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Commercialization Orientation and Food Security Nexus among Smallholder Farmers in Northwest Ethiopia: A Bivariate Tobit Approach

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Abstract: Food insecurity remains a critical challenge in developing countries like Ethiopia, where the majority of the population derive their livelihood from agriculture characterized by mixed farming systems. Smallholder farmers, the principal actors of agriculture, are facing rapidly increasing population and urbanization and have been unable to be self-sufficient in food. This paper aims to examine the role of commercialization on food security and its determinants in rural settings. We used cross-sectional data from 295 households randomly selected in northwest Ethiopia. Results from bivariate Tobit regression revealed both crop and livestock commercialization improved household food security, but in quite different ways. The income from crop sales was instrumental in allowing households to buy additional foods while livestock sales fostered crop diversity for personal consumption, by allowing farmers to purchase non-food items. We also found livestock commercialization was more important than crop commercialization in improving food security due to its strong net positive effect. Thus, agriculture-food security nexus may not require the production systems to be subsistent. Supporting investments in improving road infrastructure to function all weathers, better access to institutional services (credit and off-farm employment), and enhanced awareness of extension towards promoting commercialization and diversified food consumption seem to be more promising. The research paper concludes that commercialization is vital not just for economic growth and food security, but also for smallholder agriculture in providing additional nutrition.

Keywords: commercialization; market participation; food security; smallholders; Ethiopia

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1. Introduction

Food insecurity and malnutrition are among the key challenges in many developing countries. Food and nutrition security can play a strategic role globally in that its improvement lays a foundation for achieving many of Sustainable Development Goals (SDGs). Despite progresses in recent decades, a significant number of the global population remain chronically hungry. Between 702 and 828 million people are unable to meet their minimum dietary energy needs. The number has grown by about 150 million since the outbreak of the COVID-19 pandemic. Around 2.3 billion people were moderately or severely food insecure in 2021 and 34.4% of children under five years suffer from stunted growth, wasting or are overweight. One in three women of reproductive age were still affected by anemia in 2019 with no progress since 2012 [1], and nearly 45% of children died due to poor nutrition in 2011 [2]. The overall economic costs of malnutrition are significantly large, about USD 3.5 trillion per annum, 5% of the global GDP [3]. Such economic costs are remarkably high in several developing countries, for example, in Ethiopia the annual costs associated with child undernutrition reached 16.5% of its GDP in 2009 [4]. The challenges to ending hunger, food insecurity and all forms of malnutrition keep growing globally. As indicated in the State of Food Security and Nutrition report [1], the prevalence of the COVID-19 pandemic, the Ukraine war and extreme climate events are making world hunger and severe food insecurity more critical. A global economic slowdown or a downturn in one or more important players in the world economy can further damage

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developing economies, which can, in turn, influence food security adversely. Recent evidence suggests that the number of people unable to afford a healthy diet around the globe rose by 112 million to almost 3.1 billion in 2020, reflecting the impact of inflation on consumer food prices during the pandemic. The ongoing war in Ukraine, on the other hand, is disrupting supply chains and further boosting prices of grain, fertilizer and energy. The report [1] highlights that without intensified efforts even the gains that have been made in reducing the prevalence of child stunting by one-third in the previous two decades are now under treat by the triple crises of climate, conflict and COVID-19.

A large proportion of these food insecure people are smallholder farmers in less developed countries that depend on agriculture as their livelihood. In such a predominantly agrarian economy, a wide array of challenges in the agricultural production system itself, and the complexity of production and consumption decisions at household level, have a large impact on the food security of smallholder farmers [5,6]. Improving agricultural productivity and the linkage of agriculture with food security has been a central issue of development policies in sub-Saharan Africa [7,8]. This stems from the role the agriculture sector can play as a primary source of livelihood, including food and nutrition in the majority of the developing world and mainly in sub-Saharan Africa [5,9]. The concept of nutrition-sensitive agriculture presumes agricultural production practices have the potential to positively affect the underlying determinants of nutrition [10]. Despite this assumption, it has been difficult to empirically support, as the causal pathways hypothesized to run among agricultural commercialization (AC), diversification (AD) and food security (FS) are long and winding. A number of recent review papers also confirmed the limited evidence on how AC contributes to FS.

Theoretically, it is assumed that appropriate levels of diversification are a question of scale in which AD does not necessarily imply every single farm has to be extremely diverse. AD may promote diverse food consumption in the farm household, e.g., in sub-Saharan Africa, where smallholder farmers are often subsistence-oriented [11]. Typical farms in Africa are already quite diverse. Further diversification might prevent gains from specialization that could, in turn, lead to income losses potentially impacting HFS adversely [12,13]. Some authors point to market access being more important than AD for improved HFS [13,14]. Others argue that AD is more relevant [15,16]. This is essentially true in the context of developing countries, where smallholder farmers are significantly large in number, market infrastructure is poor and incomes unequally distributed. Even the findings of such linkages in the case of smallholders are mixed and vary through time and space. This requires continuous and extensive geographically specific studies. The geographical context of such issues is more relevant in Africa. While agriculture is the primary livelihood base for most Africans and market-oriented policies are currently promoted region-wide, food insecurity remains widespread in the region, which seems a paradox that seeks evidence-based research for effective and sustainable solutions. All these suggest the need to focus on vulnerable populations (smallholder farmers) for mounting a food security perspective in empirical analysis.

This is certainly the case in Ethiopia where agriculture has continued to be a source of livelihood for more than 66% of the population in the last two decades (2000–2019) [17]. Smallholder farmers managed 96% of agricultural land in the country [18], greater than 70% of the average in Africa [19]. Despite improvements in the sector, including a robust growth of 4.53% annually from 2014–2019, the prevalence of moderate or severe food insecurity remains on average 57.8% in the country over the same period [17]. This problem is of utmost concern in this era of SDGs in which achieving the goals by 2030 is imperative. The sector is widely recognized not only for reducing food insecurity but also to offer the required growth at various levels of the Ethiopian economy. This would, however, require transition of agriculture from subsistence to commercially-oriented production. This view was well articulated in the following series of development policies and strategies of the country [20]: the long-term strategy of Agriculture Development-Led Industrialization since the early 1990s, Sustainable Development and Poverty Reduction Program (2003-2005); Plan for Accelerated and Sustained Development to End Poverty (2006-2010); and the subsequent Growth and Transformation Plans I (2011-2015) and II (2016-2020). To better understand the extent and the role of AC on HFS, the following are the central questions to address: (i) Are commercialization practices of smallholder

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farmers associated with better HFS? If yes, which commercialization practice (crop/livestock) induces better HFS and how? (ii) Does commercialization imply trade-off/synergy between consumption of own-produced and purchased foods? (iii) What are the factors influencing commercialization of agriculture among smallholder farmers? The purpose of this study is to evaluate whether commercialization orientation in agricultural production helps improve food security in terms of food consumption patterns and dietary diversity of households among smallholder farmers in northwest Ethiopia.

This paper adds to the literature in four ways. First, we analyze effects of AC strategy on HFS operationally measured in terms of food consumption and dietary diversity. Second, differentiating HFS resulting from purchased and own-produced foods helps understand transmission channels of AC to HFS. Third, using the bivariate Tobit model, capable of jointly estimating all relevant parameters, provides evidence of jointness in decision making process. Finally, understanding AC-FS nexus is essential to shed light on the ongoing debate as to whether state-led efforts promoting AC or on-farm diversification practices of smallholder farmers in view of food sovereignty will help reduce food insecurity in the rural settings.

2. Materials and Methods

2.1. Study Settings

The study uses cross-sectional data from a household survey implemented during June and July 2020 using structured questionnaires. The survey covered a sample of 295 rural households and 12 villages randomly selected from Dangla, Bure and Bahirdar Zuria districts (*Woredas*) in northwest Ethiopia. The household selection was based on a two-stage stratified sampling. The survey team was composed of 12 experienced enumerators of agricultural experts. An intensive two days of training was given to the survey team to create understanding of the contents of the questionnaire and of the approaches and procedures of how to conduct face-to-face interviews with farmers using local language (Amharic) and how to probe answers to the difficult questions through examples and farmers' wordings. Pilot-testing of the survey instruments and fieldwork procedures were conducted prior to the main survey. The data quality was checked through close supervision of the enumerators by supervisors via checking the collected data every night, and giving them feedback every other morning by asking them further explanations for abbreviated/vague data (if any), and to recollect the data that was sought.

2.2. Measuring Household Food Security

Food insecurity continues to be a major development problem worldwide, undermining health, productivity and survival of the people. Efforts to overcome the development challenges posed by food insecurity necessarily begin with accurate measurement of key indicators at household level. Although the concept of FS is evolving, the widely accepted definition of FS is a situation that exists "when all people at all times have physical, economic and social access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" [21]. This suggests FS is a multidimensional and dynamic phenomenon that comprises four pillars: availability, accessibility, utilization and stability. The literature seems to agree that identification of household behaviors related to food access serves as a critical building block for the development of policies and programs to help vulnerable populations, and to effectively target aid and impact evaluation. This study, therefore, tried to measure FS at household level operationally conceptualized in dietary-based food consumption. Despite a variety of available approaches, food species count and food group diversity are commonly mentioned in the literature. The food species count index is a simple count of all food items/species consumed by the household, while household dietary diversity score (HDDS) and food consumption score (FCS) measure the count of food groups the household consumed in a certain recall period. Since the first approach fails to capture whether the household gets different micronutrients [13,22], we tended to focus the latter mainly on FCS for the reasons detailed therein.

HFS is conceptualized in terms of FCS as the weighted sum of food groups that any member of a household had consumed for the last 7 days prior to the survey. The food security status of households was determined based on the food consumption data gathered using the standard FCS module of [23]. We applied a list-based recall of food consumption data based on eight food groups: (1) starchy staples, (2) pulses, (3) vegetables, (4) fruits, (5) meats, fish and eggs, (6) milk, (7) sugars, and (8) fat and oils, within which were listed the food items customized in the local context. Once the data on food items were combined into food groups, the maximum value for any food group was capped at seven. Households were presented with the calculated FCS, based on possible frequency of number of days (ranging 0–7) and internationally standardized weights (0.5–4) assigned for the food groups the household consumed in the last 7 days. A weight of 0.5 corresponded to the food group with lowest nutritional contribution, and 4 for the one contributing the highest. A specific weight was assigned to each food group, to reflect not only its nutritional importance, but also to help assess whether the production systems of smallholder agriculture were nutrition sensitive or not. Using a 7 day recall period also seemed better to capture consumption habits of households than the 24 h recall that was used in HDDS. This was supported by [22] that disclosed that dietary diversity score of a 7 d recall data is highly correlated with nutrient adequacy more than when based on a 1d recall. Information about the main source of foods has its own implication in understanding how far the food consumption of households is vulnerable to the risks of food purchases. Additionally, the FCS data can be analyzed to construct the other three indicators of HFS, which were more important in the context of this study: FCS of purchased foods, FCS of own-produced foods and FS category. Equation (1) is the formula used to calculate FCS:

$$FCS_i = \sum_{j=1}^{8} W_j F_j \tag{1}$$

where FCS_i represents food consumption score of household i; W_j is the weight of food group j consumed by household i; and F_j is the frequency of number of days household i had eaten food group j in the previous week prior to the survey.

FCS is a composite and continuous score with a possible range of 0–112. FCS in general represents dietary diversity of foods consumed by households, irrespective of where they were sourced. FCS of own-produced foods refers to the calculated dietary diversity based only on own-produced foods the household consumed. FCS of purchased foods is the dietary diversity of foods the household consumed from purchases. The simplicity of gathering food consumption data by means of this qualitative approach is noteworthy and why it is preferred to the quantitative approach, which tries to measure the quantity of foods the household consumed daily, becoming technology and knowledge intensive besides being more expensive. All these imply that FCS is the appropriate approach to conceptualize and evaluate AC in the context of HFS.

Households can further be classified into food consumption groups to categorically determine the food insecurity prevalence. In formulating this categorical variable, most studies have used standardized thresholds of 21 and 35 among poor, borderline and acceptable consumption [23]. These thresholds are based on a minimum consumption of 7 d starch with 7 d vegetables as the first threshold (21), and the addition of 7 d of pulses to this gives the second threshold (35). However, there may be a situation where the thresholds may increase from 21/35 to 28/42, primarily in cases where households have a very high frequency of sugar and oil consumption. This is the fact in areas where even the poorer consumption food patterns include frequent oil and sugar consumption, such as in Ethiopia. A diet of starch and vegetables accompanied by only the addition of oil and sugar should yet be considered poor. This suggests the thresholds to be adjusted into FCS are ≤ 28, 28.5–42 and >42 in order, as poor, borderline and acceptable food consumption levels. As such, we used the latter thresholds (28/42) to assess the FS status of households in the context of rural Ethiopia. Accordingly, the FS status of households can be formulated in terms of FCS as in Equation (2):

$$FS_i = \begin{cases} 1 & if\ FCS_i > 42 \\ 0 & if\ FCS_i \leq 42 \end{cases} \tag{2}$$

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where FS_i is a binary variable that has a value of 1 if household i is food secure and 0 if is food insecure.

2.3. Measuring Commercialization Orientation

Similar to food security, commercialization is a multidimensional concept and any single indicator cannot capture all its facets. The literature applies different methods to measure the commercialization orientation of households. Several studies conceptualized commercialization orientation focusing on market participation of farm households from the output side, using the commonly cited definition of AC as a "proportion of total agricultural output sold at farm level" [24–26]. This index captures the trade-offs the households makes at any level of market engagement between production and consumption along a subsistence–commercial continuum from zero to unity. Berhanu and Moti [27] operationalize AC concepts from methodological and analytical perspectives as a combination of market orientation and participation. They explained market orientation as a situation that prevails when production decisions are based on market signals, while market participation is simply the farm produce offered for sale and use of purchased inputs. As such, it seems market orientation tends toward profit maximization, whilst market participation appears to be about utility maximization. Yet others define AC as total annual income earned from sale of crops, livestock and all agricultural byproducts [28].

The fact that there would always be some amount of output that even a subsistence household would sell at a lower end, to acquire cash income for purchasing basic necessity goods and services, does not alter the fact that the ratio of marketed output up to a certain minimum level cannot be taken as a measure of commercialization. Recognizance of this suggests that 20% marketable surplus can be used as a cut-off point in the Ethiopian context to define commercialization orientation at farm level [29]. Others have used one third of the value of total crop output sold (i.e., 33%) in the case of Nigeria [30] and half of total crop output sold (i.e., 50%) in the case of Ethiopia [24] as a threshold to define whether a household is commercially oriented in crop production. Adopting the latter threshold, we defined crop commercially oriented households as those that sold at least 50% of the total amount of crops they produced last year, while subsistence-oriented were those having lower or no sales. As the process of commercialization varied in nature between livestock and crops, and a smaller unit of participation in livestock marketing would enable farmers to reap better income relatively with little/no transaction costs, a lower threshold (10%) was used for defining commercialization orientation in livestock production in the context of Ethiopia. Livestock commercially oriented households were those that sold at least 10% of total amount of livestock output (in tropical livestock units) raised in the previous year, and those with lower or no sales were subsistence-oriented in livestock production. Constructing indices to measure participation of farm households in crop and livestock output markets using Equations (3) and (4), commercialization orientation in their crop and livestock production was determined based on the thresholds of these indices used, as in Equations (5) and (6), respectively, as follows:

$$COMPI_i = \frac{\sum_j^k CS_j}{\sum_j^k CP_j} \tag{3}$$

$$LOMPI_i = \frac{\sum_m^q LS_m}{\sum_m^q LP_m} \tag{4}$$

$$CCO_i = \begin{cases} 1 & if\ COMPI_i \geq 0.5 \\ 0 & if\ COMPI_i < 0.5 \end{cases} \tag{5}$$

$$LCO_i = \begin{cases} 1 & if\ LOMPI_i > 0.1 \\ 0 & if\ LOMPI_i \leq 0.1 \end{cases} \tag{6}$$

where $COMPI_i$ and $LOMPI_i$ represent crop output market participation index and livestock output market participation index of household i; CS_j and CP_j denote total amount of crop j sold and produced in kilograms by household i (j = 1,2,…, k crops); LS_m and LP_m were the total amount of livestock m sold and produced in TLUs by household i (m = 1,2,…, q livestock) in the last year prior

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to the survey. To better understand the relative importance of crop and livestock commercialization on HFS, we extended the Coates and Galante [28] simple definition of AC as "total agricultural income…", and used a term "relative crop commercialization orientation", operationally defined as a "proportion of crop income to total agricultural income the household earned from crops, livestock and all agricultural byproducts sold in the previous year". As this definition captures a trade-off between crop and livestock commercialization, this would mean that households better in crop commercialization would also be less/not commercially-oriented in livestock production. The relative crop commercialization orientation index ($RCCI$) was formulated as in Equation (7):

$$RCCI_i = \frac{\sum_j^k CI_j}{\sum_j^k CI_j + \sum_j^k LI_m} \quad (7)$$

where CI_j and LI_m were the income received by household i from (by)products of crop j and livestock m sold in the previous year, respectively. The denominator terms after equality sign of Equation (7) represents the total agricultural income as the sum of income the household earned from all crops and livestock (by)products sold in the year.

2.4. Empirical Model and Estimation Strategy

Several studies on agriculture and food security nexus have used a farm household model designed to capture key features of agriculture in the developing countries, such as non-separability of production and consumption decisions due to market imperfections, interconnection between transaction costs and market participation decisions, interaction among farm households for factor markets and seasonality of resource use. In this underpinning, scholars argue that local (or decision) prices are determined endogenously [31,32] by market prices and factors influencing transaction costs [33]; and transaction costs are heterogeneous across locations and households [34,35]. As markets are distant or hard to reach, the higher transaction costs are an incentive for households to stay self-sufficient, and hence food production and consumption decisions are non-separable. Studies in Tanzania [36] and in Cambodia [32] also framed their empirical models of market participation based on the non-separability assumption. However, this situation can be quite complex under increasing opportunities for market participation, where households have more opportunities to trade, generate income and purchase different types of foods [26,37,38]. With improved market access and opportunities, households' decisions on production and consumption are separable. Accordingly, the household behaves as though its production decisions are made first and then the generated full income is allocated between consumption of goods and leisure. Hence, consumption (FS) depends on production decisions and household demographic characteristics, but not vice-versa [25,39]. As production decisions contribute to income through farm profits, factors influencing production can affect income and, hence, household consumption decisions. This study was built in this context with the view that commercialization can play an important role for the well-being of households who are both sellers and buyers of foods and other agricultural commodities. With this separability assumption, we hypothesize that there is a one-way causation between commercialization and food consumption among smallholder farmers.

To guide the empirical analysis, a bivariate Tobit framework was adopted from [24,40] for joint evaluation of HFS impacts of AC, whether it would be through a trade-off or synergy effect between consumption of own-produced foods and purchased foods. We postulate that farmers follow sequential decisions in consumption of any particular food. First, whether to choose to consume a particular (produced/purchased) food. Second, to what extent is the intensity of consumption conditional on choice? In such a case, it is appropriate to use the bivariate Tobit model developed at household level using FCS of own-produced foods and FCS of purchased foods as dependent variables for joint determination of how commercialization orientation affects HFS, so as to better understand to what extent purchased foods are substituted for, or supplementary to, own-produced foods, after correcting for other covariates. The outcome function for choosing consumption of a particular foods group (measured in terms of FCS, as an indicator of HFS level) is given by Equation (8):

$$Y^* = \alpha C_i + \beta X_i + \varepsilon_i \, , \quad (8)$$

where Y^* is a latent variable representing HFS in terms of FCS of a particular foods group the household consumed; C_i is the level of relative crop commercialization orientation of household i, a key explanatory variable of this study; X_i is the vector of other regressors that may affect HFS; α is a scalar parameter of interest and β is the vector of parameters to be estimated; and ε_i is the error term distributed normally with zero mean and variance σ^2.

For households choosing consumption of own-produced foods group, Y_i^* equals the actual level of consumption (Y_i). For those who did not choose own-produced foods group, Y_i^* is an index reflecting potential consumption as in Equation (9):

$$Y_i = \begin{cases} Y^* \; if \; \alpha C_i + \beta X_i + \varepsilon_i > 0 \\ 0 \;\; if \; \alpha C_i + \beta X_i + \varepsilon_i \leq 0 \end{cases} \quad (9)$$

Before turning to the details of our estimation procedure, let us see first the brief description of the univariate Tobit model. As seen in Equation (9), a Tobit approach can also capture the decision to choose as well as the resulting outcome (intensity), while others, such as the probit or logit model, provide information on the decision to choose only. This suggests the Tobit model can be framed conceptually to evaluate the relationship of one or more independent variables with a dependent variable having continuous observations but censored to either left, right or both. In our case, the dependent variable comprised nonnegative values, and was left-censored. If this relationship were estimated using OLS regression without censoring, the resulting estimators would be inconsistent and yield downward-biased slope coefficients and an upward-biased intercept [41]. Maximum likelihood estimator (MLE) would, therefore, be consistent in the Tobit model. The fact that a significant share of households consumed a mix of purchased and produced foods over a 7 d recall period (see Table 1), meant we used a bivariate Tobit framework to capture censorship and the tradeoff/synergy effects of commercialization between these two consumption outcomes in the structural form of the model specified in Equations (10)-(14) as follows:

$$Y_{1i}^* = \alpha C_{1i} + \beta X_{1i} + \varepsilon_{1i} \quad (10)$$

$$Y_{1i} = Maximum\ (Y_{1i}^*, 0) \quad (11)$$

$$Y_{2i}^* = \alpha C_{2i} + \beta X_{2i} + \varepsilon_{2i} \quad (12)$$

$$Y_{2i} = Maximum\ (Y_{2i}^*, 0) \quad (13)$$

$$\varepsilon_{1i}, \varepsilon_{2i} \approx N[0,0, \delta_1^2, \delta_2^2, \rho_{12}] \quad (14)$$

where Y_{1i}^* denotes FCS of purchased foods consumed by household i; Y_{2i}^* represents FCS of own-produced foods consumed by household i; ρ_{12} is the correlation between the error terms ε_{1i} and ε_{2i}. The distributions are independent if the covariance between these two errors (i.e., $\rho_{12} = 0$). A positive significant value of ρ_{12} implies commercialization has a synergy effect on consumption between purchased and produced foods, and a negative value shows presence of trade-off.

Table 1. Extent of commercial orientation, food source diversity and profitability (n = 295).

HH Categories by Commercial Orientation & Food Sources	% of Total HHs	Profitability of Investment (ETB)	
		Crop Farm	Livestock Farm
Only livestock commercial oriented (CCO = 0, LCO = 1)	18.64	2.16	34.78
Only crop commercial oriented (CCO = 1, LCO = 0)	27.12	7.53	6.82
Crop and livestock commercial oriented (CCO = 1, LCO = 1)	10.51	4.63	39.21
Subsistence production oriented (CCO = 0, LCO = 0)	43.73	2.31	4.15
Consuming only purchased foods (PF = 1; OF = 0)	1.02	1.68	11.51
Consuming only own-produced foods (PF = 0; OF = 1)	2.37	2.76	5.42
Consuming purchased & own-produced foods (PF = 1; OF = 1)	96.61	4.00	14.51

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Source: Own survey data 2020. HHs = households, CCO = crop commercial oriented; LCO = livestock commercial oriented. PF = purchased foods, OF = own-produced foods.

The role of commercialization orientation of smallholder farmers on HFS was, therefore, evaluated not only based on analyzing its total effect in FCS of all foods consumed by the household using a conventional Tobit approach, but also assessed decomposing the FCS from purchased and own-produced foods as dependent variables to identify transmission channels of AC to HFS, as well as controlling for the potential endogeneity problem. Addressing the latter aspect calls for use of a bivariate Tobit, capable of jointly estimating all the parameters of interest, besides providing evidence whether trade-off/synergy effect AC has occurred between consumption of purchased and produced foods. To enhance robustness of the results, we also used HDDS as an additional HFS indicator, measured in terms of counts of food groups the household consumed in the last 24 h, for which a Poisson model was adopted to analyze impact of AC on HDDS. As has been discussed, share of crop income to agricultural income (C_i in Equation (1)) was an indicator used to measure commercialization in a way to grip the relative importance of crop and livestock commercialization to HFS that most studies were limited in addressing. C_i represented level of crop commercialization relative to AC (so-called relative crop commercialization, henceforth), so an increase in this level would also mean a decrease in livestock commercialization relative to AC (so-called relative livestock commercialization). While analyzing the effect of C_i on HFS, we also tested whether it was an endogenous explanatory variable or not. Attempting to check such endogeneity through a control function approach, we followed the two-stage method adopted from [24,26,42] by introducing the generalized residual and expectation of relative commercialization index ($\widehat{C_i}$) into Equations (10)-(14). We found the generalized residual was statistically insignificant, verifying that there was no endogeneity bias (despite this result not being shown in this paper), and, hence, a direct estimation of the original model of bivariate tobit specified in Equations (10)-(14) would yield consistent estimates.

Like food consumption, commercialization orientation is an outcome of a two-step decision process, as Bellemare and Barrett [43] revealed regarding rural households in developing countries making market participation and volume decisions sequentially. First, the farmer decides whether to choose to sell part of any agricultural (crop/livestock) output. Then, the intensity of market participation conditional on such choice must be assessed. The rate of market participation is the percentage of households that actually sell any of their agricultural output, while the intensity of market participation is the level of output sold by the household who participated in the market. As detailed above, this paper measured market participation levels of households with two indices: crop output market participation index (COMPI) and livestock output market participation index (LOMPI). Thus, as justified above, at least 50% of total amount of crop output sold (COMPI ≥ 0.5) and 10% or more of the total amount of their livestock output sold (LOMPI ≥ 0.1) were the thresholds for market participation level used to define commercialization orientation of households in their crop and livestock production conditional on positive values. Application of a censored simultaneous-equations framework was preferred for joint analysis of factors influencing crop and livestock commercialization of smallholders. However, we needed to replace the commercialization outcomes instead of the consumption outcomes as dependent variables, and exclude the C_i variable in the system of equations in this case.

2.5. Descriptive Statistics

All sample households had cultivated crops and 97% of them also raised livestock during the 12 months period covered by the survey, indicating that mixed farming systems characterized the agricultural production in the study areas. Almost 99% produced staple crops, 31% pulses, 48% vegetables, 16% fruits and 28% cash crops. Among which the proportion of households commercially oriented in production of staple crops recorded 32%, pulses 37%, vegetables 76%, fruits 75% and cash crops 92%; this was by definition of a household as being commercially oriented in crop production if it sold at least 50% of the total volume it produced in a year. While 99% of our sample sold some

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part of their farm produce, around 56% of the crop output and 86% of livestock output were kept for home consumption and other purposes. This suggested that commercialization was limited in terms of the volume of marketed surplus. The average household sold 42.5% of its farm output in our case in northwest Ethiopia, which was similar to a study in western Kenya [26], which reported the typical household sold 44% of its farm output. If we sub-divided our sample into commercialization quartiles to compare the 25% most commercialized with the 25% least commercialized households, this share ranged between 26% for the least commercialized and 59% for the most commercialized households. Overall, around 40% of households sold more than half of the total farm output they produced, despite the share of output sold varying by type of crops grown. More than 28% of our sample cultivated at least one type of cash crop. The cash crop production accounted for 3.2% of the total volume and 9.4% of the total area coverage of crop production and for 16% of total crop income. This meant that the sales of food crops generated larger total cash income than the sales of cash crops.

The sample farms were highly diversified and produced about 34 different crop species and 12 livestock species in the study communities. They produced a number of varied food crops, such as maize, millet, *teff*, wheat, barley, beans and peas. Many also kept chicken, sheep, goats, cattle and sometimes beekeeping. In terms of cash crops, the crops grown included *kchat*, coffee, hops, sugarcane, and fruit and vegetables (such as avocado, mango, papaya, potato, onion and potato). Despite high agricultural diversification in the study areas, a large proportion of households (23.4%) were food insecure, among which 19% were moderately FI and 4.4% were severely FI. This suggested not just self-production in the context of AD for own consumption could address FI, as commercialization of agriculture could also play a critical role in the link between agriculture and FS. More than 56% of households were commercially oriented in their agricultural production.

We used a one-way parametric ANOVA and Pearson's chi-squared test statistics to assess differences in household characteristics observed in quantitative and qualitative terms, respectively, across commercialization orientation and food security categories.

2.5.1. Commercialization Orientation, Food Source Diversity and Profitability

Assessing commercialization orientation of households is essential for understanding the relative importance of commercially-oriented and subsistence production to HFS. To facilitate comparisons by commercialization orientation in descriptive analysis, households were disaggregated into four groups, based on crop and livestock output market participation levels: subsistence production oriented (SPO), crop commercial oriented (CCO), livestock commercial oriented (LCO), and full commercial oriented (FCO). As detailed above, these groups were constructed based on the thresholds of the two indices (COMPI and LOMPI). SPO households were those with values of COMPI < 0.5 and LOMPI < 0.1. LCO households were those with COMPI < 0.5 and LOMPI ≥ 0.1 and CCO were those with COMPI ≥ 0.5 and LOMPI < 0.1. Those with COMPI ≥ 0.5 and LOMPI ≥ 0.1 were FCO i.e., commercially oriented both in crop and livestock production.

Table 1 presents the extent of households and profitability of crop and livestock farm investments across commercialization orientations and food source diversity. A total of four combinations of commercialization orientations and three combinations of food source diversity were observed. Among the sample households (n=295), around 19% were LCO only, 27% CCO only, more than 10% were commercially oriented in both crop and livestock production (FCO), and a significantly higher share (44%) were subsistence-oriented (SPO) in their agricultural production. Overall, households commercially oriented in livestock, crop, and either in crop or livestock production comprised 29.15, 37.63 and 56.27%, respectively. More than 56% of the households were commercially-oriented in their agricultural production. The majority (96.6%) consumed both purchased and own-produced foods, whilst few, about 1%, consumed only purchased foods and 2.4% only own-produced foods. Regarding profitability, for each ETB invested in a crop farm it was the CCO group that received the highest return (7.53 ETB), followed by FCO (4.64 ETB) and more than 2.31 ETB was earned by the SPO group. Whereas each ETB invested in livestock production would significantly imply higher returns in commercially oriented groups over their counterparts, more importantly in FCO and LCO groups. Households that consumed both purchased and produced foods were those who received the highest return from crop and livestock farm investments (see Table 1 at the bottom). This suggested that profitability of the farm investment might have positive implications on a household's decision to move towards commercialization of agriculture as expected.

2.5.2. Demographic and Socioeconomic Characteristics

Characteristics of households across commercialization orientation and food security status are presented in Table 2. Majority of the households comprised male headed families, around 91%. No significant difference was observed in sex of heads across AC and FS strata. The mean age of household heads was about 47 years. The younger the household head the higher would be the propensity of the household to be commercially oriented. However, they seemed similar in their ages across FS and FI groups.

Table 2. Household characteristics by commercialization orientation and FS status.

Characteristics	Commercialization Orientation					FS Status	
	SPO	**LCO**	**CCO**	**FCO**	***p*-Value**	**FI**	**FS**
Sex of HH head (1 = male)	88.37	96.36	91.25	93.55	0.345	91.30	91.15
Age of HH head (years)	48.37	46.96	44.11	44.65	0.027 **	46.91	46.46
Education of HH head (years)	1.58	2.64	3.34	4.06	0.000 ***	1.83	2.73 **
Family size (persons)	6.38	6.62	5.69	6.68	0.029 **	6.75	6.12 **
Family size (AEU)	4.93	5.10	4.36	5.23	0.040 **	5.13	4.74
Dependency ratio (%)	32.16	35.04	31.78	38.73	0.268	32.79	33.44
Crop farming as main livelihood (%)	65.12	36.36	71.25	54.84	0.000 ***	50.72	63.27 *
Mixed farming as main livelihood (%)	33.33	61.82	26.25	41.94	0.000 ***	47.82	34.51 **
Others as main livelihood (%)	1.55	1.82	2.5	3.23	0.926	1.45	2.21
Total cultivated land (ha)	1.45	1.64	1.57	1.80	0.058 *	1.44	1.59
Own cultivated land (ha)	1.33	1.20	1.48	1.55	0.028 **	1.09	1.45 ***
Rented-in to cultivated land (% ha)	6.83	24.10	5.34	10.05	0.000 ***	16.87	7.88 ***
Livestock owned (TLU)	5.47	5.88	4.67	6.59	0.005 ***	5.08	5.56
Distance to nearest town market (hrs)	2.28	2.97	1.99	2.10	0.000 ***	3.17	2.04 ***
Presence of local food market (1 = yes)	77.52	81.82	97.50	96.77	0.000 ***	59.42	93.81 ***
Access to all weather road (1 = yes)	42.64	41.82	58.75	74.19	0.003 ***	52.17	49.56
Access to credit service (1 = yes)	48.84	76.36	63.75	83.87	0.000 ***	44.93	66.81 ***
Access to off-farm income (1 = yes)	27.13	29.09	52.50	67.74	0.000 ***	15.94	45.58 ***
Access to extension service (1 = yes)	87.60	87.27	92.50	93.55	0.557	89.86	89.38
Access to irrigation water (1 = yes)	72.09	52.73	55.00	58.06	0.023 **	72.46	59.29 **
Bahidar Zuria district (1 = yes)	41.43	17.14	28.57	12.86	0.000 ***	14.29	85.71 ***
Dangla district (1 = yes)	51.33	25.33	12.67	10.67	0.000 ***	36.00	64.00 ***

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Bure district (1 = yes)	30.67	6.67	54.67	8.00	0.000 ***	6.67	93.33 ***
Number of observations	129	55	80	31		69	226

Source: Survey data 2020. AEU = Adult equivalent unit; TLU = Tropical livestock unit. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

In terms of education, household heads completed on average 2.52 years of schooling. All the commercially oriented groups were found to be better in formal education (between 2.6 and 4.1 years) than their counterparts (1.6 years) at 1% significant level. The education level of heads might enhance the likelihood of households becoming commercially oriented, and, hence, food secure.

Family size was the other variable expected to play a crucial role in agricultural decision making. The mean family size among sample households was 6.27 persons per household, ranging from 1-14. While FCO and LCO groups implied a significantly larger family size, both in terms of numbers and adult equivalents, than the SPO group, lower size of family was observed by the CCO group at p = 0.029 and p = 0.04, respectively. The family size was higher in the FI group than its counterpart at p = 0.03, as expected. Dependency ratio averaged to be 33.3% among sample households, despite not varying significantly across commercialization and FS strata. The larger the family size the more likely the family was to engage in agricultural commercialization, and, hence, attract larger families. This suggested the larger the family size the higher would be the likelihood of households to be engaged in commercialization, both in crop and livestock production. Households reporting crop farming as their main livelihood were more likely to be CCO (71%) and, hence, FS (63%) more than SPO (51%). Whilst those whose main livelihood were mixed (crop and livestock) farming would tend to be LCO (62%), which, on the contrary comprised a larger share of FI (48%) than FS (35%). Livestock ownership might also swell the propensity of the household to be commercially oriented, both in crop and livestock production.

Households with a larger farm size were expected to produce better marketable surplus over what was needed for own consumption, and were more likely to be CCO and, hence, FS. The mean area of land cultivated by the household was estimated to be 1.56 ha, ranging 0.25 to 4 ha. Among which own land comprised 90% (1.37 ha) and rented-in land 10% (0.19 ha). The size of land cultivated by all the commercially oriented groups was significantly larger than their counterpart. The FCO group recorded the largest (1.8 ha), LCO (1.64 ha) and CCO (1.57 ha) and more than 1.45 ha was cultivated by the SPO group, despite not varying significantly across FS status.

Access to land market (proxied by intensity of rented-in land), labor market (proxied by access to off-farm employment), and access to credit were among factor market participation indicators expected to affect both commercialization orientation and food security of households positively. Assessing the role of land transactions among farm households is indispensable for most African countries, particularly in Ethiopia, where land reform has almost been absent for a number of decades. Participation in the land market (so-called intensity of tenancy) was defined in this study as a proportion of rented-in (or shared-in) land to total area of cultivated land by the household. The intensity of tenancy was significantly highest in LCO (24%), followed by FCO (10%), SPO (6.83%) and CCO (5.34%). This might imply the larger the size of own farmland with secure rights increased the propensity of households to be commercially oriented (FCO or CCO) and FS was more than offset by the expanded land market in cultivated land with a rented-in approach, which was so expensive. On the other hand, participation in the land market seemed to enhance the likelihood of households to be LCO. This might be because households sold their livestock in need of income to share the burden of tenancy. Similarly, the intensity of tenancy was significantly higher in the FI group (17%) than its counterpart (8%), by more than two folds. This might also suggest households with larger cultivated land (1.64 ha) but comprising smaller own farmland (1.2 ha) with a larger share of rented-in land (24%) would tend to be LCO (Table 2), which, in turn, might increase the affinity of this household FI from 23 to 42% (Table 3). Put differently smaller landownership may not be offset to the extent the FI household becomes FS by expanding the land to be cultivated by 18.4% (0.35 ha) due to land transactions.

Table 3. FS, expenditure and income related indicators by commercialization and FS status.

Characteristics	Commercialization Orientation					FS Status	
	SPO	LCO	CCO	FCO	*p*-Value	FI	FS
Food consumption score (FCS)	55.5	52.1	55.9	61.6	0.119	33.8	62.3 ***
Household FS status (1 = FS, 0 = FI)	76.7	58.2	85.0	87.1	0.001 ***		76.6
Contribution of purchased foods (% FCS)	54.0	53.2	59.9	47.8	0.053 *	57.3	54.1
FCS of purchased foods	29.9	25.7	32.8	28.4	0.029 **	19.6	32.9 ***
FCS of own-produced foods	25.6	26.3	23.1	33.2	0.031 **	14.2	29.4 ***
Total HH expenditure ('000 ETB/y)	54.2	68.0	47.0	65.7	0.000 ***	64.0	53.5 **
Share of food exp. to total exp. (%)	23.0	22.23	23.2	25.6	0.655	21.0	23.9 *
Share of nonfood exp. to total exp. (%)	53.7	58.82	51.1	50.7	0.031 **	60.2	51.6 ***
Total HH income ('000 ETB/y)	23.0	56.0	88.7	143.5	0.000 ***	45.7	67.8
Share of agri-income to total income (%)	95.0	96.4	93.3	92.6	0.478	99.0	93.2 ***
Household income PAE (ETB/y)	6912	13192	24919	30686	0.000 ***	10815	16888
Crop output market participation index	0.27	0.31	0.67	0.64	0.000 ***	0.37	0.44 **
Livestock output market participation index	0.01	0.25	0.01	0.22	0.000 ***	0.11	0.07 *
Agricultural income ('000 ETB/y)	27.7	52.9	84.1	80.5	0.000 ***	45.0	55.7
Share of crop income to agri-income (%)	76.6	43.5	88.4	64.6	0.000 ***	63.3	75.1 ***
Number of observations	129	55	80	31	295	69	226

Source: Survey data 2020. Note: Average exchange rate in 2020: 1 USD = 34.9505 ETB; PAE = Per adult equivalent; FS = food secure, FI = food insecure. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Regarding other factors, around 62 and 39% of households reported they had better access to credit and off-farm employment, respectively. All commercially oriented groups showed better position in access to both credit and off-farm employment than the SPO group. This might imply that better access to credit increased the propensity of households to be commercially oriented to 84% from 49% being subsistence oriented in their farm production, which might, in turn, enhance the likelihood of the household FS (67%) more than it would be FI (45%) (Table 2). Better access to off-farm employment, on the other hand, raised the affinity of households to being commercially oriented from 27 to 68% and might also imply the FS households growth from 16 to 46%. This suggested access to factor markets (such as credit and labor) might have positive implications for household to be commercially oriented and FS.

Liquidity constraint or limited access to output markets was the other aspect that had to be assessed, as it can play a part in whether a household remained SPO and FI. Access to output markets was measured in this study using three indicators: distance to the district town market, quality of the road infrastructure connecting the village to the main road and presence of a local food market in the village. Whereas participation of households in output markets was measured with two indices: COMPI and LOMPI. The longer travel distance from market, the lower road quality and absence of local food market were hypothesized to affect commercialization adversely, which, in turn, would have negative implications on HFS. CCO and FCO groups reported lower walking hours required to reach the nearest town market in order 1.99 and 2.1 than the 2.28 h reported by their counterparts, despite longer hours by the LCO group (2.97). Similarly, a significantly higher share of households in FCO (74%) and CCO (59%) groups reported better access to quality roads (functioning in all dry and wet weathers) than their counterparts (43%), yet a lower rate was observed in the LCO group (42%). Regarding the presence of a local food market, a larger proportion of households from CCO and FCO groups (97% each) reported the existence of a local food market, followed by LCO group (82%), with more than 77% reported by the SPO. This suggested the presence of a local food market increased the likelihood of the household being commercially oriented (CCO or FCO) from 78 to 98% and, hence, FS from 59 to 84%, whilst access to quality roads improved the propensity of the household to be commercially oriented from 43 to 74%. However, all the groups seemed similar regarding access to extension services, while the SPO group showed better access to irrigation (72%) than their counterparts (53–58%), a pattern that needs more study to understand it better. Disaggregating households by districts, households in Bure were more likely to be crop commercial oriented, whereas subsistence production was the dominant orientation of households in Bahirdar Zuria and Dangla districts.

Additionally, households characterized in terms of FS, expenditure and income related measures by commercialization orientation and FS strata are presented in Table 3. The mean FCS of the sample households was estimated to be 56, ranging between 22–100.5.

Although a higher mean implied better FS and a lower mean less FS, the mean value of FCS could not reflect the FI prevalence in absolute terms. This required derivation of a qualitative indicator (so-called FS status) from FCS to categorize households so as to generate information making it simple to understand the FI prevalence qualitatively. As indicated in Equation (2) FS status is a binary variable with a value of 1 if a household is FS (i.e., FCS > 42) and 0 if it is FI (FCS ≤ 42). We found 76.6% of households were FS while the FI recorded 23.4%, among which about 19% were moderately FI and 4.4% were severely FI. The propensity of fully or crop commercial oriented households to be FS increased from 77% to 85–87%, despite reducing to 58% for households commercially oriented in livestock production (Table 3).

To differentiate HFS impacts of commercialization orientation as to whether it had been through increased consumption of purchased foods with or without replacing own-produced foods, as well as to identify which commercialization orientation was more important for better HFS, the overall FCS of households was disaggregated into FCS from own-produced foods and purchased foods. Assessing such an issue in absolute terms implied that the FCS derived from both purchased and own-produced foods consumed by the household in the FS group were 33 and 29, which were significantly higher than 20 and 14 in the FI group. The contribution of purchased foods to household FCS averaged at 55%; this figure was significantly higher among CCO households (60%) and lower in LCO (53%) and FCO (48%) and 54% among SPO households. This suggested crop commercialization might affect HFS positively through nurturing consumption of purchased foods, whereas livestock commercialization might improve HFS by enhancing consumption of own-produced food crops. The lower share of purchased foods to FCS of LCO and FCO groups would also mean better share of FCS from own-produced foods. Such results were also confirmed by a higher rate of food expenditure to total expenditure by CCO (23.2%) and FCO (25.6%) groups and a lower rate by LCO group (22.2%) than 23% by their counterpart. On the other hand, the LCO group spent a significantly larger share of non-food expenditure (59%) whilst the CCO and FCO groups spent a lower rate (51% each) than the 54% that was incurred by the SPO group, moving a step forward the view that LCO fosters own food crops consumption by allowing households to finance non-food expenditure.

The annual total expenditure of households in the year 2020 averaged at 55,986 ETB (1602 USD). Food and non-food expenditure shared around 23.2 and 53.6%, respectively. While the mean annual income a typical household earned in the study areas was estimated to be 62,658 ETB (1793 USD), of which agricultural income was responsible for 94.5%. The contribution of agriculture to total annual income of the household was significantly higher in the FI group (99%) than its counterpart (93%).

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Characterizing households into FS and FI, in terms of their expenditure and income, implied that the share of food expenditure to total expenditure was significantly larger in FS group (24%) than in FI (21%) at 10% level. By contrast, the non-food expenditure shared about 60% of total expenditure in FI group overweighed the 52% that was in FS group significantly at 1% level. AC improved not just overall annual income of households but also enhanced the income per adult equivalent by more than two folds of its counterpart.

Regarding market participation indicators, we found all commercially oriented groups recorded better COMPI than their counterparts, even by more than two folds in the cases of CCO and FCO groups. LOMPI also showed a similar pattern of a significantly higher value in LCO and FCO groups than their counterparts. While the former participation implied a positive effect on HFS, the latter might affect HFS adversely. This did not necessarily suggest participation in crop output markets could significantly improve HFS while participation in livestock markets significantly affected HFS adversely, due to issues of heterogeneity in unobserved and other observed factors and censorship, which is addressed well in the econometric results section later using a bivariate Tobit model. The income the households earned annually from farming activities was significantly higher among all commercially oriented groups than their counterparts, and AC increased household income. The relative importance of each commercialization on HFS could be captured using a relative crop commercialization index (i.e., share of crop income to agricultural income) as an indicator. An increase in crop income relative to agricultural income implied the propensity of the household to be FS (75%) and was significantly higher than 63% that would have been FI.

3. Results and Discussion

3.1. Definition and Measurement of Independent Variables

Table 4 presents definition and measurement of independent variables used in the econometric analyses and expected signs of their relationships with outcomes.

Table 4. Definition, measurement and expected sign of variables used in econometric analyses.

Variables	Descriptions	Measurements	Expected Effect		
			CCO	LCO	HFS
rcci	Relative crop commercialization index	Continuous (ranging 0 to 1)			+/−
profcrop	Profitability of crop farm	Net return per input cost	+		
proflvst	Profitability of livestock farm	Net return per input cost		+	
cdim	Crop diversity index in Meher season	Count	−		+
cdir	Crop diversity index in irrigation season	Count	−		+
ldi	Livestock diversity index	Count		−	+
aghd	Age of household head	Years	+/−	+/−	+
aghdsq	Age of household head squared	Continuous	+/−	+/−	+/−
edhdy	Education of household head	Years of schooling	+	+	+
edmoy	Education of mother	Years of schooling	+	+	+
dmalhd	Male headed household	Binary (1 if male headed)	+/−	+/−	−
hszn	Family size	Persons per HH (num.)	−	−	−
owculha	Own cultivated land size	Hectares	+	+/−	+
ldri	Land rented-in index (tenancy)	Continuous (ranging 0 to 1)	+/−	+/−	+/−
crac	Access to credit services	Binary (1 if yes, 0 no)	+	+	+/−
ofia	Access to off-farm income	Binary (1 if yes, 0 no)	+	+	+/−

mtd	Travel distance to nearest town market	Walking hours	−	−	−
plm	Presence of food market in the village	Binary (1 if yes, 0 no)	+	+	+
rodac	Access to all weather road	Binary (1 if yes, 0 no)	+	+	+
extac	Access to agri-extension services	Binary (1 if yes, 0 no)	+	+	+
irac	Access to irrigation water	Binary (1 if user, 0 nonuser)	+	+/−	+

Source: Literature review and authors 'understanding and experiences.

3.2. Econometric Results

This subsection presents and discusses the results of econometric models applied in the current study to evaluate the link between commercialization orientation and food security of households, as well as to identify joint determinants of commercialization orientation of households in their crop and livestock production.

3.2.1. Commercialization and Food Security Nexus

Estimation results of Tobit and Poisson regression models are presented in Table 5. Ceteris paribus, when relative crop commercialization level was larger by one unit, the FCS of purchased foods (FCS_{PF}) was also larger by 3.58 units, significantly lower in magnitude than it lowered the FCS of own-produced foods (FCS_{OF}) by 9.46 units, which ultimately implied the net reduction of FCS by 6.42 units. This, on the other hand, meant that commercialization orientation in livestock production was more important than in crop production for better HFS. As the converse reflected relative livestock commercialization, a unit rise in its level reduced the FCS_{PF} by 3.58 units, while improving the FCS_{OF} by 9.46 units resulting in a net increment of HFS by 6.42 units in FCS. Despite not being significant in magnitude, the Poisson result also showed the same direction of implication that confirmed LCO potentially improved HDDS whilst CCO was against it. Overall, this suggested CCO impacted HFS positively via increased consumption of purchased foods, whereas LCO improved HFS with better consumption of own-produced food crops. Despite most studies evaluating commercialization focusing mainly on either crop or livestock production, the works in Kenya [26], Cambodia [32], Tanzania [36] and the Great Lakes of Central Africa [44] confirmed participation of smallholder farmers in crop output markets improved HFS and dietary quality through increased consumption of purchased foods. It also seems consistent with [26] claiming commercialization does not reduce consumption of nutrition from own-produced foods, which, in our case, was exhibited in commercialization in livestock production helping sustain consumption of diversified food crops from own production. This suggested that the higher the level of CCO the more market oriented the crop farm towards selling majority of its produce, exceeding the pace of earned income translating into purchases of diversified foods for consumption, ultimately implying CCO impacts HFS adversely. This may work as [45] revealed in Zambia, in areas with less everyday access to a range of food items, where capital accumulation alone may not help avoid deficiencies in HFS. In livestock farming as well, the higher the level of LCO the more market oriented in selling more of its produce; enhancing consumption of own-produced food crops, this being significantly higher than the rate it could hamper consumption of purchased foods potentially made through crop sales, as the household becomes commercially oriented in livestock production, which would eventually result in better HFS.

Table 5. Estimation results of Tobit, bivariate Tobit and Poisson regression models.

Variables	Tobit	Bivariate Tobit		Poisson
	FCS	**FCS_{PF}**	**FCS_{OF}**	**HDDS**
rcci	−6.42 (3.80) *	3.58 (3.13)	−9.46 (3.45) ***	−0.007 (0.054)
cdim	1.41 (0.87) *	−1.60 (0.78) **	2.90 (0.85) ***	0.066 (0.013) ***
cdir	−2.80 (0.61) ***	−1.69 (0.68) **	−1.20 (0.75) *	−0.014 (0.012)
ldi	2.15 (0.53) ***	−0.05 (0.44)	2.23 (0.48) ***	0.011 (0.007)

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aghd	−1.76 (0.72) **	−0.57 (0.59)	−1.17 (0.65) *	−0.024 (0.01) **
aghdsq	0.02 (0.007) **	0.005 (0.006)	0.013 (0.007) **	0.0002 (0.0001) **
edhdy	−0.03 (0.34)	−0.43 (0.29)	0.43 (0.31)	0.008 (0.005)
edmoy	0.78 (0.43) *	0.17 (0.36)	0.57 (0.40)	0.003 (0.007)
dmalhd	1.00 (2.83)	1.88 (2.89)	−1.12 (3.19)	−0.019 (0.06)
hszn	0.29 (0.54)	0.20 (0.45)	0.11 (0.49)	0.005 (0.006)
owculha	2.79 (1.99)	3.92 (1.78) **	−0.98 (1.96)	0.015 (0.03) ***
ldri	−0.97 (6.42)	2.10 (4.69)	−2.84 (5.16)	−0.14 (0.083) *
crac	0.63 (2.16)	1.33 (1.74)	−0.83 (1.92)	0.007 (0.03)
ofia	−1.69 (2.07)	3.05 (1.77) *	−4.71 (1.94) **	−0.009 (0.03)
plm	10.23 (3.27) ***	6.92 (2.71) **	3.08 (3.02)	−0.013 (0.04)
mtd	−3.89 (0.75) ***	−1.08 (0.72)	−2.92 (0.79) ***	0.023 (0.01) *
rodac	0.20 (1.92)	0.64 (1.66)	−0.35 (1.83)	0.016 (0.03)
extac	−5.33 (3.02) *	−1.16 (2.84)	−4.87 (3.12)	0.058 (0.03)
irac	6.24 (2.75) **	−1.58 (2.49)	7.82 (2.74) ***	−0.068 (0.04) *
_cons	82.68 (17.85) ***	38.33 (14.56) ***	44.06 (16.01) ***	2.17 (0.25) ***
σ_1			12.64 (0.53) ***	
σ_2			13.92 (0.58) ***	
ϱ_{12}			−0.71 (0.12) ***	

Source: Survey data 2020. Wald chi²(19) = 68.15; Prob > chi² = 0.000; robust standard errors are in parentheses; FCS = food consumption score; FCS_{PF} = FCS of purchased foods; FCS_{OF} = FCS of own-produced foods. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

In order to capture issues of seasonality and the role of irrigation on HFS, the current paper tried to look at agricultural production (i.e., agricultural diversification) variables decomposed into crop diversity (further disaggregated into Meher and irrigation seasons) and livestock diversity. As Table 5 shows a one unit increase in Meher (rainy) season crop diversity implied a net increment of HFS by 1.4 units in FCS, as the positive effect of rising FCS_{OF} by 2.9 units overweighed in magnitude its adverse effect on crop commercialization being reduced FCS_{PF} by 1.6 units, controlling for confounding factors. The Poisson result also confirmed diversification of crop production in Meher season had positive implication on HDDS. Nevertheless, crop diversification in irrigation (dry) season affected HFS negatively, as this index increased by one-unit HFS reduced FCS by 2.8 units. On the other hand, livestock diversity improved HFS, directly enhancing consumption of own-produced foods. Here can be understood diversification of crops to a certain level would have positive implication on HFS if it were during Meher season, but crop specialization in the dry season improved HFS, because diversification in the latter season impacted both purchased and produced foods consumption adversely. A slightly similar result was revealed in Mali [37] where diversification of farm production after a certain level may not be an effective strategy to improve dietary diversity of smallholder farmers, and rather better access to markets, productivity-enhancing inputs and technologies were more important.

The bivariate Tobit results also demonstrated that other determinants of HFS, with varying level of influence, included education of mothers, size of own farmland, presence of local food market in the village and access to irrigation, which affected HFS positively as expected, while age of household head, distance to the nearest road/town market and access to extension influenced HFS adversely. The latter variable implied a pattern that would require more study to understand. However, other covariates, such as sex of household head, family size, access to credit and quality of the road infrastructure, would not have significant influence on HFS.

As age of household head increased HFS decreased even at the increasing rate at older ages. This was due to reducing consumption of own-produced foods. The descriptive analysis above also confirmed that families with younger heads were more likely to be commercially oriented as they might be more productive and, hence, would be better in HFS than those headed by elders. Similar results in Pakistan [46] and Nigeria [47] revealed that as the household head advances in age the propensity of the household to become food insecure rises.

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Regarding education, formal education level of mothers significantly improved HFS by enhancing consumption of both own produced and purchased foods. It was also consistent with FAO et al. [1] that argue children in rural settings and poor households, whose mother received no formal education, were more vulnerable to stunting and wasting. By contrast the head's education level seemed to improve subsistence consumption and discouraged consumption of purchased foods, despite not being significant in magnitude.

Size of own farmland had positive implications on HFS in terms of increased consumption of purchased foods by encouraging crop commercialization, whereas land transactions seemed to influence HFS negatively in terms of HDDS. The descriptive result confirmed that land area owned with secure rights could improve HFS and had been more than offset by expanding the land to be cultivated through a rented-in approach being so expensive. The previous work in Cambodia [32] was consistent with this finding, implying that size of land owned instead of the overall cultivated land has important implication as the latter has more potential for endogeneity.

The positive effect of off-farm employment on HFS enhancing consumption of purchased foods and its negative effect on HFS reducing consumption of own-produced foods being strong seemed to yield a net reduction of HFS in overall FCS and HDDS. In line with other studies in Ethiopia [27,48] and in India [49], our finding seemed to reflect the context of the farming systems in most developing countries for the fact that the majority of households engaged in off-farm activities were those which were less food secure and resource deficit. They used off-farm activities as a coping strategy for food insecurity. On the other hand, this suggested off-farm employment could improve HFS through making smallholder agriculture commercially oriented instead of being subsistent.

Similarly, presence of a local food market in the village enhanced HFS, mainly due to increased consumption of purchased foods resulting from improved commercialization of agriculture. The other indicator of access to markets was the travel distance (in waking hours) required to reach the nearest main road or town market revealed. A travel distance larger by one hour in HFS was lowered by 4 units of FCS. The longer the distance the farmer resided from the nearest main road or town market the less market integration and the higher would be the transaction costs influencing HFS adversely, mainly due to limited commercialization. However, this was mainly due to reduced consumption of own produced foods, which is a pattern that also needs further study to understand. Access to irrigation, on the other hand, enhanced HFS as expected mainly through increased consumption of own produced foods. Furthermore, a statistically significant and positive sign on the constant underscores would be unobserved factors that tended to influence HFS positively. Table 5 shows at the bottom, ($\rho_{12} = -0.71$), that as commercialization orientation of farmers improved there would be trade-off between consumption of purchased and own-produced foods statistically significant at 1% level. This showed evidence on the relevance of bivariate Tobit to capture such a non-recursive interdependence between consumption of purchased and own-produced foods resulting from commercialization.

3.2.2. Factors Influencing Commercialization Orientation

We employed a bivariate Tobit model again for joint determination of factors influencing crop and livestock commercialization orientation among smallholder farmers. Table 6 in column 2 presents profitability of crop farm, irrigation season crop diversification, education level of household head, size of own farmland, access to credit, access to off-farm employment, presence of local food market in the village and quality of the road infrastructure as factors identified to enhance transition of smallholder farmers from subsistence to commercial oriented crop production. In contrast, we found Meher season crop diversification, rented-in land and access to irrigation were among the factors impacting CCO adversely, the latter two showing a pattern that would require more study to understand.

Table 6. Joint determination of factors influencing CCO and LCO: A bivariate Tobit model.

Variables	CCO			LCO		
	Coef.	**Std. Err.**	***p*-Value**	**Coef.**	**Std. Err.**	***p*-Value**

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profcrop	0.018 ***	0.004	0.000			
proflvst				0.006 ***	0.0009	0.000
cdim	−0.049 **	0.025	0.050			
cdir	0.049 **	0.022	0.027			
ldi				0.108 ***	0.022	0.000
agehd	0.017	0.018	0.348	0.043	0.031	0.161
aghdsq	−0.0003	0.0002	0.177	−0.0005	0.0003	0.146
edhdy	0.019 **	0.009	0.032	0.004	0.014	0.778
edmoy	−0.009	0.011	0.454	0.011	0.018	0.519
dmalhd	0.045	0.091	0.619	0.032	0.154	0.835
hszn	−0.018	0.014	0.190	0.010	0.022	0.658
owculha	0.108 *	0.056	0.052	−0.067	0.077	0.384
ldri	−0.265 *	0.147	0.071	0.367 *	0.219	0.093
crac	0.100 *	0.055	0.067	0.151 *	0.086	0.080
ofia	0.129 **	0.057	0.023	−0.014	0.087	0.871
plm	0.258 ***	0.087	0.003	−0.237 *	0.133	0.075
mtd	−0.0007	0.022	0.976	0.087 ***	0.031	0.005
rodac	0.157 ***	0.052	0.003	0.127	0.080	0.113
extac	−0.013	0.089	0.886	0.173	0.147	0.237
irac	−0.167 **	0.079	0.035	0.047	0.088	0.597
_cons	−0.225	0.453	0.620	−1.896 **	0.749	0.011
σ_1	0.401 ***	0.017	0.000			
σ_2	0.553 ***	0.032	0.000			
ϱ_{12}	0.036	0.106	0.735			

Source: Survey data 2020. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Wald $chi^2(18) = 146.6$; Prob > $chi^2 = 0.000$.

Table 6 in column 5 presents estimates of variables expected to affect LCO of smallholders. Profitability of livestock farm, livestock diversification, rented-in land, access to credit and distance to district town market influenced LCO positively. Presence of local food market in the village was the only factor observed to affect LCO negatively. AS significantly negative sign on a constant implied there would be unobserved factors that tended to affect LCO adversely. As also seen in Table 6 at the bottom, there was no statistically significant interdependence between CCO and LCO.

The profitability of crop farm and livestock farm investment would have positive implication on commercialization behavior of households in crop and livestock production, respectively. This was consistent with the descriptive analysis showing households commercially oriented in crop and livestock production received more than three and eight folds of the returns their counterparts earned from each ETB invested in crop and livestock farm, respectively (Table 1).

Assessing the effect of seasonal variation in production on crop commercialization orientation of smallholder farmers, we found diversification of crop production would have negative (positive) implication on crop commercialization if it were during rainy (irrigation) season, respectively. As diversification of crop production was larger in rainy season by one unit the level of crop commercialization lowered by 0.05 unit (Table 5), which, in turn, implies HFS reduced by 1.6 units of FCS from purchased foods (Table 6). By contrast, a one unit increase in diversification of crop production in dry season would improve crop commercialization level by 0.05 unit, which might then reduce HFS by 1.2 units of FCS from subsistence production. Access to irrigation was the other dimension that significantly influenced crop commercialization adversely, as also seen in Table 5, and might imply it encouraged subsistence production, which seems a pattern that would need more study to understand.

Livestock diversification, on the other hand, had a direct implication on livestock commercialization; as livestock diversification rose by one unit commercialization of livestock improved by 0.1 units, which might, in turn, improve HFS by 2.2 units of FCS from self-produced food crops, by allowing households to finance their nonfood expenditures, as also supported by the descriptive analysis.

Education level of household head significantly affected crop commercialization positively but it did not significantly influence commercialization in livestock production. As land area owned by a household increased by 1 ha, level of crop commercialization improved by 0.1 units that consequently boosted HFS by 4 units of FCS from purchased foods. On the other hand, land transactions among farmers with a rented-in approach had negative implication on crop commercialization while it affected livestock commercialization positively. This might be due to the fact that farmers sold part of their livestock to share the burden of such tenancy in crop farm as the descriptive results also confirmed. Access to credit was the other factor that had a significantly positive effect on commercialization orientation of households in both crop and livestock production. Whereas access to off-farm employment positively affected crop commercialization, it did not significantly impact livestock commercialization.

While both availability of a local food market in the village and quality of the road infrastructure significantly improved crop commercialization, the former influenced livestock commercialization adversely but did not significantly affect the latter. Distance to district town market significantly influenced livestock commercialization positively, which seems a pattern that also seeks further study to understand. Education level of mothers, sex of heads, family size and access to extension were among the covariates considered that did not significantly affect the transition of agriculture from subsistence to commercially oriented production.

4. Conclusions and Implications

Estimates of econometric models on a relative crop commercialization index identified that livestock commercialization was more important than crop commercialization for achieving better HFS. Although CCO improved HFS through increased consumption of purchased foods, its adverse effect on subsistence consumption was significantly higher in magnitude, so ultimately it yielded a net reduction in HFS. By contrast, commercialization orientation in livestock production resulted in a net increment in HFS, as its synergy effect on crop diversification for own consumption strongly overweighed in magnitude its adverse effect in reducing consumption of purchased foods. This has crucial policy implications in food security and nutrition transition and further contributes to extant literature on agriculture–nutrition pathways.

Supporting investments in improving road infrastructure, both in terms of access and quality to function all weather conditions, establishing better access to institutional services (credit, extension, off-farm employment and land markets) and awareness creation for enhanced diversified food consumption are viable intervention areas to improve the role of AC to HFS for vulnerable households. Further increasing AD may not be the most effective strategy to improve HFS, as [12,13,37] confirmed, as diversification after a certain level might prevent gains from specialization that could, in turn, lead to income losses potentially affecting HFS adversely. Transformation of agriculture from subsistence to commercially oriented production seems to be more promising, similar to the findings of [13,14] who identified market access as more important than farm diversification for food security to improve. All these suggest AC is vital, not only for economic growth and improved wellbeing of households, but also because it plays a crucial role for the smallholder agriculture to be more nutrition sensitive.

While several tests confirmed robustness of our findings, a few limitations remain. The analysis was based on cross-sectional data limited to capture seasonal differences and identification strategy, and, as argued by [25], a household's FS position is dynamic with the possibility that a household that is FS today may not be so tomorrow and vice-versa. Using bivariate Tobit is limited to address the interaction effects between variables. Future studies with panel data considering changes in the level of AC and food security position of households over time and adopting the approach that can capture interaction effects, besides controlling for the complex relationship between variables in an integrative system, will enhance the robustness of the findings in AC–FS linkages. Additionally, some variables were found to be different from expected and when compared to other studies and need to be further researched.

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