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Research Article

# Economic Efficiency of Smallholder Farmers in Wheat Producation: In Adiyo District, Kafa Zone, Southern Nations Nationalities of People's Region, Ethiopia

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## Abstract

Ethiopian agriculture is marked by low production. To address this issue, it is becoming increasingly vital to integrate current technology with higher levels of efficiency. As a result, the purpose of this study was to assess the technical, allocative, and economic efficiencies of smallholder wheat producers and to identify factors that influence smallholder farmers' efficiencies in wheat production in the study area. A two-stage sampling procedure was utilized to select the 198 farmers that were sampled. For this study, both primary and secondary data sources, as well as qualitative and quantitative data types, were utilized. To estimate technical, allocative, and economic efficiency levels, the Cobb-Douglas production function was fitted using a stochastic production frontier approach, whereas the Tobit two-limit model was employed to identify factors affecting the sample farmer's efficiency levels. The stochastic production frontier model revealed that input factors such as oxen, labor, NPS, seed, and chemicals were significant in increasing wheat output. Wheat producer farmers' estimated mean technical, allocative, and economic efficiencies were 71.6%, 73.5%, and 52.6%, respectively. According to the Tobit two-limit model, technical efficiency is favorably and significantly affected by access to Cerdit cooperative membership, participation in off- and non-farm income, and distance to the nearest market. Furthermore, the gender of the household, the educational level of the household head, access to finance, and frequency of extension contact all have a favorable and significant impact on allocative efficiency. Allocative efficiency has a negative impact on farm land slop and land fragmentation. Finally, the sex of the household, educational level of the household, cooperative membership, access to finance, and frequency of extension contact all had a beneficial effect on economic efficiency. The findings suggested that there is space for wheat producers in the study area to improve their efficiency. In general, more focus should be placed on improving the efficiency of those less efficient farmers by adopting the methods of the area's reasonably effective farmers. Aside from that, the government's policies and initiatives should account for the a fore-mentioned determinants.

**Keywords:** Wheat; Smallholder; Efficiency; Tobit; Ethiopia

## Introduction

Agriculture is the foundation of the Ethiopian economy, generating approximately 36.3% of GDP, employing approximately 73% of the labor force, and contributing approximately 70% of total export earnings and 70% of raw materials for industries in the country [1]. Wheat is a significant crop in Ethiopian agriculture.

However, it is distinguished by low output as a result of massive variables. These include inefficient management inputs, limited use of modern agricultural technologies, obsolete farming techniques, inadequate complementary services such as extension, credit, marketing, and infrastructure, and poor and biased agricultural policies in developing countries [2].

Agricultural productivity and output can be raised by increasing input or improving technology given a certain level of input. Improving productivity also refers to increasing producer efficiency. Because cereal crops are a key contributor to the Ethiopian economy, increasing productivity and efficiency of this production could be a big step toward achieving food security [3].

Cereal production provides a source of income for millions of Ethiopian households, and it is the single most important sub-sector of Ethiopian agriculture, outnumbering all others in terms of rural employment, agricultural land use, and contribution to national income [4]. Teff, wheat, barley, maize, sorghum, and millet are the primary cereal crops farmed in Ethiopia [3].

Ethiopia is Sub-Saharan Africa's leading wheat producer, followed by South Africa [5]. Cereal crops account for 80.71% of total land from grain crops, with wheat ranking fourth, accounting for 13.38% of total areas, followed by teff, maize, and sorghum, each with a yield of 27.36 quintals per hectare [6]. It is grown in Ethiopia's highlands, primarily in the provinces of Oromia, Amhara, Southern Nations and Nationalities Peoples), and Tigray.

In southern nation nationality people republic of Ethiopia the total area covered by wheat in the production year of 2017/18 was 127,246.59 hectares of land, and 3,391,959.51quntal of wheat have been produced with average productivity of 26.66 quintals per hectare [6].

Wheat is grown on 7137.64 hectares annually, and the production is 19.02 quintals per hectare in the Kaffa zone, which is lower than the national production and regional production (27.36 qt/ha) and 26.66 quintals per hectare, respectively [7]. According to the 2019 report of the Adiyo District Agriculture and Development Office, about 3000 hectares of land were covered by cereal crops. From these, the area covered by wheat was 2142 hectares of land with a production of 51409 quintals and an average productivity of 24 quintals per hectare, which is below average national productivity.

The study aims to quantify overall efficiency and identify its determinant aspects by collecting cross-sectional data from wheat-producing smallholder farmers in the Adiyo district of southern Ethiopia.

## Statement of problem

The most significant factor for boosting overall food security and poverty reduction is efficiency, particularly in major food crop-producing potential areas of the country [8]. However, farmer productivity has remained poor due to inefficient production and efficiency disparities across producers [9]. Inefficiency not only limits the gains from existing resources, but it also diminishes the benefits that could result from the utilization of upgraded inputs.

With the rapid increase in population, demand for wheat output has increased, but productivity has not kept pace. As a result, the Ethiopian government devised a new extension package that prioritized wheat production due to its high demand, proven capacity to respond positively to enhanced ingredients, and likelihood of attaining quick productivity growth. However, the marketed technologies have not been employed to their full potential, and only a few advantages might be obtained by utilizing the technology [10].

In Ethiopia, the majority of research is focused on technical efficiency estimation studies. For example [11-16]. however, most past studies have focused solely on technical efficiency, underestimating the benefits that producers could get from improved overall performance. There has been little research on the economic efficiency of wheat production [17-20]. According to the findings of these studies, various factors can influence farmer efficiency, but these elements are not equally essential and identical in all places and at all times. A major component in one location at one time may not be a substantial factor in other locations or even at the same time.

Wheat productivity in the studied area is lower than regional and national averages. Furthermore, the production created by smallholder farmers is mostly used to support their livelihood and does not meet their demand. As a result, the study seeks to fill the information and knowledge gap.

## Objectives of the study

### General objective of the study

The general objective of the Study was to assess the economic efficiency of smallholder wheat producer's in Adiyo District of Kaffa Zone.

### The specific objectives were

- To measure the level of technical, allocative and economic efficiencies of smallholder wheat producers in the study area
- To identify the factors that affect technical, allocative and economic efficiency of smallholder wheat producers in the study area.

## Research question

This study tried to address the following main research questions

1. What are the levels of technical, allocative and economic efficiencies of smallholder wheat producers in the study area?
2. What are the factors that affect technical, allocative and economic efficiencies of smallholder wheat producers in the study area?

## Research Methodology

### Description of the study area

Adiyo district is found in Kaffa Zone, the Southern Nation Nationality of the People of Ethiopia. It is located 505 kilometers southwest of Addis Abeba.

The economy of the population in the study region is based on rain-fed agriculture and is characterized by a mixed farming system that includes crop production as well as livestock production. Crop production is one of the district's primary activities. Smallholder farmers utilize mostly rain farming and traditional farming systems, which dominate production. Wheat, barley, teff, and enset are some of the principal crops farmed in the area. The total population was 142931 people, with 73965 females and 68966 males [21].

### Location of Adiyo district

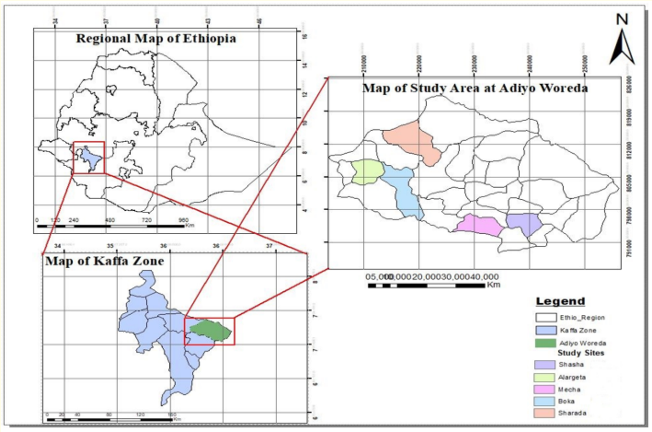


**Figure 1:** Map of the study area.

### Sampling technique and sample size determination

In this study, two-stage random sampling techniques were used to select households to draw an appropriate sample. In the first stage, five kebeles out of eighteen wheat-producing kebeles in the district were selected randomly. In the second stage, 198 sample farmers were selected using a simple random sampling technique based on a probability proportional to the number of wheat producers in each of the five selected kebeles. The sample size was determined by using the formula given by Yamane [22] as follows

$$n = \frac{N}{1+N(e)2} - - - - - 1$$

Where n = sample size

N = is number of wheat producers in the district.

e = level of precision (7%)

n = 6509 ÷ 1 + 6509(0.0049) = 198

### Type, source and method of data collection

This study incorporated both qualitative and quantitative data. Data sources included the primary and secondary sources.

Secondary data were also gathered from relevant sources such as the CSA, FAO, the district's agriculture bureau, reports of previous studies, information documented at various office levels of agricultural research institutions, and other literature.

### Method of data analysis

Both descriptive statistics and the econometric data analysis method were used. To characterize the socioeconomic, demographic, institutional, and farm characteristics of the sampled households in the study area, descriptive statistics such as mean, standard deviation, frequency, maximum, minimum, and percentage values of variables were computed. Coelli [23] employed a stochastic frontier approach to estimate the level of efficiency. Green [24] used a two-limit Tobit model to find factors influencing farmer efficiency.

| Name of sample kebeles | Numbers of wheat producing farmers | Sample size |
|---|---|---|
| Boka | 496 | 52 |
| Sherada | 374 | 39 |
| Shasha | 392 | 41 |
| Mecha | 306 | 32 |
| Alargeta | 324 | 34 |
| Total | 1892 | 198 |

**Table 1:** Sample size determination.

**Source:** Own computation.

## Specification econometric models

## Efficiency measurement

The stochastic production frontier model with Cobb-Douglas production function was used to analyze the level of technical, allocative, and economic efficiency of wheat producing farmers in the study area. The stochastic production frontier model was chosen because of its capacity to discern inefficiency from deviations caused by causes beyond farmers' control. The model includes a disturbance term that represents noise, measurement error, and external shocks that are beyond of the production unit's control, as well as a component that captures deviations from the frontier due to inefficiency [25]. created this model. The model is defined as follows

$$y_i = f(X_i.\beta) + \varepsilon_i - - - - - - - - - 2$$

Where: y_i = the ith sample farmer's output = 1, 2, 3... n Xi = vector whose values are functions of inputs and explanatory variables for the ith farmer, _i is the composed error term (V_i and U_i), and (V_i) is intended to capture the effects of stochastic noise and is assumed to be independently and identically distributed, as expressed by N (0, v2). (Ui) is a nonnegative random variable with a half-normal distribution that is assumed to account for technical inefficiency in production. n= the number of farmers who participated in the survey.

In most empirical production analysis research, the Cobb-Douglas and Translog functions have been the most commonly utilized functional forms. Each operational form each functional type has advantages and disadvantages. Some academics suggest that the Cobb-Douglas functional form is superior than the others because it allows for a comparison of adequate data fit and computational practicality. It is also useful for interpreting production elasticity and is quite conservative in terms of degrees of freedom. It is commonly utilized in studies of border production functions [26].

The Cobb-Douglas functional form has been widely employed in most empirical estimation of frontier models due to its simplicity. This simplicity, however, comes with certain limitations in that it requires constant elasticity, constant return to scale for all farms, and equal elasticity of substitution [27]. The Translog functional form, on the other hand, places no constraints on returns to scale or substitution options. However, degrees of freedom and multicollinearity are severe issues in the Translog production function [28].

Moreover, Cobb-Douglas functions were utilized in various studies of crop production efficiency, including [9,20,29,30]. As a result, Cobb-Douglas production functions were utilized in this study since the test result suggested that this functional form best fits the data.

The linear form of Cobb Douglas production function used for this study is given as follow

$$lny_i = In\beta_0 + \sum_{j=1}^{7} \beta_j \, lnx_{ij} + v_i - u_i, i = 1,2 - -n - - - - - - - - 3$$

Where ln is the natural logarithm and j is the number of inputs used. Y denotes wheat output. i = indicates the ith farmer in the sample, = denotes the vector of unknown parameters to be estimated, and v_i= takes into consideration stochastic effects beyond the farmer's control, measurement mistakes, and other statistical disturbances. u_i=represents technical inefficiency.

The variance parameters are written as 2 = v2 + u2 and = u/v, where u/v is the ratio of the non-symmetric to symmetric error term standard errors.

The generalized likelihood ratio (LR) statistic was produced to test the hypothesis that all interaction terms, including the square specification, are equal to zero (HO: ij=0) as follows

$$LR = \lambda = -2\{\mathrm{Ln}[\mathrm{L(Ho)}] - \mathrm{Ln}[\mathrm{L(H1)}] - - - - - - - - - - - - 4$$

L (H0) and L (H1) are the log-likelihood function values under the null and alternative hypotheses, respectively.

This value was then compared to the upper 5% point for the χ2 distribution, and the decision was taken based on the model's output. If the computed result of the test exceeds the critical value, the null hypothesis is rejected, and the translog frontier production function better represents farmers' production technique.

The linear functional form of Cobb Douglas production function used for this study is given by Equation

$$Ln(output) = \beta o + \beta 1 \ln(land) + \beta 2 \ln labor + \beta 3 Ln(oxen) + \beta 4 \ln(seed) + \beta 5 \ln(NPS) + \beta 6 \ln(urea) + \beta 7 \ln(chemical) + v - u - - - - - - - - - - 5$$

Where output is the amount of wheat produced (qt), land is the amount of land allocated to wheat (ha), labor is the amount of labor used (MD), seed is the amount of seed used (kg), NPS is the amount of NPS used (kg), urea is the amount of urea used (Kg), oxen is the number of oxen (OD), and chemical is the amount of chemical used for wheat production (Litter). (V) is designed to capture the effects of stochastic noise and is believed to be independently and identically distributed, as denoted by N (0, v2). (Ui) is a nonnegative random variable with a half-normal distribution that is assumed to account for technical inefficiency in production.

Assuming that the production function in equation (5) is the dual cost frontier was computed as:

$$lnCi = \alpha 0 + \alpha 1 lnW1 + \alpha 2 lnW2 + \alpha 3 lnW3 + \alpha 4 lnW4 + \alpha 5 lnW5 + \alpha 6 lnW6 + \alpha 7 lnW7 + \alpha 8 lnYi * ---6$$

Where cost of wheat production on for the ith farmer,1 is cost of land for wheat production.

W2 cost of labor, W3, cost of oxen power, W4 cost of seed, W5 cost of NPS W6 cost of urea

W7 cost of chemicals for wheat production in study area.

Y*=wheat output are parameters to be estimated

[31] suggests that the corresponding parameter of the dual cost frontier can be derived algebraically and written in a general form as:

$$Ci = C(WI, Y*, \alpha ---------------------7$$

Where Ci is the least cost of production; Wi denotes a vector of input prices for the ith firm; Yi* denotes farm output adjusted for noise vi; and is a vector of parameters to be determined from the primal function.

The least cost is calculated analytically from the production function, following (32)'s methodology. The effective cost function for a given input-oriented function can be stated as

$$Min \sum_{x} C = \sum_{j=1}^{7} X_J W_J ----------------------8$$

Subject to $Y_i^* = \hat{A} \prod X_i^{\hat{B}_j}$

Wher $\hat{A} = \exp(\hat{B}_0)$

$\omega_J$=input prices

$\hat{B}_o$ = Parameter estimates of the stochastic production function and

$Y_i^*$=input oriented adjusted output level

The following dual cost function is found by substituting the cost minimizing input quantities into equation 3.2.

$$C(Y_k^{i^*}, w) = HY_k^{i^*\mu} \Pi_n w_n^{\alpha_n} ----------------10$$

$$\alpha_n = \mu \hat{B}_n, \mu = (\sum_n \hat{B}_{n)})^{-1}, H = \frac{1}{\mu}(\hat{A} \Pi_n \hat{B}_{n)}^{\beta_{n-\mu}} ------------11$$

EE for the i[th] farmer is derived by applying Shepard's Lemma and substituting the firms input price and adjusted output level into the resulting system of input demand equations.

$$\frac{\alpha C_i}{\alpha \omega_n} = X_i^e(\omega_i Y_i^{i^*}; \alpha) ------------------12$$

Where: Θ is the vector of parameters and n = 1, 2, 3..., N inputs. The observed, technically and economically efficient costs of production of the i[th] farm are then equal to, and; respectively.

Farm-specific technical efficiency in terms of observed output (Yi) to the corresponding frontier output (Y*) using the existing technology

$$TEi = \frac{Yi}{Y*} = \frac{\exp(Xi\beta + v_{\mu i}}{\exp(\chi i\beta + v} ----------- 13$$

The farm specific economic efficiency is defined as the ratio of minimum total production cost (C*) to actual observed total production cost (C).

$$EEi = \frac{C*}{C} -----------------14$$

Following Farrell (1957), the AE index will be derived from equations (3.12) and (3.13) as follows:

$$AEi = \frac{EEi}{TEi} -------------------- 3.15$$

## Determinants of efficiency

A two-stage technique was used to study the effects of demographic, socioeconomic, farm characteristics, and institutional variables on technical, allocative, and economic efficiencies, and the efficiency scores were regressed on selected explanatory variables. On the other hand, the efficiency scores derived from the stochastic production frontier were regressed on hypothesized explanatory variables using a two-limit Tobit model. Because of the structure of the dependent variable (efficiency scores), which accepts values between 0 and 1 and yields consistent estimates for unknown parameter vectors [33], this model is best suited for this study. The regression coefficients of the two-limit Tobit regression model cannot be understood in the same way as standard regression coefficients do because they do not reflect the magnitude of the marginal effects of changes in the explanatory variables on the predicted value of the dependent variable.

Each marginal impact in a Tobit model contains both the influence of explanatory variables on the probability of the dependent variable falling in the unfiltered portion of the distribution and the expected value of the dependent variable conditional on it being greater than the lower bound. Thus, the total marginal effect accounts for the fact that a change in the explanatory variable will have a simultaneous influence on the probability of being technically, allocatively, and economically efficient, as well as the value of the technical, allocative, and economic efficiency scores [34]. Proposed a helpful marginal impact decomposition. Gould., *et al.* [39]

demonstrated the equations of three marginal effects based on the

$$\frac{\partial E(y)}{\partial x_j} = [\varphi(Z_U) - \varphi(Z_L)].\frac{\partial E(y^*)}{\partial x_j} + \frac{\partial[\varphi(Z_U - \varphi(Z_L)]}{\partial x_j} + \frac{\partial(1-\varphi(Z_U)}{\partial x_j} - - - - - (3.19)$$

likelihood function of this model indicated in equation (3.18).

$$\frac{\partial E(y^*)}{\partial x_j} = \beta_n.\left[1 + \frac{\{Z_L\phi(Z_L) - Z_U\phi(Z_U)\}}{\{(\varphi(Z_U) - \varphi(Z_L))\}}\right] - \left[\frac{\{\phi(Z_L) - \phi(Z_U)\}^2}{\{\varphi(Z_U) - \varphi(Z_L)\}^2}\right] - - - - - - (3.20)$$

upon being between the limits

$$\frac{\partial[(\varphi(Z_U) - \varphi(Z_L)]}{\partial x_j} = \frac{\beta_n}{\sigma}.\left[\phi(Z_L) - \phi(Z_U)\right] - - - - - - - - - - - (3.21)$$

3) The probability of being between the limits

Where $\varphi(.) =$ the cumulative normal distribution, $\phi(.) =$ normal density function, $Z_L = -\beta' X/\sigma$ and $Z_U = (1 - \beta X/\sigma$ are standardized variables that came from the likelihood function given the limits of , andstandard deviation of the model.

## Results and Discussion

### Descriptive statistics results

### Inputs used for wheat production

Farmers received 24.36 quintals of wheat on average, which is the dependent variable in the production function. During the study period, the amount of land dedicated for wheat production by the sampled farmers ranged from 0.125 to 4.5ha, with an average of 1.04 ha. Human labor and oxen power, like other inputs, were crucial. The average amount of seed utilized by the studied households was 84.34 kg. During the production season, sampled families employed an average of 27.76-man equivalent hours and 30.13 oxen days to produce wheat. Farmers in the study area also employed inorganic fertilizers such as NPS and UREA for wheat cultivation. Farmers utilized 77.71 kilograms for wheat production and 71.48 kg of UREA. During the production year, about 0.71 liters of chemicals (herbicides) were utilized for wheat production (Table 2).

| Variable | Units | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Output | Quintal | 24.36 | 10.42 | 6 | 43 |
| Land | Hectare | 1.04 | 0.79 | 0.125 | 4.5 |
| Labor | Man-day | 27.76 | 9.27 | 8.1 | 72 |
| Oxen power | Oxen –day | 30.13 | 22.73 | 4 | 144 |
| Seed | Kilogram | 84.34 | 48.57 | 12.5 | 350 |
| NPS | Kilogram | 77.71 | 34.18 | 12.5 | 200 |
| UREA | Kilogram | 71.48 | 33.07 | 1 | 150 |
| Chemical | Litter | 0.71 | 0.33 | 0.125 | 1.5 |

**Table 2:** Summary statistics of variables used to estimate the production function.

**Source:** own computation (2020).

Similar to the production function, the mean and standard deviation of each of the variables used in the cost function are depicted as follows

The average cost of producing a quintal of 24.36 kilos of wheat was 33386.11 birr. Among the numerous production factors, the cost of land accounted for the greatest part (3100.25 birr). Following the cost of land, the cost of oxen power accounts for the majority of the overall cost of production, which is 2268.99 Birr, with the cost of labor and seed accounting for 1665.04 and 1372.89 Birr, respectively, for sampled households in the study region. Inorganic fertilizers (NPS and UREA) account for 1185.52 and 1095.97 birr on average. Among other inputs, chemicals cost the least (281.59 Birr) of the total cost of wheat production.

### Results of econometric analysis

### Hypotheses test

Before determining the model parameters from which individual-level efficiencies are projected, alternative model definition assumptions must be considered. This study looked into three possibilities. As a result, the functional form that best fits the data was chosen by testing the null hypothesis (H0: ij = 0), which states that the coefficients of all interaction terms and square specifications in the Translog functional forms are equal to zero, against the alternative hypothesis (H1: ij 0), which claims that under the Translog functional forms, the coefficients of all interaction terms

| Variable | Units | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Output | Quintal | 24.36 | 10.42 | 6 | 43 |
| Cost of output | Birr | 33386.11 | 14916.46 | 7800 | 64500 |
| Cos of land | Birr | 3100.25 | 1397.10 | 800 | 6750 |
| Cost of labor | Birr | 1665.04 | 578.53 | 486 | 3234 |
| Cost of oxen power | Birr | 2268.99 | 1022.57 | 360 | 4580 |
| cost of seed | Birr | 1372.89 | 599.18 | 222 | 2663 |
| Cost of NPS | Birr | 1185.52 | 515.59 | 192 | 2295 |
| Cost of UREA | Birr | 1095.97 | 495.24 | 183 | 2190 |
| Cost of chemical | Birr | 281.59 | 122.23 | 46 | 545 |

**Table 3:** Summary statistics of variables used to estimate the cost function.

**Source:** own computation (2020).

and square specifications are not zero. The likelihood ratio (LR) statistics were used in this test, and they could be calculated using equation (4.1), applying the log likelihood values of both the Cobb-Douglas and Translog functional forms.

$$LR = \lambda = -2\{\mathrm{Ln}[\mathrm{L(Ho)}] - \mathrm{Ln}[\mathrm{L(H1)}] \ldots\ldots\ldots\ldots..3.1$$

The log-likelihood function values for the null and alternative hypotheses are denoted by L (H0) and L (H1). This computed value is then compared to the upper 5% critical value of the 2 at the degree of freedom equal to the difference in the number of explanatory variables used in both functional forms (the number of interaction terms and square specifications restricted to zero in the Cobb-Douglas functional form, in this case degree of freedom =28). As a result, the log probability functional values of the Cobb-Douglas and Translog production functions were -95.535 and -78.060, respectively. The calculated value was 34.95, which was less than the top 5% critical value of 2 at 28 degrees of freedom, which is 41.34 (Table 4).

| Null hypothesis | Df | | Critical value (χ2, 0.95) | Decision |
|---|---|---|---|---|
| H0: = $\beta_{ij}$ = 0 | 28 | 34.95 | 41.34 | Accept *Ho* |
| H0: γ=0 | 1 | 11.23 | 3.84 | Reject *Ho* |
| H0: = = ... =0 | 13 | 66.52 | 22.36 | Reject *Ho* |

**Table 4:** Generalized Likelihood Ratio test of hypotheses for parameters of SPF.

**Source:** own computation (2020).

This indicates that the coefficients of the interaction terms and the square specifications of the production variables are not different from zero under the Translog specifications. As a result, the null hypothesis was accepted, and the Cobb-Douglas functional form was found to be the best fit for the data.

The second test was to see if the inefficiency component of the stochastic production function's total error term existed. It is used to test the null hypothesis, which states that the inefficiency component of the error term is equal to zero (=0), and the alternative hypothesis, which states that the inefficiency component of the error term is not equal to zero ( 0).Thus, the likelihood ratio is computed and compared to the 2 value at a degree of freedom equal to the number of limitations (the inefficiency component) estimated by the complete Frontier, which in this case is 1 for all models. As shown in table 5, a one-sided generalized test of = 0 yields a statistic of 11.23, which is much greater than the critical value of 2 for the upper 5% of students at one degree of freedom. Rejecting the null hypothesis suggests that the OLS-estimated average response function, which assumes that farmers are fully efficient and that inefficiency effects are absent from the model, is an inadequate representation of the data.

The third hypothesis was tested against the alternative hypothesis, which stated that all parameter coefficients of the inefficiency effect model are not simultaneously equal to zero (H0: = _1 = _2... = _13=0). The null hypothesis states that the explanatory factors in the inefficiency effect model do not contribute significantly to explaining the difference in efficiency for wheat producing farmers. It was also tested in the same way, by calculating the value using the log likelihood function value under the stochastic frontier model (without explanatory variables for inefficiency effects, H0) and the full frontier model (with variables that are supposed to determine each farmer's efficiency level, Hi).Using the equation in Equation (4), the achieved value was 66.52, which is greater than the crucial X2value (22.36) at the degree of freedom equal to the number of limitations to be zero (in this case, the number of inefficiency impact model coefficients was 13). As a result, the null hypothesis is rejected in favor of the alternative hypothesis, which states that explanatory variables associated with the inefficiency effect model are not equal to zero at the same time. As a result, these variables explain the difference in efficiency among the sampled farmers at the same time.

## Estimation of production and cost functions

The model's results revealed that, with the exception of land and urea, the other input variables in the production function-NPS, oxy-power, labor, seed, and chemical-had a positive and substantial effect on the level of wheat output. The MLE values of the coefficients might be read as production elasticity. As a result, the high output elasticity to oxen (0.565) indicates that wheat production was relatively sensitive to oxen. Keeping all parameters unchanged, a 1% increase in the number of oxen (OD) resulted in a 0.565% increase in wheat yield. The findings are congruent with those of [36,37].

Labor was also the second most important factor in influencing the output level of wheat production in this study area, after oxen power. The labor coefficient has the expected value and is statistically significant at 1%. This means that if labor costs increase by 1%, wheat output increases by 0.219% while all other factors stay constant. The findings were similar to those of Kusse., *et al*. influencing the output level of wheat production in this study area, after oxen power. The labor coefficient has the expected value and is statistically significant at 1%. This means that if labor costs increase by 1%, wheat output increases by 0.219% while all other factors stay constant. The findings were similar to those of [15].

NPS is another major mineral fertilizer with a good positive effect on wheat yield and significance at the 1% level. The NPS coefficient was 0.160, implying that a 1% increase in NPS usage would boost wheat yield by 0.160% if all other factors remained unchanged. The findings were similar to those of [12,13]. Chemical: It is generally considered essential for farmers to produce safe, quality wheat seed at an affordable price and is also used to control weeds. The coefficient for chemicals was positive and significant at the 1% significance level. This implies that a 1% increase in the usage of chemicals would result in an increase in the output of wheat by 0.175%, keeping other factors constant. This result is consistent with the findings of [30].

Seeds are another essential input for wheat production in the research area. For production, farmers use both local and developed wheat varieties. Instead of using improved seed, the farmer prefers to use local seed. The seed coefficient of 0.056 stated that increasing the amount of seed by 1% increased the wheat yield by 0.056% while keeping all other factors unchanged. This finding is consistent with the empirical findings of [38].

| Variable | | Coefficient MLE | | |
|---|---|---|---|---|
| **Variables** | **Parameters** | **Coefficient** | **Std. Err.** | **P > z** |
| Constant | | 5.329*** | 0.297 | 0.000 |
| Lnland | | -0.014 | 0.043 | 0.743 |
| Lnlabor | | 0.219*** | 0.076 | 0.004 |
| Lnoxen | | 0.565*** | 0.098 | 0.000 |
| Lnseed | | 0.056** | 0.023 | 0.014 |
| lnNPS | | 0.160*** | 0.060 | 0.008 |
| LNUREA | | 0.035 | 0.025 | 0.170 |
| Lnchemical | | 0.175*** | 0.055 | 0.001 |
| Lambda | | 1.723*** | 0.085 | |
| Gamma (γ) | | 0.748 | | |
| Log likelihood | | -95.535 | | . |
| Return to scale | | 1.224 | . | |

**Table 5:** Estimates of the Cobb Douglas frontier production function.

**Note:** ***and **. refers to 1%and 5%. Significance level respectively.

**Source:** model output (2020).

The returns to scale analysis can serve as a measure of total factor productivity (Gbigbi, 2011). The coefficient was calculated to be 1.224, indicating increasing returns to scale (Table 6). This implies that there is potential for wheat producers to continue to expand their production because they are in stage I of the production area, where resource use and production are believed to be inefficient. In other words, a one percent increase in all inputs will proportionally increase the total production by 1.224%. Therefore, an increase in all inputs by 1% would increase wheat output by more than 1%. This result is consistent with [9,12,20]. *Who* estimated the returns to scale of 1.266, 1.214, and 1.38 in the study of economic and technical efficiency of smallholder farmers in the production of maize and wheat in Bako, Abuna Bindebert, and Sorodistrict, Hadiya Zone, Ethiopia, respectively. But contradicting the study by Tefaye_and Beshir (2014) on determinants of technical efficiency in maize production in Dhidhessa district of Illumabora zone, Ethiopia, found the return to scale 0.956, which falls on stage two.

The diagnostic statistics of the inefficiency component reveal that sigma squared ($\sigma^2$) was statistically significant which indicates goodness of fit and the correctness of the distributional form assumed for the composite error term. The ratio of the standard error of u ($\sigma u$) to the standard error of v ($\sigma v$) known as lambda ($\lambda$) was1.723. Based on $\lambda$, gamma the gamma ($\gamma$) which measures the effect of technical inefficiency in the variation of observed output which can be derived (i. e. $\gamma = \lambda 2/[1+\lambda 2]$). The estimated value of gamma was 0.748 which indicated that 74.8% of total variation in wheat farm output was due to technical inefficiency.

The dual frontier cost function derived analytically from the stochastic production frontier is given by:

$$lnCi = 0.616 + 0.126lnwland + 0.224lnwlabor + 0.269lnwoxenp + 0.016lnwseed + 0.001lnwNPS + 0.061lnwUREA + 0.126lnwchemical + 0.431lnY* --------- 3.1$$

Where C is the minimum cost of production of the $i^{th}$ farmer, Y* refers to the index of Output adjusted for any statistical noise and scale effects and ω stands for input cost.

## Efficiency scores of sampled households

According to the model output in table 7, the mean values of technical, allocative, and economic efficiencies of the sample household were around 71.6, 73.5, and 52.6%, respectively. This illustrates that the sample household performed better in allocative efficiency than in technical and economic efficiency. This indicates that the farmers in the research area were cost-effective.

| Types of efficiency | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|
| TE | 0.716 | 0.125 | 0.183 | 0.948 |
| AE | 0.735 | 0.116 | 0.307 | 0.926 |
| EE | 0.526. | 0.112 | 0.083 | 0.874 |

**Table 6:** Estimated technical, allocative and economic efficiency scores.

**Source:** Model output (2020).

The sample household's average technical efficiency was 71.6%. Farmers could reduce inputs (land, oxen, labor, NPS, UREA, chemicals, and seed) by 28.4% if they were technically efficient at producing the existing level of output. In other words, if resources were used more efficiently, the ordinary farmer could improve current output by 28.4% by utilizing present resources and technology. If the average farmer in the sample achieved the most efficient counterpart's level of technological efficiencies, the average farmer could save 24.4% [1-(0.716/0.948) *100] on inputs used to produce the most efficient counterpart's output. Similarly, if the least technically efficient farmer were to achieve the technical efficiency level of his or her most efficient counterpart, the least technically efficient farmer would reduce 80.6% [1-(0.183/0.948)*100] on inputs used to produce the most efficient counterpart's output. The estimated technical efficiency is similar to the findings of [39-41] but higher when compared to [14].

The sampled household's mean allocative efficiency was 73.5% (Table 7). The results show that if sample homes in the study area used the proper inputs and produced the right output relative to input prices and output prices, wheat output could increase by 26.5% on average. To achieve the level of the most efficient farmer, a farmer with an average level of allocative efficiency would save around 20.62% derived from (1 - 0.735/0.926). *100. The most allocatively inefficient farmer would gain 66.84% in efficiency from (1-0.307/0.925). *100. The findings are consistent with those of [8]. On the economic efficiency of smallholder farmers in maize production in Oromia national regional state, but they are greater than those of Solomon (2012) on the economic efficiency of wheat seed production in Amara region.

The sample household's mean economic efficiency was 52.6%, indicating a considerable level of inefficiency in the production process. That is, a producer with an average level of economic efficiency might lower current average production costs by 47.4% in order to achieve the possible minimal cost level without reducing output levels. It may be deduced that if farmers were to attain 100% economic efficiency, they would save 47.4% on output costs. This suggests that lowering the cost of production by removing inefficient resource use might add 47.4% to their annual income.

It additionally indicated that a farmer with an average level of economic efficiency would save around 40.38% by [1 (0.52.6/0.874) *100] to achieve the level of the most efficient farmer. To reach the level of the most efficient farmer, the most economically inefficient farmer would need to increase his efficiency by 90.5% [1-(0.083/0.874) *100]. These cost savings can also be understood as equivalent potential output gains for given input utilization in manufacturing by employing best-practice production technology. The estimations of economic efficiency were low in comparison to the results obtained by Meftu (2016) but relatively higher than the results obtained by [42]. In the study area, there was room to boost farm household productivity and economic benefits by increasing all efficiencies.

The distribution of TE scores revealed that the majority (32.8%) of the sample households had TE values ranging from 70% to 79% (Figure 2). 29.9% of the studied households had a technical efficiency score of 80%-89%. Only 1% of the households in the study scored above 90% in terms of technical efficiency. This suggests that almost 99% of households (Figure 2) can boost their output by at least 10%. Furthermore, the distribution AE scores revealed that the majority (38.8%) of examined households had discovered 70%-79%. Households in this group can save at least 20% of their current input costs by acting in a cost-effective manner. Only 27.27% of the study families had an AE score between 80 and 89.99%. According to the distribution of economic efficiency scores, 39.9% of household heads have an economic efficiency score of 50–59%. The low average level of EE was the total effect of both technical and allocative inefficiencies, indicating the presence of significant economic inefficiency in wheat production during the study period in the study area.

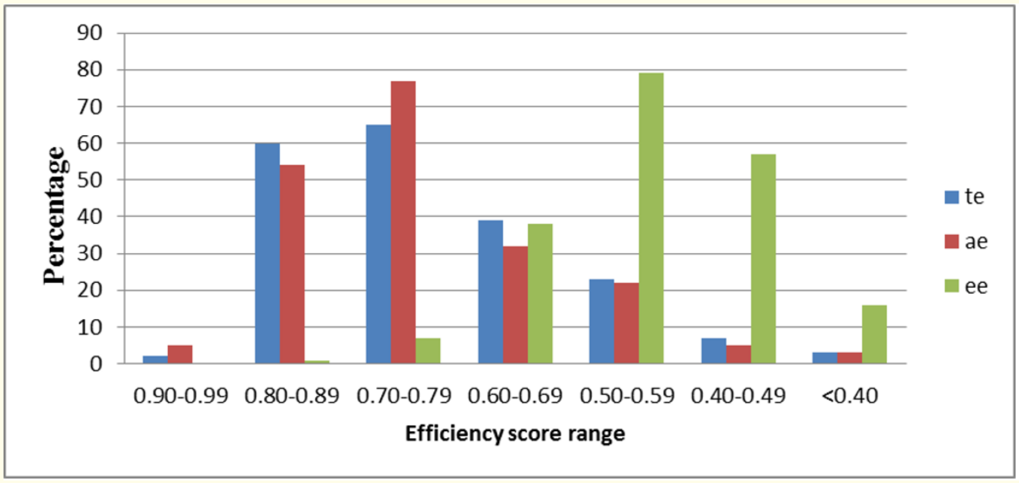


**Figure 2:** Frequency distribution of technical, allocative and economic efficiencies scores.

## Determinants of technical allocative and economic efficiency of wheat in production

After determining the presence of efficiency disparities among farmers and evaluating the level of technical, allocative, and economic efficiency, the next most significant goal of this study was to identify the mechanisms generating efficiency differentials among farmers. To demonstrate this, using a two-limit Tobit model, the technical, allocative, and economic efficiency levels produced from the stochastic frontier were regressed on factors believed to affect efficiency levels. The dependent variable in this study is efficiency scores. As a result, the marginal effect should be regarded as their effect on efficiency, and if inefficiency is to be used, the sign of the marginal effect must be changed.

According to the Tobit regression model results, membership in a cooperative and participation in non-farm income have a positive and significant impact on technical and economic efficiency, although distances to the nearest market have a negative impact on technical efficiency. Access to credit has a favorable and considerable impact on technical, allocative, and economic efficiency. Both allocative and economic efficiency are positively and significantly affected by the sex of the household head, the educational level of the household, and extension contact. Farm land sloping and land fragmentation have a negative impact on the allocative efficiency of wheat production in the studied area.

| Variable | TE | | | AE | | | EE | | |
|---|---|---|---|---|---|---|---|---|---|
| | Coefficient | Std. Err. | P>t | Coefficient | Std. Err. | P>t | Coefficient | Std. Err. | P>t |
| Constant | 0.6204*** | 0.0644 | 0.000 | 0.5194*** | 0.0520 | 0.000 | 0.3166*** | 0.0432 | 0.000 |
| AGHH | 0.0001 | 0.0009 | 0.958 | 0.0009 | 0.0007 | 0.180 | 0.0007 | 0.0006 | 0.246 |
| SEXHH | 0.0167 | 0.0245 | 0.495 | 0.08921*** | 0.0198 | 0.000 | 0.0485*** | 0.0164 | 0.004 |
| FASIZE | -0.0060 | 0.0039 | 0.127 | 0.0018 | 0.0032 | 0.569 | -0.0027 | 0.0026 | 0.302 |
| EDULHH | 0.0017 | 0.0026 | 0.497 | 0.0064*** | 0.0021 | 0.002 | 0.0039** | 0.0017 | 0.026 |
| ACREDIT | 0.0625*** | 0.0206 | 0.003 | 0.0331** | 0.0166 | 0.049 | 0.0827*** | 0.0138 | 0.000 |
| TLU | 0.0003 | 0.0019 | 0.885 | -0.0002 | 0.0015 | 0.913 | 0.0005 | 0.0013 | 0.672 |
| FEXC | 0.0013 | 0.0032 | 0.685 | 0.0104*** | 0.0026 | 0.000 | 0.0062*** | 0.0022 | 0.005 |
| MCOOP | 0.0650** | 0.0253 | 0.011 | 0.0135 | 0.0204 | 0.511 | 0.0360** | 0.0170 | 0.036 |
| PNFIA | 0.05271*** | 0.0186 | 0.005 | 0.0231 | 0.0151 | 0.127 | 0.0217* | 0.0125 | 0.084 |
| LNDFRAG | 0.0029 | 0.0073 | 0.684 | -0.0144** | 0.0059 | 0.016 | -0.0052 | 0.0049 | 0.298 |
| DSNM | -0.0017*** | 0.00061 | 0.006 | -0.0007 | 0.0005 | 0.145 | -0.0005 | 0.0004 | 0.193 |
| CLAND | 0.0079 | 0.0111 | 0.474 | -0.0005 | 0.0090 | 0.955 | 0.0075 | 0.00747 | 0.313 |
| SLOP | 0.0165 | 0.0151 | 0.277 | -0.0226* | 0.0122 | 0.066 | -0.0025 | 0.0101 | 0.804 |

**Table 7:** Determinates of technical, allocative and economic efficiency of wheat production among sampled household.

**Note:** ***, **and * significant at 1%, 5% and 10% level of significance, respectively.

**Source:** Model results.

## Sex of household head

Sex of household head: At a 1% level of significance, sex had a favorable and significant impact on economic and allocative efficiency. Male household heads were shown to be more effective than female household heads, according to the study's findings. The majority of family activities were carried out outside, particularly on farmland, by male households. These households had more regular follow-up with and supervision of their farms, and they might have completed the farming tasks more quickly than female farmers. Additionally, changing the value of the dummy variable sex from 0 to 1 would result in an overall increase in the probability and level of allocative efficiency for farmers of about 1.463% and 0.003%, as well as an increase in the expected value of allocative and economic efficiency of about 0.8613% and 0.4858%, respectively, and have a positive and substantial impact on both. In contrast to the findings of (29), a similar outcome was observed in the work of [20].

## Education of household heads

At a 1% and 5% significance level, respectively, education had a positive and significant impact on both AE and EE. Education improves farmers' ability to find and use knowledge about new technology. According to the findings, farmers who had completed more years of formal education were more productive than their counterparts. The relevance of education in raising wheat production efficiency is supported by its strong impact on AE and EE. In other words, households with higher levels of education are better able to allocate resources efficiently. Additionally, the computed marginal effect showed that the chance of a farmer being allocative and economically efficient increased by 0.0218% and 0.0001%, holding other variables constant, and the mean value of allocative and economic efficiency by about 0.0596% and 0.0388%, with overall increases in probability and level of allocative and economic efficiency of 0.0632% and 0.0388%, respectively. The outcome is consistent with the claims made by [16,30,41].

### Access to credit

At 1% and 10%, respectively, the coefficient of access credit had a significant and positive impact on the technical and economic efficiency of wheat producers as well as their ability to allocate resources. This implies that credit availability has a higher influence on technical and economic efficiency than on allocative efficiency. According to this, having access to financing enables farmers to promptly buy inputs that they otherwise would not be able to afford. Farmers that had access to credit were more productive in terms of technology, allocation, and economy. Additionally, a change in the dummy variable representing the household's credit consumption ordered from 0 to 1 would increase the likelihood that the farmers are technically, allocatively, and economically efficient by about 0.1527%, 0.0959%, and 0.0001%, respectively; improve the expected value of TE, AE, and EE by approximately 0.5877%, 0.3115, and 0.8278%; and change the probability of the farmers being technically, allocatively, and economically efficient by around 0.06189, 0.3277%, and 0.8278%, respectively, while maintaining other variables constant. This finding is in line with those of [3,8,16,37], who draw the conclusion that access to credit boosts productivity.

### Frequency of extension contact

has a statistically significant and positive link with allocative and economic efficiency (1%). Farmers who received more frequent extension contact were more allocative and economically efficient than their counterparts. A positive effect of this variable suggested that farmers who received more extension may enhance their resource allocation by facilitating the practical use of current technology, the adoption of improved agricultural production practices, and the appropriate use of inputs. Furthermore, the computed marginal effect result showed that a unit increase in the number of extension contacts increased the chance of farmers being allocative and economic efficient by 0.0355% and 0.0001%, respectively, and that the mean value of allocative and economic efficiency increased by 0.0355% and 0.0001% and the mean value of allocative and economic efficiency by 0.0971% and 0.0617%, respectively, with an overall rise in the probability and level of allocative and economic efficiency of 0.1029% and 0.0617%; cetriparibus. This result is consistent with those of [19,44,45]. Membership in cooperatives had a favorable and substantial influence on the coefficients of technical and economic efficiency of wheat production at the 5% significant level. This study reveals that the cooperatives' knowledge effect dominated the time loss effect in the wheat production process. That is, farmers who were cooperative members received more viable knowledge on productivity technology than their peers. This could assist the farmer in increasing his or her productivity. Furthermore, a unit increase in the dummy variable representing member and non-member cooperatives ordered from 1 to 0 would result in an increase in the probability of farmers falling into the TE and EE categories of 0.1309% and 0.0049%, respectively, as well as an increase in the expected value of TE and EE of about 0.6172% and 0.3601%, with a 0.6451% rise in the chance and a 0.3601% increase in the level of TE and EE, respectively. The result is consistent with the work of [14,46].

### Distance to nearest market

As planned, it had a negative and significant effect on technical efficiency at the 1% significance level. Furthermore, the marginal effect reveals that increasing the distance to the market by one minute reduces the probability of falling under TE by approximately 0.0054% and the expected value by approximately 0.0165%, with an overall decrease in probability and degree of TE of approximately 0.0175%, respectively. It implies that because farmers are located far from markets, their efficiency decreases because it costs more to transport inputs and outputs, incur transaction costs, and obtain market information. This could be because farmers are located far from markets, so they have limited access to input and output markets as well as market information, and the longer distance from markets discourages farmers from participating in market-oriented production. A similar conclusion was observed in the work of [40,42].

Land fragmentation has a detrimental impact on allocative efficiency at the 5% level of significance. Furthermore, when the farmer's number of plots grows, managing those plots may become problematic. According to the computed marginal effect, a unit increase in the number of plots would reduce the probability of a farmer being allocatively efficient by 0.049% and the mean value of allocative efficiency by about 0.1353%, for an overall decrease in the probability and level of allocative efficiency of 0.1434%. This result is consistent with the findings of [11,39].

### Summary, Conclusion and Recommendations

## Conclusion

According to the study's findings, wheat growers in the study area are not functioning at full technical, allocative, and economic efficiency. This means that there is significant space to improve the technical, allocative, and economic efficiency of wheat growers in the study area. Among the offered production functions, five factors such as oxen power, labor, NPS, seed, and chemicals have a significant and beneficial impact on wheat production in the study area. Among these five key inputs, oxen power, labor, NPS, and chemical

| Variable | Marginal effect of TE | | | Marginal effect of AE | | | Marginal effect of EE | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
| AGHH | 0 .00005 | 0.00004 | 0.00001 | 0.00097 | 0.0009136 | 0.00033 | 0.00070 | 0.00070 | 0.00000 |
| SEXHH* | 0 .01657 | 0.01566 | 0.00447 | 0.08877 | 0.08613 | 0.01463 | 0.04858 | 0.04858 | 0.00003 |
| FASIZE | -0.00597 | -0.00561 | -0.00184 | 0.00179 | 0.00169 | 0.00062 | -0.00274 | -0.00274 | -0.00000 |
| EDULHH | 0.00173 | 0.00162 | 0.00053 | 0.00632 | 0.00596 | 0.00218 | 0.00388 | 0.00388 | 0.00000 |
| ACREDIT* | 0.06189 | 0.05877 | 0.01527 | 0.03277 | 0.03115 | 0.00959 | 0.08278 | 0.08278 | 0.00001 |
| TLU | 0 .00028 | 0.00026 | 0.00008 | -0.00017 | -0.00016 | -0.00059 | 0.00055 | 0.00055 | 0.00000 |
| FEXC | 0.00131 | 0.00122 | 0.00040 | 0.01029 | 0.00971 | 0.00355 | 0.00617 | 0.00617 | 0.00001 |
| MCOOP* | 0.06451 | 0.06172 | 0.01309 | 0.01335 | 0.01266 | 0.00407 | 0.03601 | 0.03601 | 0.00049 |
| PNFIA* | 0.05224 | 0.04962 | 0.01268 | 0.02283 | 0.02136 | 0.00931 | 0.02178 | 0.02178 | 0.00002 |
| LNDFRAG | 0.00296 | 0.00277 | 0.00091 | -0.01434 | -0.01353 | -0.0049 | -0.00515 | -0.00515 | -0.00001 |
| DfNM | -0.00175 | -0.00165 | -0.00054 | -0.00075 | -0.00071 | -0.00025 | -0.00056 | -0.00056 | -0.00001 |
| CLAND | 0 .00789 | 0.00741 | 0.00244 | -0.00050 | -0.00047 | -0.00017 | 0.00756 | 0.00756 | 0.00001 |
| SLOP* | 0 .01627 | 0.01531 | 0.00486 | -0.02235 | -0.02101 | -0.00832 | -0.00253 | -0.00253 | -0.00004 |

**Table 8:** The marginal effects of change in explanatory variables.

**Note:** (Total change), (Expected change) and (change in probability).

**Source:** model result.

inputs under wheat production have considerably and favorably affected wheat productivity at the 1% significance level. This suggests that farmers with a large number of oxen, more work, and who use the suggested rate of NPS and pesticides receive higher wheat production. Seed has a favorable effect on wheat productivity and is significant at the 5% level. The coefficient of these inputs indicates that it gauges the elasticity of output. The coefficient of parameters (input variable) was estimated at 1.224, implying a growing return to scale. This means that a 1% increase in all inputs increases total output by 1.224%. As a result, a 1% increase in all inputs increases the wheat yield by more than 1%.

In order to boost wheat production, the Tobit two-limit model was utilized to discover factors that affect the efficiency of wheat farmers in the research region. Non-farm income participation has a good and considerable impact on technical efficiency. This suggests that households engaged in other farm activities were more technically efficient than counting components. Cooperative membership and participation with no or off-farm income have a favorable and significant impact on technical and economic efficiency. Thus, households that were cooperative members and participated in varied agricultural revenue were more technically and economically efficient than peers. The distance to the nearest market had a detrimental impact on technical efficiency. This suggests that households near the market were more technologically efficient than others. Allocative efficiency is favorably and significantly affected by the sex of the household head, the educational level of the household head, access to finance, and the frequency of extension contact. This suggests that households with a male sex, access to financing, and frequent visits by extension agents were more allocative and economically efficient than their counterparts.

## Recommendations

- Education has a strong and favorable impact on allocative and economic efficiency. As a result, the primary policy consequence is that adequate and effective basic educational options for farmers in the research area may be developed.
- Access to credit has a favorable impact on technical, allocative, and economic efficiencies. As a result, policymakers and the government should focus on establishing and encouraging rural microfinance, rural saving, credit, and agricultural cooperatives. It also raises awareness among farmers about the importance of improving their saving habits in order to increase asset building.
- Membership in cooperatives has a favorable and considerable impact on technical and economic efficiency. Furthermore, farmers must actively participate by providing leadership, particularly to marginalized individuals, including women, to assist member farmers in increasing their resource efficiency. As a result, district cooperative offices recruit, strengthen, and organize non-member farmers to join cooperatives, and coop-

eratives should have defined production and market-oriented purposes.

- Extension contact has a considerable and positive impact on both allocative and economic efficiency. Policies and strategies should place a greater emphasis on strengthening existing agricultural extension service provision by providing incentives and upgrading educational levels, as well as designing appropriate capacity-building programs to train additional development agents and refresh those development agents.
- The distance to the nearest market has a negative and considerable impact on technical efficiency. As a result, the government and other stakeholders could improve the efficiency of smallholder farmers by developing road and market infrastructure that reduces the distance to the nearest market, allowing farmers to easily obtain inputs, and improving communication channels to achieve a higher level of technical efficiency.

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