether OLS residual has left-skewed distribution or not. Accordingly, we found a negatively skewed value equal to -0.530 (see Appendix IIC). The negative sign of the skewedness value designates that the distribution of the residuals is in line with a production frontier specification (Kumbhakar & Wang, 2015). The Skewness statistic is also found statistically significant at less than 1% level (see Appendix IID). We also assessed the negative-skewed distribution by examining the graph of OLS residuals (see Appendix IIE). The graph confirms negative Skewness and hence, we have enough confidence to reject the null hypothesis of no negative Skewness in the data.

The second hypothesis test was choosing the proper stochastic production function specification form. The hypothesis tests were conducted based on the generalized log-likelihood ratio test

(LR) $(-2[L(H_0) - L(H_1)],)$ were$L(H_0)$ and $L(H_1)$ are the log-likelihood values under the null hypothesis H_0 (Cobb Douglas function) and alternative hypothesis H_1 (TL function), respectively, with a value of the degree of freedom computed based on the number of restrictions in the test. For that reason, as the calculated LR value is less than the critical value (see Appendix IIF), we cannot reject the null hypothesis that the Cobb Douglas production functional form adequately represents the data. Moreover, the AIC value for the Cobb Douglas production function (CD) (301.31) is relatively lower than the AIC value of the Translog production function (TL) (304.46), implying CD is more appropriate in representing the data. Hence, for its consistent results, Cobb Douglas specification has been uniformly applied in all of the estimations. Various distributional assumptions on the error components are developed to estimate the parameters and inefficiency of the stochastic production function. Of these assumptions, the truncated normal distribution is assumed for the distribution of the inefficiency error term because it has the lowest Akaike Information Criterion (AIC)'s statistic as compared to the other distributional assumptions.[14]

The other most important hypothesis test was $\mu = \sigma_u^2 = 0$, which specifies no technical inefficiency in the sample. The value of likelihood ratio statistics, λ=23.41, far exceeds the critical value of 8.273[15] at 1% level (see Appendix IIF). This value indicates that the null hypothesis of no technical inefficiency is rejected. This shows no full efficiency among the samples and technical inefficiency is one of the factors that affect the cereal outputs in the study area. On top of this, the rejection of the null hypothesis of no technical inefficiency confirmed the appropriateness of SPF over the OLS.

Once we rejected the null hypothesis of no technical inefficiency, we further investigated whether a unified conventional SPF could represent the overall data or a separate SPF should be used for the two sample study districts. This would help to meaningfully confirm the application of the stochastic meta-frontier approach. To determine this, we conducted an LR test, which is defined by $LR = -2^*(lnL_p - (lnL_A + lnL_E)$, where, lnL_p, lnL_A, and lnL_E represents the log-

[14] Akaike's Information Criterion (AIC) value for truncated-normal, half normal and exponential distribution is 254.7212, 264.8045 and 273.7771, respectively

[15] The critical values for the analysis were obtained from Table 1 of Kodde and Palm (1986)

likelihood values, which are obtained from the pooled data set of the overall stochastic frontiers and the sum of the values of the log-likelihood functions for the sample study frontiers, respectively. The degree of freedom was 22, calculated as the difference between the number of parameters estimated under pooled data and the parameters estimated in the respective study districts. Therefore, the result of the LR test [chi2=82.96 (p=.0000)] provides enough evidence to reject the null hypothesis of homogeneous production technology for the study. This implies that smallholder farmers in the sample study districts operate under different production technology and hence, SPF for the study districts should be separately estimated. The test result also profoundly confirmed the use of the stochastic meta-frontier approach to estimate the TE score among smallholder farmers in the respective study districts.

Following the test for homogeneous production technology, we carried out a hypothesis test to check whether or not the inefficiency effect model does not affect the technical inefficiency of smallholder farmers in the study area. Hence, the null hypothesis in all cases was rejected at a 1% level, representing the parameters of the inefficiency effect model are not simultaneously equal to zero. All of the hypothesis tests confirm the specification of stochastic production frontier is effective in estimating the efficiency scores.

The problem of heteroskedasticity that might exist inherently in the data was handled in the maximum likelihood estimator of the stochastic frontier model by using the observed information matrix (OIM) method during the estimation of the variance-covariance matrix (Abro, et al., 2014). Multicollinearity problem was also checked and tested during variance inflation factor (VIF) and hence, we did not find any multicollinearity problem during the estimation of process (see Appendix IIA and Appendix IIB). Moreover, the Wald chi-square value [chi2=132.65 (p=.0000)] shows the model fits the data well, indicating the absence of wrong functional form specification.

2.3.4. Estimates of stochastic production frontiers

Table 2.6 depicts the maximum likelihood estimate of the stochastic Cobb Douglas production function. The estimated value of gamma (γ) in all of the models was found greater than 0.80.

This indicates that the inefficiency effects are likely to be highly significant in the analysis of the value of the farm households (Battese & Coelli, 1995). In this study, hence, more than 80% of the total variation in the output is primarily attributed to the existence of technical inefficiency. Except for the inputs, such as labor and oxen draught power, the estimated mean output elasticity of all inputs in the Meta-frontier were positive and significant at less than 1% significant level, indicating the inputs have a positive and significant effect on cereal output. This means that for example, keeping all other inputs constant, if the area of cereal farmland increased by 10%, cereal output will be increased by 4.2%. Similarly, if the use of seed and fertilizer increases by 10%, cereal output will be enhanced by 1.7% and 2.5%, respectively. Moreover, the sum of the parameters associated with all the input is less than one, implying a decreasing return to scale. Overall, the result of stochastic frontier estimation revealed that cereal output is more responsive to cultivated land than the use of fertilizer, seed, oxen draught power, and labor, in that order.

Table 2.6: Maximum likelihoods estimate of the parameters for SFPF model

Stochastic frontier parameters		**Adea wereda**		**Enemay wereda**		**Metafrontier parameters**	
		Coeff.	***Std. Err.***	***Coeff.***	***Std. Err.***	***Coeff.***	***Std. Err.***
Constant	β_0	9.212***	0.569	8.432***	0.331	9.199***	0.060
lnAREA	β_1	0.415***	0.103	0.381***	0.075	0.423***	0.014
lnSEED	β_2	0.205***	0.066	0.036	0.037	0.167***	0.005
lnFERTILIZER	β_3	0.246	0.074	0.294***	0.047	0.248***	0.009
lnLABOR	β_4	0.010	0.064	0.115*	0.065	-0.018**	0.009
lnOXEN_DAY	β_5	-0.114**	0.047	0.063	0.060	-0.079***	0.008
Sigma2 ($\sigma^2 = \sigma_v^2 + \sigma_u^2$)		0.113***		0.125***		0.034***	
Gamma ($\gamma = \sigma_u^2/\sigma^2$)		0.837***		0.822***		0.970***	
Number of observations		150		222		374	
Log likelihood		-75.26		-61.06		396.90	

Source: Authors' analysis using primary data (2020)

Coefficients with ***, **, and * are significant at 1, 5 and 10 percent level of significance, respectively

2.3.5. Technical efficiency and technology gap ratio

We computed the average value of TE and TGR of the meta-frontier of the pooled data, as reported in Table 2.7. Besides, the table presents the statistical t-test of mean TE difference between adopters of modern technologies and non-adopters. Overall, the farm households have mean TE values of 58% that vary between 13% and 91%. The mean TE value shows that farm households produced 58% of the maximum production of the possible (frontier) output. The result further disclosed that if the farm households cultivated cereal at full efficiency level, they could increase their cereal output by 36%[16] using the existing resources and production technologies. Moreover, the corresponding mean value of TGR denotes that on average farm households produce 90% of the potential output given the overall technology available in the study area. The difference in mean TGR of the sampled study districts is statistically significant at 1%, which appears to be due to gaps in terms of access to improved technologies and information about high-yielding varieties (HYVs) and their associated better agronomic practices. The result also revealed that no farmers have a maximum value of meta technology gap ratio equal to unity (the stochastic frontier tangent to the meta-frontier), implying there are no farm households in the study area who adopt the most advanced cereal production technology. We also computed the variation of cereal output, which might be caused due to technical inefficiency. Accordingly, on average the farm households lost 32,925 ETB per hectare[17] due to technical inefficiency.

2.3.6. Effects of improved technology on technical efficiency

T-test results show that adopters of HYVs with the recommended practices have higher efficiency than non-adopters (Table 2.7). The difference in mean TEs between adopters and non-adopters of HYVs and recommended seed rate is statistically significant at 1%. Moreover, the difference in mean TE values of adopters and non-adopters of HYVs with the recommended rate of seed, nitrogen fertilizer, and row planting is statistically significant at 1%. In the same way,

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[16] The optimum possible output level that farm households can be producing using the existing resources and production technology can be computed as 1- (mean TE/Maximum TE) multiplied by 100.

[17] The yield gap due to technical inefficiency variation is derived by first calculating the potential output from TE=Actual output/Potential output, and the Yield gap is computed by subtracting actual yield of farm households from the potential output.

on-farm demonstration experiments recommend farm households strictly follow the recommended seed rate. However, many farmers in developing countries prefer to use a higher seed rate than recommended, because they perceive it as a good strategy to control weeds and reduce the risk of crop production (Woldekiros, 2020). Similarly, farmers practiced the use of a high rate of nitrogen fertilizer in the study area expecting better yield gains. Interestingly, the study unfolds those farm households who applied nitrogen fertilizer over the recommended rate were found more efficient than others. *F*-test result also confirmed there exists a statistically significant difference in technical efficiency between farm households who used below (54%), as per (56%) and over the recommended rate (60%) of nitrogen fertilizer.

Table 2.7: Meta-level technical efficiency by technology adoption status of farm households

Technology	Adopter	Non-adopter	t-value
Use of HYV	0.646 (0.013)	0.543 (0.011)	-5.935***
Recommended seed rate	0.632 (0.015)	0.562 (0.010)	-3.626***
Recommended N fertilizer rate	0.580 (0.015)	0.579 (0.011)	-0.045
Row planting	0.600 (0.010)	0.575 (0.010)	-1.173
HYV with recommended seed rate	0.652 (0.025)	0.571 (0.009)	-2.852***
HYV with recommended N fertilizer rate	0.687 (0.022)	0.564 (0.009)	-4.806***
HYV with row planting	0.644 (0.021)	0.571 (0.009)	-2.670***
HYV with recommended seed rate and N fertilizer rate	0.672 (0.045)	0.576 (0.009)	-2.042**
Participation in cluster farming	0.591 (0.016)	0.576 (0.010)	-0.740
Overall TE	Mean =0.580 (0.167) Min=0.131, Max=0.907		-
Overall TGR	Mean =0.901 (0.078) Min=0.638, Max=0.993		-

Source: Authors' analysis using primary data (2020)

Coefficients with ***, **, and * are significant at 1, 5, and 10 percent levels of significance, respectively

Figure 2.1 depicted the distribution of the efficiency scores of the farm households. The Kernel density distribution of the technical efficiency scores were also presented in Appendix IIG. About 51% of the farm households rest well above the mean value of technical efficiency score

(59%). This means that given the current production technology, still there is substantial scope for improving the cereal output of farm households in the study area. The distribution further portrayed that the positive effect of the adoption of High Yielding Varieties (HYVs) on the efficiency of the farm households.

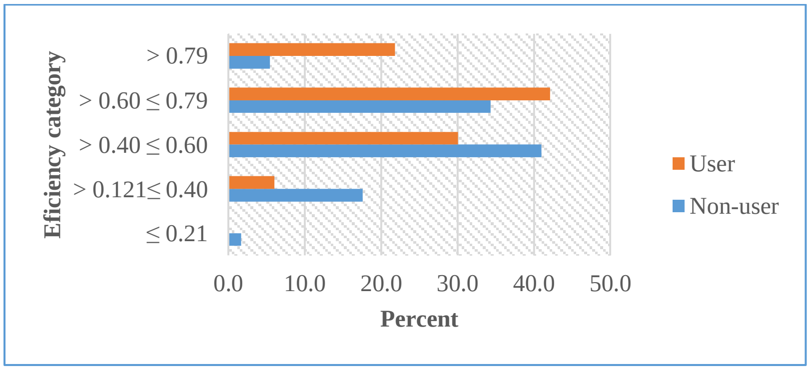

Figure 2.1: Efficiency distribution by the adoption of HYVs

Source: Authors' analysis using primary data (2020)

Table 2.8 presented the Tobit analysis of the effects of improved technologies and other factors influencing the efficiency of farm households. The coefficients of the variables were estimated using Model-1 and Model-2. Model-1 is estimated based on technical efficiency score derived from independent stochastic frontiers of the sampled study districts, whereas the efficiency scores for Model-2 is taken from stochastic meta-frontier. The results of the Model 1 and Model-2 provide just about comparable results on the significant value of the coefficients. As can be seen from the estimation from Model-2, eight variables appear to have a statistically significant effect on technical efficiency.

Table 2.8: Factors explaining efficiency of smallholder farm households

Variables	Model-1		Model-2	
	Coeff.	***S.E.***	***Coeff.***	***S.E.***
Constant	0.5020***	0.0609	0.4752***	0.0546
Socio-economic factors				
Head Sex (1 if male)	0.1125***	0.0390	0.0996***	0.0350
Head Age (years)	-0.0012*	0.0007	-0.0016**	0.0007
Family size (persons)	0.0007	0.0053	-0.0004	0.0047
Mobile telephone ownership (1 if yes)	0.0759***	0.0223	0.0677***	0.0200
Extension service (1 if yes)	-0.0084	0.0230	-0.0010	0.0208
Membership in Organization (1 if yes)	0.0532**	0.0213	0.0360*	0.0190
Farm size (ha)	-0.0258**	0.0123	-0.0087	0.0110
Access to input center (km)	-0.0091***	0.0036	-0.0083***	0.0032
TLU	0.0029	0.0032	0.0045	0.0028
Number of crops	0.0140*	0.0081	0.0068	0.0072
Land quality index	-0.0048	0.0054	-0.0079	0.0049
Stress incidence (ha)	-0.1163***	0.0204	-0.0919***	0.0182
Improved production practices				
Cluster farming	0.0586**	0.0229	0.0170	0.0205
High yielding variety	0.0724***	0.0213	0.0864***	0.0191
Seed rate/planting density	0.0550***	0.0196	0.0504***	0.0176
Fertilizer rate (UREA)	0.0157	0.0176	0.0175	0.0158
Row planting	0.0016	0.0221	0.0003	0.0198
Dependent variable	TE scores derived from Group frontiers		TE scores droved from Meta-frontier	
Number of observations	372		372	
Wald chi2(17)	127.11		133.10	
Prob > chi2	0.0000		0.0000	
Log-likelihood	162.31		201.87	

Source: Authors' analysis using primary data (2020)

Coefficients with ***, **, and * are significant at 1, 5, and 10 percent levels of significance, respectively

Use of HYVs and recommended seed rate: The use of improved cereal crop varieties and better management practices enhance the technical efficiency levels of farm households. The signs of the estimated coefficients for HYVs and seed rate are significant and positively affect the technical efficiency of farm households. The result on the adoption of HYVs is in line with the findings of (Bizuayehu, 2014). The study conducted by Chirwa (2007) showed that farm households using hybrid maize seed were more efficient than farm households using local seed. Despite the potential of modern technologies to improve farm efficiency, however, the performance of HYVs is affected by the type and quality of source seed and certified seeds. Poor performance of the seed system, the limited availability of high-quality improved seed, and the inefficiency of fertilizer use, the priority of the extension system to distribute inputs rather than provide technical advice, and the limited role of the private sector in the system were identified among the major challenges for farmers' access to modern ecologies (Yu, et al., 2011).

The finding from focus group discussions and key informant interviews revealed that seed multiplications on farms of smallholder farmers are one of the sources of poor seed quality for seeds of self-pollinated varieties. As it was confirmed both in key informant interview and focus group discussion, porr quality for improved seed is mainly associated with farmers-based seed production system. Farmers-based seed production program has been promoted to mitigate the gaps in the supply of improved seed by a formal seed system. However, as it was reported the institutional response to support the program lacks a more integrated approach and strong linkage among key actors. The approach is also reproached by key informants because of lack of compensation mechanism to any risks associated with the technology and the delivery system. The public seed enterprises, which consists of Ethiopian Agricultural Business Corporation (EABC), Oromia Seed Enterprise (OSE), Amhara Seed Enterprise (ASE), and South Seed enterprise (SSE) have multiplied a considerable amount of seeds of self-pollinated varieties on fragmented farmers' field on the bases of community based informal seed multiplication scheme due to mainly shortage of farmland. EABC, OSE, and ASE have 5015 ha, 28,846 ha, and 1163 ha of own farms, respectively. From 60 to 70 thousand hectares of seed farm, which is expected to be inspected by seed regulatory authorities across the country, 50% of the seed production is done on farmers' fields (EIAR, 2020). On account of this, as documented by the Ethiopian Institute of Agricultural Research (EIAR, 2020), from the total seed farms of self-pollinated crops, the dominant proportion of the seed farms is either not inspected or not inspected at the recommended frequency. These findings explicitly highlight the substantial role of the supply of quality seed in addition to the efforts to improve farm households' access to HYVs.

2.3.7. Other factors determining technical efficiency

Sex of the household head: The sex of the household head significantly affects technical efficiency in favor of male-headed households. The positive sign for sex of the household head implies that male-headed households were more technically efficient than their female counterparts. This is might be because of the prevalent gender disparity in rural areas of Ethiopia in terms of access to productive resources and institutional supports. Female-headed households face gender-specific constraints mainly the poor quality of farmland, limited access to institutional supports, and low level of assets and livestock ownership. Moreover, female-headed households have additional reproductive responsibility, which competes for women's time and effort. These factors affect them to access improved technologies and improve their farming outputs. The result is consistent with the findings of Mango, et al. (2015); Gebrehiwot (2017) that found a positive and significant effect sex on technical efficiency.

Age of the household head in years: The result shows that the age of the household head negatively and statistically affects the technical efficiency of farm households. The negative sign for the age of the household head indicates that the inefficiency increases with the age of the household head. Theoretically, farmers' productivity generally increases and then decreases with age, meaning that younger and older farmers are lower than middle-age farmers (Tauer, 1995). This means that farm households in the middle-age may have the physical capability to acquire resources and information as compared to households in the younger and older age category. The result endorses the studies (Bizuayehu, 2014; Sekhon, et al., 2010; Tiruneh & Geta, 2016) that found a negative effect of age on-farm productivity.

Mobile telephone ownership: Mobile telephone ownership significantly determines the technical efficiency of smallholder farmers at less than 1% level. Smallholder households who have a mobile telephone were more efficient as compared to those who do not have one. The plausible explanation for the result is that mobile telephone ownership helps smallholder farmers to access information on the availability of conventional inputs and other improved agronomic techniques and thereby improve the level of technical efficiency. Similar results on the effect of a mobile telephone on smallholder household efficiency were also reported by Debebe, et al. (2015); Kelemu (2016). For example, mobile telephone ownership increases the average technical efficiency of wheat-producing farmers in the range of 8-10% (Kelemu, 2016).

Cooperative membership: as hypothesized, membership in cooperatives positively and significantly affects the technical efficiency of farm households. The plausible explanation of the finding is related to membership in farmers' groups enhancing households' access to knowledge and information about improved technologies and better production practices thereby improving production efficiency. On top of this, cooperative facilitates agricultural inputs and outputs market outlets. Development groups help their members to improve their production through farmers-to-farmers seed exchanges and peer group influence on best practices. The finding in this study also corresponds to other studies (Debebe, et al., 2015). Wossen, et al. (2017) stated many paths through which cooperatives facilitate technology adoption and improve the welfare of farm households. Cooperative can relax the liquidity constraints, affect adoption by providing market information and better price, and pool different resources such as credit, information and labor among members.

Distance to input center in km: the estimated coefficient related to the location of farm household regarding input centers/cooperative input stores, as expected, negatively and statistically significant. The hypothesis in this study is that farm households located near the input market tend to be more technically efficient than those located in remote areas. The probable reason might be the proximity to input centers increases farmers' awareness of the availability and benefits of modern inputs. In addition to this, farm households located near input centers are encouraged to use recommended production practices and improve their efficiency. In line with the present study, studies (Kelemu, 2016; Lemessa, et al., 2017) confirmed that proximity to the source of modern inputs is one of the determinants of efficiency t of farm households.

Stress incidence: Our analysis related to stress incidences or crop damage shows a negative and significant effect on the technical efficiency of farm households. Similar result was also reported in Nisrane, et al. (2015). From the total sample households, 63.73% of them reported the occurrence of different types of biotic and abiotic stresses that cause crop damage at different intensities. The thematic analysis of the qualitative data similarly confirmed the incidence of bad weather, unexpected rain, pests, diseases, flood, etc. increasingly and adversely affects cereal production in the study area. Experts and farmers consulted during the survey linked the disease and pest outbreaks with climate change. Most of the diseases significantly affect pulse crops and interrupt the crop rotation system, which is very important for soil fertility management. Mono-cropping of cereal crops on the other hand causes low crop yield and outbreaks of disease on cereal crops. The farm households reported the incidence of new crop disease and pests mainly on *'teff'*, which are not formerly common in the area. The farm households also informed that changes in climate situation affect the crop variety choice given the rainfall distribution. Researchers and experts stated that crop pest and disease outbreaks, bad weathers, droughts, natural resource depletion, climate-change related risks, etc., growingly affect the performance of improved technologies. Similarly, the research and seed system has been constrained by a shortage of qualified staff, farmland, farm implements, laboratory chemicals, and other research infrastructures.

2.4. CONCLUSIONS AND RECOMMENDATIONS

The present study examined the effects of modern cereal crop varieties and recommended agronomic practices on the technical efficiency of farm households in cereal production. Our results have shown a low adoption rate of HYVs and improved agronomic practices. About 34% of farm households applied modern varieties and recommended rates of seed, fertilizer, and row planting at different scales of intensity. On average, about 19% of the total area under cereal crop were covered by modern varieties and recommended practices. The low level of adoption of HYVs and improved agronomic practices is mainly due to HYVs access constraints, poor quality of seed, and lack of awareness.

We have found a positive and significant coefficient for conventional inputs, such as land, seed, and fertilizer in cereal production, suggesting cereal output is more responsive to cultivated land, fertilizer, and seed, in that order than other inputs. The technical efficiency score was found 58%, suggesting the farm households can improve cereal productivity by about 36% through better use of available input resources and current technology. This result remarks that there is room to improve cereal productivity by improving the current technical efficiency of the farm households. Moreover, the results provide enough evidence that the technical efficiency of farm households is influenced by the adoption of HYVs and improved management practices. Hence, there is a great scope for improving the efficiency of farm households by promoting the adoption of modern technologies. Other sources of significant inefficiency factors include sex, age, mobile ownership, group membership, access to modern inputs.

Cereal crop production efficiency was also influenced by the level of stress incidence and its associated crop damage. The main factors for crop damage include floods, pests, and diseases, climatic conditions, etc. The principal message emerging from these findings is that the need to improve the performance of public research and development systems to adequately support farm households to implement mitigation practices and use climate change responsive modern technologies. This could be achieved by improving the public sector efficiency and enhancing complementary investments in human capital, infrastructure, and research, and development (Dang & Pheng, 2015) as well as favorable price incentives to farm households to adopt new technologies (Timmer, 1988). Empirical evidence from the intensification of the green revolution also reinforces the argument. Much of the success of the green revolution was caused by the combination of high rates of investment in crop research, infrastructure, and market development, and appropriate policy support (Pingali, 2012), implying producers were able to harness the technologies and packages of inputs. Evidence in Asia suggests that the productivity growth in the post-green revolution period has been sustained through increased input use and more recently, through more efficient use of inputs (Pingali & Heisey, 1999). Hence, promoting the use of technological advances through public and private investment can be one of the policy instruments for the successful implementation of the cereal intensification strategy of the country.

The policy should strengthen the existing breeding, seed multiplication, and extension systems, so that, alternative HYVs with the required quality can be available to the farm households. Moreover, future interventions should aim at penetrating access of agricultural inputs to remote rural areas through revitalizing the role of cooperatives and local groups, hence, barriers in acquiring modern inputs and information regarding improved agronomic practices can be addressed. To this end, agricultural development efforts should emphasize mitigating the capacity gap of agricultural cooperatives in service provision through long- and short-term loan facilitates. From findings of qualitative study, it was learned that community-based seed production program has been promoted to mitigate the gaps in the supply of improved seed by formal seed system. However, the institutional response requires a more integrated approach and strong linkage among key actors. The system should also be responsive to any risks caused by technology failures. Local seed producers and private seed companies should also be encouraged by improved access to financial services. In addition to this, the findings of the study stress the need to appropriate technology promotion strategies that should be responsive to the needs of different segments of the community. To address those human-related factors attributed to inefficiency, it is important to understand the origin of farm households' managerial inabilities and how they can be improved. The agricultural information delivery system should also be strengthened through digital agriculture and the expansion of telecom services to remote rural areas. Moreover, future policies should focus on controlling and preventing those factors responsible for crop damages by relying on scientific advances in biotechnology in addition to conventional plant breeding and agronomic practices. Finally, virtual multi-stockholder information and knowledge platform under a long-term strategy of climate-smart agriculture may assist to address the adverse effects of climate change.

CHAPTER THREE: DOES CEREAL COMMERCIALIZATION ENHANCE FARM HOUSEHOLDS' INPUT USE, EFFICIENCY, AND PRODUCTIVITY? A CONDITIONAL MIXED PROCESS (CMP) APPROACH FROM RURAL ETHIOPIA

Abstract

The paper explores how cereal commercialization affects farm households' input use, technical efficiency, and productivity in major teff-based mixed-farming areas of Ethiopia. Analytical tools which including descriptive statistics, conditional mixed process model, dose-response function, and three-stage least squares regression model (3SLS) were employed. Our results indicate that farm households sell, on average 38% of cereal crops produced with variability across the cereal crops. The simultaneous equation model estimates confer that commercialization positively and significantly increases farm households' input use and cereal yield at 1% level. Ceteris paribus, a 10% increase in the degree of commercialization increases nitrogen fertilizer, agrochemical, and cereal yield in monetary terms per hectare by 6.8%, 23.4%, and 5.5%, respectively. The results also substantiate that commercialization enhances the likelihood of using high-yielding varieties and hiring additional labor to cultivate cereal crops. Hence, the more the farm households are oriented to the market, the higher they invest in modern technologies. The 3SLS estimation was also confirmed the bi-directional causation between technical efficiency and commercialization of farm households, signifying that improving farm households' input use efficiency leads to a higher degree of commercialization and the vise-versa. Moreover, the results show that the extent of cereal commercialization positively determined by sex of the household head, land size, credit service, mobile phone ownership, improved seed, and agricultural assets, while negatively influenced by family size, dependency ratio, and non-farm employment. Therefore, the findings of this study call for policy efforts to mitigate bottlenecks in access to modern inputs and address factors that hinder the commercial transformation of farm households.

Keywords: Cereal, input use, productivity, production efficiency, commercialization, Ethiopia

3.1. INTRODUCTION

Commercial transformation of traditional agriculture has been pursued as an important pathway for the successful development of smallholder agriculture in developing countries. Commercialization is about engagement with the market by increasing fractions of crops and animal products being destined for sale (Wiggins, et al., 2011). Commercialization involves a transition from subsistence-oriented to increasingly market-oriented patterns of production and input use (Govereh, et al., 1999; Poulton, 2017). It is not only restricted to high-value cash crops but also occurs for the primary staple cereals as well (von Braun, 1995; Pingali, 1997). It is a product choice and input use decision that is based on the principles of profit maximization (Pingali & Rosegrant, 1995; Pingali, 1997; Pingali, et al., 2005). It can occur on the output side and inputs side (von Braun, 1995), where farm households can make production decisions based on market signals and significant participation in input and output markets (Gebremedhin & Jaleta, 2012). This shows that commercialization is beyond the marketing of agricultural outputs.

Commercialization allows farm households to intensify their use of productivity-enhancing agricultural technologies and inputs. It leads farm households to progressively substitute non-traded inputs in favor of purchased inputs (Pingali & Rosegrant, 1995; Pingali, 1997). According to these authors, with increase commercialization, farm households substitute non-traded inputs with modern inputs, such as high yielding varieties, chemical fertilizer, and human labor with mechanical and chemical technologies for more control-intensive operations, such as weeding and harvesting. In addition to this, a market-oriented production system helps farm households to adopt knowledge-intensive technologies (Pingali & Heisey, 1999) and thereby improve the most efficient use of smallholders' resources (von Braun & Kennedy, 1994). Through the most efficient use of capital inputs and knowledge-intensive technologies, commercialization further stimulates productivity in agricultural production (Poulton, 2017). For example, the evidence in Asia during the green revolution as documented in (Pingali & Heisey, 1999) suggests that efficient use of land augmenting technologies such as fertilizer has considerable scope to make a large contribution in cereal crop productivity.

Commercial orientation of farm households is also facilitated by the availability of new technologies, improved seeds, agronomic practices, market access, and investment in infrastructure (von Braun, et al., 1991). Similarly, Leavy and Poulton (2007) also identified population growth, technical change, enhanced market access, crop intensification, and asset accumulation as drivers of agricultural commercialization. In brief, farm households' adoption of improved technologies fundamentally affects the market participation choices by improving input use efficiency and productivity, whereas markets influence technology adoption patterns by affecting the returns to increased output (Barrett, 2008). This shows that rising agricultural productivity and increasing engagement of market participation is an inevitable policy priority for improving the welfare of smallholders in developing countries.

Despite its role in improving smallholders' welfare (Barrett, 2008), the food production system in sub-Saharan Africa (SSA) is mainly characterized as a subsistence-oriented production system. Therefore, developing countries in SSA require improving the ability of smallholder farmers to produce marketable surplus and participate actively in both input and output markets (Otekunrin, et al., 2019). In Ethiopia, as part of the efforts to commercialize smallholder agriculture, the government has been pursuing all-inclusive measures to supply and improve the use of agricultural inputs. On account of the effort, the share of smallholder farmers using agricultural inputs in the sector has been increased over the last decades. For example, the share of cereal producers using improved seed[18] has increased from 10% in 2004/05 to 21% in 2013/14; while chemical fertilizer imports have increased by 124% and fertilizer use by smallholders increased by 144% between 2004/05 and 2013/14 (World Bank, 2016). However, during the first Growth and Transformation Plan (GTP I) period the performance improved input supply still falls short of the target set. The quantity of fertilizer supplied in 2014/15 was a record 1.201 million quintals, but this was only 72.2% of the target set for the year. The supply of improved seeds was only 1.514 million quintals, which accounted for about 42% of the target set for 2014/15 (NPC, 2016). Moreover, concentrated efforts have been exerted throughout the

[18] This was driven by the rapid increase of improved maize seed adoption which increased from 12 to 28 percent over the decade (World Bank, 2016).

country in building an efficient agricultural marketing system[19], expanding rural infrastructures such as road, electricity, and telecommunication in rural areas and thereby reducing marketing costs for smallholder farmers (MoFED, 2002; MoFED, 2003; MoFED, 2006; MoFED, 2010; NPC, 2016).

However, the extent of output commercialization is very low with considerable variability across different locations in the country. For example, the 2019/20 estimate indicates, on average 23% of the grain crops produced by smallholders are marketed in 2019/20 (CSA, 2020). Existing empirical studies (Bekele, 2009; Berhanu & Moti, 2010; Abafita, et al., 2016) also reinforced the national estimates that smallholders have sold on average 25% of the crop, implying the intensity of market participation of smallholders is low. This substantiates that the requirement of better understanding the factors influencing smallholder commercialization and the policy importance of studying the input use, efficiency, and productivity effects of commercialization.

Only a few empirical studies have been conducted in developing countries to address the association between commercialization, input use, productivity, and efficiency. Strasberg et al, (1999) in Kenya studied fertilizer use and productivity effects of agricultural commercialization using the Tobit estimation procedure. Accordingly, they found that agricultural commercialization positively and significantly influences food crop fertilizer use and productivity among rural households. Consistent with this, Salau, et al. (2018) assessed the fertilizer use effect of maize commercialization in Nigeria. They found the positive effect of commercialization on fertilizer usage among maize farming households. Rios et al. (2008) is a good example of a study that analyzed the direction of causality between market participation measured by sale index and productivity measured in terms of technical efficiency for the total crops grown by farm households in Tanzania, Vietnam, and Guatemala using 2SLS procedure. The study has found a positive and significant correlation between commercialization and productivity in Vietnam and Guatemala but insignificant in Tanzania. In Ethiopia, the study by Bekele, et al. (2010) explores the productivity effect of commercialization by taking the most important cereal and pulse crops in their respective areas and showed that the productivity of

[19] The Ethiopian Government has envisaged to develop the efficiency of agricultural marketing system through grading agricultural produce, provision of market information, promoting and strengthening cooperatives, strengthening the participation of private capital in marketing, and improving rural finance (MoFED, 2003).

farm households is positively and significantly influenced by the commercialization orientation factor.

Many of the studies reviewed above address only the fertilizer use effect commercialization, suggesting the need to conduct an all-inclusive study that systematically explores the input use effects commercialization by taking improved seed, chemical fertilizer both UREA and NPS, agrochemical, and hired labor into account. Besides, except for Rios et al. (2008), most of them did not analyze the bi-directional causality between market participation and productivity. Therefore, considering the existing knowledge gap and little research on the efficiency effect of commercialization, the present study adds to the previous findings by addressing three important research questions based on plot-level data generated from randomly selected farm households: 1) how does commercialization affect input use and cereal crop productivity? To this end, the study demonstrates the application of the simultaneous mixed process model and dose-response function. 2) Is there causality between technical efficiency and cereal crop commercialization among farm households? Unlike the previous study, we estimated the bi-directional causation between technical efficiency and cereal crop commercialization using a three-stage regression framework (3SLS), which renders the simultaneous solution of all questions using generalized least square (Heck, 1977), and provides a more efficient estimate as compared to all IV estimators (Greene, 2012); and 3) What are the factors influencing the commercialization of cereal crops.

The study report is organized as follows. In the first section, the data and the methodology employed to address the research questions are introduced. Section 2 provides the key analytical results and their associated discussion. The final section presents the concluding remarks and the way forwards.

3.2. METHODOLOGY

3.2.1. Analytical approaches

Measuring agricultural commercialization: Commercialization of cereal crops was measured using Commercialization Index (CCI) proposed by von Braun & Kennedy (1994). It was computed as the share of the value of cereal crop sales to the total value of the total cereal production. This index would be zero, indicating total subsistence, while the value approaching 100 signifies a higher degree of commercialization or a great percentage of marketed cereal crops. This way of measuring smallholder commercialization allows to classify sellers and non-sellers, or producers of staple and cash crops with additional dimensions on how much of their harvest households choose to sell (Carletto, et al., 2017). The index is specified as follow:

$$CCI_{ij} = \frac{\sum_{k=1}^{K} S_{ik}\bar{P}_k}{\sum_{k=1}^{K} Q_{ik}\bar{P}_k} = \begin{cases} = non - seller \\ > 0\ seller \end{cases} \quad \text{--- (3.1)}$$

where, CCI_i a continuous variable that signifies the degree of commercialization of household from the output side, S_{ik} is the quantity of cereal output k sold by household i, $\bar{P}_j$ is the average price of cereal output k at the community level, Q_{ij} is the total quantity of cereal output k by household i.

Measuring technical efficiency: Technical efficiency scores of cereals producing farm households were constructed using a two-step meta-frontier framework of Huang, et al. (2014)[20]. This approach is used because of the prevailing heterogeneity in terms of production technology between the sample *Weredas* of the study. To determine this, we conducted an LR test, which is defined by $LR = -2^{*}(lnL_p - (lnL_A + lnL_E)$, where, lnL_p, lnL_A, and lnL_E represents the log-likelihood values, which are obtained from the pooled data set of the overall stochastic frontiers and the sum of the values of the log-likelihood functions for the sample study frontiers, respectively. The degree of freedom was 22, calculated as the difference between the number of parameters estimated under pooled data and the parameters estimated in the respective study *Weredas*. Therefore, the result of the LR test [chi2=82.96 (p=.0000)] provides enough evidence to reject the null hypothesis of homogeneous production technology for the study. Following (Huang, et al., 2014), the two-step approach to estimate the meta-frontier has two stochastic frontier production functions as defined below:

$$lny_i^k = f^k\left(x_i^k, \beta^k\right) + v_i^k - u_i^k\ ,\ \ i = 1, \ldots, n(k) \text{ ----(3.2)}$$

$$ln\hat{f}^k\left(x_i^k, \beta^k\right) = f^M\left(x_i^k, \beta\right) + v_i^M - u_i^M \text{ …..(3.3)}$$

[20]Many studies (Ng'ombe, 2017; Alem, et al., 2018) employed this approach to estimate, and compare the efficiency scores for smallholders.

where, y_i^k represents the value of total cereal output of the *i-th* sample farm household in the k^{th} *Wereda*, x_i^k is a kx1 vector of direct inputs of the *i-th* farm household; β^k a vector of unknown parameters to be estimated; v_i^k denotes the random variation in output (y_i^k) due to factors outside the control of the firm (measurement errors and other noises), and u_i^k is a non-negative technical inefficiency component of the error term that captures factors under the control of the farm; v_i^k is assumed to be independently and identically distributed as $\mathrm{N}\left(0, \sigma_v^{k2}\right)$ and is independent of u_i^k; $ln\hat{f}^k\left(x_i^k, \beta^k\right)$ is the estimate of the group-specific frontier from Eq.(3.2). Since the $ln\hat{f}^k\left(x_i^k, \beta^k\right)$ are group-specific, the SFA is estimated two times, one for each *Wereda*. The output estimates from the two *Weredas*/groups are then pooled to estimate Eq. (3.3). The meta-frontier should be larger than or equal to the group-specific frontier that is, $f^k\left(x_i^k; \beta^k\right) < f^M\left(x_i^k, \beta^k\right)$. The technical efficiency scores of the farm households by construction range between 0 and 1, indicating the value approach to 1 shows a higher level of technical efficiency.

3.2.2. Empirical model and estimation strategy

Effect of commercialization on input use and cereal yield: In our estimation of the input use and yield effects of commercialization, we considered cereal yield and five types of inputs namely the use of the improved seed, chemical fertilizers (UREA and NPS), agrochemical, and hired labor. Because the level of yield and its associated input use is dependent on each other, and similarly the use of one type of input is contingent on the other, the effects of commercialization on yield and input use of farm households are estimated simultaneously. Thus far, to account for the simultaneity, interdependency, and nature of the exogenous variables, six system equations were specified and estimated based on Conditional Mixed Process (CMP) approach. By doing so, the study represents the first application of the CMP framework in farm productivity and input use research. The framework can be applied to estimate several interdependent binary and continuous outcomes simultaneously (Roodman, 2011). The model is specified as the form stated below.

$$Y_i^* = X_1'\beta_1 + \varepsilon_{1i},$$
$$S_i^* = X_2'\beta_2 + \varepsilon_{2i}, \quad \text{---} \quad (3.4)$$

$U_i^* = X_3'\beta_3 + \varepsilon_{3i},$

$N_i^* = X_4'\beta_4 + \varepsilon_{4i},$

$C_i^* = X_5'\beta_5 + \varepsilon_{5i},$

$L_i^* = X_6'\beta_6 + \varepsilon_{6i},$

where,Y_i^*, $S_i^*, U_i^*, N_i^*, C_i^*$, and L_i^* are cereal yield, which is measured by the monetary value of cereal crops per hectare, the use of improved seed (1 if household used improved variety on some proportion of farmland, 0 otherwise), the intensity of nitrogen fertilizer (UREA) used (ETB/ hectare); NPS fertilizer (ETB/hectare); agrochemical (ETB/hectare); and the use of hired labor (1 if the household used hired labor in the production season, 0 otherwise), respectively. X_1 to X_6 are the vector of control variables; β_1 to β_6 vector of the parameter to be estimated; and ε_{1i} to ε_{6i} are error terms. It is assumed thatX_i are fixed, rank (X_i) = k_i, the mean of the error term is equal to zero $E(\varepsilon_i) = 0$, $E(\varepsilon_i \varepsilon_i') = \sigma_{ii} I_T$, where σ_{ii} is the variance of the disturbances in the $i^{th}$the equation for each observation in the sample, and the error terms are strictly exogenous, homoscedastic, and uncorrelated across observations but correlated across equations. We estimated the input and yield effects of commercialization via STATA's CMP command.

In addition to the estimation technique mentioned above, we used a dose-response function with the *Generalized Propensity Score (GPS)* to complement the findings of fertilizer (UREA and NPS) and the agrochemical use effect of commercialization. Unlike OLS regression analysis, which assumes constant effects, such estimation technique has the advantage to seize up the dynamic effects of the treatment on outcome variables at different doses/treatment levels.

In the estimation of the average dose-response function, we have a random sample of farm households, which is represented by $i = 1,2, \dots, N$, and a vector of covariates X, the level of commercialization as a treatment variable, and the potential outcomes Y_i, in our case the use of chemical fertilizer (UREA and NPS) and agrochemical. Hence, the potential outcome corresponds to the level of treatment received, $Y_i = Y_i(T_i)$. Following Hirano & Imbens (2004); Jochen, et al. (2012); Imbens (2000), the conditional density of treatment given the covariates can, therefore, be defined as:

$$r(t, x) = f_{T|X}(t|x) \quad \text{---} \quad (3.5)$$

Following this, the GPS is defined as:

$$R = r(T, X) \quad \text{---} \quad (3.6)$$

The estimation process in the dose-response function with GPS follows three steps. In the first step, the GPS is modeled and generated. To generate the GPS score, the normal distribution for the outcome variables given the covariates was fulfilled as it is specified in Eq.3.7.

$$T_i | X_i \sim N(\beta_0 + \beta_1' X_i, \sigma^2 \quad \text{---} \quad (3.7)$$

The estimated GPS is calculated as:

$$\hat{R}_i = \frac{1}{\sqrt{2\pi\{\sigma^2}} \exp\left(-\frac{1}{2\hat{\sigma}^2}\left(T_i - \hat{\beta}_0 - \hat{\beta}_1' X_i\right)^2\right) \quad \text{---} \ (3.8)$$

Our treatment variable is the level of commercialization of farm households that varies between 0 and 1. Given the distribution of the treatment variable, we decided the treatment intervals of commercialization following Gebreselassie & Sharp (2008); Goshu (2012) to estimate the average potential outcome (see Appendix IIIC Table C1). After creating the treatment intervals, following Hirano & Imbens (2004), we construct treatment cutoffs and store the values to a 10-dimensional vector. To evaluate the GPS for all sample observations (Eq. 3.8), we regressed the treatment variable on the covariates based on the maximum likelihood estimator.

In the second step, we estimate the conditional expectation of the outcome that can be represented by a function of two-scale variables T and GPS R, as specified below.

$$\beta(t, r) = E(Y | T = t, R = r) \quad \text{---} \ (3.9)$$

For our empirical implementation of the second step, we use the following approximation (Eq. 3.10) by which we regressed the outcome variable (the expected input use in ETB per ha) on the observed value of T_i, the generalized propensity scores, their squared terms, and an interaction term of these two independent variables (see Appendix IIIC Table C2, C3, and C4).

$$E[Y_i | T_i, R_i] = \alpha_0 + \alpha_1 T_i + \alpha_2 T_i^2 + \alpha_3 R_i + \alpha_4 R_i^2 + \alpha_5 T_i R_i \text{---} \ (3.10)$$

The third step is to estimate the doses response function at each particular level of treatment. The dose-response function is expressed as:

$$\mu(t) = E[\beta\{t, r(t, X)\}] \text{---} \ (3.11)$$

The average dose-response function is generated by averaging the conditional expectation function over the GPS at the particular level of treatment t. The average potential outcome at treatment level t is estimated based on the following functional form:

$$E(Y|t) = \frac{1}{N}\sum_{i=1}^{N} \hat{\alpha}_0 + \hat{\alpha}_1 t + \hat{\alpha}_2 t^2 + \hat{\alpha}_3 \hat{r}(t, X_i) + \hat{\alpha}_4 \hat{r}^2(t, X_i) + \hat{\alpha}_5 t\hat{r}(t, X_i) \text{ --- (3.12)}$$

The dose-response function is estimated using a STATA command developed by Bia & Mattei (2008).

Nexus between technical efficiency and commercialization of farm households: In this study, cereal crop commercialization is assumed to relate to the technical efficiency of farm households and the vise-versa. Moreover, both technical efficiency scores and commercialization of farm households are potential endogenous variables, and neglecting this results in biased estimates. To address the reverse causality and the possible endogeneity problem, the study made use of a method of estimation, defined as a three-stage simultaneous model (3SLS), which jointly estimates the entire system of equations. 3SLS, which was first designed by Zellner & Theil (1962) is a structural equation where some equations consist of endogenous explanatory variables among the dependent variables from other equations in the system.

In a three-stage simultaneous model, the coefficients are estimated from a three-step process. First, builds the instrumented values for all endogenous variables from the predicted values obtained from the regression of each endogenous variable on all exogenous variables within the system. Second, obtain a consistent estimate for the covariance matrix of the equation disturbances based on the residuals from a 2SLS estimation of each structural equation. Finally, using the covariance matrix estimated in the second stage and the instrumented values, the model performs a GLS-type estimation for the structural parameters of interest in the models. GLS estimator is more efficient than SUR estimator (Greene, 2012).

The 3SLS model can be specified as follow:

$$y_1 = \gamma_1 y_2 + \beta_{11} x_1 + \beta_{12} x_2 + \cdots + \beta_{1i} X_i + \varepsilon_1, \qquad \text{--- (3.13)}$$

$$y_2 = \gamma_2 y_1 + \beta_{21} x_1 + \beta_{22} x_2 + \cdots + \beta_{2i} X_i + \varepsilon_1 \qquad \text{--- (3.14)}$$

where, y_1 and y_2 refers to endogenous variables, in our case the technical efficiency scores and the commercialization index of the farm household i;γ's are the coefficients of endogenous variables;x's are control variables; ε's are the error terms with mean zero, constant variance, and zero covariance but non-zero covariance between$y$'s and ε's.

In our empirical model, to estimate consistent estimates from the structural equation (3SLS), both equations must satisfy the rank and order conditions of identification. For the rank condition to be fulfilled, the second question must contain at least one exogenous variable with a non-zero coefficient that is excluded from the first equation, whilst, for the order condition to be satisfied, at least one of the exogenous variables with a non-zero coefficient must be excluded from the first equation (Wooldridge, 2012). In addition to this, as it is stated in Gujarati (2004), for an equation to be identified in a model of M simultaneous equations, we must exclude at least $M-1$ variables, and the number of predetermined variables excluded from the equation must not be less than the number of endogenous variables included in that equation less one. Intuitively, to estimate the parameters consistently, we specified two main equations (Eq. 3.15 and 3.16) as specified below and considered several variables to be excluded from both equations.

Commercialization equation (Eq.3.15):

$$TE = \beta_0 + \beta_1 Com + \beta_2 Age\_hd + \beta_3 Edu\_hd + \beta_4 hhsize + \beta_5 Extn + \beta_6 Non\_farm + \beta_7 Coop + \beta_8 No\_Crop + \beta_9 Crop\_dmg + \beta_{10} Mkt\_info + \beta_{11} Dis\_input + \beta_{12} Pop\_pres + \beta_{13} Road\_con + \beta_{14} TLU + e_1$$

Technical efficiency equation (Eq.3.16):

$$Com = \alpha_0 + \alpha_1 TE + \alpha_2 Age\_hd + \alpha_3 Edu\_hd + \alpha_4 hhsize + \alpha_5 Extn + \alpha_6 Mkt\_dist + \alpha_7 Non\_farm + \alpha_8 Coop + \alpha_9 No\_Crop + \alpha_{10} Cell\_phone + \alpha_{11} Land\_qlty + \alpha_{12} No\_plot + \alpha_{13} Pop\_pres + \alpha_{14} Road\_con + \alpha_{15} lnAst + e_2$$

Determinants of cereal crops commercialization: The determinants of the level of farm household cereal commercialization are determined using the Tobit model. The Tobit model here is used because it allows fitting censored continuous outcomes of the commercialization that vary between zero and one. Before using the Tobit model, sample selection bias, which may result in inaccurate estimation of the parameters, was checked by using the Heckman two-step estimator. Contrary to our expectation, no sample selection bias was introduced (insignificant lambda value), hence the Tobit model was confirmed appropriate for the study. Following Tobin

(1958), the latent regression model, which will be used in the study, is specified in the following form.

$$y_i^* = \beta_0 + \beta_1 x_1 + \beta_1 x_1 + \ldots + \beta_i x_i + e = x\beta + e \quad \text{---(3.17)}$$

Following Cong (2000) the observed outcome for observation i is defined as:

$$y_i = \begin{cases} 1 \; if \; y_i^* > 1 \\ y_i^* if \; 0 < y_i^* < 1 \\ 0 \; if \; y_i^* < 0 \end{cases} \text{---(3.18)}$$

where, y_i^* is the latent variable and y_i is an observed dependent variable (the commercialization index for farm household i), x is a vector of independent variables and their prior expected effect as it is depicted in Table 3.2 below, e is the error term that is normally distributed, $e \sim N(0, \sigma^2)$.

3.2.3. Explanation of variables used in the empirical models

Table 3.1 below summarizes the dependent and independent variables used in the estimation procedures. The major dependent variables considered in the analysis include cereal yield, improved seed, hired labor, cost of nitrogen fertilizer, cost of NPS fertilizer, agrochemical, technical efficiency scores, and scale of commercialization of farm households (Table 3.1). Moreover, the study identified several covariates from the review of various theoretical and empirical literature that is to be used as a control variable in estimating the input use, yield, and efficiency effects of commercialization among farm households. In addition to this, the study also hypothesized the covariates to explore the determinants of cereal crop commercialization among farm households, and their prior expectation is presented in Table 3.2 below.

Table 3.1: Hypothesized effects of cereal commercialization on input use, TE and cereal yield

Variables	Outcome variables						
	Cereal yield (ETB/ha)	**Improved seed (Binary: yes=1)**	**Hired labor (Binary: yes=1)**	**UREA fertilizer (ETB/ha)**	**NPS fertilizer (ETB/ha)**	**Agro-chemicals (ETB/ha)**	**TE (0-1)**
Commercialization index (CI)	+	+	+	+	+	+	+
Control variables	-	-	-	-	-	-	-

Table 3.2: Hypothesized variables for the determinants of cereal commercialization

Variables	Unit	Commercialization
Dependent variable		
Commercialization index (CI)	Number (0-1)	
Independent variables		
Head gender	Binary: male=1	+
Head age	Years	-
Household size	Adult equivalent units	-
Dependency ratio	Number	-
Access to extension service	Binary: yes=1	+
Access to credit service	Binary: yes=1	+
Distance to nearest market	km	-
Cooperative membership	Binary: yes=1	+
Non-farm employment	Binary: yes=1	+/-
Household owns cellphone	Binary: yes=1	+
Land quality	Index	-
Plot owned	Number	+/-
Land owned	Hectares	+
Agricultural assets	ETB	+
Oxen-plow	Head count	+
Livestock ownership	TLU	+
Fertilizer used	Kg	+
Use of HYVs	%age of cultivated land in ha	+
Market channels		
- Village level farmer traders	Binary: yes=1	+/-
- Rural assemblers outside the village	Binary: yes=1	+/-
- Cooperatives	Binary: yes=1	+/-
- Consumers	Binary: yes=1	+/-
- Retailers	Binary: yes=1	+/-
- Wholesalers	Binary: yes=1	+/-

3.3. RESULTS AND DISCUSSION

3.3.1. Characteristics of farm household commercialization

In the study area, farm households grow *'teff'*, wheat, barley, maize, and sorghum, in order of their importance. The result shows that despite the significant variation among cereal crops, on average, farm households sold close to 38% of their cereal outputs (Table 3.2). The amount is relatively higher than the national average that, on average, farm households in Ethiopia who participated in the market sell 23% of cereals (CSA, 2020). The scale of crop commercialization in different parts of Ethiopia was reported in several studies. For example, Gebremedhin & Jaleta (2010) in three districts of Bure, Goma, and Meiso found that on average farm households sold 25% of crop output, indicating moderate market participation. In central Ethiopia, it is reported that farm households who participated in the market sold 22% of crop output (Demeke & Haji, 2014). Similarly, in Malawi, Uganda, and Tanzania, farm households sell an average of 18%, 26%, and 28% of the aggregate crop output, respectively (Carletto, et al., 2017). Moreover, on average, 59% of farm households sold 35-65% of the cereal crop produced. The majority of the farm households (82%) used a donkey and the rest 8% made use of the foot, cart, and motorized vehicle as a means to convey cereal out to the marketplaces.

Crop-wise, among cereal crops, *'teff'* is an important market-oriented cereal crop grown for food, cash, and livestock feed. A higher proportion of farm households engaged in *'teff'* marketing, suggesting *'teff'* is an important source of income for the farm households. On average, about 89% and 39% of farm households sold 39% and 18% of *'teff'* and wheat, respectively, indicating that the proportion of farm households who marketed *'teff'* and wheat is by far greater than the proportion of farm households who sold the rest of the crops. The annual average volume of cereals sold was 23,919.61 ETB. Key informant interviews (KIIs) and focus group discussions (FGDs) responses support our result that farmers are rational in crop choice decision that is based on market signals. The farm household produces white *'teff'* and wheat for the market and the rest of the corps (mixed/red *'teff'*, barley, maize, and sorghum) for home consumption because white *'teff'* and wheat fetch relatively more income for the households.

Table 3.3: Market participation and volume of sales

Crop	% households selling	% of cereal output sold	Volume of sale (ETB)
'Teff'	88.77	39.39	18715.43
Wheat	38.36	17.61	12676.48
Barely	10.05	20.99	4842.53
Maize	1.59	2.77	2787.02
Sorghum	2.38	27.93	8308.72
Overall cereals	91.27	37.72	23919.61

Source: Authors' analysis using primary data (2020)

3.3.2. Marketing channels of farm households

Farm households in the study area sold cereal outputs to multiple options of market outlets, such as farmer traders in the village, rural assemblers, cooperatives, consumers, retailers, and wholesalers. About 29% of farm households sold cereal crops to retailers, followed by farmer traders in the village (26%) and consumers (19%) (Figure 3.1). Nonetheless, about 40% of farm households who sold more than 65% of cereal crops traded a higher proportion of cereal outputs with wholesalers and retailers. This indicates that wholesalers and retailers, in that order, are the main market outlet choices of farm households for a higher volume of cereal outputs. Abate, et al. (2019) reported that the volume of crop output has a positive and significant association with the likelihood of choosing wholesaler and retailer market outlets.

Figure 3.1: Proportion of households selling market outlets

Source: Authors' analysis using primary data (2020)

3.3.3. Yield, input use, and technical efficiency by household commercialization

Table 3 presents the comparative assessment of yield, input use, and technical efficiency of farm households by their commercialization status[21]. On average, farm households earned an annual income of 36137.35 ETB/ha from cereal cultivation. On average, farm households spent up to 1785 ETB/ha, 1799 ETB/ha, and 233 ETB/ha to cover the cost of nitrogen fertilizer, NPS fertilizer, and agrochemical, respectively. Almost all farm households in the study area intensively used both nitrogen fertilizer and NPS in cereal crops. The one-way analysis of variance shows that cereal yield, the intensity of nitrogen fertilizer, and technical efficiency varied significantly across the commercialization status of farm households.

[21] Farm households were classified into three sub-groups by their commercialization status, such as subsistence, semi-commercialized and commercialized following Gebreselassie & Sharp (2008); Goshu (2012).

Table 3.4: Comparative assessment of the key continuous variables by commercialization status

Variables	Full sample [Mean]	Commercialization index Subsistence [<30%]	Semi-commercialized [30-65%]	Commercialized [>65%]	F-Value
Cereal Yield (ETB/ha) log	10.41	10.27	10.45	10.65	11.24***
Nitrogen Fertilizer (ETB/ha) log	7.23	6.97	7.33	7.44	4.42**
NPS fertilizer (ETB/ha) log	7.30	7.36	7.30	7.05	0.98
Agrochemical	2.46	3.28	3.47	4.35	1.3
Technical efficiency	0.58	0.49	0.61	0.71	33.03***

Source: Authors' analysis using primary data (2020)
Coefficients with ***, **, and * are significant at 1, 5, and 10 percent levels of significance, respectively

More than 35% of farm households used high-yielding varieties (HYVs) mainly for *'teff'*, wheat, and maize (Table 3.5). From which, about 41% and 60% of them were semi-commercialized and commercialized farm households. From the Chi-square test result, we can see that there was a significant difference in the use of high-yielding varieties across the commercialization scale of farm households. The other key variable considered in this study is the use of hired labor, assuming that with an increased level of commercialization, farm households tend to progressively hire labor in addition to the available family labor. As per our prior expectation, farm households employed additional hired labor with an increasing level of commercialization. The result of the Chi-square test also confirmed that the use of hired labor varies positively and significantly with the commercialization scale of farm households. This appears to be associated with the high demands for labor to cultivate *'teff'*, produced mainly for the market, as compared to other crops.

Table 3.5: Comparative assessment of the key categorical variables by commercialization status

Variables	Full sample [%age]	Commercialization index Subsistence [<30%]	Semi-commercialized [30-65%]	Commercialized [>65%]	Chi-square
HYVs (yes)	35.45	20.18	40.57	60.00	19.96***
Hired labor (yes)	78.04	65.54	81.97	90.00	21.63***

Source: Authors' analysis using primary data (2020)
Coefficients with ***, **, and * are significant at 1, 5, and 10 percent levels of significance, respectively

3.3.4. Input use and yield effects of commercialization

The conditional mixed process model estimation on the yield and input use effect of commercialization of cereal crops is provided in Table 5 below. As per our prior expectation, cereal crop commercialization had a positive and significant effect on yield and input use (nitrogen fertilizer and agrochemical). The model results suggest that a 10% increase in the scale of cereal crop commercialization leads to a 5.5% increase in cereal crop productivity, holding other factors being constant. In the same way, keeping other factors being constant, a 10% change in cereal crop commercialization enhances the expenditure on nitrogen fertilizer and chemicals by about 6.8% and 23.4%, respectively. Plot-level cost-benefit analysis of cereal crops was undertaken to estimate the net income and confirm the input use implication of commercialization. Accordingly, as it can be learned from cost benefit analysis (see Appendix IIID), on average, to obtain a net benefit of 29042.61 ETB/ha from producing cereal crops, the farm households are expected to incur an estimated total production cost of 7094.74 ETB/ha, excluding the cost of family labor and draft power. This validates the positive input use effects of commercialization among farm households.

Contrary to our expectation, the estimated coefficient for NPS fertilizer was found negative and insignificant suggesting that the input use effect of commercialization of food crops is more responsive to nitrogen fertilizer than NPS. The plausible explanation of the findings is related to farm households' perception that the higher yield effect of the use of nitrogen fertilizer as compared to the NPS counterparts. The use of high-yielding varieties and hired labor is also positive and significant with the scale of commercialization at 1% level, ceteris paribus, suggesting that commercialization enhances the probability of farm households using high-yielding varieties and hiring additional labor to cultivate cereal crops. Our findings support the result of earlier studies (Strasberg, et al., 1999; Salau, et al., 2018) that food crop commercialization enhances the input use and productivity of farm households.

Our empirical evidence suggested that as the degree of commercialization rises, farm households increasingly use more hired labor as a source of power than subsistence farm households. However, farm households during focus group discussion reported that wage for hired labor is rising from time to time, such that it becomes unaffordable for many households. As stated in Pingali (1997), using hired labor in conducting intensive farm operations will not be profitable under escalating farm wage conditions.

Table 3.6: CMP model result on yield and input use effect of commercialization

Variables	Yield (ETB/Ha)	UREA (ETB/HA)	NPS (ETB/Ha)	Chemical (ETB/Ha)	HYVs (Yes/No)	Hired labor (Yes/N0)
Commercialization index	0.5499*** (0.1174)	0.6808** (0.3128)	-0.2869 (0.2599)	2.3446** (1.1635)	1.6936*** (0.5048)	1.2497*** (0.4337)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Constant	10.7097*** (0.2123)	7.4181*** (0.5657)	7.8786*** (0.4683)	-1.0295 (2.1314)	-0.8027 (0.9608)	-1.5512** (0.7602)
Number of observation LR chi2(83) Prob > chi2 Log-likelihood	378 262.44 0.0000 -2387.36					

Source: Authors' analysis using primary data (2020)
Coefficients with ***, **, and * are significant at 1, 5, and 10 percent levels of significance, respectively

To triangulate the econometric model estimation of the input use and yield effects of commercialization, we further estimated the dose-response function with a generalized propensity score (GPS). Accordingly, Figures 3.2., 3.3, and 3.4 displayed the estimated dose-response function (DRF) and the marginal treatment effect function (MTE) of the effect of commercialization on input use (nitrogen fertilizer, NPS, and agrochemical) in monetary terms.

The result of the dose-response estimation in Figure 3.2 shows that the relationship between farm households' scale of commercialization and the use of nitrogen fertilizer is positive and significant, demonstrating the more the farm households earn income from the sale of marketable surpluses, the higher the farm households can cover the cost of nitrogen fertilizer, which is consistent with the result of CMP model estimation. The DRF shows that the positive effect of commercialization on nitrogen fertilizer use was increasing at a fast rate with some variability between the levels of commercialization at about 30% to 50%. However, as it is seen in Figure 3.3, the MTE displayed that the effect of commercialization on the use of nitrogen fertilizer tends to increase up to 60% of the commercialization level of farm households and starts to flatten out at about 80% and immediately after this point begins smoothly declining. This suggests that additional income greater than 60% of the sale of surplus production of cereal grains does not count any incremental effect on the use of nitrogen fertilizer.

In contrary to this situation, the input use of the effect of commercialization on NPS was found negative and insignificant, suggesting that the use of NPS fertilizer among the farm households is less responsive to additional income earned from the sale of cereal grains (Figure 3.3). Figure 3.4 displays the positive effect of commercialization on the use of agrochemicals, indicating that the more the farm households are oriented to the market, the higher they invest to purchase agrochemicals for pest, disease, and weed controls. The result on the positive and significant effects of cereal commercialization calls for an improved and efficient input supply system in the country. In relation to this, primary cooperatives are in charge of input distribution throughout the country and private vendors are also engaged in supplying agrochemicals to the farming community. The result from the focus group discussions, however, disclosed that the input market was not as efficient as expected particularly in the supply of agrochemicals on account of the limited capacity of primary cooperatives and entrusted private vendors. In theoretical literature, it is established that even though the commercialization of smallholder agriculture involves the withdrawal of government from input supply control and the removal of subsidies, the private sector is not entrusted (Sokoni, 2008) and may lead to a rapid increase in input price and adulteration. Therefore, at this stage of development, key informants informed that capacitating primary cooperatives through all-inclusive business models and financial arrangements may help to partly circumvent challenges related to input price and adulteration.

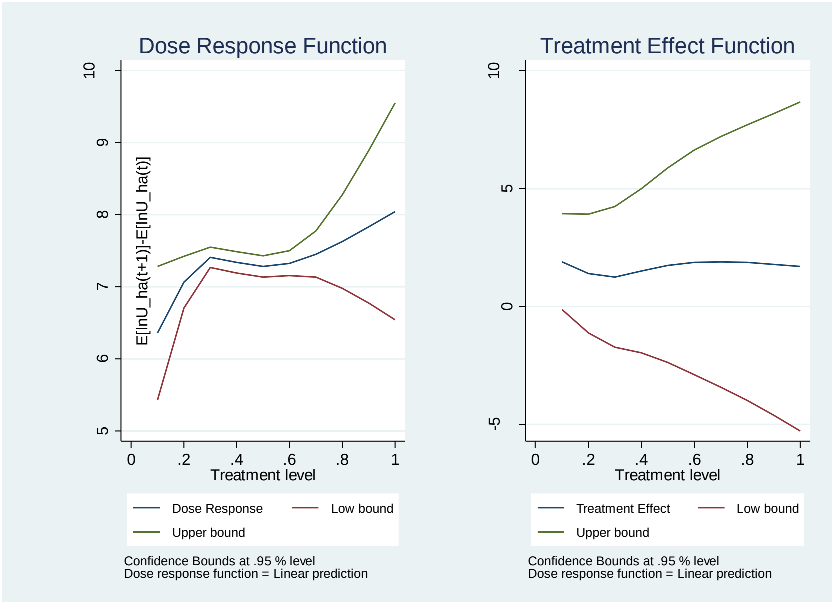

Figure 3.2: Estimated input use effect of dose-response function (UREA)
Source: Authors' analysis using primary data (2020)

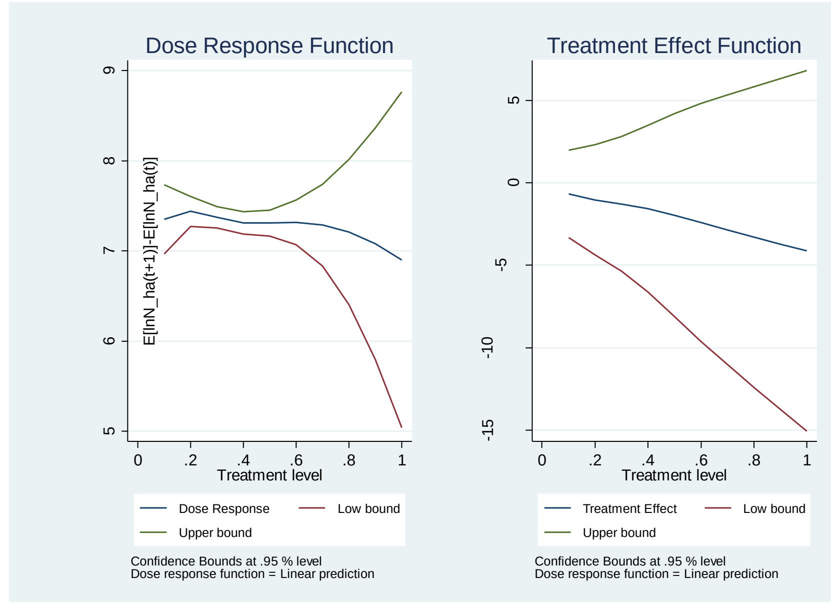

Figure 3.3: Estimated input effect of dose-response function (NPS)
Source: Authors' analysis using primary data (2020)

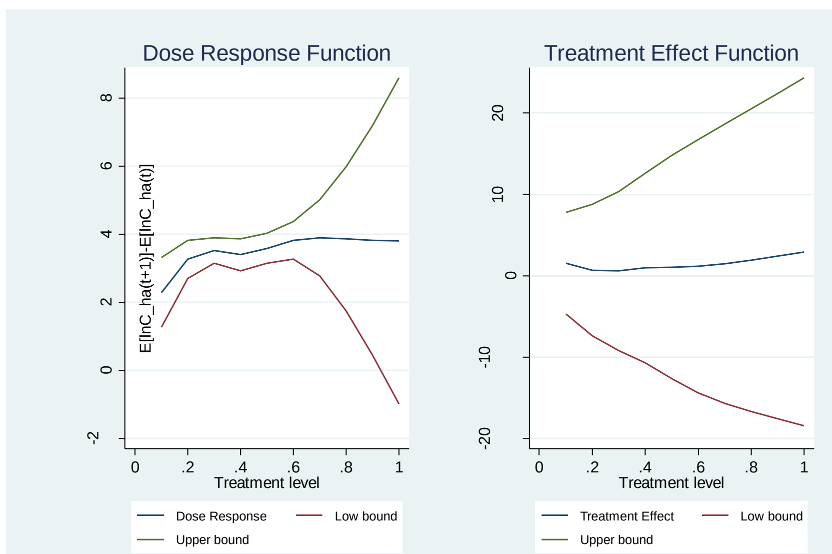

Figure 3.4: Estimated input effect of dose-response function (Chemical)
Source: Authors' analysis using primary data (2020

3.3.5. Nexus Between Technical Efficiency and Commercialization

Table 3.7 presented the three-stage estimate on the nexus between technical efficiency and commercialization of farm households. The possible endogeneity problem that might be stemmed from the endogenous regressors of technical efficiency and commercialization in both of the models was sorted out by the 3SLS model, implying the estimation is unbiased and consistent. The finding shows that there is a statistically positive relationship between technical efficiency and the commercialization of farm households. The result implies that improving the technical efficiency of farm households by 10% increases the commercialization level by 4.9%, whereas, an increase in the commercialization level of farm households by 10%, the technical efficiency level is improved by 6.1%, suggesting there is bidirectional causality between technical efficiency and commercialization among the farm households. The plausible explanation for this result is that technically efficient farm households are more likely to be commercialized and the vise-versa because commercialized farmers can purchase and use modern inputs as compared to the subsistence farmers their counterparts. The findings of this study are consistent with Rios, et al. (2008).

Table 3.7: Three-stage estimate for the nexus between technical efficiency and commercialization

Variables	Technical efficiency		Commercialization	
	Coefficients	Std. Err.	Coefficients	Std. Err.
Technical efficiency	-	-	0.4864***	0.1731
Commercialization index	0.6105***	0.1775	-	-
Control and identifier variables	Yes		Yes	
Constant	0.3462***	0.0815	0.0852	0.1232
Wald chi2	128.70		119.21	
Prob > chi2	0.0000		0.0000	
R-squared	0.294		0.221	

Source: Authors' analysis using primary data (2020)
Coefficients with ***, **, and * are significant at 1, 5, and 10 percent levels of significance, respectively

3.3.6. Determinants of cereal crops commercialization

The result of the models (Tobit model and Fractional Logit model) for the determinants of farm households' level of commercialization in cereal crops is provided in Table 3.8 below. Multicollinearity test were carried out for the categorical variables using pairwise correlation, and the test result revealed no multicollinearity among the variables (greater than 0.75). Variance Inflation Factors (VIF) test for continuous variables were also checked and the value of VIF was found to be 1.23, suggesting no multicollinearity (rule of thumb of VIF less than 10). Heteroscedasticity test was conducted using the Breusch-Pagan / Cook-Weisberg test; accordingly, enough evidence was obtained to reject the hypothesis that assume the presence of heteroscedasticity, with chi2(1) = 0.10 and Prob > chi2 = 0.7563. The Likelihood Ratio Chi-Square value (221.05) was found significant, suggesting that we have enough evidence to reject the null hypothesis of all of the coefficients in the model are simultaneously equal to zero. From the explanatory variables used in the model, we found 10 statistically significant variables that determine the scale of cereal commercialization of farm households in the study area. From these important variables, sex of the household head, land endowment, access to credit service, cell phone ownership, agricultural asset holding in value terms, the use of high yielding varieties, the quantity of chemical fertilizer used, and market outlet choices positively and significantly determines the scale of cereal commercialization among farm households. Whereas, family size, dependency ratio, and non-farm income negatively and significantly determines the scale of cereal commercialization. All coefficients were with the expected signs.

Table 3.8: Model estimate results of the intensity of cereal commercialization

Variables	Tobit Model		Fractional Logit Model	
	Coefficients	**Std. Err.**	**Marginal Effect (dy/dx)**	**Std. Err.**
Sex of the household head (male)	0.0965**	0.0406	0.1018***	0.03715
Age of the household head (years)	-0.0010	0.0007	-0.0010	0.0007
Family size in adult equivalent unit	-0.0295***	0.0089	-0.0299***	0.0087
Dependency ratio	-0.0820**	0.0383	-0.0838**	0.0399
Owned cultivated land (ha)	0.0243**	0.0119	0.0232**	0.0100
Land quality index	-0.0031	0.0056	-0.0038	0.0057
Extension service (yes)	-0.0208	0.0224	-0.0227	0.0236
Credit service (yes)	0.1077***	0.0331	0.1103***	0.0320
Cooperative membership (yes)	0.0119	0.0201	0.0109	0.0203
Nearest Market (km)	-0.0014	0.0023	-0.0006	0.0026
Household owns cell phone (yes)	0.0501**	0.0218	0.0508**	0.0220
Non-farm employment (yes)	-0.0737***	0.0236	-0.0721***	0.0267
Agricultural asset holding in ETB (log)	0.0393***	0.0115	0.0398***	0.0128
Fertilizer used in kg (log)	0.0658***	0.0150	0.0669***	0.0162
Use of HYVs (proportion of farm size)	0.0462*	0.0267	0.0451*	0.0258
Village level farmer traders (yes)	0.1360***	0.0242	0.1259***	0.0285
Rural assemblers outside the village (yes)	0.1671***	0.0448	0.1616***	0.0480
Cooperatives (yes)	0.1502***	0.0364	0.1462***	0.0419
Consumers (yes)	0.1264***	0.0250	0.1130***	0.0286
Retailers (yes)	0.1503***	0.0234	0.1392***	0.0285
Wholesalers (yes)	0.1856***	0.0279	0.1785***	0.0353
Constant	-0.4273***	0.1143		
Number of observation	377		377	
Log likelihood	123.82		-237.042	
LR chi2(21)	221.05		212.92	
Prob > chi2	0.0000		0.0000	
Left censored observations	33		-	
Shapiro-Wilk W test for normality test (Prob > z) = 0.22135				

Source: Authors' analysis using primary data (2020)
Coefficients with ***, **, and * are significant at 1, 5, and 10 percent levels of significance, respectively

Sex of the household head is one of the important demographic factors that influence the commercialization process of farm households. As one can learn from the coefficient of the

Tobit model, gender has a positive and significant effect on the level of cereal crop commercialization, implying that male-headed households are more commercially oriented than their female counterparts. The result of this study is consistent with other studies (Cunningham, et al., 2008; Rubhara & Mudhara, 2019) where male-headed households are found with improved commercialization. Low levels of cereal crops commercialization of female-headed households can be associated with limited access to productive resources and improved technologies. Moreover, women in the household are overburdened by additional reproductive responsibilities and hence lower participation in the market.

Family size in adult equivalent units negatively determines the scale of cereal crops commercialization of farm households at less than 1% level. Holding for other things being constant, a 1% increase in the number of family size decreases the scale of cereal crops commercialization by 0.02%, suggesting that farm households with a higher number of family sizes tend to sell a lower quantity of cereal output at the market. Pair wise correlation test result confirmed that more household size is significantly and positively associated with more dependent at 1 level. This means that more family size creates burden on the working hands to effectively engage on commercialization. A similar finding is also reported by Siziba, et al. (2011). However, this result contradicts the findings of Ademe, et al. (2017); Abdullah, et al. (2019) who stated that the higher the size of the number of people in the household, the greater will be the possibility to participate in the market. Similarly, dependency ratio, which measured as the ratio of active members of the household to the total family size negatively affects the scale of cereal crop commercialization, suggesting that higher dependency of family members result in a significant reduction in the commercialization of cereal crop among the farm households.

Land is one of the most important production factors among farm households in rural Ethiopia. Our estimation on the coefficient of cultivated landholding shows that the commercialization level of farm households in cereal crops is positively and significantly associated with the size of cultivated landholding at less than 5% level. This means that farm households with larger cultivated landholdings were more commercialized as compared to those farm households with smaller landholdings. For example, if the size of cultivated land raises by 1%, the expected scale of cereal crop commercialization increases by approximately 0.02%, suggesting farm households with higher landholdings produce marketable surplus and are thus able to earn additional income from the sale of cereal grains. Empirical studies on the commercialization effects of the size of cultivated land show that cultivated land size has a significant positive effect on the scale of commercialization (Alene, et al., 2008; Moti, et al., 2009; Martey, et al., 2012). The positive effect of the size of cultivated land on the scale of farm households' commercialization is partly because of its advantage to produce surplus production, which can be taken to market.

Institutional arrangements such as agricultural extension, credit service, agricultural marketing, and service cooperatives advance the smooth engagement of farm households in the input and output market (Immin & Alarcon, 1993; Lerman, 2004; Moti, et al., 2009). In this study, the estimated coefficient for extension services turned up with unexpected signs when compared with theoretical and empirical literature, suggesting that it does not have any meaningful effect as a policy intervention. Access to credit service was found as an important factor that enhances cereal crop commercialization in the study area. Credit services positively and significantly determine the scale of cereal crop commercialization at less than a 1% level. This suggests that access to credit services enhances the process of commercialization by improving farm households' ability to purchase yield-enhancing modern inputs and participation in input markets. On top of this, the availability of credit services can help farm households to be market-oriented by easing the liquidity constraints of the households (Gebremedhin & Hoekstra, 2007 ; Abafita, et al., 2016). Similar findings on the effect of access to credit services on the level of farm households' commercialization are reported in empirical studies (Abafita, et al., 2016; Rubhara & Mudhara, 2019) where the scale of commercialization of farm households mounts with credit use. As expected, cell phone ownership positively and significantly determines the level of farm households' commercialization in cereal crops at less than 5% level. Cell phone ownership assists farm households to access market-related information from different sources and thus helps to improve decisions about the type, quality, and quantity of crop output for the market.

In this study, we found participation in non-farm income generation activities negatively determines the scale of cereal crop commercialization of farm households. Our result was found contrary to the previous studies (Alene, et al., 2008; Martey, et al., 2012) who argued that farm households invest the additional income from non-farm sources to acquire high-value inputs that enhance the production of marketable surplus. It is also noted that the growth in off-farm employment opportunities leads to a substitution of non-traded for traded inputs (Pingali, 1997) and thereby tends to increase the production of marketable surplus. Nonetheless, the finding of this study shows that participation in non-farm employment decreases farm households' commercialization. This could be associated with the higher the likelihood of on-farm consumption of own products as the farmers obtain more cash from non-farm resources (Gebreselassie & Sharp, 2008). Besides, farm households who participated in non-farm income-generating activities may devote less time to agricultural production (Rios, et al., 2008).

Our econometric result confirms our expectation that farm households with larger agricultural assets holdings tend to be more commercialized than those farm households having smaller agricultural assets. The result in Table 7 indicates that a 1% increase in agricultural asset holding in ETB contributes to improving the scale of cereal crop commercialization by 0.04%. Concerning this, Moti, et al. (2009) argued that the effect of asset holding can be seen from both the production and consumption sides. Production side positive effect of an asset can be considered from its role in advancing the production of marketable surplus, while on the consumption side, asset holding plays a key role by mitigating unexpected shocks in the commercialization process.

In line with our prior expectation, the use of high-yielding varieties positively and significantly improves the scale of commercialization of farm households. Similarly, the finding of the study confirmed our prior expectation that cereal crop commercialization is enhanced by the quantity of fertilizer used by farm households. For instance, a unit increase in the use of the quantity of chemical fertilizer tends to improve the scale of cereal crop commercialization by about 0.9%. The positive effect of the use of high-yielding varieties and chemical fertilizer on the scale of cereal crop commercialization among farm households is attributed to its yield advantage. The result on the intensity of fertilizer concurs with the findings of Goshu (2012) in Ethiopia.

Improved seed and chemical fertilizer are supplied to the farmers through farmers' cooperatives with full control of the government. Farm households reported that the primary cooperatives supplied different types of chemicals as well for weed, pest, and disease control though it is not enough in terms of quantity. As a result of which, farm households were forced to buy chemicals from private stores. The farm households are complaining about the quality of the chemicals and reported it ineffective in repeated application. A similar situation is reported in the literature that even though the commercialization of smallholder agriculture involves the withdrawal of government from input supply control and the removal of subsidies, the private sector is not entrusted with the responsibility of supplying inputs to rural producers (Sokoni, 2008). Therefore, it may lead to a rapid increase in input price and adulteration.

The effect of farm households' participation in different market outlets on cereal crop commercialization was estimated as depicted in Table 7. The estimation results of the model conferred that participation of farm households in all of the market outlets had a positive and significant effect on cereal crop commercialization of farm households at less than 1% level. Despite its significant effects, the magnitude of the estimated coefficients has differed among the market outlets, such that participating in the wholesale market had a higher effect on the commercialization of the farm households as compared to participating in other market outlets. The result implies that farm households who produce a higher volume of cereal output are more likely sale the cereal grains to wholesalers than other market outlets.

3.4. CONCLUSION AND RECOMMENDATION

The study sought to investigate the input, efficiency, and productivity effects of cereal crops commercialization in the *'teff'*-based mixed farming areas of Ethiopia. Our findings revealed that, on average, farm households sold 38% of their cereal output in value terms, suggesting that farm households retained more than 60% of cereal production for household consumption and other purposes. Crop wise, among cereal crops, a higher proportion of farm households engaged in *'teff'* marketing, suggesting *'teff'* is an important source of income for the farm households. The study reveals that about 29% of farm households sold cereal crops to retailers, followed by farmer traders in the village (26%) and consumers (19%). Nonetheless, a large proportion of farm households (40%) who sold more than 65% of cereal crops preferred selling cereal grains to wholesalers, indicating wholesaler is the main market outlet for volume sales.

In this study, the input use effect of cereal crops commercialization is considered for those inputs such as high yielding variety, hired labor, nitrogen fertilizer and NPS fertilizer, and agrochemicals. From the result of the CMP estimations, we deduced that the commercialization of cereal crops has a positive effect in speeding up the use of modern input except for NPS fertilizer. The effect of commercialization is stronger in accelerating the use of nitrogen fertilizer than NPS fertilizer mainly due to its higher perceived effects among farm households on the yield and yield components of cereal grains. The use of chemicals among the farm households has also been found positive along with the increased level of commercialization of farm households, confirming the use of inorganic inputs which tends to be intensive along the transformation process from subsistence-oriented farming to market-oriented one. The findings from the dose-response function also triangulated our prior results that the effect of commercialization on the use of nitrogen fertilizer and agrochemical was found positive except for NPS fertilizer.

The productivity effect of commercialization was also verified positive on the yield of cereal crops and technical efficiency of cereal producing farm households. The findings of this study implied that farm households on the one hand can improve the level of farm-level productivity through an increased level of commercialization which is channeled through its income effects and on the other hand an increased level of productivity through efficient use of production inputs helps to produce marketable surplus and link the farm households with the market. Hence, the findings of the study shed light that alleviating bottlenecks in access to modern inputs and addressing factors associated with limited access to marketing and financial services is a key area of policy intervention.

CHAPTER FOUR: HETEROGENEOUS EFFECTS OF IMPROVING TECHNICAL EFFICIENCY ON HOUSEHOLD MULTIDIMENSIONAL POVERTY: EVIDENCE FROM RURAL ETHIOPIA

Abstract

Smallholder agriculture in developing countries is characterized by low productivity. Improving the productive efficiency of farm households is considered one of the paths to increase productivity and reduce poverty. This study analyzed the poverty reduction effects of improving the technical efficiency of cereal-producing farm households using plot-level data from rural Ethiopia. The effects were also evaluated whether they were heterogeneous relative to the level of crop diversification. Multidimensional Poverty Index (MPI) and stochastic meta-frontier approach were used to estimate the poverty status and the technical efficiency scores, respectively, and the Herfindahl Index (HI) was used to compute crop diversification. The instrumental Tobit Model was specified to estimate the poverty reduction effect of technical efficiency. Our results revealed that the mean technical efficiency of farm households was estimated to be 58%. The poverty estimate results showed that a higher proportion of farm households were multidimensional poor. The incidence of poverty and the mean deprivation score was found to be 57.9% and 44.1%, respectively. Overall, the value of MPI estimated was 31.2%, implying the farm households experienced 31.2% of the total deprivations across all indicators. The HI was 0.51, indicating a moderate degree of crop diversification among farm households. The model results showed that a 10% increase in technical efficiency significantly drives down the household multidimensional poverty by 15.3% at 1% level, keeping other things being constant. Furthermore, ceteris paribus, a 10% increase in technical efficiency significantly reduces household multidimensional poverty by 7.0% and 7.8% at 1% level among moderately diversified and least diversified farm households, respectively. In conclusion, technical efficiency has a higher effect on multidimensional poverty among moderately diversified and least diversified farm households. Therefore, enhancing the productive capacity of farm households among the lower degree of crop diversification to efficiently use production inputs may assist in poverty reduction.

Keywords: Cereal, technical efficiency, multidimensional poverty, crop diversification, Ethiopia

4.1. INTRODUCTION

Several countries where agriculture is a major economic sector have introduced programs to ameliorate agrarian productivity because of its effective contribution to poverty reduction through better food security and higher farm inflows (FAO, 2017). However, people who depend on agriculture for their living are still generally much poorer than people who work in other sectors of the economy (Cervantes-Godoy & Dewbre, 2010). In the literature (Christiaensen, et al., 2006; de Janvry & Sadoulet, 2010), growth in agriculture is much further responsible to poverty reduction than other sectors and renders advanced returns in terms of poverty reduction. The multiple routes through which growth in agrarian productivity can drive down poverty include: adding real income for the growers, employment generation, generating demand for non-agricultural goods, food price, and availability, thereby advantaging net food consumers, increasing real wages, thereby serving unskilled labor and building social capital, and rural non-farm multiplier effects (Irz, et al., 2001; Minten & Barrett, 2008; Schneider & Gugerty, 2011; Ivanic & Martin, 2017).

Growth in agriculture is also believed to bring a significant impact on poverty reduction, which comes not only from its direct poverty reduction effects but also from its potentially strong growth relation effects on the rest of the economy (de Janvry & Sadoulet, 2010). In addition, it has strong correlation with poverty reduction and large economy-wide multiplier[22] effects with other sectors in the rural economy (Suryahadi, et al., 2006; Bezemer & Headey, 2008; Bekun & Akadiri, 2019), inferring that agrarian-led development strategies are sensational to achieve poverty reduction. The experience of the Green Revolution in Asia during the 1970s and 1980s also evidenced the role of agriculture as an instrument for poverty reduction and overall economic growth (Christiaensen, et al., 2011). For illustration, the evidence documented by de Janvry & Sadoulet (2010) revealed that a 10% growth in cereal yields cut rural poverty by further than 53%. Also, the yield earnings in cereal in Latin America and the Caribbean that grew at an average annual rate of 2.5% were associated with a resultant decline in rural poverty.

[22] The extent to which an increase in income in a particular sector induces an increase in income of the whole economy is referred to as the sectoral growth multiplier. Hence, the agricultural growth multiplier quantifies the impact of a certain increase in income in the agricultural sector on the growth of income in other sectors (Suryahadi, et al., 2006).

Poverty alleviation is among the overarching goals of the government of Ethiopia. To this end, the Ethiopian Government has given heavy emphasis to the growth in agricultural productivity as a means to achieve poverty reduction and bettering the welfare of poor people in the country (NPC, 2016). In the strategy and programs (ADLI, SRDP, PASDEP, and GTP I, & II), meliorate the productivity of the cereal sub-sector through increasing the production efficiency of farm households has been one of the strategies pursued for poverty reduction for the last decades. Cereals are a dominant production choice in the country in general and that of grain-based mixed farming system of the country in particular (Chamberlin & Schmidt, 2012). Cereal production accounts for roughly 60 % of rural employment, 81 % of total cultivated land, and 30 % of GDP (Rashid, 2010; CSA, 2019). Cereals regards for 62 % of average Ethiopians' daily calorie intake and represent about close to half of consumer food expenditure for an average household (Rashid, 2010; Diao, 2010; World Bank, 2018). According to the 2018/19 Agricultural Sample Survey of the CSA of Ethiopia, cereals comprise about 81.39% of the crop area under cultivation and 87.97% of total crop output (CSA, 2019), indicating that significantly small area is allocated for the production of pulse and other crops. From the total cereal crops cultivated areas, *''teff'' (Eragrostis 'teff')*, maize, sorghum, wheat, and barley, which are the core of the country's agriculture and food economy (Seyoum, et al., 2011) took up 24.17%%, 18.60%, 14.38%, 13.73% and 6.42% of the grain crop area, respectively (CSA, 2019). This denotes that the outstanding role of cereal crops for poverty reduction in Ethiopia

In Ethiopia, cereal productivity has been growing more briskly by 7.2% annually since 2004/05, whilst the cultivated area under cereal expanded only by 2.5% with a declining rate (CSA 2004/05-2019/20). At the same time, the share of the population below the poverty line, in monetary terms, considerably decline from 45.5 % in 1995/96 and 29.6 % in 2010/11 to 23.5 % in 2015/16 (NPC, 2017). Between 2010/11 and 2015/16 approximately 5.3 million people were lifted out of poverty, implying that the economic and social performance helped to reduce the position of poverty in the country. The most recent poverty estimates reported by the Ethiopian Economic Association (EEA) revealed that the absolute poverty rate in Ethiopia was 22.1% in 2015 (Goshu, 2020). Despite the remarkable decline in the prevalence of poverty in the country, however, poverty is still a major problem in Ethiopia, where over 25 million people are still live below the poverty line and the majority of them disproportionally live in rural areas of the country. In addition, from 74% of Ethiopia's farm households who live on small farmsteads, about 67% of them are under the public poverty line (Kirchner, 2021). Furthermore, even though the multidimensional poverty index decreased from 0.545 to 0.489 between 2011 and 2016, 83.5 % of the population are still multi-dimensional poor people (UNDP & OPHI, 2019). This shows that the link between agricultural productivity growth and poverty thriving topical, researchable and policy agenda and hence, sufficient empirical evidence should be generated to develop holistic and intertwined antipoverty strategies.

In the literature, growth in agricultural productivity substantially depends on the type and quality of the inputs, and how well these inputs are combined (FAO, 2017). Type and quality of inputs represent the production technology while a blend of inputs refers to the technical efficiency of the production process. This means that productivity gains in agriculture can be achieved to a large extent through the mixed use of both technological change and more efficient use of existing resources. In Ethiopia, earlier studies on production efficiency of major crops (for example, Bizuayehu, 2014; Nisrane, *et al.*, 2015; Geffersa et al. 2019) evidenced that technical inefficiency is one of the main sources for low productivity, which have to do with farm and household-specific determinant factors.

Efficiency reflects the degree of goodness with which economic units achieve their targets (Gattoufi, et al., 2007). It is a way to identify that products are produced in the best and most profitable manner (Mardani & Salarpour, 2015). Efficiency is the ability of farm households to produce maximum possible output from a given set of inputs or produce a given degree of output using a minimum possible quantity of inputs (Farrell, 1957). Production efficiency of economic units consists of two factors, i.e. technical efficiency and allocative efficiency. As stated in Chirwa (2007), technical efficiency reflects the ability of the production unit to maximize output for a given set of inputs, while allocative efficiency represents the capability of the production unit to use available inputs at optimal proportion. As such, a farm is considered technically inefficient when it does not produce the maximum level of output that can be anticipated given the type of available inputs (FAO, 2017). This signifies that beyond crop yield, empirical evidence that provides insight regarding technical efficiency and poverty nexus is an important area of policy concern.

Numerous studies, including but not limited to, (Ahmad, 2003; Abro, et al., 2014; Dzanku, 2015; Darko, et al., 2018; Islam & Haider, 2018) have been carried out to understand the relationship between productivity and poverty in developing countries using a uni-dimensional model. Furthermore, except for studies by Ahmad (2003); Abro, et al. (2014), and Islam & Haider (2018), the rest of them have employed yield to proxy agricultural productivity, which measures partial farm productivity. In sum, it can be said that studies that link production efficiency with the poverty situation of farm households in terms of its multidimensional conception are stingy. And hence, this is where this study comes to contribute to fill of this gap using a robust econometric model and a data set collected from farm households. It also adds to the existing literature by furnishing empirical evidence on agriculture and multidimensional poverty using multidimensional poverty index. Moreover, dissimilar to the previous empirical studies, this study enriches the literature by scrutinizing the heterogeneous effects of technical efficiency on poverty by farm households' crop diversification status using an instrumental variable econometric model. To sum up, this study provides empirical evidence on how an increase in technical efficiency affects the multidimensional welfare of farm households by taking into account the existing heterogeneity in terms of crop diversification.

4.2. METHODOLOGY

4.2.1. Analytical approaches

Estimation of technical efficiency (TE): Technical efficiency in this study refers to the ability of the farm household to produce maximum possible output from a given set of available inputs. It is measured as a ratio of actual to potential output of farm households, hence, as stated by FAO (2017), a farm is technically inefficient when it does not produce the maximum level of output that can be expected given the type of available inputs. In this study, technical efficiency of farm households was estimated following a two-step stochastic meta-frontier estimation approach. The approach is chosen because it assisted to flee the possible biased estimation of technical efficiency scores that may arise from the geographical heterogeneity between the sample study districts (Orea & Kumbhakar, 2004) in terms of production technology, study-specific characteristics, and agro-ecologic conditions. Based on a two-step approach, group-specific frontiers were estimated for the sample study districts in the first step, and in the second step, a meta-frontier production function was estimated for the pooled data, as shown below.

Step 1: Estimation of group-specific frontiers: A stochastic group-specific production frontier was formulated as:

$$y_i^k = f^k\left(x_i^k; \beta^k\right)e^{\left(v_i^k - u_i^k\right)}, \;\; i = 1, \dots, n(k) \;\; \text{--- (4.1)}$$

where, y_i^k denotes the value of total cereal output of the *i-th* sample farm household in the k^{th} *Wereda*, x_i^k is a kx1 vector of direct inputs of the *i-th* farm household, and β^k is a vector of unknown parameters to be estimated. v_i^k denotes the random variation in output (y_i^k) due to factors outside the control of the farm , and u_i^k is a non-negative technical inefficiency component of the error. v_i^k is independent of u_i^k and distributed at *i.i.d.* $\mathrm{N}\left(0, \sigma_{\mathrm{v}}^{\mathrm{k2}}\right)$. Whereas, u_i^k is assumed to follow truncated normal distribution at zero, *i.i.d.* ($u_i^k \sim N^+(\mu^k\left(Z_i^k\right), \sigma^{k2})$), where Z_i^k denotes farm-specific or group-specific variables that may influence on-farm efficiency performance.

Based on the maximum likelihood estimation method in Eq. (4.1), the TE of the i^{th} farm household relative to the group k^{th} frontier can be computed as:

$$TE^k = \frac{y_i^k}{f^k\left(x_i^k, \beta^k\right)e^{\left(v_i^k\right)}} = e^{-u_i^k} \;\; \text{--- (4.2)}$$

In Eq. (2) the inefficiency component (u_i^k) of the error term is the log difference between the maximum (Y_i^k) and actual output (y_i^k).

Step 2: Estimation of meta-frontier: Following Huang, et al. (2014), the stochastic meta-frontier that envelops all frontiers k^{th}groups is defined as:

$$f^k\left(x_i^k, \beta^k\right) = f^M(x_i^k, \beta)\; e^{\left(v_i^M - u_i^M\right)} \;\; \text{--- (4.3)}$$

where, $u_i^M \geq 0$, which implies that $f^M(.) \geq f^k(.)$ and the ratio of k^{th} group's production frontier to the meta-frontier can be defined as the technology gap ratio (TGR) expressed as:

$$TGR_i^k = \frac{f^k\left(x_i^k \beta^k\right)}{f^M(x_i^k \beta)} = e^{-u_{ki}^M} \leq 1 \qquad \text{--- (4.4)}$$

Following Huang, et al. (2014), at a given input level x_i^k, the farm household's observed output $y_i^k$of the i^{th} farm household relative to the meta-frontier consists of three components, that is:

$$\frac{y_i^k}{f^M(x_i^k)} = TGR_i^k \times TE_i^k \times e^{v_i^k} \text{ ----- (4.5)}$$

where,

$$TGR_i^k = \frac{f^k(x_i^k,\beta^k)}{f^M(x_i^k,\beta)}, \text{ the farm household's technological gap ratio,}$$

$$TE_i^k = \frac{f^k(x_i^k,\beta^k)e^{(-u_i^k)}}{f^k(x_i^k,\beta^k)} = e^{-u_i^k}, \text{ is the farm household's TE, and}$$

$$e^{v_i^M} = \frac{y_i^k}{f^k(x_i^k,\beta)e^{-u_i^k}} =, \text{ the random noise component.}$$

Finally, the meta-frontier under two-step approach has two stochastic frontier production functions as specified below:

$$lny_i^k = f^k\left(x_i^k,\beta^k\right) + v_i^k - u_i^k\ ,\ \ i = 1,\ldots,n(k) \text{ ---- (4.6)}$$

$$ln\hat{f}^k\left(x_i^k,\beta^k\right) = f^M\left(x_i^k,\beta\right) + v_i^M - u_i^M \text{---- (4.7)}$$

where, $ln\hat{f}^k\left(x_i^k,\beta^k\right)$ is the estimate of the group-specific frontier from Eq.(4.6). Since the $ln\hat{f}^k\left(x_i^k,\beta^k\right)$ are group-specific, the SFA is estimated two times, one for each *Wereda*. The output estimates from the two *Weredas*/groups are then pooled to estimate Eq. (4.7). The meta-frontier should be larger than or equal to the group-specific frontier, that is, $f^k\left(x_i^k;\beta^k\right) < f^M\left(x_i^k,\beta^k\right)$. The estimated TGR must always be less than or equal to unity:

$$TGR_i^k = \hat{E}(e^{-u_i^M}|\hat{\varepsilon}_i^M) \leq 1, \text{ …. (4.8)}$$

where, $\hat{\varepsilon}_i^M$=$ln\hat{f}^k\left(x_i^k\right) - ln\hat{f}^m\left(x_i^k\right)$ are the estimated composite residual of Eq. (4.7). The TE of the i^{th} farm household to the meta-frontier is equal to the product of the estimate of the TGR in Eq. (4.7) and the individual farm household's estimated TE in Eq.(4.2), that is, $M\hat{T}E_i^k = T\hat{G}R_i^k \times \widehat{TE}_i^k$.

Measuring Multidimensional household poverty: The poverty status of farm households was measured using a Multidimensional Poverty Index (MPI). Rely on Alkire & Foster (2011), five dimensions are captured to estimate the index, such as, education, health, standard of living, wealth, and empowerment. Under these dimensions, 13 indicators were identified based on expediency, obvious normative presumption, data availability and empirical literature (Alkire, 2007; Alkire & Santos, 2014; UN, 2016; Birhanu, et al., 2021). Table 4.1 presents dimensions, indicators, deprivation cut-off points and weights to construct the MPI.

Table 4.1: Dimensions, indicators, deprivation cut-off, and weights

Dimensions	Indicators	Deprivation cut-off	Relative weights
Education (1/5)	Adult literacy	No one has completed five years of schooling	1/10
	Child enrollment	No school age child is attending school	1/10
Health (1/5)	Health care	No access to health care services	1/10
	Illness	Suffers illness	1/10
Living standard (1/5)	Electricity	No access to electricity	1/25
	Drinking water	No access to safe drinking water	1/25
	Sanitation	Household has no access to good toilet, or improved but shared with other households	1/25
	House floor	Floor made with mud, dung, clay	1/25
	Cooking fuel	Use of firewood, dung, and charcoal as fuel	1/25
Wealth (1/5)	Land (ha)	Household does not own land more than the local average	1/10
	Livestock (TLU)	Household does not own livestock more than the local average	1/10
Empowerment 1/5)	Decision making	Household decision making on the use of income is not participatory	1/10
	Cooperative membership	Member of the household is not a member of cooperatives	1/10

Following Alkire & Foster (2011), two sorts of poverty cut-off points were applied to delineate deprived farm households from non-deprived counterparts. The first cut-off point used as identification at indicator levels, while the second one used to determine the poverty status farm households based on value deprivation scores. In this study, equal weight was assigned, as employed in Alkire & Foster (2011), for each dimension due to the absence of putative argument to deliberate one dimension is more important than another. Accordingly, the multidimensional poverty status of farm households was defined as:

$$p(y_i z) = \begin{cases} 1 \; multidimensional\, poor\; (c_i \geq k), \\ 0 \;\; otherwise\; (c_i < k), \end{cases} \text{--- (4.10)}$$

where, c_i the number of deprivations experienced by the farm household i, and k is multidimensional poverty cut-off point, computed as one third of the indicators (i.e. 13) (Table 1), hence, the poverty cut-off k equals four (k=4). Finally, the aggregate measures of multidimensional poverty including the Headcount ratio (H), Intensity of poverty (A), and Adjusted Headcount Ratio (Mo) are computed using the following functional specifications:

$$H = q/n \qquad \text{--- (4.11)}$$

$$A = \sum_{i=1}^{n} c_i(k)\,/q \text{--- (4.12)}$$

$$M_0 = \text{HxA} \qquad \text{--- (4.13)}$$

where, H is the multidimensional headcount ratio, q is the number of farm households who are multidimensional poor, and n is the entire farm households under consideration. A is the intensity of multidimensional poverty, $c(k)$ is the censored deprivation score of sampled farm household i. k is the poverty cut-off and q is the number of poor farm households. M_0 is a multidimensional poverty index obtained as a product of H and A. The value (M_0) lies between 0 to 1.

Measuring crop diversification: In this study the Herfindahl Index (HI) of crop diversification was used to measure the degree of cropping diversity of farm households. The index is used here because it accounts for available land at the household level, which is an important asset and source of livelihood in rural areas of Ethiopia. We used all crops including cereals to estimate HI. The main aim of computing crop diversification is to estimate the underlying heterogeneous effect of improving TE on farm household poverty at different levels of crop diversification status. HI is estimated as the summation of all squared area shares allocated in the production of crop $i$in the total cropped area. HI for crop diversification is computed using the following functional form:

$$\text{CDI} = \sum_{\text{i}-1}^{\text{i}-\text{n}} \text{S}_\text{i}^2 \qquad \text{--- (4.14)}$$

$$\text{S}_\text{i} = \frac{a_i}{\text{A}}$$

where, $a_i$is the farm size allocated for the production of crop i in a given year; A is the total annual cultivated land determined as the sum of all cropped areas in the cropping year; and S_i represents the land share allocated to crop i. The value of the HI ranges from 0 to 1 with 0 denoting perfect diversification and 1 perfect specialization (Rahman, 2009); hence the higher the index, the lower the diversification of the crop portfolio.

Once the crop diversification index was determined, the study made use of cut-off points to categorize farm households by their crop diversification status following Goshu (2013); Nagpure, et al. (2017); Basantaraya & Nancharaiahb (2017). Accordingly, farm households were categorized into three crop diversification status of highly diversified if the index is less than 0.3, moderately diversified if the index between 0.3 and 0.6, and least diversified if the index is above 0.6.

4.2.2. Empirical model and estimation strategy

Before we built an econometric model for the estimation of the multidimensional poverty effect of technical efficiency, we scrutinized the potential endogeneity of technical efficiency (TE) following a two-step approach. In the first step, we predicted the error term by regressing the TE with independent variables summarized in Table 4.2 below. In the second stage, the potential endogeneity of TE was assessed by regressing the outcome variable by including the error term predicated in the first step. The result then evidently showed that technical efficiency is correlated with the error term, revealing the violation of the assumption of zero covariance between explanatory variables and the error term. Hence, we decided to treat TE as an endogenous variable and to draw the estimation strategy based on an instrumental variable method by selecting valid instruments.

Once we concluded the use of the instrumental variable model, we looked for excluded valid instruments for endogenous regressor TE. The instrument considered in this case must satisfy two requirements as stated in Wooldridge (2012). It must be correlated with the endogenous explanatory variable (relevance) and uncorrelated with the error term (exogeneity). Considering theoretical literature, empirical evidences, and the joint significant test, sex of the household head, quality of farmland, cell phone ownership, distance to input source, and the number of oxen were considered as instruments. The significant effect of such household idiosyncrasies on technical efficiency is documented in several empirical studies (Kelemu, 2016; Gebrehiwot, 2017; Tenaye, 2020), suggesting that the instruments are valid.

Because the values of the outcome variables (household deprivation score and adjusted headcount ratio) and endogenous covariate (technical efficiency score) are censored at 0 and 1, we specified instrumental variable Tobit framework as the functional form specified in Eq. (15).

$$y_{1i}^{*} = y_{2i}\beta + x_{1i}\gamma + u_i$$
$$y_{2i} = x_{1i}\prod_1 + x_{2i}\prod_2 + v_i \text{---} \quad (4.15)$$

where, y_{1i}^{*} is household deprivation score and adjusted headcount ratio; $i = 1, \ldots n$ is sample farm households; y_{2i} is an endogenous regressors TE; x_{1i} is $1 \times k_1$ vector of exogenous variables; x_{2i} is $1 \times k_2$ vector of additional instruments; and the equation for y_{2i} is written in reduced form; u_i and v_i are assumed to follow $(u_i, v_i) \sim (0, \sum)$. β and γ are the vectors of structural parameters; $\prod_1$ and $\prod_2$ metrics of reduced-form of parameters. Since our econometric model censors the outcome variable from above and below, the estimation is defined as follows:

$$y_{1i} = \begin{cases} 1 & if \;\; y_i^{*} > 1 \\ y_{1i}^{*} & if \;\; 0 \leq y_i^{*} \leq 1 \\ 0 & if \;\; y_i^{*} < 0 \end{cases} \qquad \text{---} \qquad (4.16)$$

4.2.3. Definition of variables

The major outcome variables considered in this study representing household multidimensional poverty are household deprivation score and adjusted multidimensional poverty. Household deprivation score shows the deprivation of farm households across multiple indicators, whilst adjusted/censored headcount ratio reflects the incidence and intensity of multidimensional poverty. Farm households' technical efficiency, which ranges between 0 and 1, was estimated using a Cobb Douglas (CD) functional specification obeying the meta-frontier approach as conferred above. The most common explanatory variables were identified based on theoretical and empirical literature and built-in econometrics models. Table 4.2 presents the summary of outcomes and independent variables used in the econometric models

Table 4.2: Definition of hypothesized variables

List of Variables	Description	Expected signs
Outcome variables		
DS	Household deprivation score	
MPI	Multidimensional poverty index	
Independent variables		
Technical efficiency (TE)	Technical efficiency scores (0-1)	-
Crop diversification status	Categorical (1= Highly diversified, 2= Moderately diversified, 3= Least diversified)	+
Male headed household	Dummy (Male=1, otherwise=0)	-
Age of the household head	Number of years	+
Head educational	Number of years	-
Household size	Number of persons in the household	-
Population pressure	Ratio of family size to farm size	+
Access to extension service	Dummy (yes=1; otherwise=0)	-
Access to credit service	Dummy (yes=1; otherwise=0)	-
Distance to input center	Location of HH relative to input center in km	+
Road condition	Dummy (Good=1, otherwise=0)	-
Land quality	Index[23]	+
Non-farm income	Dummy (yes=1; otherwise=0)	-
Cellphone ownership	Dummy (yes=1; otherwise=0)	-
No of oxen	Number	-

4.3. RESULTS AND DISCUSSION

4.3.1. Estimates of technical efficiency

In this study, several hypothesis tests were undertaken before the use of the stochastic production frontier model (the test result is presented in Appendix Table A). The first test was the Skewness test on Ordinary Least Square (OLS) residuals to check the validity of the stochastic frontier model. The test result, hence, indicated that the distribution of OLS residuals was right-skewed with a statistically significant Skewness value (-0.53) at a 1% level. The test result suggested that we are confident enough to take the next step of stochastic frontier estimations. The second important hypothesis test was choosing an appropriate functional form for the data. According to the generalized log-likelihood ratio (LR) test result, the Cobb Douglas (CD) specification is the

[23] Land quality index is constructed based on multiplying the plots slope and the fertility indicators of the plots, implying a low index value indicates better land quality, while high index value would indicate the lowest quality evaluated at household level (Nisrane, et al., 2015).

most appropriate functional form to adequately represent the data. Third, we tested a hypothesis, which specifies no technical inefficiency in the data. Because the value of likelihood ratio statistics, λ=23.41, far exceeds the critical value of 8.273 at a 1% level, we confidently concluded that there is no full efficiency among the farm households and hence, technical inefficiency is one of the factors that affects the cereal output in the study area. Once we rejected the null hypothesis of no technical inefficiency, we tested the LR test to determine the use of homogenous production technology for the entire data. However, the LR test result provided enough evidence to reject the null hypothesis of homogeneous production technology for the sample study districts. Therefore, the study employed a stochastic meta-frontier to estimate the technical efficiency of farm households while addressing heterogeneity between study districts.

From the stochastic meta-frontier analysis, the mean technical efficiency for cereal farmers was found to be 58% that varies between 13% and 91%. The result suggests that farm households produced 58% of the maximum production of the possible (frontier) output. In addition to this, if the farm households cultivated cereal crops at full efficiency level, they could increase their cereal output by 36%[24], indicating that there is still a possibility to significantly improve the cereal productivity using the existing resources and production technologies. Our finding is lower than the average technical efficiency score reported by Alemu, et al. (2009) and Wassie (2014). They found the average technical efficiency of the major crop to be about 76% and 65%, respectively. However, our estimate of technical efficiency is comparable with, in the same range, and greater than the estimate reported by Asefa (2011) in Ethiopia, Wongnaa & Awunyo-Vitor (2018) in Ghana, and Oyetunde-Usman & Olagunju (2019) in Nigeria, in that order. The mean value of TGR was estimated at 0.901, denoting that, on average, farm households produce 90% of the potential output given the overall technology available in the study area. Added to this, the difference in mean TGR of the sampled study districts was found statistically significant at 1%, which appears to be due to production technology gaps. The results also revealed that no farmers have been found with a maximum value of TGR that is equal to unity (the stochastic frontier tangent to the meta-frontier), suggesting that there are no farm households in the study area who adopt the most advanced cereal production technology.

[24] The optimum possible output level that farm households can produce using the existing resources and production technology can be computed as 1- (mean TE/Maximum TE) multiplied by 100.

4.3.2. Crop diversification status

Farm households cultivated several crops including cereals and the cropping pattern appears moderately diversified. The result in Table 4.3 shows that the average Herfindahl Index (HI) was 0.51, indicating the presence of a moderate degree of crop diversification among farmers. Similar results were reported in Ethiopia and elsewhere in developing countries. For example, Manjunatha, et al. (2013) reported that the average HI of crop diversification was 0.55 for farmers in the Easter Dry Zone (EDZ) of south India. Based on the value of the crop diversification index, we further grouped the farm households into highly diversified with HI values below 0.3, moderately diversified with HI values between 0.3 and 0.6, and least diversified with HI values above 0.6. Accordingly, the average HI of crop diversification was found to be 0.257, 0.447, and 0.798 in the highly diversified, moderately diversified, and least diversified categories, respectively, implying that there is a high level of variation among farm households across the crop diversification categories.

Table 4.3: Crop diversification status of farm households

Variables	Mean	St. Dev.	Minimum	Maximum
Overall	0.508	0.191	0.163	1
Highly diversified	0.257	0.033	0.163	0.294
Moderately diversified	0.447	0.083	0.300	0.594
Least diversified	0.798	0.162	0.603	1

Source: Authors' analysis using primary data (2020)

4.3.3. Multidimensional poverty status

As can be seen in Table 4.4 below, the headcount ratio for the farm households was 58%, indicating more than half of the farm households are classified as multidimensional poor. The mean total deprivation score was found to be 0.44 with a variation between 0.1 and 0.8, implying the average household suffers from 44% of the possible deprivation. Moreover, the average multidimensional poverty intensity (A), which measures the average share of the deprivation suffered by the poor farm households was 0.54. The average Multidimensional Poverty Index (MPI) was estimated to be 0.31. Following the OPHI classification, about 36% of the farm households were living in severe poverty. Moreover, the level of multidimensional poverty estimated by this study is far below as compared to the national and rural areas average. The Oxford Poverty and Human Development Initiative (2020) report shows that at the national level and in rural areas of Ethiopia, 83.5% and 91.8% of people are multidimensional poor, respectively. Multidimensional poverty estimates between 2000 and 2014 by Tigre (2018) showed that despite the decreasing trend on the estimates over time, still large proportion of the population (71.8%) is under multidimensional poverty line in rural Ethiopia. A more recent estimate by Alemu & Singh (2021) in three districts of rural Ethiopia revealed the prevalence of severe multidimensional poverty, which was estimated to be 84.2%. Low MPI rates reported in this study were appeared to be the study area is characterized by high potential for crop production and located near to urbans centers where the farm HHs can be able to access production inputs and markets. In addition to this, different from previous studies, our MPI estimation method used deprivation indicators, such as wealth (land and livestock) and empowerments, which are important indicators that determine the poverty status of farm households in rural Ethiopia. Our MPI results were found consistent with the finding of the study by Gebrekidan, et al. (2020) conducted in Dega Temben. The result indicates that improving the poverty situation of farm households in terms of multiple deprivations continues to be the major challenge for the government and non-government organizations that implemented anti-poverty programs. Table 4.4 depicted the average estimate of multidimensional poverty for farm households.

Table 4.4: Multidimensional poverty estimates

Poverty indices	**Mean**	**St. Dev.**	**Minimum**	**Maximum**
Deprivation score (DS)	0.441	0.141	0.1	0.8
Incidence of poverty (H)	0.579	0.494	0	1
Intensity of poverty (A)[25]	0.538	0.095	0.4	0.8
Multidimensional poverty index (MPI)	0.312	0.276	0	0.8

Source: Authors' analysis using primary data (2020)

[25] The mean difference of the Intensity of poverty (A) was computed for poor farm households only.

4.3.4. Multidimensional poverty vis-a-vis crop diversification

Our analysis in this regard indicated that from the total farm household grouped under highly diversified, moderately diversified, and least diversified, 43%, 55%, and 72% were found multidimensional poor, respectively. Other poverty estimates, such as deprivation score, poverty intensity, and MPI also showed that poverty incidence was high among least diversified farm households. The one-way analysis of variance also supports our result that the poverty estimates significantly varied across the diversification status. The results suggest that farm households with high crop diversification values can earn higher income from the marketing of multiple crops as compared to the least diversified farm households. Higher income obtained through producing multiple crops supports farm households to improve their material wellbeing and reduce production risks. Table 4.5 summarized the multidimensional poverty estimates by the crop diversification status of farm households.

Table 4.5: Multidimensional poverty estimates by crop diversification status

Poverty indices	**Highly Diversified**	**Moderately diversified**	**Least diversified**	**F-Value**
Deprivation score (DS)	0.389 (0.121)	0.433 (0.135)	0.487 (0.156)	7.14***
Intensity of poverty (A)	0.505 (0.740)	0.531 (0.090)	0.563 (0.105)	3.40**
Multidimensional poverty index (MPI)	0.219 (0.259)	0.294 (0.273)	0.405 (0.270)	7.26 ***

Source: Authors' analysis using primary data (2020)
Coefficients with ***, **, and * are significant at 1, 5, and 10 % level of significance, respectively

4.3.5. Technical efficiency vis-a-vis multidimensional poverty status

As it can be seen from Table 4.6 below, the mean difference between the lowest and highest quartile of the technical efficiency category of farm households in all of the poverty estimates was found to be statistically significant. This implies that non-poor farm households are technically more efficient than poor farm households. However, our analysis showed about 41% of multidimensional poor farm households recorded a technical efficiency score of 60% and above all, which implies that there are farm households who are technically efficient and at the same time multidimensional poor. The technical efficiency scores of farm households by multidimensional poverty status are provided below in Table 4.6. These findings render an insight in favor of *'efficient but poor'* hypotheses, which is forwarded by Schultz in his seminal 1964 study of Guatemalan Indian villages.

Schultz (1964) stated that farmers in traditional agriculture are poor but efficient albeit there are comparatively few significant inefficiencies among farmers in the allocation of factors of production. This means that inefficiency is not the only factor for multidimensional poverty but also different idiosyncrasies of community, household, and plot-level factors may appears to be responsible for being multidimensional poor in the study area.

Table 4.6: Multidimensional poverty estimates by technical efficiency

Poverty indices	**Lowest Quartile (25%)**	**Upper Quartile (25%)**	**Mean difference**
Deprivation score (DS)	0.465 (0.150)	0.421 (0.137)	2.1056***
Intensity of poverty (A)	0.555 (0.097)	0.525 (0.101)	1.5656*
Multidimensional poverty index (MPI)	0.358 (0.278)	0.271 (0.274)	2.1524***

Source: Authors' analysis using primary data (2020)
Coefficients with ***, **, and * are significant at 1, 5, and 10 % level of significance, respectively

4.3.6. Effects of technical efficiency on household multidimensional poverty

We employed an instrumental Tobit model to estimate the relationship between the technical efficiency of farm households and farm households' multidimensional poverty status. Households' deprivation scores (DS) and Multidimensional Poverty Index (MPI) were regressed by the technical efficiency and other control variables. At the beginning of our investigation, we attested to the potential endogeneity of technical efficiency. The test result showed that the technical efficiency of the farm households is correlated with the error term, indicating that our estimation violated the assumption of zero covariance between explanatory variables and the error term. As a remedy to such a problem, we used a set of instrumental variables. In the first stage of the model estimation, we instrumented technical efficiency by the quality of farmland, distance to the input source, cell phone ownership, and the number of plowing oxen. These instrument variables are correlated with the farm households' technical efficiency but do not correlate with the error term. To make sure of the relevance of the instrument variables, we determined the joint significance test. The test result (chi2 (4) =41.58, p-value> chi2 =0.0000) on the instrument variables supports the rejection of the null hypothesis that the coefficients on the instruments are equal to zero, implying that the instrument variables are relevant. In addition to this, as presented in Table 4.7, the Wald Diagnostic Test values are statistically significant at less than1% level, suggesting that variable technical efficiency is endogenously determined.

Table 4.7: Multidimensional poverty effects of technical efficiency (IV Tobit)

Variables	**Deprivation score (HDS) [Coef./SD]**	**MPI [Coef./SD]**
Instrumented technical efficiency	-0.5535*** (0.1469)	-1.5321*** (0.4735)
Head sex	-0.0051 (0.0383)	0.0007 (0.1204)
Head age	-0.0021*** (0.0007)	-0.0062*** (0.0022)
Head education	-0.0046* (0.0025)	-0.0163** (0.0083)
Household size	-0.0269*** (0.0042)	-0.0712*** (0.0139)
Access to extension service	-0.0152 (0.0173)	-0.0566 (0.0553)
Access to credit service	0.0100 (0.0295)	0.0330 (0.0967)
Road condition (good)	-0.0253(0.0162)	-0.0930* (0.0518)
Population pressure	0.0058*** (0.0011)	0.0144*** (0.0035)
Participation in non-farm activities	-0.0310 (0.0225)	-0.1020 (0.0736)
Constant	0.9959*** (0.0835)	1.7736*** (0.2699)
Number of observations	372	372
Wald chi2(13)	156.82	102.82
Prob > chi2	0.0000	0.0000
Joint significant test [a]	41.58***	41.58***
Wald test of exogeneity $x^2(1)$	15.62**	9.15***

Source: Authors' analysis using primary data (2020)
Coefficients with ***, **, and * are significant at 1, 5, and 10 % level of significance, respectively
NB: [a]The joint significance test was carried out using a fractional response regression model because technical efficiency is a censored variable that ranges between 0 and 1.

As can be learned from Table 4.7 above, keeping all other factors being constant, a 6% reduction in household deprivation score (HDS) is linked with a 10% increase in technical efficiency of farm households, indicating that rising the technical efficiency of farm households leads to the reduction of the deprivations that both poor and non-poor farm households experienced in multiple indicators. Similarly, a 10% increase in technical efficiency of farm households drives down the poverty status by 15.3%, which is measured by multidimensional poverty index (MPI), at 1% level. The results convey that an improvement in the technical efficiency appears to have a substantial poverty reduction effect among the poor farm households. A similar finding on the poverty reduction effect of technical efficiency has been reported by Islam & Haider (2018), who find that technical efficiency significantly reduces poverty incidence and poverty gap, which is exclusively measured by monetary poverty measures. The welfare effect of improving technical efficiency can be considered through income effect or higher farm profits, lower real food prices, and higher wages (Minten & Barrett, 2008). Ivanic & Martin (2017) also stated that most of the reduction in poverty gained from an increase in agricultural productivity arises from direct increases in agricultural profits and, albeit much smaller in the corresponding wage implication.

4.3.7. Heterogeneous effects of technical efficiency

In addition to the above overall poverty reduction effect of improving technical efficiency has among the farm households, we further attempted to understand the relationship between technical efficiency and multidimensional poverty by taking into account the crop diversification status of farm households. In such a way, we could learn and identify the leverage point at which the farm households would be able to maximize the gain from the poverty reduction effect of technical efficiency. Accordingly, three independent models were fitted to examine the relationship between household deprivation score and technical efficiency. The models were specified based on farm households' crop diversification status, i.e., highly diversified, moderately diversified, and least diversified.

Before embarking on the estimation of the parameters of interest, we considered for each model whether technical efficiency is endogenously determined or not. Accordingly, except for the model estimated among the highly diversified farm households, the rest two models were affected by the potential endogeneity problem. Therefore, the technical efficiency among moderately diversified farm households was instrumented by gender of the household head, cell phone ownership, distance to input sources, and the number of oxen owned, whiles the technical efficiency for least diversified farm households was instrumented by non-farm income participation and the number of oxen. The joint significance test values, presented in Table 4.8, among moderately diversified and least diversified farm households, respectively, offered sufficient confidence to reject the null hypothesis that the coefficients on the instruments are equal to zero. Moreover, the Wald Test of exogeneity indicated the multidimensional poverty effect of technical efficiency was endogenously determined among moderately diversified and least diversified farm households.

The estimation results disclosed that the poverty reduction effect of technical efficiency is heterogeneous by farm households' crop diversification level. The study found a statistically significant and negative association between multidimensional poverty and technical efficiency among moderately diversified and least diversified farm households. A 10% increase in technical efficiency reduces household multidimensional poverty by 7.0% and 7.8% among moderately diversified and least diversified farm households, respectively, holding other factors constant. The results suggest that the poverty reduction effect of technical efficiency is relatively higher among moderately diversified and least diversified households. One of the possible reasons is that cropping of diversified crops probably reduces the efficiency of farm households in allocating available factors of production, while cropping of fewer crops or specialization may lead to higher efficiency gains in the management of available productive resources. As evicted in the results, the mean number of crops grown by moderately diversified and least diversified farm households is estimated at 3 and 2, respectively, which is substantially lower than highly diversified farm households who grow, on average, 5 crops in a year. Therefore, farm households that grow three and fewer crops can gain the best out of poverty reduction effect of technical efficiency. The multidimensional welfare effect of technical efficiency among farm households by their crop diversification scale is presented below in Table 4.8.

Table 4.8: Poverty reduction effect of technical efficiency by household crop diversification status

	Tobit model	IV Tobit Model	
Variables	Highly diversified [Coef./SD]	Moderately diversified [Coef./SD]	Least diversified [Coef./SD]
Technical efficiency	-0.1228 (0.1183)	-0.6989*** (0.2278)	-0.7791*** (0.2748)
Head sex	-	-	0.0629 (0.0740)
Head age	-0.0016 (0.0015)	-0.0009 (0.0009)	-0.0051*** (0.0015)
Head education	-0.0320*** (0.0067)	-0.0021 (0.0034)	-0.0049 (0.0058)
Household size	-0.0183* (0.0094)	-0.0261*** (0.0058)	-0.0280*** (0.0099)
Access to extension service	-0.0734 (0.0495)	-0.0228 (0.0264)	0.0212 (0.0350)
Access to credit service	0.0282 (0.0627)	-0.0080 (0.0370)	0.1776* (0.1047)
Distance to input center	-0.0050 (0.0081)	-	0.0016 (0.0071)
Land quality index	0.0073 (0.0115)	-0.0076 (0.0068)	-0.0077 (0.0145)
Road condition	-0.1316*** (0.0382)	0.0005 (0.0251)	-0.0617* (0.0365)
Population pressure	0.0040 (0.0034)	0.0056***(0.0016)	0.0067*** (0.0021)
Participation in non-farm activities	-	-0.0642** (0.0297)	-
Cell phone ownership	-0.0006 (0.0395)	-	-0.0358 (0.0437)
Number of plowing oxen	-0.0069 (0.0189)	-	-
Constant	0.8263*** (0.1430)	1.0332***(0.1442)	1.2405*** (0.2010)
Number of observations	30	260	82
Wald chi2(13)	34.09	75.60	52.35
Prob > chi2	0.0007	0.0000	0.0000
Joint significant test [a]	na[b]	22.38***	14.08***
Wald test of exogeneity	na	15.41***	9.14***

Source: Authors' analysis using primary data (2020)
Coefficients with ***, **, and * are significant at 1, 5, and 10 % level of significance, respectively
NB: [a]The joint significance test was carried out using a fractional response regression model because technical efficiency is a censored variable that ranges between 0 and 1, and [b] Not applicable

Moreover, it is worthy to indicate that there is a statistically significant mean difference in terms of total cultivated land between farm households in the highest and lowest quartile of crop diversification scale at less than 5% level. This tends to suggests that farm households having small land holdings focus on producing fewer crops, which have high remunerative advantages. In contrast to this, large farms may be more diversified as compared to small farms and hence, they may suffer from inefficiency problems in the allocation of scarce resources, suggesting that they become constrained to maximize the gains from the welfare effect of technical efficiency. Some studies (Benin, et al., 2003; Shahbaz, et al., 2017) support our position that, among others, large farms are associated with greater crop diversity, indicating that farm size may affect the decision to diversify and extent of diversification. Therefore, farm household with larger farm size tends to cultivate diversified crops, and because of this, they may not probably be able to take full advantage of the poverty reduction effect of technical efficiency.

Besides, as compared to highly diversified farm households, moderately diversified and least diversified farm households allocate more land for *‘‘teff’’ (Eragrostis ‘teff’)* production than for the production of other crops. For example, from the total cultivated land available at the household level, moderately diversified and least diversified farm households allocated 57% and 84%, respectively, of the cultivated land for *‘teff’ (Eragrostis teff)* production, which is higher than the share of the cultivated land (45%) under *‘teff’ (Eragrostis teff)* production among highly diversified farm households (Appendix IVB). On top of this, the share of cultivated land under *‘teff’ (Eragrostis teff)* production was found significantly greater between the highest quartile of crop diversification scale as compared to the lower quartile category at less than 1% level. Given the small size of cultivated land, the results possibly signify that those farm households having medium and low crop diversification status offer a considerable focus for those crops having high market value. From the findings of this study, hence, we can infer that the food crop choice rationale of farmers given scarce resources accord with the highest gain from the sale of their crops.

Some literature supports our findings that *‘teff’ (Eragrostis teff)* fetches the highest market price of any food grain in Ethiopia (Samuel & Sharp, 2007). The higher price in the market and the growing demand by better-off households in urban areas make *‘teff’ (Eragrostis teff)* an appealing cash crop for farm households (FAO, 2015; Lee, 2018). In addition to this, on account of its high nutritional value, global demand for *‘teff’ (Eragrostis teff)* is also rising (Vandercasteelen, et al., 2016) and consumers are willing to pay premiums for *‘teff’ (Eragrostis teff)* (FAO, 2015; Zhu, 2018; Lee, 2018). This shows that *‘teff’ (Eragrostis teff)* is an important cash crop having an enormous opportunity for the country in general and those of the smallholders who grow *‘teff’ (Eragrostis teff)* in particular.

4.4. CONCLUSIONS AND IMPLICATIONS

The study confirmed that technical inefficiency was one of the reasons responsible for low cereal output. Hence, farm households can improve cereal output with the current level of input mix and technologies. The overall crop production pattern was also appeared to be moderately diversified. Concerning the incidence of poverty, more than half of farm households in the study area were multidimensional poor. They were deprived of close to one third of the total deprivation across all indicators. The one-way analysis of variance showed that the poverty estimates significantly varied across the crop diversification status and high among least diversified farm households. The results revealed that multidimensional non-poor farm households are more technically efficient than poor farm households. However, the results also showed that farm households can also be simultaneously poor and efficient. These results favor the "poor but efficient" hypothesis, which is proposed by Schultz (1964) that inefficiency alone cannot be the root cause for being multidimensional poor. Added to this, the econometric model results revealed that technical efficiency gains in cereal output appear to have a substantial poverty reduction effect. Finally, the study has showed that the effects of technical efficiency are heterogeneous relative to crop diversification status. This means that improving technical efficiency of cereal production has higher poverty reduction effects among moderately diversified and least diversified cropping systems. Therefore, identifying and addressing the causes of technical inefficiencies should lie at the heart of policies and strategies that aim to improve cereal outputs and reduce poverty. Organizations working to improve cereal productivity should strive to improve technical efficiency based on the existing input mix and production technology. In addition to this, emphasis should be given for wider adoption of modern productive inputs, and improved farming practices. Furthermore, supporting farm households who grow fewer crops through modern production inputs and information particularly on those cereal crops having superior economic advantages may assist to take full advantage of the poverty reduction effect of improving technical efficiency.

CHAPTER FIVE: THE EFFECTS OF COMMERCIALIZATION OF CEREAL CROPS ON MULTIDIMENSIONAL POVERTY AND VULNERABILITY TO MULTIDIMENSIONAL POVERTY AMONG FARM HOUSEHOLDS IN ETHIOPIA

ABSTRACT

The study examined the effects of cereal commercialization on multidimensional poverty among farm households in teff-based mixed farming areas of Ethiopia. It applied instrumental Tobit regression and conditional mixed-process models to estimate the overall and dimensional effects of commercialization on household multidimensional poverty (MP) and vulnerability to multidimensional poverty (VMP). The result showed that the mean commercialization scale of the farm households was 38%. The headcount ratio (H) was found to be 58%, implying the poverty situation continues to pose major challenges upon the well-being of farm households. The average estimate of multidimensional poverty index (MPI) and household vulnerability to MP among sampled rural farm households was 0.31 and 0.52, respectively, with a statistically significant mean difference of commercialization status being at 1% level. Ceteris Paribus Assumption, a 10% increase in the degree of cereal crop commercialization is likely to reduce MPI deprivation, MPI poverty, and VMP by 5.4%, 16.3%, and 2.2%, respectively. Cereal commercialization also significantly reduces MPI dimensions that are measured exclusively through living standard and wealth dimensions. Thus, the commercial transformation of smallholders through a well-integrated market and improved infrastructure are key areas of policy intervention to improve the well-being of farm households in rural areas.

Keywords: Cereal, commercialization, multidimensional poverty and vulnerability, Ethiopia

5.1. INTRODUCTION

Smallholder agriculture is continued to be the main source of livelihood for over 2 billion people worldwide. It provides up to 80% of the food supply in Asia and sub-Saharan Africa (SSA) (FAO, 2012; IFAD, 2013; Abdullah, et al., 2019), which shows that the development of smallholder agriculture is commendable to raise rural income, increase food production and reduce poverty in developing countries (Wiggins & Keats, 2013). Furthermore, it contributes to developing countries' path to a much broader transformation process (Salami, et al., 2010).

Despite the key roles that smallholders play in achieving food security and poverty reduction, they account for significant proportion of the world's poor. They have also become increasingly vulnerable to emerging challenges that threaten their livelihoods (Fan & Rue, 2020). In sub-Saharan Africa, the number of people living in extreme poverty has been on the rise as compared to other regions. It has grown from an estimated 278 million in 1990 to 413 million in 2015, where the poverty rate stood at about 41% (World Bank, 2018; FAO, 2020), which is higher than all other regions of the world. As per the Global multidimensional poverty index report in 2019, from the total population multidimensionally indexed as poor across 101 countries, about 57.5% have been found in sub-Saharan Africa (UNDP & OPHI, 2019) that implies poverty reduction has to remain as a top development policy in SSA.

In Ethiopia, the situation of poverty has been showing a downward spiral over the past decades. The share of the population below the national poverty line dropped from 39% in 2005 to 24% in 2016 (NPC, 2017). The Ethiopian government has been working hard to expand health, education, water supply, sanitation, finance, and other social services to the rural areas of the country (MoFED, 2010; NPC, 2016). Consistent public investments made in road construction, technological expansion and modernization of the telecom sector, and the spread of cell phone technology, access to markets, expansion of urban centers and services, and access to information for millions of people in rural Ethiopia, etc., have been some of the development outcomes signalling pathways in required direction (Dorosh & Rashid, 2012). Market access has been increasing due to expanded transportation and communication networks (Chamberlin & Schmidt, 2012). But, there are still about 23 million poor people in the country who are below the poverty line, measured by monetary terms, in the country with a high rate of prevalence in remote rural areas. In terms of multidimensional poverty measures, 83.5% of people were classified as multidimensional poor (UNDP & OPHI, 2019). Hence, like many developing countries in SSA, eradication of poverty is a top development agenda in Ethiopia.

The literature in agriculture and scholars argued that commercialization of smallholder agriculture is a key vehicle to reduce poverty among smallholders due to the fact that poverty reduction cannot be achieved through subsistence agriculture alone (Pingali, 1997). Commercialization of subsistence agriculture is an important strategy to increase income and improve living standards in rural areas of many developing countries (von Braun & Kennedy, 1986). Commercial production system triggers rapid income growth due to its comparative advantages in terms of efficient resource use over a subsistence production (Kirimi, et al., 2013). It benefits smallholders through generating employment and increase agricultural labor productivity (von Braun, 1995). Commercialization at the household level creates new opportunities, permits asset accumulation, and provides a capability to acquire capital inputs and good agricultural practices (Poulton, 2017). To enhance its efficacy in reducing poverty, commercial transformation requires a paradigm shift in agricultural policy formulation and research priority setting (Pingali & Rosegrant, 1995). Furthermore, the product market must become better integrated with those of the rest of the economy (Timmer, 1988).

Ethiopia has adopted the commercialization of smallholder agriculture as a fundamental policy tool to speed up economic transformation (MoFED, 2003). Under Agricultural Development Led Industrialization (ADLI) was a strategy composed of series of development programs that have been launched consecutively including, but not limited to, SDPRP (2002/03 to 2004/05); PASDEP (2005/06-2009/10); Agricultural Growth and Rural Development Strategy, and Program (2004); Food Security Program (2004); GTP I and II (2011/12 to 2019/20). Transformations of smallholder agriculture through commercialization thereby achieve poverty reduction and overall economic development was the heart of all of these programs. Great attention has been given to achieve agricultural transformation in the country through progressive transition from subsistence to market-oriented production system by putting in place an efficient agricultural marketing system (Berhanu & Moti, 2010; NPC, 2016). The main assumption of the progressive transition of the production system has been aimed to help smallholders to link with the market with surplus production and fetch an income that supports to induce real changes in household welfare. Among the crops grown in the country, the major focus has been given for cereal production (NPC, 2016) because cereal crops are the most important sources of income for the majority of smallholders and hence, have strong potential to substantially alleviate rural poverty (Diao & Pratt, 2007; Hagos & Geta, 2016).

Existing studies on the scale of smallholders' commercialization in Ethiopia present mixed assessments. According to Gebremeskel, et al 1998, quoted in Gebre-Selassie & Sharp (2007), only 28% of the total national grain production was marketed in 1996. The study by Ethiopian Economic Association (EEA) (2004) noted that grain farmers marketed, on average, about 33% of their output. More recent empirical studies by Berhanu & Moti (2010); Abafita, et al. (2016) stated that, on average, smallholders have sold 25% of the crop they produced, slightly higher than the national average. According to Central Statistic Authority (CSA), about 23% of the grains produced by smallholders are marketed in 2019/20, which pinpoints low output market participation by rural farmers (CSA, 2020). The volume of annual crops produced and poor linkage between the market and the farm sector appeared to be a primary factor for the poor performance of smallholder participation in the output market (Gebre-Selassie & Sharp, 2007; Berhanu & Moti, 2010).

In the strands of existing empirical evidences, studies found a positive effect of crop commercialization on farm household poverty in a developing country context. For example, Boka (2017) finds that decision to participate in the output market improves farm household welfare in Ethiopia. A study by Ouedraogo (2019) in Burkina Faso also shows crop commercialization reduces the possibility of sliding into poverty among farm households. Using Heckman two-stage model, Awotide, et al. (2016) stated that an increase in farm household welfare is conditional on the probability of participating in the output market in Nigeria. However, most of these studies consider poverty from income and asset-based measures and overlook other dimensions of poverty. The literature on poverty measures, however, shows that poverty is multidimensional and hence, it is a multi-causal in nature that could not be captured by a few or a single indicator (Sen, 1976; Alkire & Santos, 2013) and similarly people who are identified as poor in social indicators may not coincide with those who are income poor (UN, 2016). Ogutu & Qaim (2018) examine the effect of commercialization using ex-post poverty measures in Kenya and find a positive effect of agricultural commercialization on multidimensional poverty. This shows that there is the absence of empirical research that examines the poverty effect of commercialization by taking ex-post multidimensional poverty and ex-ante vulnerability to multidimensional poverty measures into account, which provides particular importance for anti-poverty strategies. Overall, considering heterogeneous effects of commercialization that highly depend on location and policy environment, empirical evidence on the effect of crop commercialization on household multidimensional poverty is meagre in developing countries in general and Ethiopia in particular.

Considering the backdrops explained above, this study explores the welfare effect of cereal crop commercialization using multidimensional poverty indicators based on primary data collected from cereal farm households in *teff*-based mixed farming areas of Ethiopia. In doing so, this work contributes to the literature in several ways. First, the study employed Multidimensional Poverty Index (MPI) to measure the poverty status among farm households. This benefits policymakers and planners by providing insight on the level of contribution of different dimensions and indicators on the farm household multidimensional poverty. Second, unlike previous studies, the paper contributes by providing empirical evidence on the effect of commercialization on the MPI deprivations, adjusted MPI, and household vulnerability to multidimensional poverty by using the instrumental variable Tobit (ivtobit) model. The method fits models with censored dependent variables and endogenous covariates and helps to circumvent the potentially biased parameter estimates that may stem from the potential endogeneity of commercialization. Finally, the paper contributes by assessing the differential effects of cereal commercialization by MPI dimensions using Conditional mixed-process model (CPM).

The rest of the paper is structured into five sections. Section 2 discusses the conceptual framework of the study. Section 3 provides the specification of the econometrics models and estimation strategies applied for the study. Section 4 presents the major findings of the models and their discussion. Finally, section 5 draws conclusions and policy recommendations from the findings.

5.2. METHODOLOGY

5.2.1. Analytical approaches

Measuring agricultural commercialization: Commercialization of cereal crops was measured using Commercialization Index (CCI) proposed by von Braun & Kennedy (1994). It was computed as the share of the value of cereal crop sales to the total value of the total cereal production. The index is specified as follow:

$$CCI_{ij} = \frac{\sum_{k=1}^{K} S_{ik}\bar{P}_k}{\sum_{k=1}^{K} Q_{ik}\bar{P}_k} \quad --- \quad (5.1)$$

where, CCI_i a continuous variable that signifies the degree of commercialization of household from the output side, S_{ik} is the quantity of cereal output k sold by household i, $\bar{P}_j$ is the average price of cereal output k at the community level, Q_{ij} is the total quantity of cereal output k by household i. A value of zero indicates total subsistence, while a CCI value approaching 1 signifies a higher degree of commercialization or a great percentage of marketed cereal crops. This way of measuring smallholder commercialization assists to make classification between sellers and non-sellers, or between staple and cash crop producers with additional dimensions on how much of their harvest households choose to sell (Carletto, et al., 2017).

Measuring Multidimensional household poverty: The study used Multidimensional Poverty Index (MPI) to measure the poverty status of farm households. The index, which consists of 13 deprivation indicators across five dimensions, was constructed based on the methodological approach proposed by Alkire & Foster (2011) and Alkire & Santos (2014). Education, health, the standard of living, wealth, and empowerment are the dimensions of MPI that were considered in this study. The dimensions and indicators were selected based on convenience, explicit normative assumptions, data availability, and empirical evidence concerning what people do value or should value. Such a method of selection on the dimensions and indicators is allowed in the literature to fit the local context (Alkire & Santos, 2014). A multidimensional measure of poverty offers a high degree of flexibility in the choice of dimensions and indicators (UN, 2016).

Table 5.1 presented the dimensions and indicators considered in this study. Households are considered as deprived in the education dimension if no family member has completed five years of schooling and no school-aged children are presently attending school. Due to data constraints, we replaced nutrition with access to health care services. On top of this, because 99.7% of the sample households had no child died below five years, we replaced child mortality in the health dimension with illness. Hence, households are considered as deprived in health dimensions if they lack access to health care services and suffer from illness. The health indicators used in this study are supported in the literature (World Health Organization, 2012; Adeoti, 2014; Adeoye, et al., 2019). Households are deprived of other indicators of standard of living if they are below the deprivation cut-off as specified in Table 5.1.

The wealth of the farm household was indexed using landholding and livestock ownership. Land is considered as a key variable because it is one of the basic factors of production in rural Ethiopia, where most of the people depend on agriculture for their income and subsistence (Gebreselassie, 2006), hence, land is an important asset in any attempt to eradicate poverty (Anaafo, 2014). Next to land, livestock is the most important asset for farm households in Ethiopia. It plays multiple roles in the lives of rural communities by providing draft power, transport, food, income, and energy and serves as an indicator of wealth and prestige for rural farm households in Ethiopia. Empirical evidence also showed that poverty correlates highly with these physical assets (land and livestock) (Bogale, et al., 2005; Abebaw & Admassie, 2014). Therefore, households are considered deprived in the wealth dimension if they do not own land and livestock (TLU) more than the local average. Many studies used landholding and livestock ownership to index the wealth status of households in developing countries (For example, Hargreaves, et al., 2007; Chasekwa, et al., 2018; Gebrekidan, et al., 2020).

In addition to the wealth indicators, cooperative membership and intra-household decision-making processes were employed to proxy the empowerment dimension of poverty. Household empowerment is one of the key areas of poverty reduction strategy in developing countries. Conceptually, empowerment can be certainly linked with disempowerment and leads to the process of denying the ability of the denial of chosen and acquiring such ability (Abrar ul haq, et al., 2018). To this end, among others, cooperatives and intra-household decision-making processes substantially determine the household's empowerment in the community. Cooperative empowers its members through its collective action beneficial to bring an impact among poor households. Cooperative membership facilitates empowerment, reduces risks, and enhances security (Kwapong & Hanisch, 2013) among households. Cooperative can relax the liquidity constraints, affect adoption by providing market information and better price, and pool different resources such as credit, information, and labor among members (Wossen, et al., 2017). Hence, in this study, households are considered deprived if at least one of the members of the household is not a member of cooperatives.

Similarly, the intra-household decision on household resource allocation plays a considerable role in improving the welfare outcomes in rural areas. For example, empirical studies in Ghana showed that women's participation in intra-household decision-making, such as household purchases was significantly associated with higher dietary diversity (Amugsi, et al., 2016). Lecoutere & Jassogne (2016) also argued that participatory decision-making is associated with cooperatives' actual outcomes such as greater investment in sustainable intensification, consideration of women's interests, fairer reproductive intra-household labor division, more balanced control over cash crop income, and improved livelihoods. This means that intra-household decision-making, among rural farm households, can be a good indicator of household empowerment. Therefore, in this study, households are considered deprived in this indicator if the decision-making process of the household on income allocation is not participatory. Studies like Batana (2013); Gebrekidan, et al. (2020) used the empowerment dimension to construct MPI.

Table 5.1: Dimensions, indicators, deprivation cut-off and weights

Dimensions	Indicators	Deprivation cut-off	Relative weights
Education (1/5)	Years of schooling	No household member has completed 5 years of schooling	1/10
	Child attendance to school	No school age child is attending school	1/10
Health (1/5)	Health care	No access to health care services	1/10
	Illness	Suffers illness	1/10
Living standard (1/5)	Electricity	No access to electricity	1/25
	Drinking water	No access to safe drinking water	1/25
	Sanitation	No access to good toilet, or improved but shared with other households	1/25
	Flooring	Floor made with mud, dung, clay	1/25
	Cooking fuel	Use of firewood, dung, and charcoal as fuel	1/25
Wealth (1/5)	Land (ha)	Household does not own land more than local average	1/10
	Livestock (TLU)	Household does not own livestock more than local average	1/10
Empowerment 1/5)	Decision making	Household decision making on the use of income is not participatory	1/10
	Cooperative membership	Member of the household is not a member of cooperatives	1/10

Once the indicators and dimensions were defined, the study employed two forms of cut-offs to identify the poor farm households. The first cut-off is the direct method of identifying the level of achievement considered sufficient to be deprived or non-deprived in each indicator, while the second is used to delineate how widely deprived a person must be in order to be considered poor (Alkire & Foster, 2011). Following Alkire & Foster (2011) and Alkire & Santos (2014), suppose that n refers to the number of sampled farm households and d≥2 is the number of dimensions under consideration, then $y = [y_{ij}]$ denotes n x d matrix of the MPI achievements, where the typical entry $y_{ij} \geq 0$ is the performance of the household $i = 1,2, \dots, n$ in dimension $j = 1,2, \dots, d$. Each row vector $y_{ij} = y_{i1,}y_{i2,} \dots, y_{id}$ lists the household's $i's$ scores in different dimensions, while each column vector $y_{ij} = y_{1j,}y_{2j,} \dots, y_{nj}$ gives the distribution of dimension j performance across the set of farm households. Let a vector $z = (z_{1,}z_{2,} \dots, z_n)$ be deprivation cut-off below which a farm household is considered to be deprived in dimension j. Hence, if the achievement of the farm household in a given dimension j becomes below the predetermined deprivation cut-off z_i, the sampled farm household was considered as deprived in that indicator $\left(y_{ij} < z_i\right)$, and if the performance of the farm households is greater than the predetermined threshold $\left(y_{ij} > z_i\right)$, then the household was considered as non-deprived in that specific dimension. The study employed an equal weight approach to each dimension as analogously used in Alkire & Foster (2011) since we do not have compelling reasons to consider one dimension to be more important than another.

Once we determined the status of farm households against each dimension of the indicators, the next step is identifying the poor farm households using the second poverty cut-off. For doing that, a column vector $c = (c_1 \dots c_n)'$ of deprivation counts, which reflects the breadth of each of the household's deprivation is compared against a poverty cut-off k. The poverty cut-off k that satisfying $0 < k \leq d$ determines whether a person has sufficient deprivations to be considered as poor. In the union method k=1, whereas in the intersection approach k=d. For our case, the highest value of k is 13, which is the number of total indicators used in this study. One-third of these indicators equal to 43%, computed following the common threshold of 33% used by Alkire & Foster (2014) to calculate the global MPI. Hence, the poverty line of this study becomes four (k=4), then, the farm household is regarded as poor if the deprivation score is k or above$(c_i \geq k)$, and non-poor $(c_i < k)$, otherwise.

Headcount ratio $(\boldsymbol{H})$***:*** the headcount ratio $H = H(y; z)$ is defined by:

$$H = q/n \qquad \text{--- (5.2)}$$

where, H the number of the poor farm households identified using dual cut-off, q is the number of farm households who are multidimensional poor, and n is the entire farm households under consideration. The headcount ratio obtained from this methodology is entirely analog to the income headcount ratio, which measures the partial index of poverty. The headcount ratio violates 'dimensional monotonicity', "which says that if poor person i becomes newly deprived in an additional dimension, then overall poverty should increase" (Alkire & Foster, 2011).

Intensity of poverty (A): The intensity of poverty among the poor shows the fraction of possible dimensions *d* in which the average poor person is deprived. It is computed as the ratio of the sum of the total deprivation score of each person to that of the number of the person whose total deprivation score is below the poverty cut-off. The intensity of poverty among the poor defined by:

$$A = \sum_{i=1}^{n} c_i(k) \,/ q \text{--- (5.3)}$$

where A is average deprivation share across the poor, $c(k)$ censored vector of deprivation score of the farm household i. k is the poverty cut-off and q is the number of poor farm households.

Adjusted Headcount Ratio (MPI): The measure MPI is a simple product of the two partial indices H and A, and sensitive to frequency and the breadth of multidimensional poverty. The poverty measure MPI ranges in value from 0 to 1. The adjusted Headcount Ratio can be defined in the following form.

$$MPI = \text{HxA} \quad \text{--- (5.4)}$$

Measuring household vulnerability to multidimensional poverty: Considering a cross-sectional study, this study applied the Vulnerability to Expected Poverty (VEP) method proposed by Chaudhuri, et al. (2002) to measure households' vulnerability to multidimensional poverty. Following Chaudhuri, et al. (2002), the succeeding functional form defined the expected level of deprivation of household i, generated from the multidimensional deprivation score of household i.

$$d_i = X_i\beta + e_i \quad \text{--- (5.5)}$$

where, d_i denotes the expected level of deprivation of the household i that replaces the consumption expenditure used by Chaudhuri, et al. (2002). X_i stands for a vector of household characteristics. β is a vector of the parameter to be estimated using OLS, and e_i the random error term.

Because farm households face different risks and have different risk management strategies (Chaudhuri, et al., 2002), the error term is assumed to be heteroscedastic, meaning the variance of the error term vary between farm households. Hence, the Ordinary Least Square (OLS) method yields an inefficient estimate of the coefficients. Instead of OLS, hence, a three-step Feasible Generalized Least Square (FGLS) method was applied as proposed by (Amemiya, 1977).

The heteroscedastic error term is used to measure the variance of the household multidimensional deprivation score is specified as follows.

$$\delta^2_{OLS,i} = X_i\theta + u_i \quad \text{--- (5.6)}$$

In the first step, equation 5 is estimated using the OLS procedure. In the second step, we squared the estimated residual obtained from equation 5.5 and used it as dependent variables in equation 6. Then, the predicted value obtained from equation 5.6 is used to transform equation 5.6 as follows.

$$\frac{\delta^2_{OLS,i}}{X_i\hat{\theta}_{OLS}} = \left(\frac{X_i}{X_i\hat{\theta}_{OLS}}\right)\theta + \frac{u_i}{X_i\hat{\theta}_{OLS}} \quad \text{--- (5.7)}$$

The standard deviation of the variance can be produced by the following equation:

$$\hat{\sigma}_i = \sqrt{X_i\hat{\theta}_{FGLS}} \quad \text{--- (5.8)}$$

In the third step, we used the predicted standard deviation to transform equation 5.5 to obtain the asymptotically efficient estimate of $\hat{\beta}_{FGLS}$ as:

$$\frac{d_i}{\hat{\sigma}_i} = \left(\frac{X_i}{\hat{\sigma}_i}\right)\beta + \frac{e_i}{\hat{\sigma}_i} \quad \text{--- (5.9)}$$

Finally, the household's vulnerability to multidimensional poverty one period ahead is provided by using the formula specified below.

$$V_{i,t} = P_r\left(d_{i,\ t+1} > Z \middle| X_i\right) = \phi\left(\frac{X_i\hat{\beta}_{FGLS} - Z}{\hat{\sigma}_{i,t+1}}\right) \quad \text{--- (5.10)}$$

where, V_i is the estimated vulnerability to multidimensional poverty of household i, indicating the probability that the household will experience weighted deprivation counts over Z, Z is the threshold for multidimensional poverty applied in MPI estimate, ϕ denotes the cumulative density function of the standard normal distribution, $X_i\hat{\beta}_{FGLS}$ and $\hat{\sigma}_{i,t+1}$ represents the expected mean of the household deprivation and the estimated variance in the household deprivation.

5.2.2. Empirical model and estimation strategy

Effects of commercialization on household poverty status: commercialization is assumed to be related to household poverty status. This is because households with a higher level of commercialization might have better income and improved household welfare. The potential endogeneity of the commercialization variable could affect the estimated parameter, because of a potential reverse causality between the level of commercialization and household multidimensional poverty. Controlling such endogeneity biases is an important step before estimating the parameters (Wooldridge, 2010). Hence, the study employed ivtobit regression framework based on two-step estimators, because the dependent variables (total deprivation score, MPI, and vulnerability to multidimensional poverty) and endogenous covariate (commercialization) are censored. The ivtobit regression framework is stated as the functional form specified below.

$$y_{1i}^{*} = y_{2i}\beta + x_{1i}\gamma + u_i$$
$$y_{2i} = x_{1i}\prod_1 + x_{2i}\prod_2 + v_i \qquad \text{---} \quad (5.11)$$

where, $i = 1, .. n$; y_{2i} is a $1 \times p$ vector of endogenous variables; x_{1i} is $1 \times k_1$ vector of exogenous variables; x_{2i} is $1 \times k_2$ vector of additional instruments; and the equation for y_{2i} is written in reduced form; u_i and v_i are assumed to follow $(u_i, v_i) \sim (0, \sum)$. β and γ are the vectors of structural parameters, $\prod_1$ and $\prod_2$ metrics of reduced-form of parameters. We do not observe y_{1i}^{*}; instead, we observe:

$$y_{1i} = \begin{cases} 1 & if \;\; y_i^{*} > 1 \\ y_{1i}^{*} \;\; if & 0 \le y_i^{*} \le 1 \\ 0 & if \;\; y_i^{*} < 0 \end{cases} \qquad \text{---} \qquad (5.12)$$

To account for the potential endogeneity of the commercialization variable, we identified valid instrument variables (IV) following (Baum & Schaffer, 2007). We selected ownership of cell phone, asset holding, and the number of plots as the best candidate instrument variables for our estimation. To ascertain the validity of the instrument variables, we conducted a joint significance test for the instruments.

In this study, the effect of commercialization on household multidimensional poverty was also examined by modeling the independent dimensions of MPI as a function of commercialization index and control variables. For this intention, the Seemingly Unrelated Regressions (SUR) model was specified following Zellner (1962). The parameter of the model is estimated based on the Conditional mixed-process (CMP) modeling framework following (Roodman, 2011). The framework was chosen on account of its merit over the SUR estimator that the individual equations need not inevitably be classical regressions with a continuous dependent variable. Hence, CMP provides that much flexibility in estimating the parameters of interest while keeping the nature of the dependent variables. For this case, considering the censored nature of our dependent variables, that is deprivation scores of the MPI dimensions, the model can be specified as:

$$\begin{aligned} E_i &= X_1\beta_1 + C_i\gamma_{1\text{i}} + e_{1i} \\ H_i &= X_2\beta_2 + C_i\gamma_{2\text{i}} + e_{2i} \\ L_i &= X_3\beta_3 + C_i\gamma_{3\text{i}} + e_{3i} \qquad \text{---} \qquad (5.13) \\ W_i &= X_4\beta_4 + C_i\gamma_{4\text{i}} + e_{4i} \\ M_i &= X_5\beta_5 + C_i\gamma_{5\text{i}} + e_{5i} \end{aligned}$$

where, E_i, H_i, L_i, W_i, and M_i are the deprivation score of the farm households in terms of education, health, the standard of living, wealth and empowerment dimensions, C_i is the commercialization index, X_1, X_2, X_3, X_4, and X_5 are a vector of explanatory variables; $\beta_{1,}$ β_2, β_3, β_4, and β_5 are the vector of the parameter to be estimated; and e_{1i}, e_{2i}, e_{3i}, e_{4i} and e_{5i} are error terms.

5.2.3. Explanation of variables used in the empirical models

The dependent variables of this study are total deprivation score, multidimensional poverty status (MPI), and level of household vulnerability to multidimensional poverty. The deprivation score for each household is obtained by adding up the weighted deprivation for the dimensions. The study employed farm-specific characteristics and socio-economic variables as independent variables for this study, which were chosen based on the review of theoretical expositions and previous empirical literature (Bogale, et al., 2005; Tsehay & Bauer, 2012; Azeem, et al., 2016). The independent variables included in the model are described in Table 5.2 below.

Table 5.2: Hypothesized variables

List of Variables	Description	Expected signs
Dependent Variables		
DS	Deprivation score	
MPI	Multidimensional poverty index	
VMP	Vulnerability to multidimensional poverty	
Independent Variables		
Commercialization index	Share of cereal output sold (0-1)	-
Head age	Number of years	+
Head education	Household head educational status in years	-
Head marital status	Dummy (Married=1; otherwise=0)	-
Adult workers	Number of persons between 15 and 64 years	-
Mobile telephone ownership	Dummy (yes=1; otherwise=0)	-
Population pressure	Ratio of family size to farm size	+
Membership in cooperative	Dummy (yes=1; otherwise=0)	-
Access to extension services	Dummy (yes=1; otherwise=0)	-
Access to credit	Dummy (yes=1; otherwise=0)	-
Distance to input center (km)	Location of HH relative to input center in km	-
Non-farm income	Dummy (yes=1; otherwise=0)	-
Crop production diversity	Number of crop grown	+/-
Assets holding (log)[26]	Total household asset holding in ETB	-
Number of plots	Number of plots owned by the household	+/-

5.3. RESULTS AND DISCUSSION

5.3.1. Cereal crop production in major teff-based mixed farming areas of Ethiopia

Cereals in Ethiopia remain the primary source of food, income, and employment for more than 16 million smallholders and are therefore critical to food security and poverty reduction in the country. Among cereal crops, the five major kinds of cereal, such as *'teff'*, wheat, maize, barley and sorghum are at the heart of the country's agriculture and food economy and dominates the Ethiopian smallholder agriculture (Seyoum, et al., 2011; Chamberlin & Schmidt, 2012). *'Teff'* is widely growing for food, feed, and cash in Ethiopia. As it is shown in Table 5.3, close to 82% of *'teff'* comes from 23 zones in Tigray, Amhara and Oromia regions, and therefore considered as major *teff* growing areas of the country. East and West Gojjam zone in Amhara region and East

[26] Monetary value of assets in ETB that the household used either in the house or in farming excluding land, house and livestock.

and West Shewa zone in Oromia region cover 38% of the national annual *'teff'* production. In terms of overall cereal production, in 2019/20 cropping year, *'teff'*-based mixed farming areas of the country cover more than 63% of the national annual cereal production, from which *'teff'* takes the lion's share in terms of crop area and volume of grain production.

Table 5.3: Cereal production in major 'teff' productions zones in Ethiopia (2019/20)

Cereals	Cereal production in *'teff'* based mixed farming areas			Share from the national annual cereal production			
	Area (000 ha) [a]	Production (000 Mt) [b]	Yield (Mt/Ha)	Overall area (000 ha) [c]	Area share (%) [a/c]	Overall production (000 Mt) [d]	Production share (%) [b/d]
'Teff'	2460	4676	1.9	3101	79.3	5736	81.5
Barely	606	1543	2.5	951	63.8	2378	64.9
Wheat	1153	3389	2.9	1789	64.4	5315	63.8
Maize	1327	5760	4.3	2274	58.3	9636	59.8
Sorghum	872	2575	3.0	1828	47.7	5266	48.9
Millet	318	781	2.5	456	69.7	1126	69.4
Oat	3	3	1.0	21	12.9	46	6.0
Rice	30	98	3.2	58	52.7	171	57.7
Total	***6736***	***18723***	***2.8***	***10478***	***64.3***	***29673***	***63.1***

Source: Author compilation from CSA Data (2019/20)

5.3.2. Descriptive statistics

Table 5.4 summarizes the descriptive statistics of both continuous and categorical variables used in the model by farm household multidimensional poverty status. On average, sample farm households sell 38% of their cereal output, higher than the national average. In Ethiopia, about 23% of cereals produced by smallholders were used for sale (CSA, 2020). Carletto, et al. (2017) found that farmers in Malawi, Uganda, and Tanzania sell 18%, 26%, and 28% of the aggregate crop output, respectively. The mean difference in the volume of cereal output sold between multidimensional poor and non-poor farm households was also found significant at a 1% level. As clearly shown in Table 5.4, household multidimensional poverty status also significantly varies across all of the socio-economic lines except non-farm income and access to credit.

Table 5.4: Summary statistics by Multidimensional poverty status

Variables	Overall	Non poor	Poor	t-test/ χ^2-values
	Mean/%age	Mean/%age	Mean/%age	
Commercialization (0-1)	0.38 (0.19)	0.41 (0.17)	0.35 (0.20)	3.1777 ***
Age of household head	45.36 (12.79)	48 (12.32)	43 (12.68)	4.0840***
Education of household head	3.01 (3.08)	3.42 (3.18)	2.72 (2.98)	2.1849**
Married household head	91	44	56	6.4506**
Adult workers	3.25 (1.41)	3.68 (1.45)	2.93 (1.30)	5.2726***
Mobile telephone ownership (yes)	81	45	55	6.4171**
Population pressure	5.12 (3.84)	4.35 (4.42)	8.21 (7.98)	-5.5139***
Membership in cooperative (yes)	74	51	49	38.8677***
Access to extension services	73	47	53	11.2377***
Access to credit (yes)	7	44	56	0.0412
Distance to input center (km)	2.44 (2.56)	1.87 (1.78)	2.86 (2.94)	-3.7871***
Non-farm income (yes)	0.16	46	54	0.3926
Crop production diversity	2.85 (1.10)	3.25 (1.13)	2.55 (0.99)	6.3935***
Assets holding (log)	10.59 (1.03)	11.06 (0.84)	10.25 (1.02)	8.1665***
Number of plots	3.66 (1.76)	4.41 (2.08)	3.12 (1.23)	7.5498***

Source: Authors' analysis using primary data (2020)
Coefficients with ***, **, and * are significant at 1, 5, and 10 percent level of significance, respectively
NB: Figures in parenthesis are standard deviations

5.3.3. Multidimensional poverty and vulnerability to multidimensional poverty

The average estimate of multidimensional poverty (MPI) for the rural farm households, as presented in Table 5.5, is 0.31, indicating the farm households experienced 31% of the total deprivations across all indicators. The multidimensional deprivation headcount (H) is 0.58, showing a higher proportion of farm households (58%) were classified as multidimensionally poor. Whereas, the average multidimensional poverty intensity (A) was found 0.54, which indicates the average share of deprivations experienced by the poor farm households is 54%. The incidence of poverty and MPI among the farm household is substantially lower than the national poverty estimates in rural Ethiopia reported by OPHI (2018), where the incidence of poverty, the intensity of poverty and MPI is 92%, 60%, and 55%, in that order. The mean total deprivation score was found 0.44, implying the average household suffers from 44% of the possible deprivation. The mean difference of the deprivation of the farm households in all of the poverty estimates by their commercialization status is significant at 1% level, indicating that multidimensional poverty is high among least commercialized farm households. As it is supported by literature (Chaudhuri, et al., 2002), the average vulnerability level of the farm households is 0.52, which is reasonably closer to the predicted household multidimensional poverty rate (0.58). Moreover, the result revealed statistically significant mean difference of the vulnerability score by commercialization status at 1% level, suggesting the least commercialized farm households are more vulnerable to multidimensional poverty as compared to the most commercialized farm households. The mean difference in *'teff'* and wheat commercialization is also significant between multidimensional non-poor and poor farm households at less than 1% significant level. The findings on the poverty rates imply that the poverty situation continues to pose major challenges for the government and development partners in the rural areas.

Table 5.5: Multidimensional poverty estimates

Poverty indices	Full sample mean	Lowest Quartile (25%)	Upper Quartile (25%)	Mean difference
Deprivation score	0.441 (0.141)	0.478 (0.150)	0.410 (0.131)	3.1961***
Incidence of poverty (H)	0.579(0.494)	0.684 (0.467)	0.464 (0.502)	3.0355***
Intensity of poverty (A)[27]	0.538(0.095)	0.557 (0.107)	0.526 (0.091)	1.5136*
Multidimensional poverty index (MPI)	0.312(0.276)	0.381 (0.275)	0.244 (0.271)	3.3480***
Vulnerability to multidimensional poverty	0.516 (0.056)	0.590 (0.059)	0.492 (0.052)	3.1875***

Source: Authors' analysis using primary data (2020)
Coefficients with ***, **, and * are significant at 1, 5, and 10 percent level of significance, respectively
NB: Figures in parenthesis are standard deviations

[27] The mean difference of the Intensity of poverty (A) was computed for poor farm households only.

5.3.4. Dimensional contribution to MPI

Figure 5.1 presents the percentage contribution of individual indicators to the overall multidimensional poverty. Accordingly, the wealth dimension contributed about 29.4% to the total multidimensional poverty, suggesting rural households in Ethiopia are asset poor. Next to this, the contribution of the standard of living (29.1%) was found high, revealing the farm households have a low standard of living. The results also show that empowerment, health, and education dimensions of poverty contribute 21.4%, 13.7%, and 6.4% to multidimensional poverty, in descending order. Among the indicators used in multidimensional poverty, deprivation in cultivated farmland, which was accounted for 15% of the total MPI was found the larger contributor followed by livestock holding (14.4%), and household decision-making on income (14.3%), in descending order of importance. The result appears to confirm that land is the primary means for generating a livelihood for most of the poor in developing countries by allowing them to make productive use of their labor and reducing their vulnerability to shocks (World Bank , 2003).

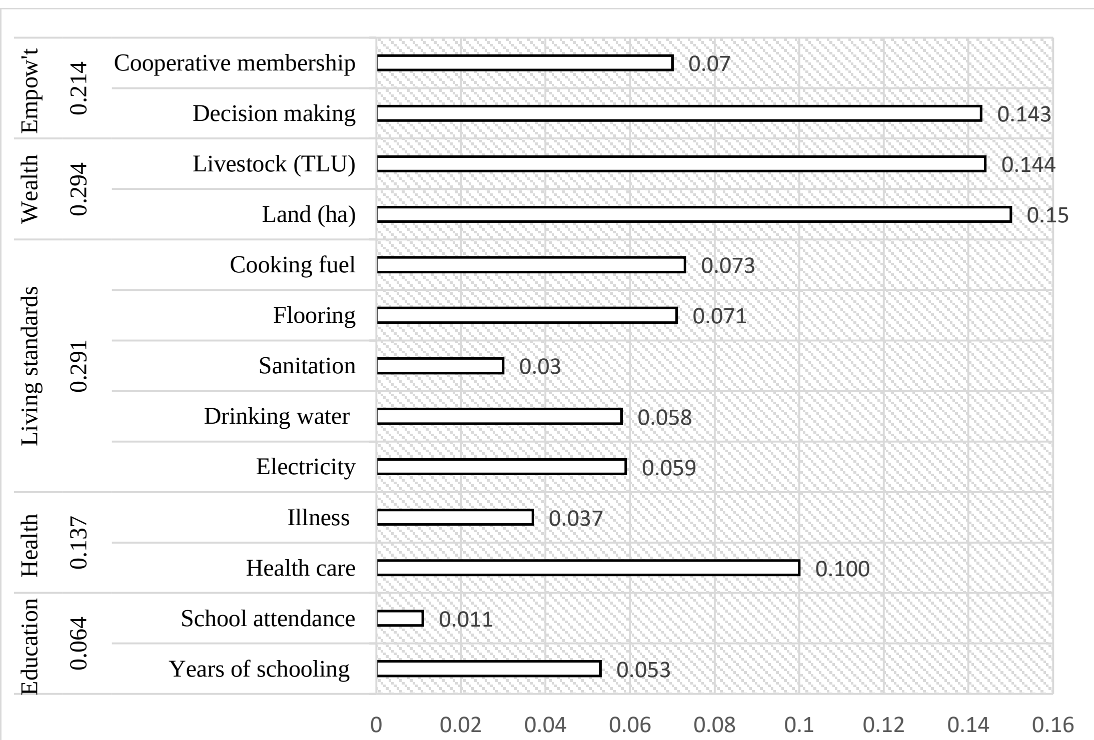

Figure 5.1: Dimensional and Indicators' contribution to the over multidimensional poverty
Source: Authors' analysis using primary data (2020)

5.3.5. Multidimensional poverty effect of farm household commercialization

Overall effect: We examined the effect of cereal crops commercialization on the overall multidimensional poverty and vulnerability to multidimensional poverty status of farm households using Instrumental Variable (IV) models. We used the IV model as a remedy to the endogenous regressors of commercialization of cereal crops and obtained consistent parameter estimates. The validity tests on the instruments for multidimensional poverty and commercialization indicate the instrument variables used are valid. The first test for joint significance rejects the null hypothesis of the coefficients on the instruments are equal to zero (also called weak instruments test) at 1% level, so that our instrument variables are relevant. The Wald test of exogeneity was found significant at 1% level, indicating we have sufficient information to reject the null hypothesis of no endogeneity. The test result also supported our choice of a Tobit model that accounts for endogeneity. Based on the test results, hence, ownership of cell phone, asset holding, and the number of plots were selected as valid instruments for the model.

The effect of commercialization on multidimensional poverty is shown in Table 5.6 below. The estimates for deprivation score, MPI, and vulnerability to multidimensional poverty are provided. The study found that commercialization of cereal crops negatively and significantly associated with overall multidimensional deprivation, MPI, and vulnerability to multidimensional poverty at 1% level, with different levels of magnitude, implying that using both *ex-post* and *ex-ante* poverty measures provide all-inclusive policy implications. Controlling for other factors, a 10% increase in the degree of cereal crop commercialization is likely to reduce MPI deprivation, MPI poverty, and vulnerability to multidimensional poverty by 5.4%, 16.3%, and 2.2%, respectively. The result is in line with theoretical literature that increases the commercialization of subsistence agriculture reduces household poverty (Timmer, 1988; von Braun & Kennedy, 1994; Leavy & Poulton, 2006). This is on account of its relative comparative advantage over subsistence production in generating more household income (Moti, et al., 2009).

Table 5.6: IVTobit estimate for the effect of commercialization on household poverty

Variables	Deprivation score [Coef./SD]	MPI [Coef./SD]	Vulnerability to MP [Coef./SD]
Commercialization index	-0.5435*** (0.1522)	-1.6291*** (0.5072)	-0.2198 *** (0.0608)
Head age	-0.0019*** (0.0006)	-0.0061*** (0.0022)	-0.0008*** (0.0003)
Head marital status	-0.0171 (0.0265)	-0.0050 (0.0823)	-0.0074 (0.0106)
Head education	-0.0064** (0.0025)	-0.0223*** (0.0082)	-0.0025** (0.0010)
Adult workers	-0.0258*** (0.0057)	-0.0729*** (0.0188)	-0.0102*** (0.0023)
Population pressure	0.0037*** (0.0012)	0.0082** (0.0036)	0.0015*** (0.0005)
Distance to input center (km)	0.0015 (0.0031)	0.0037 (0.0096)	0.0006 (0.0012)
Access to formal credit	0.0382 (0.0339)	0.1388 (0.1099)	0.0158 (0.0136)
Access to extension service	0.0155 (0.0184)	0.0502 (0.0591)	0.0068 (0.0074)
Cooperative membership	-0.0621*** (0.0194)	-0.1656*** (0.0606)	-0.0243*** (0.0077)
Participation in non-farm activities	-0.0644*** (0.0246)	-0.2150*** (0.0799)	-0.0261*** (0.0098)
Crop production diversity	-0.0207*** (0.0071)	-0.0879*** (0.0238)	-0.0081*** (0.0029)
Constant	0.9247*** (0.0732)	1.6955*** (0.2438)	0.6978*** (0.0292)
Number of obs.	378	378	378
Wald chi2(13)	167.72	119.48	164.91
Prob > chi2	0.0000	0.0000	0.0000
Joint significant test [a]	26.62***	26.62***	26.62***
Wald test of exogeneity	17.04***	10.15 ***	17.95***

Source: Authors' analysis using primary data (2020)
Coefficients with ***, **, and * are significant at 1, 5, and 10 percent level of significance, respectively
NB: [a]The joint significance test was carried out using a fractional response regression model because commercialization is an indexed variable that ranges between 0 and 1.

Dimensional effects: The effect of commercialization on the deprivation status of farm households was examined by each dimension of MPI using a conditional mixed-process model as shown in Table 5.7. The results of the model show that cereal commercialization has a decreasing effect on all MPI deprivations. Nonetheless, the MPI effect of commercialization is statistically significant merely for wealth and standard of living deprivations at 1% and 5% level, respectively.

Farm households' deprivation in the wealth dimension, as indicated in section 2, was indexed using two essential household holdings, such as land and livestock ownership (TLU). Both indicators are among key assets that extensively determine the poverty situation of farm households in rural Ethiopia. The model results show that a 10% increase in farm household commercialization reduces the level of MPI deprivation by 0.81%, which is measured exclusively through the wealth dimension. Commercialization of cereal crops can assist farm households to improve the productivity of cultivated land and accumulate livestock holdings through its direct income effects. An income earned from the sale of surplus produce enables poor farm households to acquire modern inputs and livestock production resources. The findings complement the conceptual literature that commercialization at household level creates new opportunity and permits asset accumulation and provide a capability to acquire capital inputs and good agricultural practices (Poulton, 2017).

The commercialization effect on acquiring additional land through direct purchase is hard to explain in this study because the land tenure system in Ethiopia merely provides use rights. However, access to land through land renting/leasing can reduce poverty. Literature stated that land tenure reforms can reduce poverty when the ability of the poor is enhanced to access, withdraw, manage, exclude and alienate land resources (Anaafo, 2014). Nonetheless, non-poor farm households with a higher level of commercialization might have an economic advantage over their MPI poor counterparts to access additional cultivated land through land rent arrangement for a curtailed period. Moreover, as literature stated that when land markets are imperfect, for example, farm households with larger farm holdings are more likely to be market-oriented and have higher market participation (von Braun & Immink, 1994) because ownership of these resources matters for efficiency and productivity (Sadoulet & de Janvry, 1995). Hence, because land holding accumulation depends on the land reform legislation, the commercialization effect on MPI deprivation can be associated with retaining additional cultivated land through a rent in arrangement, land fertility improvement and conservation.

Cereal crop commercialization may have both direct and indirect effects on livestock ownership (TLU). The direct effect of commercialization on herd size might be channeled through its direct income effects. Whereas, the indirect effects of commercialization might be linked with the farm households' capability to purchase livestock feeds and other inputs. Holding the size of cultivated land and livestock (TLU), may have reverse effects on the level of cereal crop commercialization. Ownership of livestock (TLU) may positively affect the volume of cereal grain sales because income obtained from livestock may also help the farm households to acquire crop production resources (Berhanu & Moti, 2010). The wealth status of farm households particularly in terms of land and livestock holding also helps the farm households to cope with challenges of competitiveness and integration in the new markets (Nagayets, 2005).

Table 5.7 presented that farm household commercialization has a negative and significant effect on the living standard dimension of MPI. For example, other factors being constant, a 10% increase in the level of farm household's commercialization reduces the condition of farm household poverty by 0.18% as measured exclusively through this dimension. The plausible explanation is linked with an increased farm income through commercialization enables farm households to improve material wellbeing, which is reflected in terms of household consumption level, housing condition, sanitation, nutrition, social services, security, and overall quality of life. Although access to water, electricity, and other infrastructures is beyond the control of the farm households, an increase in farm income may stimulate demand for improved access to goods and services. Literature also stated that an increase in farm income could stimulate demand for infrastructure and generate social capital accumulation through increased interactions between farmers and other agents in agricultural and related sectors (Irz, et al., 2001).

Smallholders can improve their living standards if they have better access to the market, well-developed infrastructure, strong farmers' organizations, and market linkages (Leavy & Poulton, 2006). However, Moti, et al. (2009) noted that unless rural markets are well-integrated and risks are low to influence household decision behavior, the commercialization of the crop may lead to adverse consequences mainly by exposing households to volatile food market prices and food insecurity. In addition to this, the substantial role of commercialization in reducing poverty in developing country is limited by market failure. The literature stated that market failure in developing countries is, in most instances, induced by high transaction costs and credit constraints. These factors impend farm households to participate and reduce the volume of sales in the product market (Renkow, et al., 2004). This shows that for a successful pro-poor growth strategy, the efforts in improving agricultural sector productivity should be accompanied by improved access to markets. Hence, farmers can rely increasingly on the market for the sale of products and the acquisition of production inputs, including labor (Poulton, 2017).

Table 5.7: Conditional mixed process model result on MPI effect of cereal crop commercialization

	MPI Dimensions				
Variables	**Education**	**Health**	**Living standard**	**Wealth**	**Empowerment**
Commercialization index	-0.0135 (0.0117)	-0.0074 (0.0149)	-0.0167** (0.0077)	-0.0812*** (0.0192)	-0.0011 (0.0186)
Control variables	Yes	Yes	Yes	Yes	Yes
Constant	0.0882*** (0.0135)	0.1267*** (0. 0172)	0.1665*** (0.0089)	0.3356*** (0.0222)	0. 1346*** (0. 0208)
Number of observations	378				
LR chi2(25)	253.58				
Prob > chi2	0.0000				
Log-likelihood	3120.37				

Source: Authors' analysis using primary data (2020)
Coefficients with ***, **, and * are significant at 1, 5, and 10 percent level of significance, respectively

5.4. CONCLUSIONS AND IMPLICATIONS

In Ethiopia, a higher proportion of people are classified as multidimensionally poor. Many of these poor people reside in rural areas and drive their income from smallholder farming. Eradication of poverty, therefore, remains a top development priority in Ethiopia. Over the past couple of decades, the commercial transformation of smallholder agriculture has been considered as one of the most effective means of reducing poverty and improving the welfare of farm households in rural areas. This paper, hence, examined the role of smallholders' commercialization in reducing multidimensional poverty among farm households in rural Ethiopia. The paper estimated the poverty effect of commercialization using *ex-post* multidimensional poverty (MP) and *ex-ante* vulnerability to multidimensional poverty (VMP) measures. Instrumental variable Tobit (ivtobit) and Conditional Mixed-Processing (CMP) framework were applied to examine the poverty reduction effect of commercialization using primary data drawn from intensive *teff*-based mixed farming areas of Ethiopia. The framework fits the model with censored dependent variables and accounts for the potential endogeneity of commercialization.

Our findings of *ex-post* and *ex-ante* poverty measures show a statistically significant decreasing effect of cereal commercialization on multidimensional poverty and vulnerability to multidimensional poverty among farm households. Keeping other factors constant, a 10% increase in the degree of cereal crop commercialization is likely to reduce MPI deprivation, MPI poverty, and vulnerability to multidimensional poverty by 5.4%, 16.3%, and 2.2%, respectively. In addition to this, farm households' deprivation measured through wealth and living standards dimensions were found sensitive to the level of farm household commercialization. This revealed that commercialization reduces the level of poverty and vulnerability to the poverty of farm households through income channel, by which they become capable to access productive resources, goods, and services necessary for advancing wealth and living standards.

The study concludes that significant proportion of the population is classified as multidimensionally poor. Furthermore, the results substantiate that commercialization can be considered as a key pro-poor growth strategy, among others, to reduce the poverty situation of farm households in rural Ethiopia. For a successful commercial-oriented strategy, nonetheless, policymakers should give particular attention to strengthening rural institutions to address bottlenecks and risks associated with access to modern technologies, well-integrated markets, financial services, etc. From our thematic analysis, it was learned that unaffordable price for farm inputs and inflated price for household consumables may impair the potential role of commercialization in reducing poverty prevalent in rural areas. Hence, key informants suggested that the supply of household consumables through farmers' cooperatives and local youth groups can be helpful to benefiting the farm households from the sale of their surplus production. Moreover, the findings emanated from the dimensional effect of commercialization imply the revising of the existing tenure system of cultivated land in Ethiopia in such a way to improve access to more cultivated land through a provisional land transfer system among farm households following either rent or lease system. Overall, for effective poverty reduction effect of commercialization, improved access to drinking water, sanitation facilities, modern energy sources and infrastructure, and access to modern livestock breeds and cultivated land improvement technologies hence, are key areas of policy interventions

CHAPTER SIX: SUMMARY, CONCLUSIONS AND POLICY AND DEVELOPMENT IMPLICATIONS

This section presents the major findings, conclusions and policy recommendations drawn from the findings of the study. The conclusions and the policy recommendations were discussed by supporting related theoretical and empirical literature.

6.1. OVERVIEW

The primary focus of this dissertation was to answer the following major research questions: How do improved cereal crop varieties and production methods affect farm households' efficiency? What other factors determines the technical efficiency of farm households? What are the effects of farm households' cereal commercialization on input use, efficiency, and productivity? What are the drivers of cereal commercialization among farm households? Are there any two-way relationships between farm households' technical efficiency and cereal commercialization? How does technical efficiency affect the multidimensional poverty of farm households? Does the effect of technical efficiency on the multidimensional poverty of farm households differ by crop diversification status? How cereal commercialization does affect farm households' multidimensional poverty? What are the channels through which cereal commercialization affects multidimensional poverty? What other factors determine household multidimensional poverty?

For guiding the study, agricultural development theories, agricultural household models, and poverty reduction approaches were considered as theoretical frameworks of the study. To achieve the purpose of the dissertation, the study followed concurrent embedded research design in which the study conducted an intensive quantitative survey along with an embedded qualitative design. Primary data were collected using a structured questionnaire administered by a cross-sectional survey in *'teff'*-producing mixed farming areas of Ethiopia in the year 2019/20. The study also used semi-structured checklists applied using key informant interviews (KIIs) and focus group discussions (FGDs). This study focused on the primary cereal crops, such as *'teff'*, wheat, barley, maize, and sorghum. Analytical strategies, such as Stochastic Meta-Frontier Approach, Tobit Model, Fractional Logit Model, Multidimensional Poverty Index (MPI), Vulnerability Analysis Model, Instrumental Tobit Model, Conditional Mixed Processing Framework, Dose-Response Function, Three-Stage Least Square Regression Model were applied in this study. For the analysis of qualitative data, the study employed thematic analysis approach. The use of multiple analytical methods allowed us to compare and triangulate the results and thus, provide robust evidence for policymaking. The remaining section of this chapter presents the synthesis of the key findings, the conclusions, and the policy recommendations of the dissertation by key components.

6.2. KEY FINDINGS

1) Use of high yielding varieties and production practices of cereal crops and farm households' technical efficiency

In Ethiopia, cereal grain production plays an important role in the economy by contributing its largest share in terms of rural employment, agricultural land use, calorie intake, and national income. Therefore, improving the productive efficiency of cereal-producing farm households can be one of the paths to increase productivity and ensure the welfare of farm households. The analysis presented in Chapter two shows that the adoption of agricultural technologies is very low. For example, only about 34% of the farm households used improved cereal crop varieties and recommended rates of seed, fertilizer, and row planting at different scales of intensity. In addition, on average, about 19% of the total area under cereal crop were covered by HYVs and recommended practices. The low adoption rate of modern technologies can be linked with access constraints, poor quality, and a low level of awareness.

Similarly, the results of the efficiency analysis revealed cereal output have a positive response to cultivated land, fertilizer, and seed, and a negative response to labor and oxen draught power, which means labor and oxen were over utilized. In addition, in our focus group discussion, it was reported that the rate of nitrogen fertilizer application has been increasing beyond the scope of the recommendation rate since recently. Key informants reported that the steady decline in production and higher yield response were among the main reasons for higher rate of nitrogen fertilizer than before. In addition, the average technical efficiency score of farm households have found to be 58%, indicating that about 36% of cereal crop production is lost due to inefficiency.

The econometrics model results showed that the key factors responsible for the existing efficiency gaps among farm households include sex of the household head, age of the household head, mobile ownership, cooperative membership, access to modern inputs, low rate of technology adoption, and stress incidence and its associated crop damage. Interestingly, the finding of the efficiency analysis further confirmed that neglecting heterogeneity that may exists between sample study districts leads biased estimate of technical efficiency scores.

2) Extent of Cereal Crops Commercialization and its Effects on Input Use, Efficiency, and Productivity among Farm Households

As can be seen in this study, farm households produced a range of cereal crops partly for home consumption and partly for marketing. The results revealed about 38% of the cereal grain produced is commercialized and more than 60% is used for home consumption and other purposes. These extents of commercialization indicate that farm households are semi-commercialized with considerable disparities in the commercialized quantities and the type of cereal crops among the farm households. The findings favor the theory of the agricultural household model (Singh, et al., 1986; de Janvry, 1991), which connotes that production and consumption decisions are non-separable. Our qualitative study results (Chapter 3) also show that farm households allocate their production resources, such as cultivated land, labor, and capital for the production of different crops considering household consumption and market. For example, most farmers in the study area produce white *'teff'* for the market, while brown *'teff'* for home consumption. Farm households were also prudent in their choice of market outlets. For example, farm households who produce higher marketable surplus preferred selling cereal grains to wholesalers than other market outlets. This shows that farm households' production and marketing decisions are guided by home consumption, market value, and volume of surplus production.

From the results obtained from our simultaneous equation model estimation, except for NPS fertilizer, it is evidenced that cereal commercialization promotes the use of modern input, such as improved seed, nitrogen fertilizer, agrochemicals, and higher labor among farm households. For example, keep other factors being constant, a 10% increase in the degree of commercialization increases nitrogen fertilizer and agrochemical by 6.8%, and 23.0%, respectively. Similarly, the commercialization of cereal crops provided farm households with opportunities to entertain additional yield gains. For instance, ceteris paribus, a 10% increase in the degree of commercialization increases cereal yield by 5.5%, respectively. From the findings of our 3SLS model estimation, we inferred bi-directional causation between technical efficiency and commercialization of farm households. The findings of this study implied that farm households on the one hand can improve the level of farm-level productivity through an increased level of commercialization which is channeled through its income effects and on the other hand an increased level of productivity through efficient use of production inputs helps to produce marketable surplus and link the farm households with the market. In addition, in this study, the degree of cereal crop commercialization is positively influenced by the size of own farmland, credit service, agricultural asset holdings, use of improved seed and fertilizer, market outlet choice, whilst negatively affected by the sex of the household head, family size, non-farm income.

3) Poverty Reduction Effects of Technical Efficiency and Its Heterogeneous Effects by Crop Diversification Status of Farm Households

Growth in agricultural productivity has long been regarded as a fundamental instrument in reducing poverty and improving the welfare of smallholder farmers in developing countries including Ethiopia. Such an objective can be achieved primarily through either advancing technological innovations or improving the productive efficiency of farm households. This study hence, assessed the effect of productive efficiency and multidimensional poverty among the farm households. The results show that a higher proportion of farm households (58%) were classified as multidimensional poor, suggesting that multidimensional poverty is still persistent in rural areas and continues to be the major challenge for the wellbeing of farm households. The study has found multidimensional non-poor farm households more technically efficient than poor farm households, indicating multidimensional non-poor farm households have the relatively higher capability in terms of accessing and using modern productive inputs, improved farming practices, and market-related information. Interestingly, however, there are also farm households who were, at the same time, efficient and multidimensional poor, which sympathies with the renowned *'efficient but poor'* hypotheses, forwarded by Schultz in his 1964 seminal study at

Guatemalan Indian villages (Schultz, 1964). The result does not plainly mean efficiency has no effect and associated with multidimensional poverty. The result, however, designated the manifestation of other factors responsible for household multidimensional poverty over and above farm-level efficiency and productivity.

Our empirical results showed that technical efficiency has a significant and negative effect on household multidimensional poverty, suggesting that, controlling for other factors, multidimensional poverty can be reduced by increasing the efficiency of cereal crops production. Moreover, the study showed that the effects of technical efficiency on household multidimensional poverty are heterogeneous by crop diversification status, indicating improving technical efficiency, Ceteris Paribus Assumption, has higher poverty reduction effects among farm households with a moderate and lower degree of crop diversification status. This appears to be farm households having high crop diversification status have greater resilience capacity to bear any risks associated with crop production than farm households with low diversification status and thus, unlikely to slide into poverty. Farm households with higher crop diversification status can cope with those weather and any other shocks, which may drive them into vulnerability to poverty because they can recover from any form of crop damages and make rural households' livelihood more stable.

4) Effects of Cereal Crops Commercialization on Household Multidimensional Poverty

In this study, we explored the effects of cereal crop commercialization on household multidimensional poverty and vulnerability to multidimensional poverty. Our empirical findings showed that increased involvement of farm households in cereal crop commercialization has significant and negative effect on household multidimensional poverty and vulnerability to multidimensional poverty. In addition, it has been found that cereal crop commercialization reduces the level of household multidimensional deprivations, which are measured exclusively through the wealth, which was indexed using landholding and livestock ownership and living standard dimensions. From the findings of the focus group discussion, it was also reported that farm households who have low land holdings borrow money from other better-off farm households by leasing their land as collateral to alleviate their financial hardship in the event of a family crisis. Other factors affecting multidimensional poverty were including age and education of the household head, adult workers in the households, population pressure, cooperative membership, participation in non-farm activities, and level of crop diversification.

Overall, the findings of this study provided the following important insights. One of the insights could be farm households with increased farm income from the sale of cereal grains can be able to acquire productive resources, goods, and services necessary for advancing wealth and living standards. It enables farm households to access additional cultivated land through a rent in arraignment and improve land productivity through the use of capital inputs and improved agricultural technologies. Farm households can also contribute to poverty reduction by creating an agricultural wage for landless daily laborers, injecting an income through purchasing services and goods from the non-farm sector, and directly investing in the non-farm sector. The second insight from the findings of the study could be associated with due to increased income inequalities, farm households among the lower categories of farm holdings may become poor and vulnerable to socio-economic crises and forced to rent out their cultivated land.

The result further revealed that cereal crop commercialization may either increase herd size that might be channeled through its direct income effects or improve livestock productivity by enhancing the farm households' capability to purchase livestock feeds and other inputs. An increased farm income through commercialization may also enable farm households to improve material wellbeing, which is reflected in terms of household consumption, housing condition, sanitation, nutrition, social services, security, and overall quality of life.

6.3. OVERALL CONCLUSIONS, AND POLICY AND DEVELOPMENT IMPLICATIONS

- ***Recognize differences among farm households***: From the findings, the study concludes individual farmers' achievement in terms of efficiency significantly varies by household-level characteristics mainly sex and age of the household head. In addition to this, in our qualitative study, other differences in terms of human factors that are associated with farm households' ability, limitation, and characteristics are also reported as among key factors for farm households' inefficiency and low farming performance. Literature, concerning this, stated that human factors, such as personal and family characteristics and considerations affect farm earnings (Pond & Wilcox, 1932). Hence, any agricultural development efforts geared towards improving quality and productivity should involve gathering information about human abilities, limitations, and other characteristics and applying it to tasks, tools and equipment, and the environment (Patel, 2017). This further implied that the importance of understanding the origin of farm households' inabilities and how they can be improved. This would assist to address those human-related factors (particularly cognitive, emotional, and cultural factors) attributed to inefficiency beyond the common variables including sex and age variables to make up the complete causes of farm households' inefficiency. The results of the efficiency analysis also suggest that there is a significant scope to substantially improve cereal output with the current level of input mix and technology. This informs policy makers and outreach efforts to focus on production strategies that address inefficiency gaps among farm households.

- ***Improve input market integration:*** The result from the empirical model result reveals that proxy to input markets has a positive and significant effect on farm household efficiency (Chapter 2). This study, therefore, concludes that improved access to input centers could facilitate widespread adoption of agricultural technologies and hence, improve technical efficiency. Inputs such as seed, chemical fertilizer, and agrochemicals (pesticides, herbicides, and insecticides) are essential elements of crop production that improves efficiency, productivity, and income of smallholders in developing country (Rosegrant, et al., 2001; Bank, 2013). Hence, future policies should focus on penetrating access of technologies, modern inputs and agronomic information to remote rural areas with affordable prices. This can be strengthened through revitalizing the role of cooperatives and local youth groups to address barriers in acquiring information regarding improved technologies. In addition to spatial proximity to the market center, literature also suggests the importance of taking individual differences, such as household endowments (land, labor, and capital) and individual characteristics into account to enhance farm households' access to inputs and services required to upsurge efficiency (Meijerink & Roza, 2007).

- ***Expand digital extension and advisory services through public-private partnership:*** The results of this study showed that access to mobile phones enhances the technical efficiency of farm households. The study, therefore, concludes that ownership of mobile phones facilitates information exchanges between farm households and other sources of information. It helps to convey messages about improved crop varieties and farming practices to farm households and thus, enables technology adoption and addresses the efficiency gap. Empirical evidence shows that improving farm households' input market integration by addressing information asymmetry contributes to innovation and adoption among farm households and in turn influences the sustainable use of agricultural land (Ullaha, et al., 2020). Therefore, improving the information delivery system through raising mobile phone coverage and other related digital agriculture may help to address inefficiencies that might be originated from production and market information asymmetry.

- ***Strengthen the capacity of primary cooperatives & local youth groups through long- and short-term loan:*** The conclusion drawn from the findings suggests that membership in cooperatives assists farm households to improve production efficiency. This conclusion is in line with Olagunju, et al. (2021) that cooperative membership favors efficient use of resources thereby making members more productive than non-members. Membership in farmers' groups can enhance households' access to knowledge and information, enable farmers-to-farmers seed exchange, and facilitate peer group influence on best practices. Therefore, policy should focus on addressing key socio-economic and plot-specific constraints that impede farm households to participate in agricultural cooperatives. Moreover, from the finds of the qualitative study, it has been realized that cooperatives faced significant limitations in the supply of agrochemicals, especially in terms of type, quantity, and timing. Similarly, they played a limited role in providing agricultural knowledge and information to farm households. In Ethiopia, the primary role of the agricultural cooperative is mainly to capacitate farm households to cope with challenges related to production and marketing. Cooperative mediates input delivery system mainly for improved seed, chemical fertilizer, and agrochemicals (pesticides, herbicides, and insecticides). Literature supports that at an early stage of development, government agricultural services and cooperatives are necessary to perform the supply of inputs, such as seed, chemical fertilizer, and agrochemicals (Haessel, et al., 1972). It is, therefore, agricultural development efforts should emphasize mitigating the capacity gap of agricultural cooperatives in service provision. Building the capacity of primary cooperatives and local groups through long- and short-term loans facilitates a better supply of agricultural inputs, such as improved seeds, chemical fertilizers, agrochemicals, various pre-and post-harvest machinery, chemical sprayers, etc. In addition, farm households may have improved access to pre-and post-harvest machinery if the machinery rent mechanism can be arranged at an affordable price and thus, likely to improve the efficiency of farm households. Moreover, linking agricultural cooperatives with research centers and universities may facilitate farm households' access to knowledge and information and improve the efficiency of their members.

- ***Emphasis for the breeding and agronomic research investments to develop appropriate, suitable, and alternative cereal varieties:*** In this study, the role of adopting agricultural technologies to improve efficiency was confirmed. Therefore, the study asserts that the use of high-yielding crop varieties together with the joint introduction of other packages of production methods improve the productive efficiency of farm households. Literature also strongly favors the strategy of introducing high-yielding varieties with the joint popularization of modern inputs and thus far, increasing output per unit of input (Tolley, 1969). This is therefore, improving the breeding and agronomic research is one of the important strategies to improve efficiency and thereby register rapid productivity growth in cereal output. At this juncture, the work of crop-breeders should be directed at developing varieties characterized by a strong response to farming practices (for example, applications of fertilizer), which play a necessary part in realizing the full potential of the new varieties (Johnston & Mellor, 1961). Our result also favors the diffusion model of agricultural development that explains the path to agricultural development is through more effective dissemination of technologies and production methods and a diminishing of the productivity differences among farmers and regions (Udemezue & Osegbue, 2018). Therefore, efforts should be strengthened to sustainably generate appropriate, suitable, and alternative technologies that are more adapted to the needs of farm households. Highly productive, early matured, disease and pest-resistant crop varieties that recognize household and plot level differences can help to address efficiency and productivity gaps. The efforts should also pay an emphasis to enhancing the capacity of source seed multiplication and dissemination of full packages through public-private investment.

Empirical evidence from the intensification of the green revolution also reinforces the argument. Much of the success of the green revolution was caused by the combination of high rates of investment in crop research, infrastructure, and market development, and appropriate policy support (Pingali, 2012), implying that producers were able to harness the technologies and packages of inputs. The high payoff input model of agricultural development also supports the requirement of investment in agricultural research to successfully develop new, suitable, and high-productive grain varieties. Empirical experience in Mexico, beginning in the 1950s, and in the Philippines in the 1960s, shows that the development of new high-yielding wheat and rice varieties, in that order, which was more productive and highly responsive to industrial inputs led to the swift dissemination of high yielding varieties among producers in various countries in Asia, Africa and Latin America (Udemezue & Osegbue, 2018). Hence, promoting the use of technological advances through public and private investment can be one of the policy instruments for the successful implementation of the cereal intensification strategy of the country.

- ***Expand non-agricultural employment in rural areas***: From the key findings of chapter 3, the study asserts that, population pressure, which is measured by the number of family members in the households to the total own cultivated land, was found to significantly determine the poverty situation of farm households (Chapter 4). The study, therefore, concludes there exists surplus family labor, who works on a piece of farmland. With surplus labor who work on the land, Arthur Lewis (1954) in his structural economic growth/dualistic economy model underscore that if there exist surplus agricultural workers on the land, it will result in dimensional marginal returns, and thus far, surplus labor should migrate to cities and employed in manufacturing activities. Of course, as Johnston & Mellor (1961) stated that among the most important ways in which increased agricultural output and productivity contribute to overall economic growth, the labor force must be drawn mainly from agriculture. However, given the unbalanced expansion of industries at urban centers, rural-urban labor migration may result in high unemployment and hence, aggravate urban poverty.

In this study, therefore, it is argued against the *'Lewis dual-sector model'* and suggested the expansion of small-scale agro-industries in rural areas that may help to absorb the growing rural youth through expanding finical and advisory services into remote rural areas. Added to this, agricultural development policies should give sufficient emphasis on the role of the rural non-farm sector, and its synergies with agriculture. Concerning this, the literature suggests that rural development programs should put considerable emphasis on non-farm activities, such as the processing of raw agricultural materials and the manufacturing of agricultural equipment, tools, and inputs (Meijerink & Roza, 2007).

- ***Expand rural market centers to remote areas***: Our analysis buttressed that the commercialization of cereal crops improves the input use capacity of farm households (Chapter 3). Moreover, our results also bolstered that farm households' input use efficiency leads to a higher degree of cereal commercialization and cereal commercialization improves the input use capacity of farm households (Chapter 3). The study also confirmed that access to financial services enhances the process of commercialization (Chapter 3) by improving farm households' ability to purchase yield-enhancing modern inputs and participate in input markets. On top of this, the availability of financial services can help farm households to be market-oriented by easing the liquidity constraints of the households (Gebremedhin & Hoekstra, 2007 ; Abafita, et al., 2016). Cell phone ownership has also a significant positive effect on the level of farm households' cereal commercialization. The study therefore, concludes that cell phone ownership facilitates access to market-related information so that it helps to improve production and marketing decisions. Therefore, the result substantiates that in addition to improving the efficiency of farm households, it is equally important to expand rural marketing services to achieve sustained growth in cereal output. In favor of these findings, Johnston & Mellor (1961) stressed that expanding the availability of the market is a necessary condition for the rapid growth of output. To this end *'how rural market can be expanded?'* is one among the important questions that require to be addressed. For the improved expansion of the rural market, measures should be taken to improve rural roads and rural transport, market information, rural electrification, insurance and banking, warehouses and communication facilities, etc. Coupled with expanding rural infrastructures, creating market hubs and distribution models to expand the marketing services to remote villages may assist to make the supply and price of agricultural commodities remain more stable throughout the year. Then, as stated by Meijerink & Roza (2007) the ability of farmers to respond to the growing demand for food in urban areas can be improved.

- ***Consider transaction cost segregated by market outlets:*** In this study, it was found that market channel choice of farm households positively and significantly associated with the level of cereal crop commercialization with different magnitude. The study therefore concludes that farm households rationally tend to choose market outlets depending on the volume of sale and the likely transaction cost for the bulk sale of the crops. To this end, the theory of transaction cost suggests that farm households self-select not to participate in the market when transaction cost is high (de Janvry, 1991; Barrett, 2008), indicating that the transaction costs that are associated with the volume of sale may affect farm households' choice of market outlets and deter market participation at main market centers. Therefore, policy measures should take different market outlets into account and allied challenges, such as poor infrastructure, less competitive marketing system, and limited availability of market support services.

- ***Special focus for farm households who grow fewer crops:*** The findings of this study highlight that improving cereal crops production efficiency reduces household multidimensional poverty. In addition to his, our findings revealed that gains from improving technical efficiency appear to be considerably higher among moderately and least diversified farm households. This suggest that responding to those farm households who grow fewer crops assists to reduce the number of people sliding into multidimensional poverty.

- ***Progressive land reforms for cultivated land and regulation of land rent in/out practices:*** Our results substantiate that cereal commercialization can be considered as a key pro-poor growth strategy, among others, to reduce the poverty situation of farm households in rural Ethiopia (Chapter 5). From the econometric model results, the study further concluded that cereal commercialization reduces multidimensional deprivation, which is exclusively measured in wealth and living standard dimensions. From these findings, it is possible to conclude that the effects were channeled through its direct income effects. The direct income effects that are related to arable land depend on the prevailing land tenure policy of the country. Of course, in most developing countries land market may not be functioning because farmers do not have the right to sell their land, or incomplete because selling and buying of land is hardly taking place (Meijerink & Roza, 2007). Such land tenure arraignment is similar in Ethiopia in that farmers cannot access additional arable land through direct purchasing. This mean that on the one hand farm households among highest land holding category, through rising income, tend to rent more arable land from other poor farm households and invest more capital to increase soil fertility by using both organic and inorganic fertilizers. On the other hand farm households among the lowest land category may be forced to rent out their land due to risks and income inequality, ultimately may slid to multidimensional poverty. For a successful commercial-oriented strategy, nonetheless, policymakers should give particular attention to progressive land reforms for cultivated land and regulation of land rent in/out practices rural areas. Literature also suggested that reducing poverty by enhancing asset ownership for the poor (e.g. through investment in infrastructure, credit targeted to the poor, land redistribution, and education) is among the important mechanisms to make growth 'pro-poor (Meijerink & Roza, 2007). Moreover, introduction of new crop cultivars, which can be applied with a double/inter cropping scheme together with irrigation can be considered as the crucial areas of policy interventions.

From our findings, livestock ownership was found to be an important wealth that determines the status of household multidimensional poverty, thus far, enhanced access to improved livestock breeds helps farm households to bear from driving into multidimensional poverty. However, the adoption of improved livestock breed is constrained by availability and affordability, which is mainly associated with a lack of institutions engaged in the multiplication of livestock breed and other technologies. Therefore, future policy should address the institutional gap in livestock technology multiplication. The poverty reduction effect of cereal commercialization measured in living standard dimensions also supports the connotation that an increase in farm income could stimulate demand for infrastructure (Irz, et al., 2001). However, electrification and access to safe drinking water are determined by not only the functional capacity of rural households but also a public investment to expand the services to remote rural areas. Therefore, rural electrification, the expansion of safe drinking water, sanitation, and modern energy sources should continue to be the focus of future infrastructural intervention.

6.1. Limitations and Future Research Prospects

1) In this study, the multidimensional poverty effect of improving production efficiency and commercialization of cereal crops was assessed based on primary data generated following a cross-sectional research design. This means that the present study has limited in terms of dealing with dynamics and causalities, hence, subsequent studies can use panel data to study the potential long-term effects and binary relationships between productive efficiency, commercialization, and multidimensional poverty using causality econometric models. Added to this, the results of this study are inferences for cereal-producing farm households in major *''teff''* growing areas in Ethiopia; thus far, a similar study can be conducted by other farming areas of similar agro-ecologies and nationally.
2) Our qualitative findings revealed that farmers have increasingly applied nitrogen fertilizer mainly for cereal crops beyond the scope of research recommendations. The main reason for the increased application of nitrogen fertilizer is its high rate of yield response. Therefore, this calls for the need to revise the existing recommendations for fertilizer rates based on agronomic trials.
3) Our empirical evidence shows that efficiency and market improvements contribute to the reduction of household multidimensional poverty. This clearly shows that an increased annual income gain from the sale of cereal crops is one of the sources of improvement in material wellbeing. In addition, agriculture is believed to play a key role in reducing rural poverty by providing capital for the establishment of other non-agricultural sectors. In this regard, literature stated that balanced growth is needed in the sense of simultaneous efforts to promote agricultural and industrial development (Johnston & Mellor, 1961) for improved welfare. Considering this connotation, future research questions can be posed that how additional income from agriculture can form adequate capital that is to be reinvested to expand non-agricultural sectors in rural areas? Do any additional capital outside the agricultural sector and advisory services are required to stimulate the formation of a non-agricultural sector?

4) Farm household inefficiency level may not only be determined by factors that are associated with household characteristics but also it can be considerably governed by individual factors in terms of determination, commitment, motivation, etc. To this end, the qualitative study found that differences in farm households' attitudes, determination, commitment, and motivation may create efficiency and productivity differences. In addition, differences in terms of innovativeness among farmers can also lead to differences in efficiency and productivity. In this regard, most of the previous empirical researches fail to quantitatively address these key factors for efficiency because of the challenge to measure them directly. Hence, we recommend further studies on farm households' determination/ commitment/ motivation and its effect on their level of production efficiency beyond other factors commonly hypothesized and assessed using econometric models.
5) In our study, emphasis was given to the channels through which productive efficiency and commercialization can affect household multidimensional poverty. However, other areas for example market outlet choices, transaction cost, and multidimensional poverty linkage can be a topic of investigation for future research.
6) Due to the outbreak of disease and pests on pulse crops, it has become difficult for farm households to practice a crop rotation system. The yield effects of crop rotation and its interruption on cereal crops as well as market conditions can be one of the future research topics.

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APPENDICES

Appendix: Report on Plagiarism Assessment

Addis Ababa University
College of Development Studies
Office of the Associate Dean for Research and Technology Transfer
Template for Reporting Plagiarism Assessment

Name of the Center: Center for Rural Development Program of study: Regular Program level (Masters/PhD): PhD Please, check one: Regular/Continuing

Name of the Adviser/s: Dr. Abrham Seyoum and Dr. Dawit Alemu

Topic of the dissertation/thesis: Production Efficiency, Commercialization of Cereal Crops and Multidimensional Poverty among Farm Households in Major '*Teff*' Growing Areas of Ethiopia

S/N	Name and ID.NO. of the student/candidate	Percentage of plagiarism confirmed	Comments given and improvements made by the student/candidate
1	Fisseha Zegeye Birhanu (ID: GSR/5490/11)	**1%**	Matched texts are changed as attached shown in Plagiarism correction format

Remark by adviser/s
____
____
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Name of the center head/coordinator ___________ Signature ___________ Date________

1. Name of the adviser/s_________________Signature _____Date _______
2. Name of the adviser ___________ Signature ___________Date ___________

Note that:

1. All Centers and their faculty members should carefully read, understand and brief students/candidates working under their supervision about the plagiarism policy and the checker software.
2. By adopting the use of the software, it is assumed faculty members have read and shared the key provisions in the guidelines with students/candidates working with them.
3. Thesis/dissertation advisors shall first run and report the level of plagiarism on the submission of the thesis/dissertations of their respective students/candidate
4. The anti-plagiarism policy of the university allows for a maximum of 20% report (green color) and, with further qualitative analysis and interpretation over this 20% report itself by the advisor/s. Please refer to the anti-plagiarism guideline for assessment results more than 20%.
5. Center heads/ coordinators shall further verify the plagiarism assessment results reported by the adviser/s
6. A thesis/dissertation not assessed through the university software and not signed by the adviser/s will not be endorsed by the head /coordinator to proceed for defense.

7. The final plagiarism assessment report will be attached with the thesis/dissertation for the consumption of examiners.

No	Matched Text	Changed Text	Page
1/17	On average, agriculture grew by 6.6% during the first Growth and Transformation Plan (GTP	During 2010/11-1014/15 (GTP I), the agricultural sector, on average, grew by 6.6%.	3
2/17	Out of the total grain crop area under cereals, teff, maize, sorghum, wheat,	From the total cultivated farmland under cereals, teff, maize, sorghum, wheat, and barley, which are the heart of the country's agriculture and food economy (Seyoum, et al., 2011) …	4
3/17	complex land and labor-intensive cropping system, the production and the use of organic manures, and labor-intensive capital formation	Conservation model involves the execution of complicated land and labor-exhaustive farming system, the application of organic manures, and labor-intensive capital creation through the use of intensive labor, and facilities effective utilization of land and water resources.	20
4/17	the route to agricultural development can be attained through more effective dissemination of technical knowledge and reduction of productivity gaps between farmers and regions.	From the perspective of the diffusion model, successful diffusion of technical knowledge and decline of productivity gaps between farmers and regions are the main path to agricultural development.	20
5/17	mix of traded and non-traded inputs Moderately specialized Agricultural and non-agricultural Commercial systems Profit maximization Predominantly traded inputs Highly specialized Predominantly non-agricultural	Not changed because words are standard words	-
6/17	the value of 1.96; e is the desired level of precision; p is the estimated proportion of an attribute present in the	e is the required degree of precision; p is the estimated proportion of an attribute that exist in the population with a value of 0.5 to get the desired minimum sample size of the household at 95% confidence level and ± 5% precision;	48
7/17	The negative sign indicates that the distribution of the residuals is consistent with a production frontier specification	The negative sign of the skewedness value designates that the distribution of the residuals is in line with a production frontier specification (Kumbhakar & Wang, 2015).	70
8/17	Out of the total grain crop area under cereals, 'teff' (Eragrostis teff), maize, sorghum, wheat,	From the total cereal crops cultivated areas, *'teff' (Eragrostis teff)*, maize, sorghum, wheat	
9/17	permits to go beyond the traditional dichotomies of sellers versus non-sellers, or between staple and cash crop producers	allows to classify sellers and non-sellers, or producers of staple and cash crops	89
10/17	no household member has completed five years of schooling and if no primary school-aged child is currently attending school.	no family member has completed five years of schooling and no school-aged children are presently attending school.	141

11/17	permits to go beyond the traditional dichotomies of sellers versus non-sellers, or between staple and cash crop producers	assists to make classification between sellers and non-sellers, or between staple and cash crop producers	140
12/17	Education (1/5) Years of schooling No household member has completed 5 years of schooling Child attendance to school No	Not changed because they are standard single words or phrases used to contract MPI)	-
13/17	result also shows there is a statistically significant mean difference	Moreover, the result revealed statistically significant mean difference	151
14/17	technical knowledge and a narrowing of the productivity differences among farmers and regions	production methods and a diminishing of the productivity differences among farmers and regions	168
15/17	rapid diffusion of the new varieties among farmers in several countries in Asia, Africa, and Latin America	swift dissemination of high yielding varieties among producers in various countries in Asia, Africa and Latin America	169
16/17	*teff*, wheat, maize, barley, and sorghum are the core of the country's agriculture and food economy	*teff*, wheat, maize, barley and sorghum are at the heart of the country's agriculture and food economy	149
17/17	households. This result is consistent with the findings of Nisrane, et al. (2015).	Similar result was also reported in Nisrane, et al. (2015).	80

Appendix IIA: Collinearity test for continuous variables using VIF

Variable	VIF	1/VIF
Farm_size	1.48	0.674858
TLU	1.29	0.773747
Age	1.28	0.782128
HH_Size	1.2	0.834109
No_Crop	1.14	0.876182
Land_quality	1.05	0.951179
Stress_Inc	1.02	0.9767
Input_center (km)	1.02	0.981368
Mean VIF	***1.19***	

Source: Authors' analysis using primary data (2020)

Appendix IIB: Pair-wise correlation for dummy variables

	Sex	Mobile	Extn_access	Mem_cop	Cluster	USE_IMPS	Seed_dum	UREA_dum	Row_dum
Sex	1.0000								
Mobile	0.0213	1.0000							
Extn_access	0.1143	0.0601	1.0000						
Mem_cop	0.0378	0.0132	0.2210	1.0000					
Cluster	0.0700	0.0035	0.1703	0.2398	1.0000				
USE_IMPS	0.0878	0.0828	0.4535	0.0598	-0.2179	1.0000			
Seed_dum	0.0176	-0.0006	-0.0894	0.1264	-0.0965	0.0458	1.0000		
UREA_dum	-0.1129	0.0670	-0.0878	0.0130	0.0866	-0.0376	-0.0838	1.0000	
Row_dum	-0.0445	-0.1556	0.0512	0.1278	-0.1610	0.2137	0.0266	0.0333	1.0000

Source: Authors' analysis using primary data (2020)

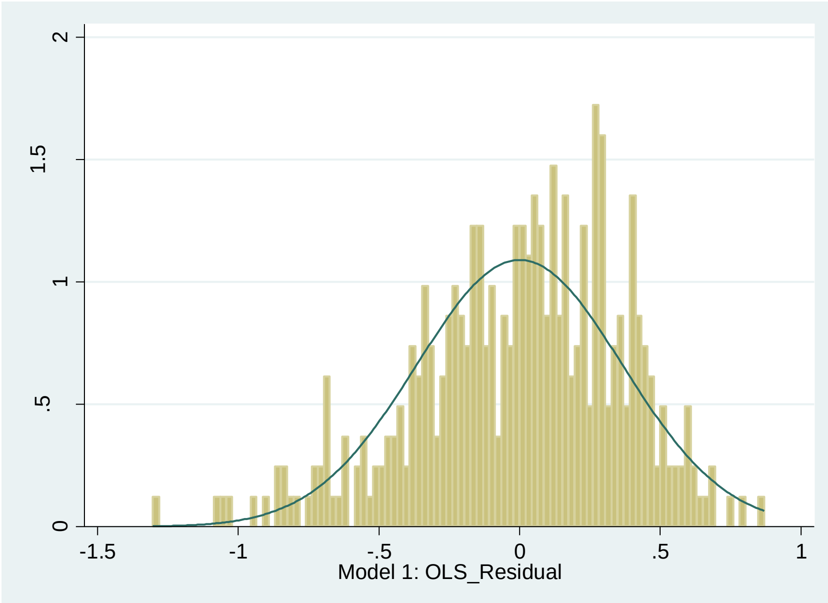
Appendix IIC: A Skewness test on OLS residual

```
. sum e, detail

                          Residuals
-------------------------------------------------------------
      Percentiles      Smallest
 1%    -1.040765      -1.303489
 5%    -.6849221       -1.06963
10%    -.4756001      -1.058858       Obs                 374
25%    -.2228247      -1.040765       Sum of Wgt.         374

50%     .0405046                      Mean           2.44e-10
                        Largest       Std. Dev.      .3658769
75%     .2707711       .6841195
90%     .4324658       .7444348       Variance       .1338659
95%     .5281246       .7872564       Skewness      -.5304617
99%     .6841195       .8693118       Kurtosis        3.20568
```

Appendix IID: A Skewness test on OLS residual with p-value

```
                  Skewness/Kurtosis tests for Normality
                                                     ------ joint ------
    Variable |        Obs  Pr(Skewness)  Pr(Kurtosis)  chi2(2)   Prob>chi2
-------------+------------------------------------------------------------
           e |        374     0.0001        0.3463      17.10       0.0002
```

Appendix IIE: Distribution of OLS residual



Appendix IIF. Hypothesis tests for the models

Null hypothesis	x^2 statistics	DF	Critical value $X^2_{v0.99}$	Decision
Cobb-Douglas SFPF and Translog SFPF $H_0: \beta_6 + \beta_7 + \cdots \beta_{20} = 0$	26.86	15	29.927	CD is proper
Homogeneous production technology across geographical regions $H_0: \beta_j = \delta_j = \gamma_j$	82.96	22	38.304	Reject H_o
No technical inefficiency in the model $\sigma_u^2 = 0$ and $\mu = 0$,[28]				
▪ Group 1 (Adaa)	10.42	2	8.273	Reject H_o
▪ Group 2 (Enemay)	17.96	2	8.273	Reject H_o
▪ Pooled	23.41	2	8.273	Reject H_o
Inefficiency parameters have no effect on technical inefficiency $H_0: \delta_1 = \delta_2 = \cdots \delta_{17} = 0$				
▪ Group 1 (Adaa)	148.15	17	32.766	Reject H_o
▪ Group 2 (Enemay)	118.15	17	32.766	Reject H_o
▪ Pooled	284.87	17	32.766	Reject H_o

Source: Authors' analysis using primary data (2020)

[28] In the case of assuming Truncated normal distribution for the inefficiency error term, the LR test has two degrees of freedom because the null hypothesis has two restrictions, such as $\sigma_u^2 = 0$ and $\mu = 0$ (Kumbhakar, et. al., 2015).

Appendix IIG: Kernel density estimates

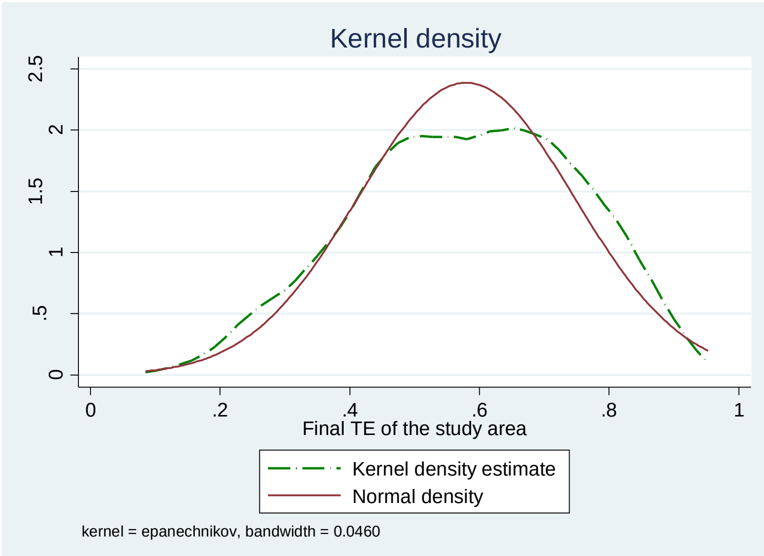


Figure G1: Kernel density of Meta-TE

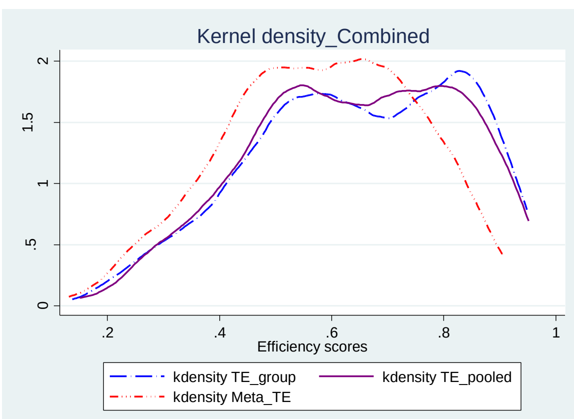


Figure G2: Kernel density of different TE scores

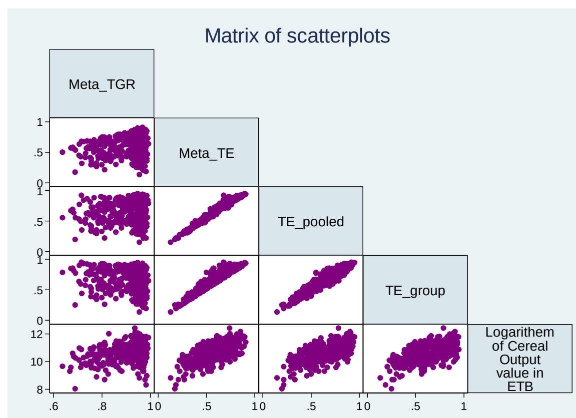


Figure G3: Matrix scatterplots

Appendix IIH: Recommended seed and fertilizer rate by crop

Crop	Seed rate (kg/ha) Vertisols		Seed rate (kg/ha) Clay soil		Seed rate (kg/ha) Light soil		UREA [Kg/ha]	NPS [Kg/ha]
	Broadcast	Row	Broadcast	Row	Broadcast	Row		
Tef	20-25	10	25	15	25-30	15-20	100	100
Wheat	125-150	100-125	125-150	100-125	125-150	100-125	100	100-125
Barely	125	85	125	85	125	85	100	100
Maize	-	-		23-30	-	-	200	200
Sorghum	-	-	15-20	8-10	-	-	100	100

Source: EIAR (1999); MoA (2010)

Appendix III: Conversion factor for man-equivalent

Age groups (Years)	Male	Female
<10	0	0
10-13	0.2	0.2
14-16	0.5	0.4
17-50	1.0	0.8
>50	0.7	0.5

Source: Storck et al. (1991).

Appendix IIIA: Fractional response (logit) model specification

Following Papke & Wooldridge (1996) the conditional expectation of fractional response variable is $E(y_i|x_i) = G(x_i\beta), i = 1, \ldots, N$. Hence, functional form for fractional logit model is specified as: $E(y_i|x_i) = exp(x\beta)/(1 + \exp(x\beta)$, where, y_i is the dependent variable range between 0 and 1, x_i is $1 \times k$ vector of explanatory variables, $G(.)$ is the link function satisfying $0 \leq G(.) \leq 1$.

Appendix IIIB: Collinearity test for continuous variables

Variable	VIF	1/VIF
Head_AGE	1.45	0.691437
Head_Edu	1.17	0.855593
Cultivated_land	1.6	0.625381
Household_size	1.37	0.730115
ln_Fertili	1.28	0.780291
lnAsset_Ag	1.2	0.831653
Land_Quality	1.12	0.895278
Prop_USE	1.11	0.899289
Nearst_Market	1.11	0.904329
DEP_RATIO	1.09	0.915075
Mean VIF	***1.25***	

Source: Authors' analysis using primary data (2020)

Appendix IIIC: Dose-response function estimation

Table C1: Distribution of treatment interval

Level of cereal crops commercialization	Number of HH	Percentage (%)
Treatment interval 1 (below 0.30)	81	23.48
Treatment interval 2(from 0.30 to 0.65)	244	70.72
Treatment interval 3(from 0.65 to 0.90)	20	5.08
Total	345	100

Source: Authors' analysis using primary data (2020)

Table C2: Estimated OLS Coefficients given treatment variable and GPS (UREA)

Outcome variables: UREA in ETB/ha (log)	OLS Coefficients	Standard Errors
Treatment	2.6443	1.5057
treatment_sq	-0.3917	1.5901
pscore	2.9759	1.1859
pscore_sq	-1.1565	1.3845
Treatment*pscore	-4.2343	1.8285
Constant	6.0590	0.2274

Source: Authors' analysis using primary data (2020)

Table C3: Estimated OLS Coefficients given treatment variable and GPS (NPS)

Outcome variables: NPS in ETB/ha (log)	OLS Coefficients	Standard Errors
Treatment	1.7698	1.2787
treatment_sq	-1.9898	1.3504
pscore	0.1035	1.0071
pscore_sq	-0.3497	1.1758
Treatment*pscore	-0.4313	1.5529
Constant	7.1938	0.1931

Source: Authors' analysis using primary data (2020)

Table C4: Estimated OLS Coefficients given treatment variable and GPS (Chemical)

Outcome variables: Chemical in ETB/ha (log)	OLS Coefficients	Standard Errors
Treatment	-0.7879	3.8392
treatment_sq	1.5062	4.0545
pscore	5.6270	3.0238
pscore_sq	-5.3842	3.5302
Treatment*pscore	0.4141	4.6624
Constant	2.2719	0.5797

Source: Authors' analysis using primary data (2020)

Appendix IIID: Plot-level Cost-benefit analysis by cereal crops

Cost-benefit indicator	Overall	*Teff*	White *teff*	Brown *teff*	Wheat	Barely	Maize
Value of gross production (ETB/Ha) [Q]	36137.35	39158.92	40767.04	30456.06	35134.37	34590.72	14414.95
Production cost per hectare							
▪ Seed (ETB/Ha)	1405.06	1065.91	1074.47	919.85	2271.88	1501.66	608.49
▪ Chemical fertilizer (ETB/Ha)	3390.86	4022.05	4136.70	4249.71	3494.63	2626.70	1163.81
▪ Hired labor (Person Day ETB/Ha)	2066.88	2508.38	2546.24	2180.31	2483.52	684.24	42.82
▪ Agrochemicals (ETB/Ha)	231.94	277.01	285.03	200.84	306.12	25.84	-
Total production cost (ETB/Ha) [TPC]	7094.74	7873.35	8042.43	7550.71	8556.15	4838.44	1815.12
Net-value benefit per hectare [Q-TPC]	29042.61	31285.57	32724.61	22905.35	26578.22	29752.28	12599.83

Source: Authors' analysis using primary data (2020)

Appendix IVA: Spearman correlation between MPI indicators

	YS	CSA	HC	ILL	WAT	SAN	CK	FL	EL	TLU	LAND	DS	COP
YS	1												
CSA	-0.0034	1											
HC	0.0542	-0.076	1										
ILL	-0.0211	0.1824	-0.2759	1									
WAT	0.0085	-0.0666	0.2016	-0.1427	1								
SAN	0.0957	0.0672	-0.2081	0.1712	-0.505	1							
CK	0.0856	-0.1063	0.0273	-0.0846	0.047	0.0613	1						
FL	0.123	0.0565	0.1055	-0.1217	0.2236	-0.1202	0.0766	1					
EL	0.0519	0.0717	-0.2767	0.0637	-0.2266	0.1171	0.0675	0.0414	1				
TLU	0.1391	-0.0737	0.1394	-0.0632	0.2214	-0.0831	-0.032	0.0858	-0.1354	1			
LAND	0.2362	-0.0478	0.1285	0.0096	0.0288	0.0428	0.0902	0.0419	-0.0805	0.2401	1		
DS	0.0133	-0.1262	0.1144	-0.118	-0.027	0.1219	0.1034	0.0555	0.0795	-0.0055	-0.063	1	
COP	0.0004	-0.0054	0.0389	-0.0001	-0.3691	0.2194	-0.0017	-0.078	0.0231	0.1135	0.2006	0.0597	1

Appendix IVB: Cultivated land under *'teff'* production by crop diversification scale

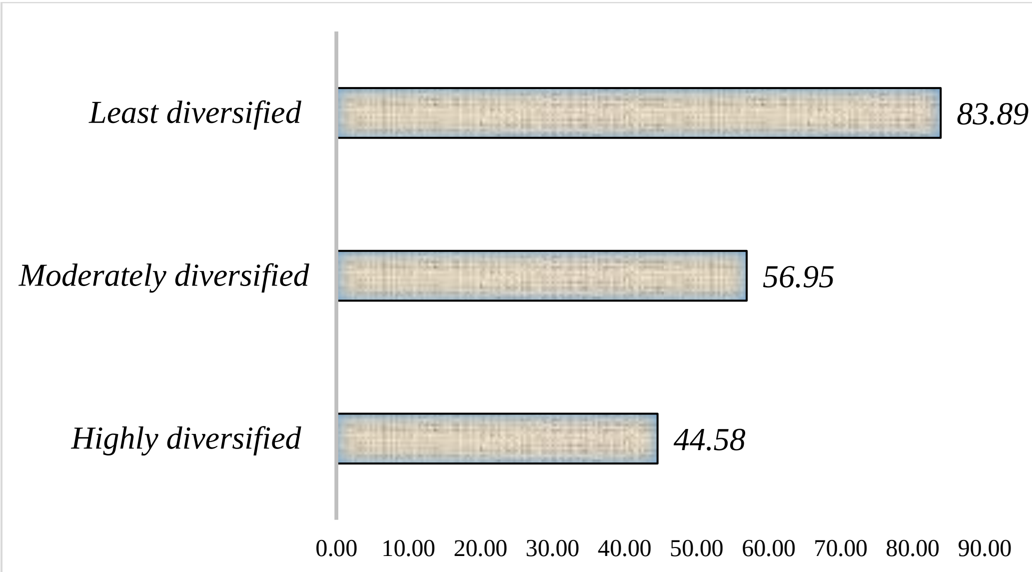


Figure A: Proportion of cultivated land under '*teff'* production by crop diversification scale

Source: Authors' analysis using primary data (2020)

Appendix A: Household Sample Survey Interview Questionnaire

Addis Ababa University
College of Development studies
Center for Rural Development

Dear Respondents

Introduction: We are conducting this survey to study production efficiency, commercialization of cereal crop and household multidimensional poverty among smallholder farmers in your area. The study is carried out in a partial fulfillment of a Doctor of Philosophy (PhD) degree at Addis Ababa University. You are chosen randomly for the purpose and kindly requested to respond some questions about your household. We ensure you that the information you are going to provide will be used for academic purpose. Hence, we are kindly requested you to give credible information for all of the questions. We thank you in advance for your time and kind cooperation.

Consent: We are glad to inform you that you have the right to NOT participate and can decide which questions that you do not wish to answer. If you do not have time right now, I can come back later when it is more convenient for you.

Anonymity: We assure you that the information you will be sharing with us will remain confidential and be used only for the purpose, and your name will not appear in any public documents. Do you have ANY questions before we begin?

Dear Enumerators

Please make a careful attempt to get a response and make a record for all questions.

PART I: IDENTIFICATION, AND HH CHARACTERISTICS

Section 1A: Identification Information and Interview Details

Household Identification	**Name/Code**
1. Region (1=Oromia, 2=Amhara)	
2. Zone (1=East Shewa, 2=East Gojam)	
3. District: (1=Adea, 2=Enemay)	
4. Kebele Administration (KA):	
5. Got/sub-PA	
6. Name of household head	
7. Sex of household head (1=Male, 0=Female)	
8. Name of respondent's spouse	
9. Cell phone number:	
Interview details	
1. Date of interview (dd/mm/yyyy):	
2. Time started and ended (12 HR)	
3. Name of enumerator	
4. Name of supervisor	
5. Agro-ecology (1=Dega, 2=W/dega, 3=Kola)	

Section 1B: Household Composition and Characteristics

1.1. Number of family members and structure. Please include all members of the household.

S/N	Name of household member (Start with respondent)	Sex **Codes A**	Marital status **Codes B**	Age in years	Education (years) **Codes C**	Relation to HH **Codes D**	Occupation **Codes E**		Own farm labour contribution **Codes F**
							Main	Secondary	
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									

Codes A	**Codes B**	**Codes C**	**Codes D**	**Codes E**		**Codes F**
0. Female 1. Male	1. Married living with spouse 2. Married but spouse away 3. Divorced/separated 4. Widow/widower 5. Never married 6. Other, specify……	0. None/Illiterate 1. Adult education or 1 year of education * Give other education in years	1. Household head 2. Spouse 3. Son/daughter 4. Parent 5. Son/daughter in-law 6. Grand child 7. Other relative 8. Hired worker 9. Other, specify…	1. Farming (crop + livestock) 2. Salaried employment 3. Self-employed off-farm 4. Casual labourer on-farm 5. Casual labourer off-farm	6. School/college child 7. Non-school child 8. Herding 9. Household chores 10. Other, specify…………	1. Full time 2. Part time 3. Not a worker

1.2. How many years have you engaged in farming? ____________ Years

1.3. Are you a model farmer? 1=Yes, 0=No

1.4. Is the household head disable to undertake farming? 1=Yes, 2=No

PART II: CROP PRODUCTION, TECHNOLOGY ADOPTION AND INPUT UTILIZATION

Section 2A: Land holding, plot characteristics, crop grown and technology utilization

1.1. Land holding (ha) during 2011/12 EC cropping season/year

Land category	Cultivated	Uncultivated (e.g., grazing, homestead etc.)
1. Own land used (A)		
2. Rented in/shared-in land (B)		
3. Rented out/ shared-out land (C)		
4. Total operated land (A+B)		
5. Total owned land (A+C)		

1.2. Do you have land certification book? 1. Yes 2. No

1.3. How do you see the trend of land holding as compared to five years ago?

1. Increasing, 2. No change, 3. Decreasing

1.4. Plot information, crop cultivated and improved farming practices (2011/12 EC production season)

S/N	Plot ID [Start with one next to residence]	Plot location name	Plot area [kert/timad]	Plot distance to residence [Walking minutes]	Soil fertility **Code A**	Plot slope **Code B**	Soil type **Code C**	Soil depth **Code D**	Used [season] **1=Belg 2=Meher**	Main crops grown during 2011/12 EC **Annex 1 Code**	Amount of seed used (Kg)	Planting method **1.Row 2.Broadcasting**	Crop rotation every year **0=No 1=Yes**	Soil & water conservation method* **0=No 1=Yes**	Irrigation 1=Irrigat-ed 2=Rain-fed
	1														
	2														

***Terraces, mulching, grass strips, trees on boundaries, no till, minimum till, soil bunds, stone bunds, other**

Codes A	**Codes B**	**Codes C**		**Code D**
1. Good/fertile	1. Gently slope (flat)	1. Black	4. Grey	1.Shallow
2. Medium/normal	2. Medium slope	2. Brown	5. Other, specify…	2.Medium
3. Poor/infertile	3. Steep slope	3. Red		3.Deep

1.5. Crop production, variety grown and improved seed utilization in 2011/12 EC cropping year

S/N	Plot ID **(Same order as in above)**	Main crops grown on [PLOT] **Annex 1 Code**	Use of improved variety during 2011/12 EC **1=Yes, 2=No**	Name of variety grown on [PLOT] **Annex 2 Code**	**Seed use**						Is the crop produced under cluster approach **1=Yes, 2=No**	Purpose of crop production** **1=Grain 2=Seed**	Crop harvested (Kg)
					Main source of seed **Code A**	Bought seed/seedlings applied on the plot during 2011/12 EC		Generation of improved seed **Code B**	Non-bought Seed/seedlings*				
						Quantity (kg/No)	Total cost (ETB)		Quantity (kg/No)	Total cost (ETB)			

*Own saved, farmers to farmers exchange, etc., ** Purpose of crop production is asked for those who are engaged in community based informal seed association

Codes A			Code B
1. Own saved seed 2. Government extension 3. Trader 4. Private seed suppliers 5. Gift from family/neighbour	6. Farmer to farmer seed exchange 7. Local market 8. On-farm trials 9. Extension demo plots	10. Farmer groups/Coops 11. Local seed producers 12. Provided free by NGOs/govt 13. Research centres 14. Other (specify)..................	1= Breeder seed 2= Pre-basic 3= Basic, 4= Certified seed 1, 5= Certified seed 2, 6= Certified seed 3

Section 2B: Input utilization

1.6. Input utilization and production cost

S/N	Plot ID **(Same order as in above)**	Main crop grown (**Annex 1 Codes**)	**Fertilizer (If not used, put Zero)**						**Herbicides**		**Pesticides**		**Manure (Dry equivalent)**		
													Own	Bought	
			Amount of DAP (Kg)	Total cost (ETB)	Amount of Urea (Kg)	Total cost (ETB)	NPS fertilizer (Kg)	Total cost (ETB)	Liters	Total cost (ETB)	Liters	Total cost (ETB)	Quantity (Kg)	Quantity (Kg)	Total Cost (ETB)

1.7. Labour utilization [labor required in person days]

Plot ID **Same order as in above**	Main crop grown **(Annex 1 Codes)**	**Plowing**				**Planting/sawing**				**Weeding**				**Harvesting**				**Threshing**			
		Family				Family				Family				Family				Family			
		Men	Women	Children	Hired	Men	Women	Children	Hired	Men	Women	Children	Hired	Men	Women	Children	Hired	Men	Women	Children	Hired

1.8. Cost of hired labour, oxen and machinery cost of production

S/N	Plot ID **(Same order as in above)**	Main crop grown (**Annex 1 Codes**)	Total cost of hired labour (ETB)	**Oxen-days**			**Use of machineries/mechanizations-cost**							
							Plowing/planting		Weeding/chemical application		Harvesting		Threshing	
				Plowing Freq	Total Plowing days	Total cost of hired oxen	Own fuel cost (ETB)	Hired total cost (ETB)	Own fuel cost (ETB)	Hired total cost (ETB)	Own fuel cost (ETB)	Hired total cost (ETB)	Own fuel cost (ETB)	Hired total cost (ETB)

1.9. Production stress, and major constraints

S/N	Plot ID (**Same order as in above**)	Main crop grown (**Annex 1 Codes**)	Stresses				Three major constraints in access to key inputs [1-3 Ranking order] **Code C**		
			Stress incidence on [PLOT]? **1.Yes 0.No**	Two major stresses **Code A**		Level of stress **Code B**			

Code A		Code B	Code C	
1. No Stress 2. Insects/pests 3. Disease 4.Water Logging 5.Drought	6.Frost 7.Hailstorm 8.Animal trampling 9.Floods 10.Other, specify…………….	1.Moderate 2.Severe 3.Catastrophic	1. Timely availability of improved seed 2. Prices of improved seed 3. Quality of seed 4. Availability of credit to buy seed 5. Timely availability of fertilizer	6. Price of fertilizer 7. Availability of credit to buy fertilizer 8. Access to markets and information 9. Reasonable grain prices

Section 2C. Cluster farming and community based informal seed production

1.10. Do you participate in cluster farm in your area? 1= Yes, 2=No

1.11. If the answer for Q1.10 how long since you start cluster farming? ______________ Years

1.12. How do you define cluster farming? ____

____

1.13. What are the main objectives of participating in cluster approach at your areas? ________________________________

____

1.14. Do you participate in informal community-based seed production system in your area? 1=Yes,2=No

1.15. If the answer for Q1.14 is ‘Yes’ what is the name of seed producer association? __________________________

1.16. When did you start producing seed under this seed production scheme? ________Years

PART III: CROP MARKETING AND COMMERCIALIZATION

3.1. Crop harvested and utilization (2011/12 EC production season)

Season	Type of Crop **Annex 1 code**	Total crop harvested (Qnt)	From the total available stock after season harvest						Still stored (at the time of survey) (Qnt)	Amount bought (kg)	Food aid/borrowed /gifts received (kg)
			Quantity sold (Qnt)	In-kind payments (labour, land & others) (Qnt)	Quantity used for seed (Qnt)	Quantity consumed (Qnt)	Quantity used for animal feed (Qnt)	Gift to the donations given (Qnt)			
Beleg											
Meher											

3.2. Marketing of crops (From 2011/12 EC Belg and Meher season harvest) **one row per sale (different months, different buyers), per crop and per season**

Crop **Annex 1 code**	Main purpose of production **Code A**	Quantity sold **(Kg)**	Price **(ETB /kg)**	Main buyer **Code B**	Quality **Code C**	Market sold **Codes D**	Month sold **Codes E**	Who sold **1. Male 2. Female 3. Jointly**	Who make the decision to sale **1. Husband 2. Wife 3. Jointly 4. Other HH member**	Major reason for the choice of this buyer? **Code F**	Who set your selling price? **Code G**	If buyers set price, what is the reason? **Code H**	How do you sale your produce? **Code I**	Was the product weighed by the buyer? **1=Yes 2=No**

Code A	Codes B	Code C	Codes D	Codes E	Codes F	Codes G	Codes H	Code I

1) Own consumption 2) Supply to the market totally 3) Both for consumption & market 4) if others_________	1. Farmer 2. Farmer-trader in village 3. Rural assembler from outside village 4. Farmer Union or Coop 5. Consumer 6. Miller 7. Broker/middlemen 8. Rural grain trader 9. Rural wholesaler 10. Urban wholesaler 11. Urban grain trader 12. Exporter, 13. Govt 14. Other, specify…….	1. Below average 2. Fair and Average 3. Above average	1. Farm gate 2. Village market 3. Main/district market 4. Farmer coop/union 5. Trader shop (fixed) 6. Road side	1. January 2. February 3. March 4. April 5. May 6. June 7. July 8. August 9. September 10. October 11. November 12. December	1. He gives higher prices 2. He accepts large quantities 3. He accepts small quantities 4. He gives advances when needed or lends me money if needed 5. He pays immediately 6. He is close by 7. There is no real difference with other traders 8. There is only a single buyer 9. I trust his weighing 10. The buyer is a relative 11. He buys at the farmgate 12. Buyer has the needed grains inputs 13. No relation but not a long time buyer 14. No relation but a long term 15. Other :_______________	1. Yourself 2. Buyers 3. Negotiation 4. other (specify) _______	1. They have better information 2. Farmers lack awareness about prices 3. They are few in number 4. Others___________ _	1. Sack 2. Weighing in a standard balance 3. Any other (specify) ______________

Marketing of crops continue ….Qn. 3.2.

Crop **Annex 1 code [Same order as above]**	Before selling to this buyer, did you contact other buyers? **1=Yes 2=No**	If yes, how many other buyers did you contact before settling on this one? **[Number]**	Is there interlinked contract between producers and collectors ? **1=Yes 2=No**	Is the contract is land base? **1=Yes 2=No**	What was the most important means of transport ation? **Codes J**	What was the total cost spent on transport and the trip **(ETB)**	Time spent to travel to place of sales? **(Minutes)**	Time spent on place of sales? **(Minutes)**	Percent paid immediat ely **[%]**	If not paid immediately, paid after how many days? **[Number of days]**	Were you in contact with the buyer by phone prior to the sale? **1=Yes 2=No**	If yes, did you agree on a price by phone prior to the sale? **1=Yes 2=No**	Did you receive (input) advanc es from the buyer? **1=Yes 2=No**	How many time did you sell at the market per year?

Code J	
1. By foot /Back/head load	6. Rented cart
2. Own donkey	7. Motorized vehicle
3. Other donkey	8. Hired truck
4. Own and other donkey	9. Public transport
5. Own cart	10. Other, specify___________

3.2.1. What did you do when the grains you offered for sale is not sold?

1. Take back home, 2. Take to another market , 3. Sold at a lower price , 4. Sold on other market day 5. Any other (specify) _______________

3.2.2. If did not sale the crop you produce during 2018/19, what were the main reasons?

1) No surplus produce for sell at the market, 2) Low market price, 3) Store for future consumption 4) Other specify ____________

Part 4. POVERTY STATUS OF SMALLHOLDER FARMERS
Section 4A: Livestock Production, Ownership and Income in 2011/12 EC

4.1. Type and number of livestock ownership and income from livestock sale for the last 12 months

Livestock type	Number	Livestock type	Number	If sold how much Income [ETB]
Cattle		**Other livestock**		
1. Cow		10. Donkeys (Mature)		
2. Oxen for ploughing		11. Donkeys (Young)		
3. Bulls		12. Horses		
4. Heifers		13. Mules		
5. Calves		14. Mature chicken		
Goats		15. Local Bee hives		
6. Goat (Mature)		16. Modern Bee hives		
7. Goat (Young)		17. Other		
Sheep				
8. Sheep (Mature)				
9. Sheep (Young)				

4.2. Income from livestock sale during the last six months________________ Birr
4.3. Income from livestock products' sale during the last six months ____________ Birr

Section 4B: Sources and Amount of Income (for the last 12 months)

4.4. Do you have non/off farm income in this year? ______________(1=Yes, 0=No)

Source of income	Total income (cash & in-kind)		Total income (ETB)
	Cash **(ETB)**	Payment in kind **Cash equivalent**	
1. Sale of crop residues			
2. Income from casual labor (on-farm)			
3. Income from casual labor (off-farm)			
4. Trading			
5. Income from salaried employment (Guard, civil servant)			
6. Revenues from leasing/renting out land			
7. Sales of firewood, brick making, charcoal making, poles etc.			
8. Rental property (other than land and oxen)			
9. Sales of firewood, brick making, charcoal making, poles etc.			
10. Other (specify)			
Total			

4.5. How do you compare income situation with one year ago?
1. Increased 2. Decreased 3. Same
4.6. The minimum monthly income with which your household can live well? __________ETB
4.7. How do you rate your monthly income against your monthly expenditure?
1) My income covers my expenditure 2) My income does not cover my expenditure

4.8. What do you do if your household income does not cover your household expenditure?

____

Section 4C: Production Equipment and Major Household Furniture

Asset Category	Asset type	Does the household own [...]: 1= Yes 0=No	No. owned	Average selling price per unit (ETB)	Current Value each (ETB) if they can sell [item] today
Farm implements	Sickle				
	Hoe				
	Spade or shovel				
	Axe				
	Knapsack sprayer				
	Ox-plough				
	Water pump (manual)				
	Water pump (motorized)				
	Tractor				
Transport	Horse/mule cart				
	Donkey/oxen cart				
	Horse/mule saddle				
	Push cart				
	Bicycle				
	Motorbike				
	Car				
Household Furniture	Improved charcoal/wood stove				
	Kerosene stove				
	Water carrier				
	Fridge,				
	Table, sofas, chairs, and beds				
Communication	Radio				
	Mobile phone				
	Cassette or CD player				
	TV				
Jewelry	Gold,				
	Silver,				
	Wristwatch				
Trees	Fruit trees				
	Other trees (e.g. eucalyptus)				
Land	Land owned (ha)				
House	House				

Section 4D: Household Expenditure of the Last 12 Months

4.9. How much did your household spend on the following food items in the last one month?

Food Item	Sources	Value ETB	Food Item	Sources	Value ETB
Staple foods	Teff		Fruits	Oranges	
	Wheat			Mangoes	
	Maize			Pawpaw	
	Barley			Pineapple	
	Rice			Sugar cane	
	Sorghum			Bananas	
	Millet		Beverages and drinks	Tea	
	Faba bean			Coffee	
	Field pea			Soft drinks	
	Lentils			Beer	
	Chick pea		Animal products	Milk	
Vegetables, root and tubers	Potato			Meat	
	Sweet potato			Butter	
	Tomatoes			Chicken	
	Onions			Egg	
	Cabbage			Cheese	
	Kale		Oil crops	Sesame	
	Carrot			Nug	
	Pumpkin			Sunflower	
	Pepper			Linseed	
	Garlic			Rape seed	
	Funegreen/ Abish		Other	Sugar	
				Salt	
				Ginger	

4.10. How did your household spend on the following non-food items in the last one year?

Expense Item	Expense ETB	Expense Item	Expense ETB
1. Clothing		17. Mobile phone air time (voucher)	
2. Beddings		18. Kitchen utensils	
3. Electricity		19. Household hygiene (soaps, toothpaste etc)	
4. Fuel wood		20. Furniture (tables, chairs, beds etc)	
5. Charcoal		21. Home repairs	
6. Kerosene		22. Purchase of bicycle, motorcycle etc	
7. Batteries		23. Repairs for vehicles, bicycles etc	
8. School fees		24. Petrol and engine oils for cars	
9. School books and supplies		25. House rent	
10. Health care (medicare, treatment etc)		26. Utility bills (water, telephone etc)	
11. Grain milling		27. Cigarettes, tobacco etc	
12. Church contributions		28. Remittances paid	
13. Contributions to associations/cooperatives		29. Ceremony and other entertainments	
14. House building/construction		30. Taxes	
15. Newspapers, magazines etc		31. Agricultural costs	
16. Travel expenses			

Section 4E: Multi-Dimensional Poverty

Dimension of poverty	Questions	Response
Education	4.1. What is the highest years of schooling currently completed in your household? **[Years]**	
	4.2. Are there any household members not completed five years of schooling? **[0=No, 1= Yes]**	
	4.3. Are there school aged children in your household member who are not attending school? **[0=No, 1= Yes]**	
	4.4. If the answer for Q4.3 is "Yes', what are the possible reasons? **[Code A]**	
Health	4.5. Do you and your household members have health care access? **0=No, 1= Yes]**	
	4.6. Does any member in your household faced any health problem at least once during the last 12 months? **[0=No, 1= Yes]**	
	4.7. Does any member of your household unable to carry out his/her activities due to serious health problem for the last three months? **[0=No, 1= Yes]**	
	4.8. Are there any child (below five years) in your household died in the past five years? **[0=No, 1= Yes]**	
	4.9. If the answer for Q4.8 is 'Yes' what was the cause for death? **[Code B]**	
	4.10. Is there any household member under nourished? **[0=No, 1= Yes]**	
Living standard	4.11. Do your household have access to clean drinking water in the last 12 months? **[0=No, 1= Yes]**	
	4.12. What are the primary sources of drinking water for your household? **[Code C]**	
	4.13. If your household use unimproved water sources, do you boil the water before drinking it? **[0=No, 1= Yes]**	
	4.14. What is the main sources of water used by your household for other purpose such as cooking and hand washing? **[Code D]**	
	4.15. What kind of toilet facility do members of your household usually use? [**Code E]**	
	4.16. What is the primary sources of light for the household? [**Code F]**	
	4.17. What type of energy do your household mainly/frequently use for cooking? **[Code G]**	
	4.18. From what material the floor of the main dwelling is primarily made? [**Code H]**	
	4.19. What is the main wall construction material of your house? **[Code I]**	
	4.20. Form what main material the roof of your dwelling is made? **1) Grass/straw, 2) Iron sheet, 3) Other specify ________**	
	4.21. How do you evaluate the quality of your house? **1=Good, 2=Medium, 3=Poor**	
	4.22. How many rooms in the household used for sleeping? _________	
	4.23. Do more than three people live/sleep in one room? **[0=No, 1= Yes]**	
Empowerment	4.24. Who made purchase decision in your household? **[Code J]**	
	4.25. Does any of your household members become the member of cooperative in the area? **[0=No, 1= Yes]**	

Code A	Code B	Code C	Code D	Code E
1=No access to school, 2=Finial problem, 3=To help family, 4=Disability/illness 5=Not willing to attend, 6=Other, specify _____	1=Diarrhea, 2= Accident, 3=Malaria, 4=Pneumonia, 5=other specify _________	1=Piped water, 2=Piped water into dwelling, 3=Piped into yard or plot, 4=Protected dug well 5=Protected tube well/borehole, 6=Unprotected well, 7=Protected spring 8=Unprotected spring, 9= Surface water (river, stream, dam)	1) Piped water, 2) Piped water into dwelling, 3) Piped into yard or plot, 4) Protected dug well 5)Protected tube well/borehole, 6) Unprotected well, 7) Protected spring, 8)Unprotected spring, 9) Surface water (river, stream, dam)	1=Open 2=Flush to piped sewer system or ventilated pit latrine-private 3= Flush to piped sewer system or ventilated pit latrine-compound 4= Communal (shared by small community) flush toilet or ventilated pit latrine 5=Pit latrine private not ventilated 6=Pit latrine shared not ventilated 7=Forest/field 8=Other specify________
Code F	**Code G**	**Code H**	**Code I**	**Code J**
1) Electricity mater-private, 2) Electricity meter-shared with neighbor, 3) Solar energy 4) Biogas, 5) Kerposene lamp (Kuraz), 6) Other specify __________	1) Electricity, 2) Fire wood, 3) Biogas, 4) Charcoal, 5) Kerosene 6) Animal dung, 7) Straw/ shrub/grass, 8) Other specify _________	1) Mud/dung, 2) Parquet or polish wood, 3) Stone with cement, 4) Plastic tiles, 5) Cement tiles, ceramic/marble tiles, 6) Other specify _____	1) Brick with cement, 2) Stone with cement, 3) Wood with mud 4) Wood and cement, 5) Other specify _________	1) Only the head of the household, 2) Some members of the household, 3) All member of the household

PART 5: ACCESS TO FINANCIAL CAPITAL, INFORMATION AND INSTITUTIONS

5.1. Did you need credit during 2011/12 EC cropping season? ____________1=Yes, 0=No

5.2. If 'Yes' for Q5.1 then did you get it? ______________________1=Yes, 0=No

S/N	Financial institution	Sources 1=Yes, 2=No	Amount in 2011/12 EC (ETB)	Purpose of credit Code A	If you have not taken credit, why? Code B
1	Bank				
2	Micro-finance institution				
3	Credit and saving cooperatives				
4	Relatives and friends				
5	Other, specify ____________				

Code A	Code B
1) For purchase of seed and fertilizer, 2) For renting in land/ hiring oxen, 3) For starting-up capital for petty trade, 4) For purchasing of chemicals, 5) For purchase of farm equipment, 6) Other, specify ________________	1) Fear of ability to pay 2) lack of collateral 3) Interest rate was high 4) Religious case 5) enough amount of credit is not available, 6) No credit facilities 7) Others specify________________

5.3. If you have not taken credit, why? __________Code B

5.4. Did you receive extension training/advice/information on crop production during 2011/12 EC? 1=Yes, 0=No

5.5. If 'Yes' for Q5.4 what are the main sources of extension training/advice/information?

1) Government extension service, 2) Farmer Coop or groups, 3) Neighbor farmers, 4) Seed traders/enterprises, 5) Non-profit NGOs, 6) Research center, 7) Radio/TV, 8) Other, specify……

5.6. Number of contacts during 2011/12 EC ___________________(days/year)

5.7. For what purpose did you receive the extension service?

1) Seed preparation 2) Spacing 3) Post harvest handling 4) Fertilizer and Chemical applications

5) Marketing 6) If other (specify) ___________________________

5.8. Did you get market information before you decided to sell the crop?_____________1=Yes, 0=No

5.9. If yes for Q5.8 where did you get the information?

1) Government extension service, 2) Farmer Coop or groups, 3) Neighbor farmers,

4) Seed traders/enterprises, 5) Non-profit NGOs, 6) Research center,

7) Radio/TV, 8) Other, specify……

5.10. Are you satisfied with information you receive from the above source/s?

1. Very satisfied, 2. Satisfied, 3. Moderately satisfied, 4. Unsatisfied, 5. Very unsatisfied

5.11. If you are not satisfied, what are the major reasons?

1) Infrequent information 2) Inaccurate information 3) High cost of getting information

4) Variability of information among different sources 5) other (specify) _____________

PART 6: SOCIAL CAPITAL, NETWORKING AND INFRASTRUCTURE

6.1. Are you currently a member of any of the following group?

Formal/Informal group	Response 1=Yes, 0=No	Level of participation		
		Low	Medium	High
1. Farmers' cooperative				
2. Edir/Equib				
3. Saving and credit association				
4. Farmers' input supply group				
5. Crop or seed production group Cluster/Seed production				
6. Water user association				
7. Crop marketing group				
8. Women associating/group				
9. Youth association				

6.2. Does the household have access to any of the following infrastructure?

Type of infrastructure	Distance	
	Km	Minute
Major town		
Main road		
Road condition, 1 if road condition is good, 0 otherwise		
Village market center		
Main market center		
Source of seed dealer		
Source of fertilizer dealer		
Source of herbicides and pesticides		
Nearest dealer from residence		
Agricultural extension office		
Health center/post		
Main water source for drinking from residence		
Pharmacy		
Primary school		
Secondary school		
Grain mill		
Veterinary center		
Telephone facilities		
Transportation		

6.3. How many years you have been staying in the village?________ years

6.4. How many grain traders do you know within this village who could buy your grain?

6.5. How many grain traders do you know outside of this village who could buy your grain?

6.6. Generally speaking grain traders can be trusted.

1=Strongly disagree; 2=Disagree; 3=Neither agree or disagree; 4=Agree; 5=Strongly agree

6.7. Which types of traders do you trust more (rank 3)?

1=Wholesalers; 2=Retailers; 3=Assemblers; 4=Brokers; 5=others (specify)....................

6.8. Main reason for trusting traders in Q6.7

1=Relatives, 2=Regular customer, 3=Give always better price, 4= Has reliable scale, 5=Provide credit, 6= Other (specify)…………

ANNEX 1: CROP CODES

Cereals	Other Pulses (legumes)	Oil Crops	Root rops/tubers/ vegetables	Perennial crops	Fodder legumes
1. White Teff	12. Field pea(*Ater*)	18. Nigerseed (*Nug*)	24. Irish potato	37. Coffee	46. Sesbania
2. Red Teff	13. Faba bean	19. Sunflower	25. Sweet potato	38. Chat (*khat/miraa*)	47. Vetch
3. Mixed Teff	14. Lentil (*Miser*)	20. Sesame	26. Carrot	39. Banana	48. Alfalfa
4. Bread Wheat	15. Grass pea (*guaya*)	21. Linseed	31. Tomato	41. Orange	51. Lablab
5. Durum Wheat	14. Kabuli Chickpea	22. Rapeseed (*Gomenzer*)	32. Cabbage	42. Mango	52. Clover
6. Barley	17. Desi chickpea	23. Lupin	33. Onion	43. Hop (*Gesho*)	53. Grazing land
7. Maize			34. Garlic	44. Eucalyptus	54. Fallow land
8. Sorghum			35. Pepper	45. Sugar cane	55. other crops
9. Finger Millet			36. Kale		
10. Pearl millet					
11. Rice					

ANNEX 2: CROP VARIETY CODES

Teff	11) Kena (23-Tafi-Adi-72)	21) Yilmana –(DZ-01-1868)	31) Gibe /DZ-Cr-255/
1) Dagem (DZ-Cr-438 (RIL No. 91A)	12) GEMECHIS/DZ-CR-387 (RIL-127)/	22) Zobel /DZ-01-1821/	32) Dukem /DZ-01-974/
2) Abola (7 Quncho X Key Muri (Code1))	13) MECHARE /Acc. 205953/	23) Ajora ([GRC/E 205396)	33) Tseday /DZ-Cr-37/
3) Bulluq (ETBW 5484)	14) Amarech- (Ho-Cr-136)	24) Gola (DZ-01-2054)	34) DZ-Cr-44
4) Liben (ETBW 5653)	15) Guduru- /DZ-01-1880/	25) Gerado (DZ-01-1281)	35) DZ-Cr-82
5) Kora [DZ-CR-438 (RIL NO. 133B)]	16) Quncho- /DZ-Cr-387(RIL-355)/	26) Key Tena /DZ-01-1681/	36) DZ-Cr-99
6) Worekiyu (214746A)	17) Dega-Tef /DZ-01-2675/	27) Koye (DZ-01-1285)	37) Magna /DZ-01-196/
7) Boset [DZ-CR-409(RIL-50D)]	18) Dima- /DZ-01-2423/	28) Ambo Toke /DZ-01-1278/	38) DZ-01-787
8) Lakech (RIL 273)	19) Genete /DZ-01-146/	29) Holetta Key /DZ-01-2053/	39) DZ-01-01
9) Simada /DZ-CR-385(RIL 295)/	20) Gimbichu (DZ-01-889)	30) Ziquala /DZ-CR-358/	40) DZ-01-99
10) Etsub (DZ-01-3186)			41) Enatit /DZ-01-354/
Wheat	13. Senkegna	26. Magala	39. KGB-01
1. Kubsa	14. Tay	27. Tusie	40. Warkaye
2. Galema	15. Densa	28. Tura	41. Alidoro
3. ET-13	16. Guna	29. Katar	42. Sulla
4. Digelu	17. Dinknesh	30. Simba	43. Inseno
5. Millennium	18. Bollo	31. Hawii	44. Qulqullu
6. Mada-Walabu	19. Menzie	32. Wetera	45. K6290-Bulk
7. Sirbo	20. Tossa	33. Sof-Oumer	46. K 6290-4A
8. Gasay	21. Shina	34. Dure	47. K6295-4A
9. Pavon	22. Abola	35. Doddota	48. Shorima
10. Meraro	23. Jiru	36. Bobitcho	49. Hidase
11. Danda'a (Danphe)	24. Mitikie	37. Dereselign	50. Huluka
12. Kakaba (Picaflor)	25. Wabe	38. Dashen	51. Olgolcho
Maize	11. Melkasa-1	21. Morka	31. Jabi
1. BH-660	12. Melkasa-2	22. Pioneer HB	32. Rare-1
2. BH-540	13. Melkasa-3	23. Shashamane	33. Shindi
3. BH-140	14. Melkasa-4	24. CG 3253	34. PHB30H83 (Tabor)
4. BH-543	15. Melkasa-5	25. DEBUB AFRICA	35. PHB30G19(Shone)
5. BHQPY-545	16. Melkasa-6Q	26. Fetene	36. Welel
6. BH-670	17. Melkasa-7	27. PROTEN	37. PHB30D79(Agar)
7. BHQP-542	18. PHB 3253	28. AMH-851 (Jibat)	49. Other improved
8. Kuleni	19. Burre	29. A-511	50. Local
9. Gibe-1	20. AM-800 (Ar'gene)	30. Abo-Bako	
10. Gutto			

Barely 1. Basso (4731-7) 2. Mezezo (4748-16) 3. Abay /3357-10/ 4. Abdane (Aruso/EH956/F2-8H-6-4SNR FBC99G003-21) 5. AGEGNEHU (218950-08) 6. Ahor 880/61 7. Aquila 8. Ardu 12 -60B 9. Atlas 53 10. Atlas 57 11. Atlas kinderd 12. Barler 13. Beecher 14. Bentu (EMBSN 5th 2/95-3-3-3) **15.** BIFTU (SHASHO #22 GO-1)(SN 98B)	16. BMC 17. C-63 18. Chile common 19. Comply 120 20. Composite 29 21. Cross # 41/98 22. Dafo (Aruso (42) 4 (SN 99G) 23. Desta (EMBSN 5th 46/95-9-9-5) 24. Dimtu (3369-19) 25. Dinsho (Wadago-4) 26. Diribe(7th EMBSN 19/98) 27. DZ-02-72 28. Egypt 20 29. EH 1493/F6.32H.3 30. EH 163/ F3 45.3H.3.3	31. Estayish (218963-4) 32. Felamit 33. Fetina (SXH, T182) 34. Frti-1 (Mekel 4) 35. GABULA (Acc. 231222/MS) 36. Gobe (CBSS96M00487T-D-1M-1Y-2M-OY) 37. Golden eye 38. GUTA (Acc.3260-18) 39. Harbu (Aruso Bale# 10-1) 40. Hb-1307 (EH 1700 / F7 1.B1 .63.) 41. HB-16 42. HB-28 43. HB-42 44. Hriti (SXH, S106) 45. IAR 14/445	46. Kenya research 47. Mari 48. Meserach (Kulumsa 1/88/) 49. Mezezo (4748-16) 50. Mulu (3371-03) 51. Peru 52. Proctor 53. Setegn (3369-17) 54. Shedho (3381-01) 55. Shege 56. SHIRE (3297-06) 57. TILLA(EMBSN 14/98) 58. Trit (215235-2) 59. Unitan 60. Walker 61. Yedogit–(BI 95 IN 198)
1. Malt barely 2. Bahati 3. Beka 4. Bekoji-1(EH1293/F2-18B-11-1-14-18) 5. CDC Select 6. EH 1609 7. EH1847/F4.2P.5.2 (Bea/Ibon64/91) 8. Grace 9. Haruna Nijo 10. HB 15 11. HB -7	12. HB-120 13. HB-1533 14. HB-26 15. HB-52 16. HKBL 1512-5 (Fanaka) 17. Holker 18. IBON 174/03 19. Kiflu -B (Miscal 21) 20. Sabini 21. Traveler 22. ፍሬገብስ (EH1609-F5-B3-10)		

Appendix B: Checklist for Key Informants (KIIs) and Focus Group discussion (FGDs)

Part I: Checklist for Key Informant Interview (KII) (Farmers)

A) Place time and setting the scene

1. Name KII: ____________________________
2. Region _______________District ____________________Kebele __________________
3. Strat time: _______________Ending time:___________ Date ___________
4. Welcoming, introduction and purpose of the discussion

B) Cereal production, commercialization and household multidimensional poverty

5. How do you explain the trend of landholding and cereal production in the area?
6. How do you see HHs' access to and utilization of various agricultural inputs and technologies in the area?
7. What are the major challenges in the use of input and technology, cluster farming, marketing and commercialization of cereal grains in the area?
8. What are the advantage and disadvantage of cluster farming?
9. What are common place and time of sales for cereal grain in the area?
10. What are the average prices over the last 12 months for major cereals grown in the area?
11. How do you describe the collection and assembly of cereal output, mode and cost of transportation, storage, grading and standardization, marketing channels, and vending of cereal at the local market?
12. What are the strategies that HHs follow to fetch premium price for the grain they produce and sale at the market?
13. How do you understand the situation of poverty in the area? How do you evaluate the existing infrastructure and basic services in the area?

14. How do you describe poor and non-poor/rich HHs in your area and their differences in production efficiency and commercialization of cereal production in the area?
15. What should be done to harness the role of production efficiency and commercialization in improving the welfare of smallholders?

Part II: Checklist for Key Informant Interview (KII) [DAs/Experts]

A) Place time and setting the scene

1. Name KII: ________________________
2. Region _______________District ___________________Kebele _________________
3. Strat time: _______________Ending time:___________ Date ___________
4. Welcoming, introduction and purpose of the discussion

B) Cereal production, commercialization and welfare of stallholders

5. What extension services have been delivered to improve the production efficiency and commercialization of smallholder HHs in your area?
6. How smallholder HHs accept and evaluate the advisory services?
7. How do you evaluate the performance of the extension service in terms of delivering input and technology, creating market linkage to improve the production and marketing of smallholders in the area?
8. How do you perceive cluster farming? Explain the purpose, the process and criteria followed in forming a cluster? How does the cluster coordinate planting and production?
9. How would you define successful/unsuccessful groups? Explain present obstacles and problems and how it was solved (cluster conception and initial stage)
10. What are the merit and demerit of clustering approach? What institutional supports are required to facilitate the success of the cluster?
11. What are the major challenges farmers face in producing and commercializing cereals in the area? Do you think male and female headed HHs face the same challenges? If not why?
12. How do you evaluate the provision of various rural infrastructural and basic services in the area?
13. How do you describe poor and non-poor/rich HHS in your area and their differences in production efficiency and commercialization of cereal production in the area?
14. What should be done to improve production efficiency and commercialization and bring sustainable impact on the welfare of smallholder HHs in the area?

Part II: Checklist for Focus Groups Discussion (FGD)

A) Place, time and setting the scene

1. Name KII:
2. Region _______________District ___________________Kebele _________________
3. Strat time: _______________Ending time:___________ Date ___________
4. Welcoming, introduction and purpose of the discussion

B) Cereal production, commercialization and household multidimensional poverty

5. How do you see the trend of landholding and cereal production in your area?
6. How do you see access and utilization of inputs, improved cereal varieties and other technologies in the area? What are the major challenges in the use of production inputs?
7. How do you see male and female headed household in accessing and utilizing production inputs and improved technologies?

8. How do you understand cluster farming? What are the purposes of forming cluster to produce cereal in your area?
9. What are the advantage and disadvantage of cluster farming in terms of technology adoption, knowledge transfer, yield, quality, post-harvest management, marketing, pest, disease and weed management?
10. What should be done by farmers, development agents, agricultural offices, research organizations and other stockholder in improving agricultural production and productivity among smallholders in your area?
11. How do you explain the major challenges and opportunities in commercializing cereal among producers?
12. How do you perceive and understand poverty? Explain the intensity of poverty in the area?
13. What are the causes and consequence of poverty in the area?
14. How do you describe accessibility and quality of rural infrastructure (such as education, health, electricity, water, road, telecommunication and market), facilities, and services?
15. How do explain the role of production efficiency and commercialization in improving the welfare of smallholders in your area?