Economic Efficiency of Cow Milk Production in West Hararghe Zone, Oromia National Regional State, Ethiopia

Azeb Lemma*

***Mengistu Ketema, Jemma Haji, & Abule Mehare School of Agricultural Economics and Agribusiness, Haramaya University, Ethiopia

***Corresponding Author:** - Azeb Lemma
*Email: azeblemma13@gmail.com

Abstract
Livestock play great roles in developing countries, especially to improve and augment livelihood of the poor in the rural setup. In Ethiopia's, milk has a significant social and economic role since it provides food and a source of income for dairy farmers. Understanding the production efficiency outcomes would be a significant step toward improving food securities conditions, while ensuring sustainable and increased agricultural production. Therefore, this study examines economic efficiency of cow milk producers' using a cross-sectional data obtained from 385 randomly selected sampled households from West Hararghe Zone, Oromia National Regional State of Ethiopia. The data were analyzed using descriptive statistics and econometric models. The Stochastic frontier model result revealed that the mean technical, allocative and economic efficiency scores were found to be 76, 57 and 41 percent, respectively. This indicated that there exist considerable inefficiencies in milk production in the study areas. The Tobit model result also indicate that extension contacts, farm size and ownership of improved breed cow has positively and significantly affected technical, allocative and economic efficiencies, and sex of household head, and market information was also found significantly and positively influence allocative and economic efficiencies. Technical and allocative efficiency was positively and significantly influenced by education, while technical efficiency was positively and negatively influenced by livestock owned and age, distance to water source. This study suggests that the government should focus on creating favorable policy environment for dairy enterprise development, and encourage use of crossbred cows and upgrading local cow performance, strengthening the provision of formal and informal education, promoting and empowering young people in dairy production and delivering market information timely.

Keywords: Cow milk, Economic efficiency, Stochastic frontier approaches, Tobit model, West Harerghe zone

1. INTRODUCTION

Livestock subsector has an enormous contribution to national economy and livelihoods of many Ethiopians and still promising to rally round the economic development of the country. Livestock contributes at ETB 150.7 billion per year, which amounts to 12–17 percent of the total and 30–35 percent of agricultural GDP, respectively (FAO, 2019). The dairy industry is not as developed as it may be given its considerable potential and the contribution cattle provide to farmers' livelihoods. This is a result of the country's traditional milk production system, which accounts for around 95% of the nation's total yearly milk production and is dominated by native breeds with little genetic potential for milk production (CSA, 2018).

According to CSA, (2018) livestock survey, the most important norms for cattle rearing are to obtain milk for home consumption and sale. However, milk yield of indigenous cattle is very low in addition to poor reproductive performance in terms of late age at first calving and long calving interval. The average daily milk production per cow in Arsi and East Shewa zones is 1.8 and 1.77 litters/cow/day respectively, while it is 1.65 liters per cow per day in West Hararghe zone and 2±0.23 liters per cow per day under transhumance cattle production system in Amhara region in North Gondar zone. The difference even within the same country indicates there may be an opportunity to increase milk yield in the country and also in the study areas.

Since dairy inputs and services are still in their infant stage and the expansion of improved dairy cows is constrained in the country, empirical literatures argue that the total annual milk production has been increasing at a moderately slow rate. This is primarily because the increase in milk production may have come from the increased number of milking cows rather than increased productivity (Nathaniel *et al.,* 2014). The current study find that the indigenous and cross breeds has an average milk production of 1.56 and 5 liters per cow per day with average lactation period of six and eight months.

This may suggest that the country unable to meet the demand for this product and spends a tremendous amount of hard currency per annum for importing milk in different forms. Key evidence affirms the country has imported 24.11 million liters of dairy products from 69 countries from over the period 2009 - 2018 and for which it has spent over 2.615 billion

Ethiopian birr. Further indicates that Europe, Asia and Africa were the three leading continents that contributed to 76.04%, 12.38% and 7.48% of the total milk products imported by Ethiopia respectively (Mulugeta *et al.*, 2019). This needs attention in order to increasing milk production and productivities not only for improved food security and wellbeing of households but also for promoting commercialization of the dairy industry.

This necessitates being aware of the dairy industry's degree of milk production efficiency and recognizing the causes of inefficiency. The outcomes of such analysis should help to prioritize actions in the sector and better inform decisions about research, development, and policy. Despite the fact that there have been numerous research on efficiency analysis in the dairy industry Makombe *et al*., 2011; Mosisa, 2014; Lemma *et al.*, 2013; Ajabush *et al.*,2018) all of them have a technical efficiency focus on cow milk production. To the best of our knowledge, neither the country nor the research areas have any studies on the economic efficiency of milk production. In radiance of these issues, the study was designed and executed to answer the following key research questions: What is the level of technical, allocative and economic efficiencies and which factors are responsible for the inefficiency differentials among smallholder milk producers in the West Haraghe Zones of Ethiopia's Oromia National Regional State.

2. RESEARCH METHODOLOGY

2.1. Description of the Study Area

The three districts of Gemechis, Oda Bultum, and Mieso in the West Hararghe zone of Ethiopia's Oromia National Regional State were the sites of the study. Astronomically, the zone is located between latitudes of 70 08' 58" and 80 49' 00"N and longitudes of 380 41' 55" and 400 43' 56"E. The Shebelle River, which separates it from Bale on the south, Arsi to the southwest, the Afar Region to the northwest, the Somali Region to the north, and East Hararghe Zone to the east, all encircle the zone and also the zone has 15 districts and its zonal town is Chiro (ZoARD, 2010).
The altitude of the zone ranges from 1400 to 2300 meters above sea level. The temperature and rainfall of the district range from 9 - 25 degree celsius and 700 – 1200 millimeters, respectively (Tekalign, 2013).
The Zone is known for its crop-animals mixed farming system, where dairy production in particular and livestock in general make substantial contributions to the livelihood of the farmers. The selected study districts has high production of milk potential and the produced milk is distributed in and outside of those districts areas. And there are well developed milk cooperatives in Gemeches districts that distribute milk in the district town which is known as Kuni and also in different towns of the zone such as Bedessa and Chiro town. Therefore, the milk producers and also consumers suggest that they are highly benefited from this cooperative. Sorghum, maize, barley, wheat, and pulses are among the main crops farmed in the region. Additionally, khat and coffee are significant cash crops in this region (CSA, 2014).

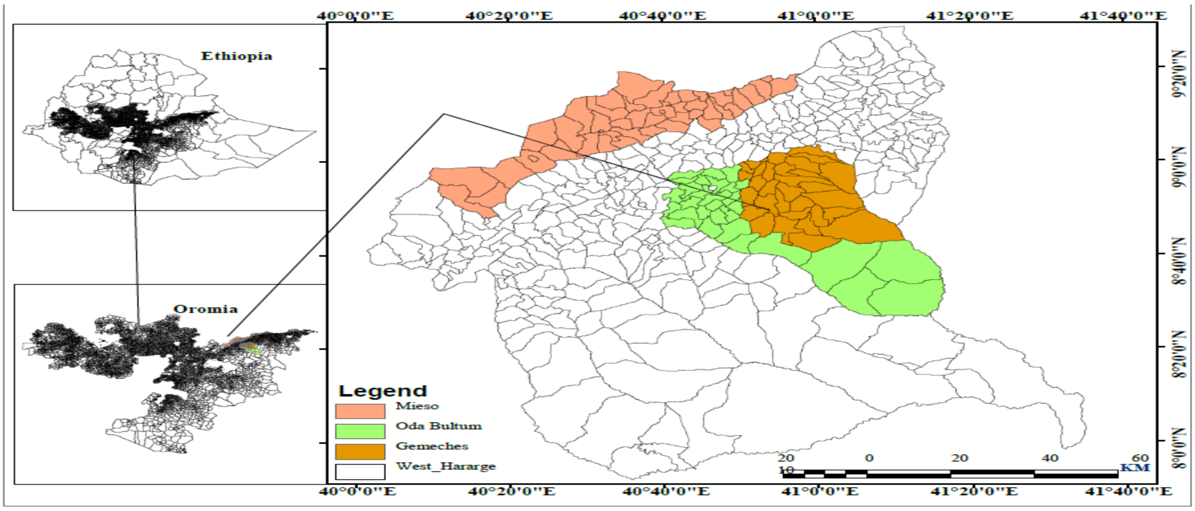

Figure 1. Map of the study areas

2.2. Source of Data and Sampling Procedure

We used both primary and secondary data. Face-to-face interviews were used to gather primary data using a well-structured questionnaire, while secondary data came from a variety of sources, including reports from the Bureau of Agriculture at various levels, NGOs, the CSA, and previous research findings. To draw a representative sample multi-stage random sampling technique was implemented; in the first stage, three districts, namely Gemeches, Odabultum and Mieso were randomly selected from the 15 milk producing districts of West Harerge zone. And, nine kebeles were selected from the indicated districts in the second step based on probability proportional to size. In the third stage, the kebeles' sample frame was updated, and a total of 385 household were selected randomly using a probability proportional to the size of the population. The study used Kothari, (2004) formula to determine a representative sample size as:

$$N = \frac{Z^2Pq}{e^2} = \frac{(1.96)^2\,(0.5)(0.5)}{(0.05)^2} = 385$$

Where N is the sample size, Z is the inverse of the standard cumulative distribution that corresponds to the level of confidence, e is the desired level of precision, p is the estimated proportion of an attribute that is present in the population and q = 1-p. The value of Z is found from statistical table which contains the area under the normal curve of 95% confidence level.

2.3. Efficiency Measurement Approaches

Technical Efficiency (TE) refers to achieving the highest possible output from certain input quantities while taking physical production relationships into account. Input and output-oriented frameworks are the two basic categories in which TE is measured. According to Farrel, (1957 and Kopp, (1980) the possible input decrease that a farm could implement without lowering its output level is provided by TE in an input-oriented paradigm. When used in an output-oriented framework, TE provides details on the possible output increase a farm could accomplish without increasing its input usage. While allocative efficiency (AE) relates to the capacity to mix inputs and outputs in the best possible manner given current prices. Therefore, AE demonstrates if the employment of various production factor ratios ensures the achievement of maximal production at a specific market price (Farrel, 1957, Kopp, 1980). Further, economic efficiency (EE) can be interpreted as the potential reduction in production costs (cost efficiency) or the potential increase in revenue (revenue efficiency) that a farm could apply in order to operate at the point of TE, AE and EE enables conclusions to be drawn on whether the farm operates at optimal or suboptimal size. Therefore, in this study the three efficiency types are analyzed based on the data collected in 2021.

The two approaches that are commonly used in literature to measure efficiency in production are non-parametric and parametric frontier approaches. Stochastic frontier methodology is a parametric approaches designed to estimate the underlying production technology represented by production, cost, or other functions while accounting for random noise and incorporating inefficient behavior of firms). Battese, and Coelli, (1995) argued that estimating the efficiency analysis using the parametric approach in the field of agriculture provides better results as compared with the non-parametric approaches. They justified their reasoning based on the fact that the parametric approach accounts exogenous factors in addition to accounting for measurement errors, which are inherent in agriculture production.

The non-parametric frontiers do not impose a functional form on the production frontiers and do not make assumptions about the error term. They use linear programming approaches, and the most popular nonparametric approach has been the Data Envelopment Analysis (DEA). However, DEA is a non-parametric method that estimates the efficiency of production a group of farms, sometimes called decision-making units (DMU). Since DEA is a non-parametric method, no information is provided by the analysis as to the reasons or sources of inefficiencies (Coelli *et al.*, 2005). Also, DEA does not make allowance in the analytical method for measurement error or missing data or information in estimating the efficiencies of production. Therefore, this study used the stochastic frontier approaches (SFA).

There are two estimation methods in the literature on stochastic frontier analysis that often used to examine factors influencing agricultural production efficiency. The first method recommends a two-stage estimation process in which the initial efficiency scores are determined using either parametric or non-parametric methods. The efficiency score derived from the first stage is now used as the dependent variable in the next step to analyze its determinants applying either OLS or two-limit Tobit models. Due to the heteroskedasticity issue caused by the OLS model as the dependent variables used have values between 0 and 1, the parameter estimates obtained are ineffective, and conventional hypothesis tests like t-ratios are incorrect (Gujarati, 2010). However, the two-limit Tobit model is appropriate to provide the most accurate estimates for the parameters vector of these kinds of dependent variables (like efficiency scores in our case) (Maddala, 1992). Several researches have employed this method to determine the causes of technological inefficiency in agricultural production (e.g. Mosisa, 2014; Lemma *et al.,* 2013).

The second method is a one-stage approach that simultaneously estimated the level of inefficiency and its determinants in which the impacts of inefficiency are explicitly represented as a vector of different independent variables. This method has been challenged for the inability to estimate the causes of allocative and economic inefficiencies. It is best suited to estimate solely the determinants of technical inefficiency (Bravo-Ureta and Rieger, 1991; Coelli *et al*., 1998). Thus, the current paper has employed the parametric model developed at household level using the two-stage estimation framework.

The Cobb-Douglas function has been the most commonly used function in the specification and estimation of production frontiers in empirical studies. It is attractive due to its simplicity and because of the logarithmic nature of the production function that makes econometric estimation of the parameters a very simple matter. Furthermore, Coelli and Perelman (1999) points out that if an industry is not characterized by perfectly competitive producers, then the use of a Cobb-Douglas functional form is justified. The choice of flexible second order functional form (e.g. translog) relaxes the restrictions on demand elsticities and elasticity of substitution but it is not monotonic or globally convex as in the Cobb-Douglas model (Coelli *et al*., 2005). Therefore, after testing the hypothesis this study used Cobb-Douglas functional form.

2.4. Methods of Data Analysis

The collected data was analyzed using STATA version 14 software and also SPSS version 16 was used for data management. Descriptive statistics such as percentage, mean and standard deviation and econometric model such as Stochastic Frontier and Tobit model was used for data analysis. Stochastic Frontier model introduced by Aigner, *et al*., (1977) was used; and for n sample farms, it can be written as:

The parametric specification in the Cobb Douglass for one output and six inputs is given by:

$lnY_i=\beta_0+\beta_1 lnNcowi+\beta_2 lnLoBRi+\beta_3 lnHEEi+\beta_4 lnCROPRDi+\beta_5 lnGFOi+\beta_6 lnConi+v_i-u_i$ (1)

Where: Yi = Cow milk produced in litter by the i^{th} household in the production year 2021

βi= Vector of parameters to be estimated

(Ncow is total number of lactating cows owned by the i^{th} household; LoBR is total number of labor available for feeding, herding and milking; CROPRD *is* amount of crop residue in kg per year; Con *is* total amount of concentrate in kg per year; GFO *is* total amount of green fodder consumed by dairy cows in kg per year; HEE *is* total health expenditure per cow per year by the i^{th} household. Whereas v_i is a symmetric random error, which represents random variations/ shocks in milk production that accounted for factors outside the control of farmers, is assumed independently and identically distributed as $N(0,\sigma^2)$. The error term u_i is a one-sided non-negative variable which measures technical inefficiency of the i^{th} household, the extent to which observed output falls short of the potential output for a given technology and input levels. All the dependent and explanatory variables that used in the production frontier and cost function were transformed in logarithms before the data analyzed for estimating efficiency.

The method helps decompose deviation of the actual observed milk output from the estimated frontier into random variations and inefficiency. Hence, $u_i = Z_i\delta + w_i$. Where, Z_i is a vector of variables that explain inefficiency of the i^{th} household, δ is a vector of unknown coefficients that are to be estimated in the model, and $w_i \geq -Z_i\delta$ to ensure that $u_i \geq 0$ (Battese and Coelli, 1995).

Following Bravo-Ureta and Rieger, (1991) adjusted output Y* is used to derive the technically efficient input vector, X*. The technically efficient input vector for i^{th} firm, is derived by simultaneously solving equation and the observed input ratio $\frac{X_1}{X_i}$=k (i>1) where K_i is equal to the observed ratio of the two inputs in the production ofY*.Sharma *et al.* (1999) suggests that the corresponding parameter of the dual cost frontier can be derived algebraically and written in a general form as:

$C_i=C(\omega_i, Y_i^*;\alpha)$

Where C_i is the minimum cost of production; ω_i is a vector of input prices for the i^{th} firm; Y_i^* refers to farm output which is adjusted for noise v_i and α is a vector of parameters to be estimated from primal function. To estimate the minimum cost frontier analytically from the production function, the solution for the minimization problem is given as:

$$\text{Min} \sum_{x} C = \sum_{j=1}^{6} X_j \omega_j$$

$$\text{Subject to} \quad Y_i^* = \hat{A} \prod X_j^{\hat{\beta}_j}$$

Where $\hat{A} = \text{Exp}(\hat{\beta}_o)$, ω_j is input prices, $\hat{\beta}_j$ is parameter estimate of the stochastic production function and Y_i^* is input oriented adjusted output level. Then, substituting the input demand equations derived using shepherd`s lemma and output adjusted for stochastic noise in the minimization problem above, the dual cost function can be written as follows:

$$C(Y_i^*, \omega, \alpha_j) = HY_i^{*\mu} \prod_j \omega_j^{\alpha_j}$$

Where; $\alpha_j = \mu\hat{\beta}_j$, $\mu = (\sum \hat{\beta}_j)^{-1}$ and $H = \frac{1}{\mu}\left(\hat{A} \prod \hat{\beta}_j^{\hat{\beta}_j}\right)^{-\mu}$

The economically efficient input vector for the i^{th} firm, X_{ie} derived by applying Shepard's Lemma and substituting the firms input price and adjusted output level into the resulting system of input demand equations.

$\frac{\partial C_i}{\partial \omega_n} = X_{ie}(\omega_i, Y_i^*; \alpha)$

Where n = 1, 2, 3...n are inputs used. The observed, technically and economically efficient costs of production of the i^{th} firm are then equal to $\omega_i' X_i, \omega_i' X_{it}, \omega_i' X_{ie}$ respectively. Those cost measures are used to compute TE, AE and EE induces for the i^{th} firm as follows:

$TE_i = \omega_i' X_{it}/\omega_i' X_i = Y_i/Y_i^*$

Where, Y* = frontier output and Y= actual yield

$EE_i = \omega_i' X_{ie}/\omega_i' X_i = C^*/C$

Where, C* = minimum (efficient) cost C= actual cost

$AE_i = \omega_i' X_{it}/\omega_i' X_i$ $AE=EE_i/TE_i$

The current study also estimated allocative efficiency with the input-output relationships formulated using a Cobb-Douglas cost function specified in Equation (2) as follows,

$\ln C = \beta_0 + \beta_1 \ln P_1 + \beta_2 \ln P_2 + \beta_3 \ln P_3 + \beta_4 \ln P_4 + \beta_5 \text{In}P_5 + \beta_6 \ln P_6 + \beta_7 \ln Yi + vi - ui$ (2)

Where C = total cost of milk production by the i^{th} household (Birr) per year, P_1=Cost of lactating cows per year, P_2= cost of labour (Birr) per year, P_3= cost of health care (Birr) per year, P_4= cost of crop residue (Birr) per year, P_5= cost of green fodder (Birr) per year, P_6=cost of concentrate (Birr) and Y is total milk output in littre, adjusted for any statistical noise. Finally, economic efficiency was determined by multiplying technical efficiency with allocative efficiency.

The fact that farm households' milk production inefficiencies fall within the ranges of 0 and 1, various socioeconomic and institutional variables were regressed on inefficiency estimations using a two limit Tobit regression model. Following Tobin (1958) the Tobit model can be specified as:

$$E_i^* = \sum_{i=1}^{n} \beta_j X_j + V_j \quad (3)$$

Where Ei*= latent variable representing the efficiency scores of farm j, β_j = a vector of unknown parameters, Xj = a vector of explanatory variables (m = 1, 2, ..., k) for farm j and vj= an error term that is independently and normally distributed with mean zero and variance σ^2. Denoting E_i as the observed variable, the two limit Tobit model is specified by a set of equation (3-6):

$$E_i = \begin{cases} 1 & \text{if } E_i^* \geq 1 \\ E_i^* & \text{if } 0 < E_i^* < 1 \\ 0 & \text{if } E_i^* \leq 0 \end{cases}$$

McDonald and Moffit (1980) approach were also followed to decompose marginal effects in order to assess the effect of a change in an explanatory variable on the dependent variable. The interpretations of these marginal effects depend on the point of interest-based on the focus of the study (Greene, 2003). These are:

a) The marginal effect on the latent variable (unconditional expected value)

$$\frac{\partial E(Y/X)}{\partial x_k} = \beta_k \Phi\left(\frac{x\beta}{\sigma}\right) \quad (4)$$

b) The marginal effect on the expected value of observations conditional on being uncensored

$$\partial E\left(\frac{Y/X, y>0}{\partial x_k}\right) = \beta_k + \beta_k \frac{\partial \lambda(c)}{\partial c} = \beta_k \{1 - \lambda(c)[c + \lambda(c)]\} < \beta_k \quad (5)$$

Where, $\lambda(c)$ is called the inverse mill's ratio. It captures the change in the dependent variable (conditioned on y>0) when changing x.

c) The marginal effect on the probability that the observations are uncensored

$$\frac{\partial \Pr(y > 0/x)}{\partial x_k} = \phi\left(\frac{x\beta}{\sigma}\right)\frac{\beta_k}{\sigma} \quad (6)$$

3. Results and Discussion

3.1. *Demographic and Socio-Economic Characteristics of Sample Households:*

It is important to describe the socioeconomic, institutional, and farm characteristics of the sample households before embarking to the efficiency status of sample households. About 79.2% were male-headed and the remaining 20.8% were female-headed. The result further shows that 64.4% of household heads were members of farmers' cooperatives where cooperatives membership was believed to enhance information exchange and experience sharing among farm households on the use of improved agricultural technologies. Furthermore, the result indicated that 70.4% of respondents get market information from different sources such as milk seller neighbors, traders, and customers. About 44.2% farmers in the study areas have engaged themselves in various off/nonfarm activities parallel with the main farming activities (Table 1).

Table 1. Summary statistics of sample households (dummy variables)

Variable	Description	No. of respondents (n=385)	Percent
Sex of household head	Female	80	20.8
	Male	305	79.2
Cooperative membership	Yes	248	64.4
Market information access	Yes	271	70.4
Off/non-farm participation	Yes	170	44.2
Access to improved cows	Yes	83	21.6

Source: Computation from 2021 survey data.

The age of the sample respondents ranges from 20 to73 years with the average age of 48.07 years. The household size ranges from 2 to 16 members per family and the average household size per sample household was 6.7. The average years of schooling of the sample respondents were 2.20. In addition, the sampled households walked on average 36.76 and 42.68 minutes to reach the development agents and water sources respectively (Table 2).

The average landholding size in the study area was 0.94 hectares per household which was much lower than the national average land holding size of 1.17 ha per household that reported by CSA (2014). And the average land allocated for major crop was 0.68 ha during the survey period. A typical farmer in the study areas received about 6 types of extension services per year (Table 2).

Table 2. Summary statistics of the sample households (continuous variables)

Variables	Min	Max	Mean	Std.Err
Age of household head (years)	20	73	48.07	0.507
Educational level of household head (grade)	0	9	2.20	0.131
Household size in (adult equivalent)	3	14	6.812	0.121
Distance to water source (walking minute)	25	90	42.68	1.45
Distance to animal health clinic (walking minute)	20	85	30.54	0.85
Distance to development agents (walking minute)	20	65	35.46	0.94
Farm size (hectare)	0.34	1.15	0.68	0.15
Extension contacts (number of contact per year)	1	9	6.53	1.54
Total number of livestock (TLU)	1.34	18.05	5.31	0.15

Source: Computation from 2021 survey data.

3.2. Milk Output and Amount of Inputs Used

The milk output obtained from each breed is highly different. Even though it is known as input difference between breed, the milk yield from crossbreed cow is higher than milk yield of local breed cow during production year. Farmers indicated that milk yield is highest during the first four months of lactation and declines thereafter. However, it depends on the month of calving, feed availability, milking experience etc. Milk production is high in amount during June to December since feed supply is adequate than the other months.

The average milk yield obtained by household during the survey year was 1640.80 liters per year The average amount of crop residue and green fodder given to milking cows per sampled family during the 2021 production year was 2124.0 and 1691.1 kg per year, respectively, as shown in (Table 3).

Table 3. Descriptive statistics of input and output variables used in efficiency analysis

	Local Cow (302)		Cross breed (83)		Total	
Variables	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Output (lit)	1312.40	1022.30	3115.70	2206.51	1640.80	1564.60
Milked cow (No)	1.89	0.55	2.23	1.10	1.95	0.90
Labor (Man-days)	187.40	15.20	288.10	29.30	202.00	20.80
Green fodder (kg)	1338.30	745.20	2757.50	932.30	1691.10	1023.00
Crop residue (kg)	2071.91	479.80	3480.40	1211.50	2124.00	1023.50
Concentrate (kg)	360.70	266.40	878.02	231.20	635.70	289.20
Health Cost (ETB)	103.00	13.10	153.31	16.22	118.31	15.11

Source: Computation from 2021 survey data.

The milking cows received 635.7 kg of additional concentrates on average per year. This demonstrates that cross-breed cow owners have utilized more concentrate feed (878 kg) than local cow owners (361 kg).

Table 4. Descriptive statistics of production inputs cost

	Local Cow (302)		Cross breed (83)		Total	
Variables	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Cow cost (ETB)	12560.30	345.32	22570	385.60	13940.50	1121.21
Labor cost (ETB)	2034.4	57.2	3078.1	76.2	2180.2	93.1
Crop residue cost (ETB)	1545.04	418.31	2746.06	467.51	1763.41	402.81
Green fodder cost (ETB)	1695.37	145.30	2780.10	198.84	1890.54	155.03
Concentrate cost (ETB)	595.37	495.3	1098.37	695.3	795.37	405.23

Source: Computation from 2021 survey data.

The average number of man-days per household per year that spent for managing milking cows was 202.0, with a standard deviation of 20.8. The price of hired labor was computed using the daily average wage rate. As a result, the opportunity cost of family work as well as the cost of hired labor made up the total cost of labor input. Milk production throughout the study period needed 202 man-days annually on average costing 2180.20 ETB (Table 4). Green fodder and agricultural residue had average yearly costs of 1890.54 and 1763.41 Birr, respectively.

3.3. Econometric results

Hypotheses Testing

The likelihood ratio test was used to identify the functional form of production function which properly fit the data set. LR denotes log likelihood ratio =-2[L(H0) - L (H1)], where L (H1) and L (H0) are the values of the loglikelihood ratio under the alternative and null hypothesis, respectively. The LR test statistic of the first null hypothesis was 13.64, significantly less than the critical value of 30.58 at 15 degree of freedom, which informed us not to reject the null hypothesis. The test result revealed that Cobb-Douglas Stochastic Frontier model best fit the data compared to the more flexible translog frontier model. The second null hypothesis tested was ($H0: \gamma = 0$) which states that there is no efficiency variation (households are efficient in resource use) in milk production that was represented by the model is rejected in favour of the alternative one.

When test linear hypothesis imposed on stochastic frontier model, to that of the second null hypothesis, the LR test (chi2 (1)) was 11.23, but still significantly greater than the critical value 6.63 and leads us to accept the alternative one. Therefore, the test result indicates that there is statistically significant inefficiency in the milk production.

Table.5 Hypotheses Testing

Null hypothesis	Log likelihood value	Degree of freedom	Critical value ($\chi2$, 0.01)	Decision
$H0 = \beta ij = 0$	13.64	15	30.58	Accepted
$H0: \gamma = 0$	11.23	1	6.63	Rejected

Source: Model output based on survey data, 2021

Estimation of Technical Efficiency: As shown in (Table 6) the labor force, number of lactating cows, crop residues, feeds, and concentrates, which had the highest total coefficients (0.88, 0.64, 0.073, 0.058, and 0.059), each contributed the most to milk production in the study area. Maina *et al.* (2018) found that fodder concentrate and number of lactating cows influence milk production levels statistically and also significantly. Significance of labor and number of lactating cows were found to be in agreement with what has been testified by Zewdie *et al.* (2015). Nakanwagi and Hyuha (2015) stated that labor had positive and significant effect on milk output.

Table 6. Estimates of the stochastic frontier production function.

Variables	Coefficients	Std.Err	P>z
ln number of lactating cows	0.6374***	0.04789	0.000
ln green fodder	0.0580***	0.0096	0.000
ln crop residue	0.0736***	0.0261	0.005
ln labour	0.8827***	0.0502	0.003
ln concentrate	0.0593*	0.0316	0.061
ln health cost	-0.0057	0 .0045	0.202
Constant	2.0238***	0.6434	0.002
Sigma (u)	0.3908	0.0485	
Lambda (λ)	2.045	0.071	
Gamma (γ)	0.806		
Wald χ^2 statistic	248.02		
Log likelihood	-215.806		
Likelihood-ratio test of sigma=0 prob >= chibar2=0.003	11.23***		
Number of observations	385		

***p< 0.01; **p< 0.05; *P< 0.10 Source: Model output based on survey data, 2021

And a high value (0.806) of gamma (γ) estimate shows the occurrence of significant inefficiencies in milk production. That means about 80.6 percent of the differences between the observed and maximum production frontier outputs were due to farmers' inefficiencies which are in the control of the farmers and can be reduced to improve technical efficiency of the farmers in the study area.

Estimation of Allocative Efficiency

A firm or farm should select the ideal combination of inputs to produce output at the lowest possible cost if they want to achieve allocative efficiency.

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

$$\mathbf{lnCi} = 1.767 + 0.1260\ln \mathbf{Y_i} + 0.0345\ln\varpi_{\mathbf{Nocow}} + 0.4181\ln\varpi_{\mathbf{grfodder}} + 0.6340\ln\varpi_{\mathbf{Crresidue}} + 0.0879\ln\varpi_{\mathbf{labour}} + 0.0209\ln\varpi_{\mathbf{concentrate}} + 0.0269\ln\varpi_{\mathbf{health}}$$

Where C is the minimum cost of production of the i^{th} farmer, Y refers to milk output adjusted for any statistical noise and scale effects and ϖ stands for input prices.

By utilizing their inputs in the best possible proportions given the input prices, farmers can still reduce their production costs at the existing level of resources.

3.4. Efficiency Scores

The output presented in Table 8 indicated that farmers in the study area were relatively good in technical efficiency than allocative efficiency or economic efficiency. The mean technical efficiency of dairy farmers in the study areas was 76 percent with minimum and maximum technical efficiency of about 43 and 93 percent respectively. It indicated that farmers on average could decrease the amount of inputs (number of cows, labor, and feeds) used by 24% to attain the milk yield they currently obtained if they were technically efficient.

The mean allocative efficiency (AE) was found to be 0.57, indicating the AE of farm households revealed 43% increase in output by improving AE, with the existing technology. For instance, farmer with average level of allocative efficiency would enjoy a cost saving of about 43% derived from (1–0.57/1) *100 to attain the level of the most efficient farmer. The combined effect of technical efficiency and allocative efficiency factors showed that the average economic efficiency level was 0.41. Moreover, the result also means that farmers with average level of economic efficiency would enjoy a cost saving of about 59% derived from (1-0.41/1) *100 to attain the level of the most efficient farmer.

Table 8. Summary statistics of efficiency measures

Efficiency level	Technical efficiency		Allocative efficiency		Economic efficiency	
	No of HHs	Percentage (%)	No of HHs	Percentage (%)	No of HHs	Percentage (%)
1-20	0	0.00	39	10.13	80	20.78
20-40	0	0.00	53	13.66	138	35.84
40-60	116	30.13	131	34.02	144	37.40
60-80	199	51.69	155	40.18	19	4.93
80-100	70	18.18	7	2.01	4	1.05
	TE		AE		EE	
Minimum	0.43	-	0.11	-	0.09	-
Maximum	0.93	-	0.92	-	0.91	-
Mean	0.76	-	0.57	-	0.41	-
Std.Dev	0.12	-	0.18	-	0.15	-

Source: Computation from 2021 data.

3.5. Determinants of Inefficiencies in Milk Production

The presence of multicollinearity issue among explanatory variables used in the model was checked using a variance inflation factor (VIF) test and we found each variable has a mean of 1.62, which is less than the threshold value of ten. This suggested none of the hypothesized variables in the model have a multicollinearity problem.

Table 9. Tobit results on technical, allocative and economic inefficiency

Variable	Technical inefficiency		Allocative inefficiency		Economic inefficiency	
	Marginal Effect	Std.Err	Marginal Effect	Std.Err	Marginal Effect	Std.Err
Sex	-0.006	0.012	-0.135***	0.021	-0.113***	0.027
Age	0.177**	0.083	0.002	0.003	0.001	0.003
Education	-0.039*	0.022	-0.063**	0.027	-0.007	0.022
Household size	-0.002	0.003	-0.003	0.004	-0.006	0.004
Distance to market	0.003	0.012	0.004	0.051	0.005	0.012
Distance to water source	0.083***	0.025	0.004	0.006	0.043	0.061
Distance to main road	0.004	0.013	0.001	0.002	0.001	0.003
Distanc livestock clinic	0.042	0.071	0.021	0.043	0.022	0.031
Farm size	-0.163***	0.045	-0.211***	0.052	-0.126***	0.047
Number of lactating cow	-0.068	0.056	-0.002	0.003	-0.022	0.048
Owning improved cow	-0.051**	0.023	-0.026*	0.014	-0.036**	0.017
Market information	-0.001	0.041	-0.114**	0.053	-0.038*	0.021
Cooperative member	-0.020	0.013	- 0.006	0.012	-0.006	0.015
Extension contacts	-0.124***	0.041	-0.146**	0.059	-0.159***	0.037
Off-farm participation	0.001	0.002	-0.016	0.024	-0.034	0.022
Livestock holding	-0.055**	0.024	-0.007	0.008	-0.012	0.024

*, **and *** represent statistical significance at 10%, 5% and 1% levels respectively

Source: Model output based on survey data, 2021

The results of the Breusch-Pagan test also affirmed that heteroskedasaticity was not an issue in our data sets (chi-square values of 0.05 for TE, 0.02 for AE, and 0.03 for EE). The Tobit model result showed that technical, allocative and economic efficiency of cow milk producers was significantly influenced by the variables stated below.

Sex: It was found that sex of household head has positive and significant impact on allocative efficiency and economic efficiency at 1% significance level. The possible enlightenment is that male headed households might have better practical experiences in dairy production and one might argue that females are too much occupied with additional responsibilities within the household and had little time for the management of their dairy cow that led to low production efficiency levels. The survey result indicated that being male headed farmer increases allocative efficiency and economic efficiency by 13.5% and 11.3% respectively.

Age: Age of the household head has a negative and significant 5% impact on technical efficiency because older farmers may insist on continuing with outdated practices. Ajabush *et al.* (2018) claim that because older farmers are risk adverse, they are slow to adopt new technology that would increase operational efficiency. According to this study, young farmers produce milk at a 17.7% higher technical efficiency. The fact that younger people adopt new dairy technology and correctly manage their cows suggests that they are more technically proficient than older people.

Education: It has a positive and significant effect on technical and allocative efficiency of milk production at 10% and 5% level of significance respectively. Smallholder farmers who were better educated can understand agricultural instructions easily, have higher tendency to adopt improved dairy technologies, have better access to information and are able to apply technical skills imparted to them than uneducated ones Zewdie *et al*. (2016). Moreover, a one-year increase in educational level of the household head would have increased technical and allocative efficiency by 3.9% and 6.3% respectively.

Distance to water sources: As hypothesized, it was found to have significant and negative impact on technical efficiency at 1% significance level. Farmers who were nearer to the water sources could easily get an opportunity for enough water for their dairy cow which is related with the response of the farmer who suggest that when the cow drink enough water, they would consume their fodder properly this ultimately resulting in increased milk output. The study result showed that a 1km increase in the distance from farm household residents to water sources, there would have the probability of decreasing the level of technical efficiency by 8.3%.

Farm size: It has positive and significant effect on technical, allocative and economic efficiency at 1% significance level. Land allocated to crop production was a continuous variable indicating whether or not the producer allocates enough land for major crop production purpose. Ajabush *et al.* (2018), found a positive and statistically significant relationship between farm size and technical efficiency of milk. The result of the study indicated that an increase in allocated land size for major crops by one ha increases technical, allocative and economic efficiency by 16.3%, 21.1% and 12.6% respectively. Owning land where the cattle can scratch crop by- products reduces expenses the farmer would have otherwise incurred in purchasing feed.

Access to market information: It is influence allocative and economic efficiency of milk producers positively and significantly at 5% and 10% respectively. Farmers who received market information on how to sell, where to sell and how much to sell might have motivated to supply their product to the proper market and those who allocate their resource properly become efficient producers. Therefore, this finding show that access of market information by the household head increase allocative and economic efficiency by 11.4% and 3.38% respectively.

Ownership of improved breed cow: There was a significant and positive influence among technical, allocative and economic efficiency at 5%, 10% and 5% significance level. Lemma, (2013) in his study revealed that there was a positive impact and significant relationship between improved breed of cow and technical efficiency. Thus, smallholder farmers who has improved breed cow increase technical, allocative and economic efficiency by 5.1%, 2.6% and 3.6% respectively.

Frequency of extension contact: It is positively and significantly affected technical, allocative and economic efficiency at 1%, 5% and 1% significance level. Zewdie *et al*. (2016) pointed out that advisory service rendered to the farmers can help farmers to improve their average performance in the overall farming operation as the service widens the household's knowledge with regard to the use of agricultural technologies. The result show that smallholder farmers who had more extension contacts increase technical allocative and economic efficiency by 12.4%, 14.6% and 15.9% respectively.

Livestock owned (TLU): The coefficient of livestock ownership for technical efficiency is positive and statistically significant at 5%. The result also showed that an increase in livestock by one TLU increases technical efficiency by 5.5%. This result is similar with Mosisa, (2014), who confirmed that the considerable contribution of livestock in reducing the current cost of inputs in milk production.

4. CONCLUSION AND RECOMMENDATIONS

The factors that contributed most to milk production in the research area were labor, the number of lactating cows, crop residue, green fodder, and concentrate, which had the highest overall coefficients (0.88, 0.64, 0.073, 0.058, and 0.059 respectively. Therefore, in order to enhance profitability and efficiency of dairy production in the study areas and in the country the governments and other concerned stakeholders need to work on those significant variables.

The male headed households were more likely efficient, than female headed households. The probable reason might be female headed households have resource constraints and likely not capable of adopting new and expensive dairy technologies which limits their production capabilities. Therefore, governmental and non-governmental organizations should empower female headed households through different policy initiatives and interventions to boost their production and productivity.

Age of the household head affect efficiency negatively and significantly. The older the farmer becomes, the more he or she is unable to combine his or her resources in an optional manner given the available technology. These results call for the government for the need to encourage the rural youth to engage in dairy production.

Education level of the household head was the other factor that found to have positive and significant effect on the level of milk production efficiency. In this regard, the regional and local governments should strengthen the existing formal and informal education through facilitating the provision of all the necessary materials.

The negative relation between distance to the water and efficiency shows that the households located far away from the water source have poor water access than others which increases walking hours and does not motivate farmers to have more dairy cows and reduce the quantity of milk output. This suggests the concerned bodies shall play an important role in providing water supply in the strategic locations around the farming areas and support infrastructure development programs.

Land allocated for crop production has a positive and significant effect on efficiency of milk production in the study areas. The results show that crop residue highly affects milk production, in addition to green fodder. Hence, ways of integrating cereal production with dairy production and efficient utilization of existing feed sources should be encouraged by extension workers towards the milk producer households.

The current study also affirmed that market information has a significant and positive effect to milk production efficiency. This however requires timely delivery of market information for which the government should take responsibilities to develop and facilitate market information systems that can symmetrically addressable to the stakeholders.

The findings of this study pointed out that livestock holding and ownership of improved breed cow positively influence milk production efficiency. Farmers should be encouraged to engage in livestock husbandry as well by providing improved livestock breeds to increase production and productivity of the livestock sector and encourage milk production also.

Extension contact is a significant contributor to production efficiency of milk producers in the study areas. Therefore, joint effort of development agent, agricultural experts, researchers and other stakeholders on identifying and solving problems, availing of new dairy technology, transfer of improved technology and information to farmers are necessary to enhance production efficiency. As a result, policies should place more emphasis on strengthening the existing agricultural extension service provision through short and long-term training.

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5. REFERENCES

1. Adane Zewdie, Shiferaw Kaleb and Berhanu Gebremedin. (2016). Estimation of technical efficiency of smallholder cow milk producers in central zone of Tigray Ethiopia African Journal of Agricultural Research.11 (19):1777-1786.
2. Aigner, D. J., Lovell, C. A. K. and Schmidt P. J. (1977). Formulation and Estimation of Stochastic Frontier Production Function Models. Journal of Econometrics 6:21-37.
3. Aigner, D.J. and S.F. Chu. (1968). Estimating the industry production function. *American Economic Review*, 58:826-839.
4. Ajabush Defar, Belaineh Legesse, and Mangistu Ketema. (2018). Estimation of technical efficiency of smallholder cow milk producers in eastern Harerghe zone Ethiopia Journal of Economics and Sustainable Developmen.1:18 – 38.
5. Battese, G. E. and Coelli T. J. (1995). A Model for Technical Efficiency Effects in a Stochastic Frontier Production Function for Panel Data. Empirical Economics, 20: 325-32.

6. Bravo-Ureta BE, Rieger L. (1991). Dairy farm efficiency measurement using stochastic frontier and neo-classical duality. American Journal of Agricultural economics 73:421-428.
7. CSA (Central Statistical Agency). (2018). The Federal Democratic Republic of Ethiopia Central Statistical Agency agricultural sample survey report on area, production of major crops and livestock and their products Statistical Bulletin 2016/2017.
8. CSA (Central Statistics Agency of Ethiopia). (2014). Ethiopian Statistical Abstract, Central Statistical Authority, Ethiopia.
9. FAO. (2019). Food and agriculture organization Ethiopia country programming framework. Office of the FAO representative in Ethiopia to AU and ECA Addis Ababa, 2019.
10. Farrel, M. J. (1957). The Measurement of Productive Efficiency. Journal of Royal Statistical Society, Series A 120:253-290.
11. Gujarati, D.N. & Porter, D.C. (2010). Essentials of Econometrics. 4 th ed. New York: McGraw Hill International.
12. Kopp R, Smith V. (1980). Frontier production function estimates for steam electric generation. Southern Economic Journal, 47: 1049–1059.
13. Kothari, C. R. (2004). Research Methodology: Methods and techniques (^{2nd} Edn.). New Age International, New Delhi, India.
14. Lemma Fita, Trivedi, M., Patel, A., Tassew, Belay. And Joshi, C. (2013). Determinants of Technical Efficiency of the Dairy Farmers in Ada'a District of Oromia State, Ethiopia. Iranian journal of Applied Animal Science 3(1): 59-65.
15. Maddala, G.S. (1992.) Introduction to Econometrics Second Edition. Macmillan Publishing Company, New York.
16. Maina, F., Mburu, J., Gitau, G., VanLeeuwen, and Negusse Yigzaw. (2018). Economic efficiency of milk production among small-scale dairy farmers in Mukurweini, Nyeri County, *Journal of Development and Agricultural Economics* 3(1): 59-65.
17. Makombe, G. Regasa Namara, Fistum Hagos, Sileshi Awulachew, Mekonin Ayana and Deborah Bossio. (2011). A comparative analysis of the technical efficiency of rain-fed and smallholder irrigation in Ethiopia. Colombo, Sri Lanka: International Water Management Institute: WMI Working Paper 143 37p.
18. McDonald, John F., Moffitt, Robert A. (1980). The uses of Tobit analysis. Rev. Econ. Statistics 318–321.
19. Mosisa Hirpesa. (2014). Technical efficiency in Milk production: The case of Agarfa District, Bale Zone of Oromia National Regional State, Ethiopia. M.Sc. Thesis presented at Haramaya University, Ethiopia.
20. Nathaniel, Mekonin. Tsehay, Reda, Jan van der, L., Raphael, M. and Akke van der Zijpp. (2014). White Gold: Opportunities for Dairy Sector Development Collaboration in East Africa Centre for Development Innovation.
21. Tekalign, Alemnewu. (2013). Variability of rainfall and its current trend in Oromia region, Ethiopia. MSc Thesis Haramaya University, Ethiopia.
22. Tobin, J. (1958). Estimation of relationships for limited dependent variables. Econometrica, 31,24-36.
23. Wageningen Coelli, T., Rao, D.S.P. and Battese, G. (1998). An Introduction to Efficiency and Productivity Analysis. Boston: Kluwer Academic Publishers.
24. ZoARD (Zonal Agriculture and rural Development Office). (2010). Annual report, West Hararge, Ethiopia.