Estimating Economic Efficiency Levels and Identifying Its Determinants for Milk Producers' Households in North Shewa Zone, Oromia Region, Ethiopia

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Abstract
This study aimed to estimate economic efficiency levels and identifying its determinants for milk producers' households in North Shewa Zone, Oromia Region, Ethiopia. Three stages random sampling technique was used to select 400 sample farmers. The data was analyzed using descriptive statistics and econometrics model. The result of stochastic frontier model showed significant and positive elasticity of lactation cow, green forage and crop residue. The estimated mean values of technical, allocative and economic efficiency were 58%, 77.6% and 44.7% respectively. The yield gap due to technical inefficiency was 9.6 liter per cow per day. A two-limit Tobit model result shows that education, amount of concentrate feed used, grazing land, type of breed and frequency of extension contact contributed significantly and positively to technical efficiency. Moreover, total land, dairy farm experience, dairy membership and type of breed affect allocative efficiency significantly and positively while the amount of concentrate feed used had a significant and negative effect on allocative efficiency. Economic efficiency also affected significantly and positively by education level, total land, grazing land, type of breed and frequency of extension contact. To improve the efficiency level of farmers, due attention should be given to use concentrate feed , improving feed availability, adequate and proper management of grazing land, using of improved breed and dairy cooperatives.
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Introduction

Ethiopia has the tenth largest livestock inventory in the World. The country has the largest number of livestock, more than any other country in Africa. Ethiopia leads with a staggering 60.39 million cattle, while Tanzania, in the second position, has an estimated total of 33.9 million cattle (Africa Census, 2020). Though Ethiopia has a large livestock inventory, the productivity of cattle remains low.

According to CSA (2020), there are around 7.56 million dairy cows in Ethiopia. Of these, 15.04 million are milking cows. On average, each cow produces 1.48 liters of milk daily. Nathaniel *et al*. (2014) indicated that since dairy inputs and service provisions are still at infant stage and the development of improved dairy cows is limited in the country. The increase in milk production may have come mostly from increased number of cows rather than increased productivity. Nega and Simeon (2006) indicated the inefficiency among smallholder dairy producers due to inefficient use of scarce resources. Understanding the existence of inefficiency and different factors contributing to the inefficiency by farmers and policy makers helps to improve efficiency with a view to bring a desired change in the sector. However, most efficiency studies in agricultural economics focus on technical efficiency, which is just one component of overall economic efficiency. Focusing only on technical efficiency (TE) understates the benefits that producers could from improvements in overall performance. Unlike technical efficiency, research done on economic efficiency, especially in milk production is limited. In addition, this, many empirical studies did not consider yield gaps because of technical inefficiency among milk producers.

North Shewa Zone, Oromia Region in Ethiopia has milk production potential, and the demand for milk and milk products has been increasing while output is not able to meet the higher demand. Moreover, there is an output difference among dairy producers. Dairy producers have little knowledge on how to use minimum cost (cost efficiency) in the study area. Therefore, knowledge about the level of economic efficiency of smallholder milk production and the underlying socio-economic and institutional factors causing inefficiency may help to assess the opportunities for increasing milk production. Additionally, to our best of knowledge no studies have been conducted in the area of economic efficiency (EE) of milk production especially in the study area. Hence, there is a need to fill the existing knowledge gap by addressing issues related to technical, allocative efficiency (AE), and EE of smallholder milk production in the study area by providing empirical evidence on smallholder milk producers.

Objectives of the Study
General objective

- The objective of this study was to estimate economic efficiency levels and identify the determinants for milk producering households in North Shewa Zone, Oromia Region, Ethiopia

Specific objectives

1. To estimate the level of technical, allocative and economic inefficiencies of smallholder milk producers in the study area
2. To identify factors that affects the efficiencies of smallholder milk producers in the study area.
3. To estimate yield gap due to inefficiency in milk production in the study area

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Method and Materials
Study Area

This study was conducted in North Shewa Zone of Oromia Regional state, Ethiopia due to its high potential in milk production. It has a total of 13 *districts* and is bordered on the South by Oromia Special Zone Surrounding Addis Ababa, on the South West by West Shewa, on the North by the Amhara Region, and on the South East by East Shewa.

Sampling Techniques and Sample Size Determination

Three stages of random sampling procedures were employed to draw a representative sample. In the first stage, four districts, Degem, Wuchale, Debra Libanos and Girar Jarso, out of 13 milk producing districts in the zone, were purposively selected. In the second stage, two *kebeles* from each district, with a total of eight *kebeles,* from four sampled districts, were selected purposively due to their high dairy production potential. In the third stage, 400 sample farmers were selected using simple random sampling technique based on probability proportional to the size of milk producers in each of the eight selected *kebeles*. Sample size was determined by using formula provided by Yamane (Yamane, 1967).

Accordingly, the sample size for the study is determined based on the following formula:

$$\mathrm{n} = \frac{N}{1+N(e)^2} = \frac{37243}{1+37243(0.05)^2} = 400 \ldots\ldots(1)$$

Where, n = sample size (including non-response rate of 1%), N = Total milk producers in the study area, and e = Level of precision considered.

Table 1: Sample size distribution

No.	Name of sampled district	Total household milk producers	Sampled household	Proportion (%)
1	Degem	5570	60	15.00
2	Wuchale	13880	149	37.25
3	Debralibanos	4273	46	11.50
4	Girarjarso	13520	145	36.25
Total		37243	400	100

Source: North Shewa Livestock and Fishery Development Office (2020)

Types, Sources and Methods of Data Collection

The research is accomplished using primary and secondary data sources, which are qualitative and quantitative nature. The primary data necessary to achieve the designed objectives were obtained from sample households through structured questionnaire for sampled household and checklist for focus group discussion and key informants interview. Secondary data was collected from relevant sources such as, articles, proceedings, journals, CSA, and district annual reports which were vital to the study.

Data measurement

i. Output variable: It is defined as the actual quantity of milk produced and measured in liter (lt) during the 2020 production year by sample households. This is a dependent variable of the production function taken as a continuous variable.

ii. Input variables: Defined as the total inputs used by sample household in the production of milk namely: lactation cow (number), labor (Man-day), Green forage (*beli*) and crop residue (*beli*) in 2020 production year

(*1beli=1kg*).

iii. Dependent variables: The dependent variables for this study are; TE, AE and EE scores of milk production obtained from stochastic frontier function.

iv. Inefficiency variables

1. **Sex:** This is a dummy variable which was measured as 1 if the household head is male and 0, otherwise.
2. **Education**: It is a continuous variable which is defined as the education level of the sample household head. This variable was measured in terms of years of schooling.
3. **Concentrate**: the total amount of concentrate used by sampled households to produce milk in quintals (Qt).
4. **Total land**: refers to the total area cultivated (own, shared or rented in) land that the sample household managed during 2020 production year measured by hectare (ha).
5. **Extension**: The frequency of extension agent contact farmers and vice versa, measured by number of contact per production year.
6. **Grazing land**: it refers to the total grazing land area allotted by the sample household for cow milk production during 2020 that was measured in ha.
7. **Type of breed**: It is a categorical variable that takes a value of 1 if the farmers uses local breed, 2 if the farmers use both local breed and cross breed, and 3 if the farmers use cross breeding cows.
8. **Dairy experience**: It is a continuous variable and refers to the total years that the household participated in milk production, which is measured in years.
9. **Distance** It is defined as the distance of the nearest market from the house of the household head in walking minutes.
10. **Membership**: It is the dummy variable which takes a value 1 if the sampled farmer is in a dairy cooperative member and 0 otherwise.
11. **Feeding method**: It is a dummy variable equal to 1 for the farm that uses the total mixed ration (TMR) and 0 if the farm uses the pasture feeding method.
12. **Housing System**: It is a dummy variable which takes 1 for farms that use free stall housing and 0 otherwise.

Method of Data Analysis

Descriptive statistics

Descriptive statistics such as mean, minimum, maximum, percentages, frequencies and standard deviation or standard error were applied to describe demographic, socio-economic, farm characteristics, institutional characteristics and distribution of efficiency levels of milk producers in the study area. After coding and feeding the collected data into the computer, STATA version 15 was used for the analysis.

Econometric analysis

Specification of an econometric model

Coelli, Rao, and Battese (1998) recommended that Stochastic Frontier Production Function (SFPF) is more appropriate than DEA and deterministic models in agricultural applications, especially in developing countries, where measurement errors generally influence the data are generally influenced by measurement errors and the effect of weather, disease and pests play a significant role. Some researcher argues that Cobb-Douglas functional form has advantages over the other functional forms in that it provides a comparison between adequate fit of the data and computational feasibility. It is also convenient in interpreting elasticity of production and it is very parsimonious with respect to degrees of freedom and it is convenient in interpreting elasticity of production.

In addition, the Cobb-Douglas production function is attractive due to its simplicity and because of the logarithmic nature of the production function that makes econometric estimation of the parameters a simple matter.Translog production function is more complicated to estimate the parameters having serious estimation problems. One of the estimation problems is as the number of variable inputs increases, the number of parameters to be estimated increases rapidly. Another problem is the additional terms require cross products of input variables, thus making a serious multicollinearity problem (Coelli, 1995). Therefore, this study used stochastic production frontier to estimate the TE, AE and EE levels of smallholder milk producing farmers in the study area.

Following Aigner *et al.* (1977) and Meeusen and Van den Broeck (1977), the general functional form of the stochastic frontier model for this study is specified as follows:

$$Y_z = f(X_z; \beta_z) + \varepsilon_z \quad \text{......(2)}$$

Where z = 1, 2, 3... n; Y_z represent the observed milk output level of the z^{th} sample farmer; f (X_z; β_z) is the convenient frontier production function (e.g. Cobb-Douglas or Trans log); X_z denotes the actual input vector by the z^{th} farmer; β_z stand for the vector of unknown parameters to be estimated; ε_z is a composed disturbance term made up of two error elements (V_z and U_z) and n represents the number of farmers who will involve in the survey.

The stochastic frontier functional approach requires a priori specification of the production function to estimate the level of efficiency. Among the possible algebraic forms, Cobb-Douglas and trans- log functions were the most popularly used models in the most empirical studies of agricultural production analysis. Therefore, Cobb- Douglas production function was adopted for this study. Thus, Cobb-Douglas frontier function was specified as follows:

$$Y_z = AX_1^{\beta 1}X_2^{\beta 2}..X_n^{\beta n} \text{.......} (3)$$

The linear form of Cobb-Douglas production functions for this study was defined as:

$$\ln(Y_z) = \beta o + \sum_{j=1}^{4} \beta_j \, lnX_{jz} + \varepsilon_z \text{.......}(4)$$

$$\ln(Y_z) = \beta o + \beta 1 \ln(LACTATION\ COW) + \beta 2 \ln(GREEN\ FODDER) + \beta 3 \ln(CROP\ RESEDUE) + \beta 4 \ln(LABOR) + \varepsilon_z$$

$\mathcal{E}_z = V_z - U_z$

Where, *ln* denotes the natural logarithm (i.e., base e); j represents the number of inputs used; z represents the z^{th} farm in the sample; Y_z represent the observed milk output of the z^{th} sample farmer; X_{jz} denotes z^{th} farm input variables used in milk production of the z^{th} farmer; β_0 represent intercept; $\beta_1 - \beta_4$ stands for the vector of unknown parameters to be estimated and represent elasticity of milk production; $\mathcal{E}_z$ is a composed disturbance term made up of two error elements (V_z and U_z); the symmetric component (V_z) is assumed to be independently and identically distributed as random errors with zero mean and variance N (0, σ^2v), which captures inefficiency as a result of factors beyond control of farmers and U_z proposed to capture inefficiency effects in the production of milk.

Assuming that the production function in equation (4) is self- dual (e.g. Cobb Douglas), the dual cost function of the Cobb-Douglas production function can be specified as:

$$lnC_z = \alpha_0 + \sum_{j=1}^{4} \alpha_j lnW_{jz} + \alpha_j lnY^* + V_z + U_z \text{.......}(5)$$

Where z refers to the z^{th} sample farm; j is number of input; C_z is the minimum cost of production; W_{jz} denotes input prices of z th farm; Y* refers to milk output in litre; α's are parameters estimated; V_z denotes random variables assumed to be independent and identically distributed random errors with zero mean and variance and U_z denotes non-negative random variables which are assumed to account for cost inefficiency and assumed to be independent and identically distributed random errors with zero mean and variance.

Sharma *et al*. (1999) suggests that the corresponding dual cost frontier of the Cobb-Douglas production functional form in equation (5) can be rewritten as:

$C_z = C(W_z, Y^*, \alpha) + \varepsilon_z$ z=1, 2, 3…..n

The economically efficient input vector of the z^{th} farm X_z^e is derived by applying Arega and Rashid (2005) and substituting the firms input prices and adjusted output level, a system of minimum cost input demand equation can be expressed as:

$$\frac{\partial C_z}{\partial W_z} = X_z^e (W_z, Y^*; \alpha) \text{.......} (6)$$

We can define the farm-specific TE in terms of observed milk output (Y_z) to the corresponding frontier milk output (Y^*) using the existing technology.

$$TE_z = \frac{Y_z}{Y^*} = \frac{f(X_z;\beta)\exp(V_z - U_z)}{f(X_z;\beta)\exp(V_z)} = \exp(-U_z) \text{.......} (7)$$

The cost efficiency of an individual farm is defined in terms of the ratio of the observed cost (C) to the corresponding minimum cost(C^*) given the available technology. That is, cost efficiency (C_E):

$$C_E = \frac{C}{C^*} = \exp(U) \text{.......} (8)$$

Where the observed cost (C) represents the actual production cost whereas the minimum (efficient) cost (C^*) represents the frontier total production cost or the least total production cost level.

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

$$AE_z = \frac{1}{C_E} = \frac{C^*}{C} \text{.......} (9)$$

Following Ali *et al*. (2012), the EE index was derived from equations (8) and (9) as follows:

$$EE_z = AE_z x TE_z \text{.......}(10)$$

Determinants of inefficiencies

In this study, Tobit regression model was used, which is specified as:

$$y_z^* = \beta_0 + \sum_{k=1}^{12} \beta_k X_{kz} + U_z \qquad (11)$$

Where: y_z^*, a latent variable representing the efficiency scores of farm z (TE, AE and EE); β_o intercept; β_k unknown parameter; X_{kz} are demographic, institutional, socio-economic and farm-related variables which are expected to affect TE, AE and EE; k is a number of explanatory variables that affect TE, AE and EE and U_z is an error term that is independently and normally distributed with mean zero and variance σ^2.

Denoting y_z as the observed variables:

$$y_z = \begin{cases} 1 & \text{if } y_z^* \geq 1 \\ y_z^* & \text{if } 0 < y_z^* < 1 \\ 0 & \text{if } \boldsymbol{y_z^* \leq 0} \end{cases} \qquad (12)$$

Likelihood ratio statistic

Aigner *et al.* (1977) proposed the log likelihood function for the model in equation (3) assuming normal distribution for the technical inefficiency effects (U_z). They expressed the likelihood function using λ parameterization, where λ is the ratio of the standard errors of the non-symmetric to symmetric error term (i.e. $\lambda = \sigma U / \sigma v$). According to Bravo and Pinheiro (1997) gamma (γ) can beformulated as:

$$\gamma = \frac{\lambda^2}{1 + \lambda^2} \qquad (13)$$

In this study, the likelihood ratio test was conducted to select the appropriate functional form that best fits the data. The value of the generalized likelihood ratio (LR) statistic to test the hypotheses that all interaction terms, including the square specification is equal to zero (H_0: $\beta_{jz}=0$) was calculated as follows.

Following Greene (2003) the hypothesis tests were conducted using the log-likelihood ratio (LR) statistics, λ which is defined in equation (14):

$$LR(\lambda) = -2\ln\left[L(H_0)/L(H_1)\right] = -2\left[lnL(H_0) - lnL(H_1)\right] \qquad (14)$$

Where: LR= Generalized log-likelihood ratio

$L(H_o)$ = Denotes the likelihood function value under the null (H_o)

$L(H_1)$ = Denotes the likelihood function value under alternative hypothesis (H_1)

This value was compared with the upper 5% point for the χ^2 distribution and the decision was made based up on the model result. If the calculated χ^2 value is less than the tabulated upper 5 percent point of the critical value, we accept the specified null hypothesisis at a 5 percent level of significance.

Milk yield gap

Yield gap is the difference between yield potential and actual farmers' yields over a given spatial or temporal scale (Ittersum *et al.*, 2013). The study measured the milk yield gap to determine how much milk output is lost because of inefficiency variation among milk producing farmers in the study area. From the stochastic model defined in equation (15), TE of z^{th} farmer was estimated as follows.

$$TE_z = \frac{Y_z}{Y_z^*} = \frac{f(Xz;\beta)\exp(Vz - Uz)}{f(Xz;\beta)\exp(Vz)} = \exp(-Uz)$$

Then solving for Y_z^*, the potential milk output (liter/cow/day) of each sample household is represented as:

$$Y_z^* = \frac{Y_z}{TE_z} = f(Xz;\beta)\exp(Vz) \qquad (15)$$

TE_z= technical efficiency of the z^{th} sample household in milk production

Y_z^*= the frontier or potential output of the z^{th} sample household in milk production in liter/cow

Y_z=the actual or observed output of the z^{th} sample household farmer in milk production in liter. Hence, milk yield gap (liter/cow/day) =potential yield (liter/cow/day)-actual yield (liter/cow/day).

Thus, Milk Yield gap $= Y_z^* - Y_z$ ....(16)

Results and Discussions
Descriptive Statistical Results

Table 2: Descriptive statistics of dummy variables

Variables	Description	Frequency	Percent
Sex	Male	357	89.25
	Female	43	10.75
Type of breed	local	10	2.5
	Both	200	50
	Cross	190	47.5
Housing system	Not	122	30.5
	Free stall	278	69.5
Feeding method	Not	96	24
	Total mixed ratio	304	76
Dairy membership	Not member	301	75.25
	Member	99	24.75

Source: Own computation (2020)

Table 3: Descriptive statistics of continuous variables

Variable description	Mean	Std. Dev.	Minimum	Maximum
Family size(AE)	3.86	1.63	1	9.05
Education (year of schooling)	3.69	3.84	0	15
Dairy farm experience(years)	14.96	10.73	1	60
Total land(ha)	2.24	1.72	0.125	10
Grazing land(ha)	0.48	0.46	0	3
Amount of concentrate feed used(qt)	20.58	77.68	0	1300
Frequency of Extension(number)	4.34	14.29	0	24
Distance from home to market(minute)	45.84	31.75	1	180
Total livestock owned (TLU)	4.69	2.67	0	17.77

Source: Own computation (2020)

Inputs used for milk production and cost function

The production function for this study was estimated using four input variables. On average, sample households produced 4989.03 lt of milk per lactation period, which is the dependent variable in the production function. The number of lactation cows, by sample households during the study, ranged from 1 to 9 with an average number of 2.94. On average, the amount of human labour, green forage and crop residue used by the sampled milk producers was 717.45man day (MD), 202.3qt and 38.2qt respectively(qt=quintals). Among the various cost of factors of production, the cost of lactation cow accounted for the highest share (56112.5birr). Following the cost of lactation cow, cost of labour takes major share out of total cost of production which is 21523 birr. Besides, cost of crop residue takes the smallest share (3152.56 birr) out of the total cost of milk production (Table 4).

Table 4: Summary statistics of variables used to estimate milk production and cost function

Variable	Unit	Mean	Std. Dev.	Minimum	Maximum
Milk output per lactation	Liter	4989.03	5161.66	300	48000
Lactation cow	Number	2.94	2.03	1	9
Labor	(MD)	717.45	410.76	54	3078
Green forage	*Beli*	202.30	1243.97	2	24300
Crop residue	*Beli*	38.20	59.74	1	560
Cost of lactation cow	Birr	56112.5	63394.22	8000	320000
Cost of labor	Birr	21523	12322.82	1620	92340
Cost of green forage	Birr	18676.63	106405.1	160	2065500
Cost of crop residue	Birr	3152.56	3775.36	97.5	42000

Source: Own computation (2020)

Econometric Results
Hypothesis Testing

The first null hypothesis tested was, test for the selection of the appropriate functional form for the data; Cobb-Douglas versus Translog production function. The functional form that can best fit to the data was selected by testing the null hypothesis. The result indicated that the null hypothesis was accepted and Cobb-Douglas functional form best fits the data. The second null hypothesis tested was, the test for the existence of the inefficiency component of the composed error term of the Stochastic Frontier Model (SFM). This is made in order to decide whether the traditional average production function (OLS) best fits the data set as compared to the stochastic frontier model selected for this study. The result showed that the SFPF was an adequate representation of the data. The third null hypothesis is explored that farm-level technical inefficiencies are not affected by the farm and farmer-specific variables, and/or socio-economic variables included in the inefficiency model. The result indicated that the null hypothesis is rejected in favor of the alternative hypothesis that explanatory variables associated with inefficiency effect model are simultaneously not equal to zero. Hence, these variables simultaneously explain the difference in efficiency among sampled farmers (Table 5).

Table 5: Generalized likelihood ratio tests of hypothesis for the parameters of the SFPF

Null hypothesis	Df	LR	χ^2 value at 5%	Decision
$H_0 = \beta_{zj} = 0$	10	15.46	18.31	Accept H_0
$H_0 = \gamma = 0$	1	10.04	3.84	Reject H_0
$H_0: \delta_0 = \delta_{1=}\delta_{2=}..\delta_{12} = 0$	12	149.38	21.03	Reject H_0

Source: Own computation (2020)

Parameter estimates of the SFPF model and cost function

The maximum likelihood estimate of the parameters of the SFPF for milk producers in North Shewa Zone was presented in Table 6. The results of the model showed that the input elasticity for each input in the SFPF. Among four input variables analyzed in the stochastic frontier model, the parameter for lactation cow and crop residue were found to be significant at 10%, as hypothesized as well as green forage found be to be significant at 5% . The parameter estimate for labor turned out to be insignificant. The insignificance of the estimated coefficients for labor implies that use of this input has no significant effect on milk production in the study area.

Table 6: MLE for the parameters of the SFPF

Variables	Parameter	Coef.	Std. Err.
Intercept	β_0	7.645	0.527
Ln lactation cow	β_1	0.109*	0.062
Ln labor	β_2	0.101	0.074
Ln green forage	β_3	0.062**	0.084
Ln crop residue	β_4	0.074*	0.039
Variance parameter:			
$\lambda = \sigma_{u/}\sigma_v$		1.33	0.173
Gamma (γ)		0.64	

Note: ** and * refers to5% and 10% significance level, respectively.

Source: Model output (2020)

The SFPF model results reveal that the estimated positive and coefficient of lactation cow (0.109), green forage (0.062) and crop residue (0.074) was found to significant and positive at 5% (green forage) and10% (lactation cow and crop residue) probability level. This indicated that lactation cows, green forage and crop residue were the most important determinant inputs of milk production in the study area. This suggests that a one percent increase in lactation cow for milk production, all things being equal, would lead to an increase of 0.109% in the output of milk production. In the same way, on average a one percent increase in the quantity of green forage and crop residue, milk output would increase by 0.062% and 0.074% respectively.

The diagnostic statistics of inefficiency component reveals that sigma squared (σ^2) was statistically significant at 5% 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 (σ_u) to the standard error of V (σ_v), known as lambda (λ), is 1.33. Based on λ, gamma (γ) which measures the effect of technical inefficiency in the variation of observed output can be derived (i.e.$\gamma = \frac{\lambda^2}{[1+\lambda^2]}$) (Bravo and Pinheiro, 1997). The estimated value of gamma (γ) was 0.64 which indicates that 64% of total variation in milk output from the frontier is due to technical inefficiency among sample farmers in the study area and 36% of the variation in output from the frontier is due to random noise or random error (beyond the control of the farmers).

The dual frontier cost function derived analytically from the stochastic production frontier shown in Table 6 is given by:

$lnCz = 1.9186 + 0.0113lnW_{1jz} + 0.0261lnW_{2jz} - 0.0141lnW_{3jz} - 0.0301lnW_{4jz} + 1.0043lnY^*$. Where C_z

is the minimum cost of production of z^{th} sample farmers; W_{jz} denotes input prices of z th farm; Y* refers to milk output in liter.

Efficiency scores and their distribution

The MLE results of the stochastic frontier production functions estimated for the individual farm level TE, AE and EE independently for sample smallholder farmers. The model output presented in Table 7 indicates that the mean TE of sample farmers was about 0.580 with a minimum level of 0.156 and the maximum level of 0.842. This means that if the average farmer in the sample was to achieve the technical efficient level of its most efficient counterpart, then the average farmer could realize 31.12% derived from (1-0.580/0.842)*100 increase milk output by improving TE with existing inputs and technology, using the resource at their disposal in an efficient manner without introducing other improved or external inputs and practice.

In addition, Table 7 shows that the average AE of the sample farmers was about 0.776 with a minimum of 0.299 and a maximum of 0.979. This shows that farmers are not allocatively efficient in producing milk. Hence, a farmer with average level of AE would enjoy a cost saving of about 20.74% derived from (1 – 0.776/0.979)*100 to attain the level of the most efficient farmer. Similarly, the mean EE of the sample farmers was 0.447 implying that there was a significant level of inefficiency in the production process. That is the producer with an average EE level could reduce current average cost of production by 44.81% which derived from (1-0.447/0.810)*100 to achieve the potential minimum cost level without reducing output levels. It can be inferred that if farmers in the study area were to achieve 100% EE, they would experience substantial production cost saving of 44.81%. This low average level of EE was the total effect of both technical and allocative inefficiencies.

Table 7: Estimated TE, AE and EE scores

Types of efficiency	Mean	Std. Dev.	Min	Max
TE	0.580	0.141	0.156	0.842
AE	0.776	0.148	0.299	0.979
EE	0.447	0.133	0.102	0.810

Source: Model output (2020)

The distribution of the TE scores showed that about 47% of the sample households had TE scores of 0.6 to 0.799. 11% of the households' TE scores fell in the range 0.2-0.399. On average, households in this cluster have a room to enhance their milk production at least by 42%. Out of the sample households, only 2% had TE score of greater than 0.8. This implies that about 98% of the households can increase their production at least by 20%. The AE distribution scores indicated that about 59.25% of milk producers operated above 0.8 efficiency level. The distribution of EE scores also implies that 51.75% of the household heads have an EE score of 0.4-0.599. This also indicates the existence of substantial economic inefficiency than technical and allocative inefficiency in the production of milk during the study period in the study area (Table 8).

Table 8: Distribution of TE, AE and EE

Efficiency range	TE		AE		EE	
	Frequency	%	Frequency	%	Frequency	%
<0.2	3	0.75	0	0	15	3.75
0.2-0.399	44	11	1	0.25	124	31
0.4-0.599	157	39.25	77	19.25	207	51.75
0.6-0.799	188	47	85	21.25	53	13.25
0.8-0.999	8	2	237	59.25	1	0.25

Source: Model output (2020)

Yield gap due to technical inefficiency

Yield gap analysis is an essential tool to measure to what extent the production could be increased if all factors are controlled. Using the actual output values of the predicted TE indices, the potential output was estimated for each household in milk production per cow per day. Hence, the mean level of the actual and potential milk yield per cow per day was 10.1 liter /cow/day and 19.7 liter /cow/day, respectively. Using the t-test method, the mean difference of the actual and the potential yield was found to be statistically significant at 1% level of significance. Therefore, the average of milk yield gap that is lost due technical inefficiency, which was the mean difference between actual (10.1 liter/cow/day) and the potential output (19.7lit/cow/day) was, 9.6lt/cow/day (Figure 1). This indicates that there is room to boost milk production on average by 9.6 liter/cow/day with the existing level of input use. On average, the money value of milk output that lost due to technical inefficiency (yield gap) was 153.6birr/cow/day, since the value of 1lt of milk is 16 Ethiopian birr.

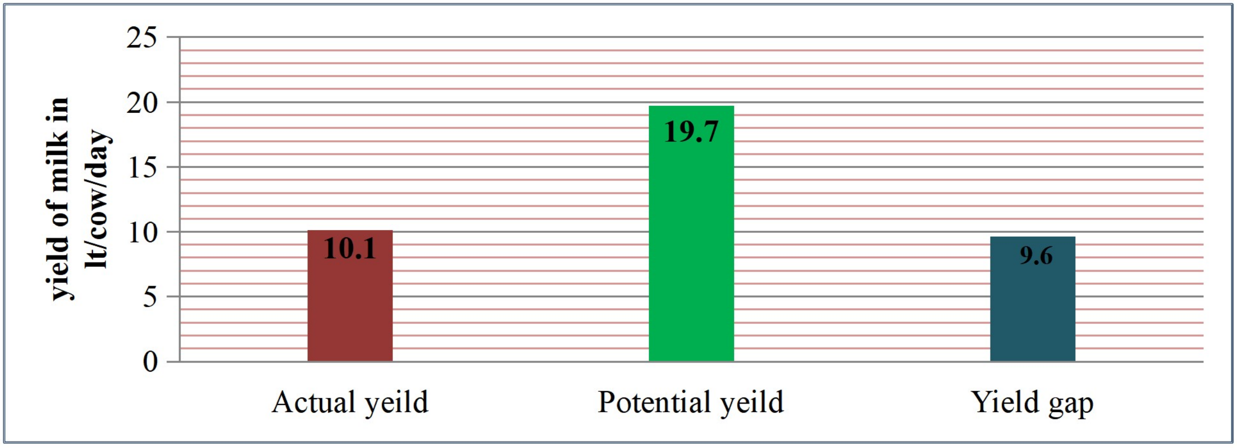

Figure 1: Distribution of actual and potential level of milk output
Source: Own computation (2020).

Determinants of inefficiencies

The result of two- limit Tobit model (Table 9) for each significant variable and its marginal effects of change in explanatory variables (Table 10) on TE, AE and EE were discussed as follows.

Educational: The findings of the study show that education affected TE and EE of milk producers significantly and positively at 1% significance level. The positive sign implies that more educated farmers tend to be more efficient in milk production than the less educated in the study area. This is due to the fact that better educated household head can use dairy technology easily and are able to apply technical skills imparted to them. A one year increase in educational level of the household head increases the probability of a farmer being technically efficient and economically efficient by 0.34% and 0.01%, and the mean values of technical and economic efficiencies by about 0.92% and 0.97% with an overall increase in the probability and levels of technical and economic efficiencies by 1%, and 0.98%, respectively. The result is agreed with the finding of Al-Sharafat (2013).

Total land: The result indicated that total land was positive and significant effect on AE and EE at 1% level of significance as expected. This implies that, total land is an important factor in influencing the level of AE and EE in the production of milk or positively contributes to AE and EE of milk production in the study area. This implies that households who have more land were relatively better in AE and EE. A unit increase in total land (ha) would increase the probability of the farmer being AE and EE by about 1.09% and 0.01% and the expected values of AE and EE by about 0.94% and 0.86% with an overall increase in the probability and levels of AE and EE by 1.13% and 0.87%, respectively.

Dairy experience: Experience significantly and positively affected AE of sampled households at 10% level of significance, which is in line with the hypothesis made. The possible reason is that having more experience and knowledge on dairy production methods, would increase the probability of the farmers to participate in dairy production. The more dairy production experience, the higher the likelihood of accumulating physical and social capital. The accumulations of physical and social capital can offer farmers' better exposure and capacity to produce more dairy production. The study result revealed that, a one year increase of experience in dairy farming would increase the mean values of AE by about 0.04% with an overall increase in the probability and the level of AE by about 0.04%. The finding of this study agrees with the earlier research finding of Al-Sharafat (2013).

Dairy membership: It was found to have a significant and positive effect on AE 10% significance level. The result indicates that the sample farmers who participate in dairy member were more efficient than others. This is because farmers who participate in dairy cooperative can get different knowledge, information, training and market access. Moreover, the computed marginal effect result also shows that, a change in the dummy variable, dairy member from (0 to 1), would increase the probability of the farmer being allocatively efficient by about 4.35% and the expected values AE by about 3.22% with an overall increase in the probability and levels of AE by 3.92%.

Amount of concentrate used: The result revealed that, amount of concentrate feed used by sampled households affected TE positively and significantly at 1% and affect AE negatively and significantly at 5%. This may due to the fact that concentrate feed provide different nutrients for milking cows which increase the productivity of lactation cow. But the price of this feed is become increasing due to this, farmers may fail to allocate (minimize) cost of this feed. Furthermore, the computed marginal effect result shows that, a unit increase in concentrate (qt) would increase the probability of TE and decrease the probability of AE by 0.01% and 0.01% and increase mean values of TE and decrease the mean values of AE by 0.02% and 0.01% with an overall increase in the probability and the level of TE and decrease an overall AE by about 0.02% and 0.02% respectively. This is in line with the research results of Amlaku *et al*. (2013).

Grazing land: Grazing land significantly and positively affected both TE and EE of the sampled households' at1% level of significance, which is in line with the hypothesis made. The possible reason is that having more grazing land provides more of feed for the milking cows which results increase in milk output. It is the main resource needed by the farmers to feed their livestock which is the main source of feed by providing different fodder and grasses. A unit increase of grazing land would increase the probability of a farmer being both technically and economically efficient by 1.97 % and 0.04% and the mean values of TE and EE by about 5.58% and 3.92% with an overall increase in the probability and the level of TE and EE by about 5.85% and 3.96% respectively.

Type of breed: The result indicated that type of breed was positive and significant effect on TE at 5% and AE and EE at 1% level of significance respectively as expected. This implies that, cross breed is an important factor in influencing the level of TE, AE and EE in the production of milk or positively contributes to TE, AE and EE of milk production in the study area. Breeds are believed to be genetically improved which makes them more efficient than local breed. A change from local to cross breed of milking cows increases the probability of a farmer being TE, AE and EE by 0.85%, 8.69% and 0.07% and the mean values of technical, allocative and economic efficiencies by about 2.33% ,7.54% and 7.61% with an overall increase in the probability and levels of technical, allocative and economic efficiencies by 7.53% , 9.02% and 7.69 %, respectively. The result is in line with previous studies by Mekdes (2017).

Frequency of extension contact: The result showed that the variable had positive sign and significant effect on TE and EE at 1% level as expected. The reason is that farmers who had more frequency of extension; could lead them to improvements in resource allocation, facilitates practical use of modern techniques and use inputs in appropriate way during dairy production. A one times increase in frequency of extension of household head increases the probability of a farmer being technically efficient by 0.17% and the mean values of technical and economic efficiencies by about 0.46% and 0.42% with an overall increase in the probability and levels of technical and economic efficiencies by 0.5% and 0.42%, respectively. The finding is in line with the study of Fita *et al*. (2013).

Table 9: A two-limit Tobit regression results of determinants of TE, AE and EE

		TE		AE		EE	
Variables	Parameters	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Const	δ_0	0.4261***	0.0479	0.4517***	0.0430	0.4517***	0.0430
Sex	δ_1	0.0272	0.0203	0.0029	0.0215	0.0221	0.0178
Education	δ_2	0.0102***	0.0017	0.0026	0.0018	0.0098***	0.0015
Total land	δ_3	0.0008	0.0038	0.0120***	0.0040	0.0087***	0.0033
Experience	δ_4	-0.0003	0.0006	0.0012*	0.0006	0.0004	0.0005
Membership	δ_5	-0.0246	0.0150	0.0422*	0.0159	0.0061	0.0131
Concentrate	δ_6	0.0002***	0.0001	-0.0002**	0.0001	0.0001	0.0001
Grazing land	δ_7	0.0595***	0.0139	-0.0129	0.0147	0.0397***	0.0122
Type of breed	δ_8	0.0257**	0.0118	0.0960***	0.0125	0.0770***	0.0103
House system	δ_9	-0.0051	0.0091	0.0094	0.0096	0.0010	0.0080
Type of feeding	δ_{10}	-0.0052	0.0153	0.0248	0.0162	0.0130	0.0134
Extension	δ_{11}	0.0051***	0.0080	0.0005	0.0017	0.0042***	0.0014
Distance	δ_{12}	-0.0002	0.0031	0.0000	0.0022	-0.0002	0.0002

Note: ***, ** and *sign represents significance at 1%, 5% and 10% levels, respectively.

Source: Model output (2020)

Table 10: Marginal effects of change in explanatory variables

Variables	Marginal effect of TE			Marginal effect of AE			Marginal effect of EE		
	$\partial E(y)$	$\partial E(y^{*})$	$\partial[\varphi(Z_U)-\varphi(Z_L)]$	$\partial E(y)$	$\partial E(y^{*})$	$\partial[\varphi(Z_U)-\varphi(Z_L)]$	$\partial E(y)$	$\partial E(y^{*})$	$\partial[\varphi(Z_U)-\varphi(Z_L)]$
Sex	0.0268	0.0249	0.0074	0.0027	0.0022	0.0025	0.0220	0.0218	0.0004
Education	0.0100	0.0092	0.0034	0.0025	0.0021	0.0024	0.0098	0.0097	0.0001
Total land	0.0007	0.0007	0.0002	0.0113	0.0094	0.0109	0.0087	0.0086	0.0001
Experience	-0.0003	-0.0002	-0.0001	0.0011	0.0009	0.0011	0.0004	0.0004	0.0000
Membership	-0.0242	-0.0224	-0.0073	0.0392	0.0322	0.0435	0.0061	0.0060	0.0000
Concentrate	0.0002	0.0002	0.0001	-0.0002	-0.0001	-0.0002	0.0001	0.0001	0.0000
Grazing land	0.0585	0.0538	0.0197	-0.0121	-0.0101	-0.0117	0.0396	0.0392	0.0004
Type of breed	0.0253	0.0233	0.0085	0.0902	0.0754	0.0869	0.0769	0.0761	0.0007
House system	-0.0050	-0.0046	-0.0017	0.0089	0.0074	0.0085	0.0010	0.0010	0.0000
Type of feed	-0.0051	-0.0046	-0.0017	0.0234	0.0197	0.0208	0.0130	0.0129	0.0002
Extension	0.0050	0.0046	0.0017	0.0005	0.0004	0.0005	0.0042	0.0042	0.0000
Distance	-0.0002	-0.0002	-0.0001	0.0001	0.0001	0.0001	-0.0002	-0.0002	-0.0000

Note: $\frac{\partial E(y)}{\partial X_j}$ (total change), $\frac{\partial E(y^{*})}{\partial X_j}$(expected change) and $\frac{\partial[\varphi(Z_U)-\varphi(Z_L)]}{\partial X_j}$ (change in probability).

Source: Model result (2020)

Conclusion and Recommendation

Conclusion

The study estimated efficiencies using the stochastic production frontier model. The findings indicated that number of lactation cows, green forage and crop residue were significant determinants of production level. The study also found that farmers can increase milk production by 42% without increasing inputs if they were technically efficient, reduce current cost of inputs by 22.4% with cost minimization way and improve EE by 55.3% when resources are used efficiently. The positive and significant variables namely; education, total land, dairy experience, dairy membership, amount of concentrate feed, type of breed and frequency of extension in the present study imply that they play great role in enhancing efficiency and productivity of milking cow. An important conclusion coming from the analysis is that, milk producers in the study area are not operating at full TE, AE and EE level which implies that there is an opportunity for milk producers to increase output at existing levels of inputs and minimize cost without compromising yield with present technologies.

Recommendations

The result of the study provides information and got some policy recommendations to policymakers and extension workers as follows:

- Regional government should have responsibility to keep on the provision of education, adequate extension services in this area so that farmers can use the available inputs more efficiently under the existing technology.
- Livestock office should give great attention on cross variety of cows by using artificial insemination in the study area.
- Dairy cooperative should be encouraged by the concerned body like *woreda*, zonal and regional government.
- The study revealed that the number of lactating cows, green forage and crop residue were found to be highly significant hinting that these are the most critical input to increase milk production and productivity. So that producers and policy makers should use this opportunity to alleviate the existing level of food deficiency & poverty that is to say in designing development policy specifically for improving milk production.
- Adequate and proper management of grazing land should be done by the farmers and concerned body.

Conflict of interest

All authors declare that there is no any conflict of interest regarding publication of this manuscript.

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