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Does Cereal Commercialization Enhance Farm Households' Input Use, Efficiency, and Productivity? A Conditional Mixed Process (CMP) Approach from Rural Ethiopia

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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 included 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 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 vice-versa. Moreover, the results show that the extent of cereal commercialization is 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

Introduction

Commercial transformation has been pursued as an important pathway for successful smallholder agriculture development in developing countries. Commercialization entails a transition from subsistence-oriented to market-oriented patterns of production (Govereh, *et al.*, 1999; Poulton, 2017). Market-oriented production systems enable farm households to adopt knowledge-intensive technologies (Pingali & Heisey, 1999) and thereby improve the most efficient use of available resources (von Braun & Kennedy, 1994). Farm households' adoption of improved technology further alters market participation choices by increasing input utilization efficiency and productivity (Barrett, 2008; Poulton, 2017). Evidence from Asia during the green revolution (Pingali & Heisey, 1999) shows that efficient application of land-augmented technologies has considerable scope to significantly increase cereal crop yield, implying a contribution to the improvement of smallholder welfare.

In Ethiopia, it has prioritized food security, poverty reduction, and improved smallholder welfare through productivity growth and market-oriented production transition (MoFED, 2003; NPC, 2016). To this end, the government has been pursuing all-inclusive measures to supply and improve the 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.

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, weak introduction of technologies, inadequate marketing infrastructure (MoFED,2014; Yu, et al., 2011; Dorosh & Rashid, 2012; Tilahun, 2014; Urgessa, 2015; Merga & Haji, 2019). The extent of output commercialization is also 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 were 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 the requirement of better understanding of 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 shows that the productivity of farm households is positively and significantly influenced by the commercialization orientation factor.

Many of the studies reviewed above address only the fertilizer use effect of commercialization, suggesting the need to conduct an all-inclusive study that systematically explores the input use effects of commercialization by taking improved seed, chemical fertilizers 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, the current study expands on earlier empirical findings using plot-level data collected from randomly chosen farm households in rural Ethiopia. Unlike previous studies, the current study included a simultaneous mixed process model, dose-response function, and three-stage regression framework (3SLS). The 3SLS method was used to determine the bidirectional causation between technological efficiency and cereal crop commercialization. This renders the simultaneous solution of all questions using generalized least squares (Heck, 1977), and provides a more efficient estimate as compared to all IV estimators (Greene, 2012).

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 two provides the key analytical results and their associated discussion. The final section presents the concluding remarks and the way forward.

Methodology

Description of the study area

The empirical analysis of this study is based on a plot- and household-level survey carried out in Oromia and Amhara, major *teff*-producing regions of Ethiopia (Figure 1). Together, the regions accounted for 81% of cereal cultivated land, 82% of total cereal production, 85% of *teff* cultivated land, and 87% of total *teff* production in the country (CSA, 2020). From the region, East Shewa in the Oromia region and East Gojjam in the Amhara region are two of the country's most intensive *teff*-based mixed farming areas, where crop and livestock production are the primary sources of income for households.

Method of data collection

Using a cross-sectional survey, primary data were generated from 392 farm households randomly drawn from six *Kebeles* in intensive teff-based mixed farming areas of Ethiopia. The study also used semi-structured checklists applied using key informant interviews and focus group discussions. Secondary data was also gathered from zonal and '*Weredas'* level agricultural offices, CSA cereal production and productivity data, other policy documents, and specific studies carried out in Ethiopia.

Sampling strategy

The study's population and unit of analysis were farm households in Oromia and Amhara, the two main *"teff"*-growing regions. Following multi-stage stratified sampling procedures, the final sample farm households were chosen at random from the final study districts, Adea and Enemay Wereda, taking into account the Weredas' high potential and suitable agro-ecology for *"teff" production*. A total of six kebeles, or three kebeles per Wereda, were chosen at random from all of the rural *'Kebeles'* in the study '*Weredas'* given the time, resources, and existing similar production system. The sample size of 392 farm households, including a 10% contingency, was determined at random using the formula developed by Kothari (2004), as specified below. We excluded 14 observations out of 392 due to missing information. Cereal, such as teff, wheat, barley, maize, and sorghum were the major crops considered in this study.

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

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 desired level of precision; p is the estimated proportion of an attribute present in the target 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.

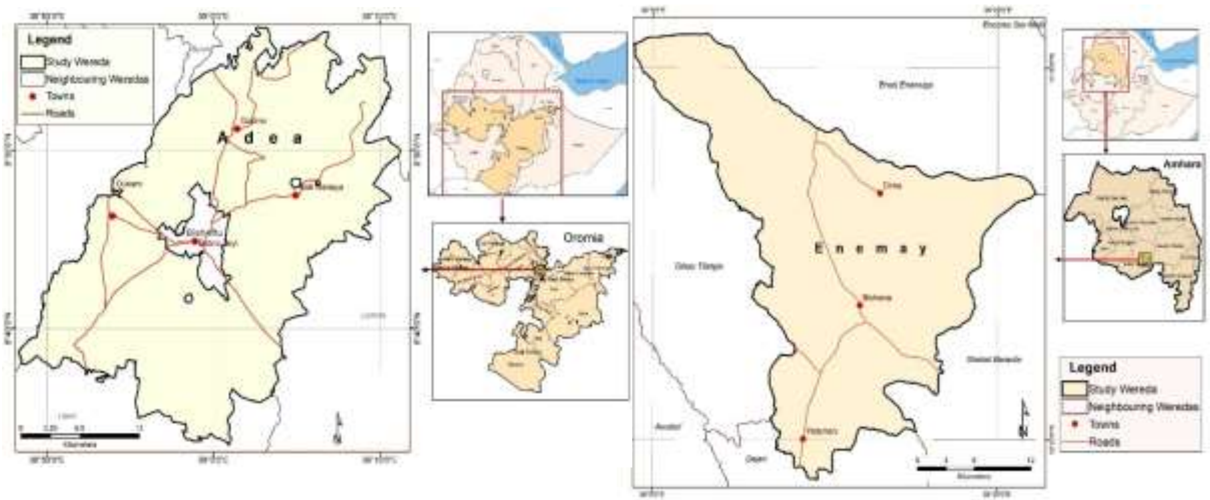

Figure 1: Location map of the study areas

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 a value approaching 100 signifies a higher degree of commercialization or a great percentage of marketed cereal crops. The index is specified as follows:

$$CCI_{ij} = \frac{\sum_{k=1}^{K} S_{ik}\bar{P}_k}{\sum_{k=1}^{K} Q_{ik}\bar{P}_k} = \begin{cases} = non - seller \\ > 0\ seller \end{cases} \quad \text{--- (2)}$$

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)[1]. 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 estimating the meta-frontier has two stochastic frontier production functions as defined below:

$$ln\ lny_i^k = f^k\left(x_i^k, \beta^k\right) + v_i^k - u_i^k\ ,\ \ i = 1, \dots, n(k) \text{ ----(3)}$$

$$ln\hat{f}^k\left(x_i^k, \beta^k\right) = f^M\left(x_i^k, \beta\right) + v_i^M - u_i^M \text{.....(4)}$$

where, y_i^k represents the value of the 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^kdenotes the random variation in output (y_i^k) due to factors outside the control of the firm

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

(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 $N(0, \sigma_v^{k2})$ and is independent of u_i^k; $ln\hat{f}^k(x_i^k, \beta^k)$ is the estimate of the group-specific frontier from Eq.(3). Since the $ln\hat{f}^k(x_i^k, \beta^k)$ 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). 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 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.

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.

$$\begin{aligned} Y_i^* &= X_1'\beta_1 + \varepsilon_{1i}, \\ S_i^* &= X_2'\beta_2 + \varepsilon_{2i}, \\ U_i^* &= X_3'\beta_3 + \varepsilon_{3i}, \\ N_i^* &= X_4'\beta_4 + \varepsilon_{4i}, \\ C_i^* &= X_5'\beta_5 + \varepsilon_{5i}, \\ L_i^* &= X_6'\beta_6 + \varepsilon_{6i}, \end{aligned} \quad \text{---} \quad (5)$$

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) (following Hirano & Imbens, 2004) 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 techniques have the advantage of seizing up the dynamic effects of the treatment on outcome variables at different doses/treatment levels. 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 vice-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, build 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 follows:

$$y_1 = \gamma_1 y_2 + \beta_{11} x_1 + \beta_{12} x_2 + \cdots + \beta_{1i} X_i + \varepsilon_1, \text{---} \ (6)$$

$$y_2 = \gamma_2 y_1 + \beta_{21} x_1 + \beta_{22} x_2 + \cdots + \beta_{2i} X_i + \varepsilon_1 \qquad \text{---} \ (7)$$

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 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. 8 and 9) as specified below and considered several variables to be excluded from both equations.

Commercialization equation (Eq.8):

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

Technical efficiency equation (Eq.9):

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

Explanation of variables used in the empirical models

The major outcome 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 1). Moreover, the study identified several covariates (Table 2) from the review of various theoretical and empirical literature that are to be used as a control variable in estimating the input use, yield, and efficiency effects of commercialization among farm households.

Table 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)	+	+	+	+	+	+	+

Table 2: Control variables used in the model

Variables	Unit
Head age	Years
Head education	Years
Household size	Adult equivalent units
Access to extension service	Binary: yes=1
Distance to input center	km
Distance to nearest market	km
Road condition	Binary: good=1
Cooperative membership	Binary: yes=1
Non-farm employment	Binary: yes=1
Market information	Binary: yes=1
Population pressure	Ratio of family size to farm size
Number of crops	Number of crops grown by the HH
Household owns cellphone	Binary: yes=1
Land quality[2]	Index
Total assets owned (log)	ETB
Livestock ownership	TLU
Crop damage	Proportion of area of cultivated land affected by stresses
Number of plots	Number of plots owned by the household

Results and Discussion

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. 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

[2] 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).

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.

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. Twenty nine percent of farm households sold cereal crops to retailers, followed by farmer traders in the village (26%) and consumers (19%) (Figure 2). Nonetheless, 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.

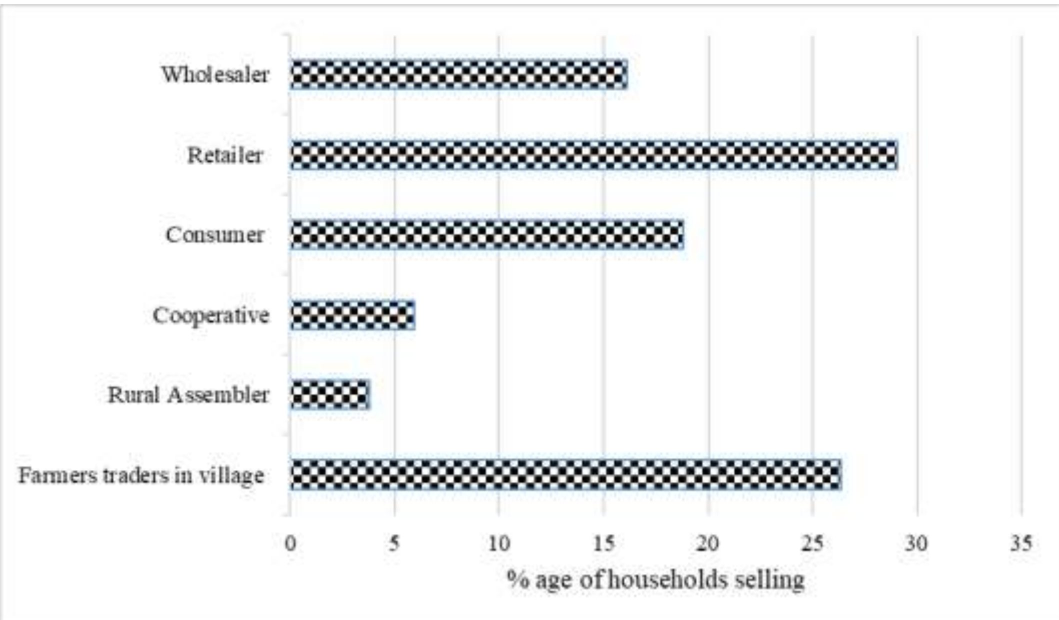

Figure 2: Proportion of households selling market outlets
Source: Authors' analysis using primary data (2020)

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[3]. 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 agrochemicals, 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.

Table 3: Comparative assessment of the key continuous variables by commercialization status

Variables	Full sample [Mean]	Commercialization index			F-Value
		Subsistence [<30%]	Semi-commercialized [30-65%]	Commercialized [>65%]	
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
Agrochemicals	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 and 5 percent levels of significance, respectively

More than 35% of farm households used high-yielding varieties (HYVs) mainly for *'teff'*, wheat, and maize (Table 4). From which, 41% and 60% of them were semi-commercialized and commercialized farm households, respectively. 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 demand for labor to cultivate *'teff'*, produced mainly for the market, as compared to other crops.

[3] 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 4: Comparative assessment of the key categorical variables by commercialization status

Variables	Full sample [%age]	Commercialization index			Chi-square
		Subsistence [<30%]	Semi-commercialized [30-65%]	Commercialized [>65%]	
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 *** is significant at 1 percent levels of significance

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 constant, a 10% change in cereal crop commercialization enhances the expenditure on nitrogen fertilizer and chemicals by 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, 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 of 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 5: 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 observations 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 and 5 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, 4, and 5 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 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 30% to 50%. However, as it is seen in Figure 4, 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 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 contrast 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 4). Figure 5 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.

Nexus between Technical Efficiency and Commercialization

Table 6 presents 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 the existence of 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 vise-versa because commercialized farmers can purchase and use modern inputs as compared to subsistence farmers and their counterparts. The findings of this study are consistent with Rios, et al. (2008).

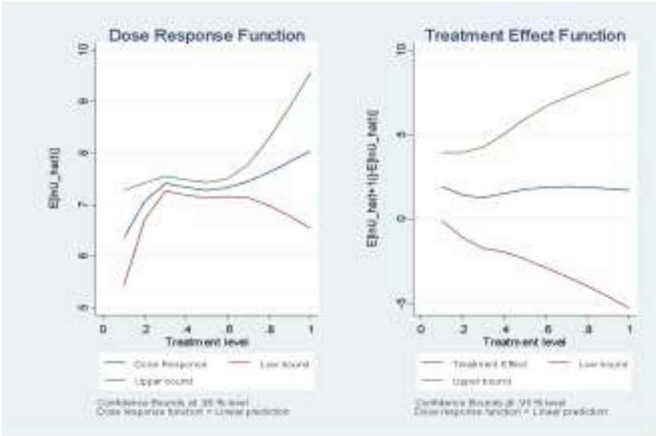

Figure 3: Estimated input use effect of dose-response function (UREA)
Source: Authors' analysis using primary data (2020)

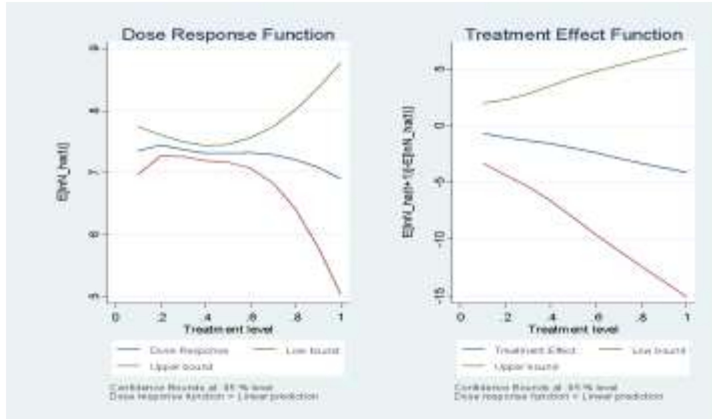

Figure 4: Estimated input effect of dose-response function (NPS)
Source: Authors' analysis using primary data (2020)

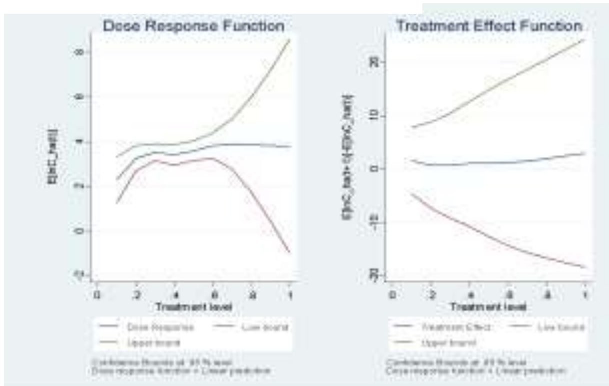

Figure 5: Estimated input effect of dose-response function (agrochemicals)
Source: Authors' analysis using primary data (2020

Table 6: 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 *** is significant at 1 percent levels of significance

Conclusion and Recommendation

The study sought to investigate the input, efficiency, and productivity effects of cereal crop 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 farm households. The study reveals that 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 crop commercialization is considered for those inputs such as high-yielding variety, hired labor, nitrogen fertilizer, 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 agrochemicals among 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 agrochemicals was found positive except for NPS fertilizer.

The productivity effect of commercialization was also verified as 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.

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Appendix

Table A1: Distribution of treatment interval

Level of cereal crops commercialization	Number of farms 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 A2: 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 A3: 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 A4: 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)