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TECHNICAL EFFICIENCY OF SMALLHOLDER DAIRY FARMERS IN URBAN ETHIOPIA: THE CASE OF SULULTA TOWN

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ABSTRACT

This study aimed to estimate the level of technical efficiency of smallholder dairy farmers and identify determinants of technical inefficiency, in Oromia National Regional State, Ethiopia. To accomplish these objectives, cross-sectional data for the year 2017/18 were collected from 112 dairy farmers from Sululta town by using a systematic random sampling technique. To analyze the data both descriptive and econometric techniques were used and a stochastic production frontier of the Cobb-Douglas functional form was found to be the best fit for the data. The findings of the analysis showed that the mean level of technical efficiency score was 81% with a discrepancy ratio (γ) of 91%. Similarly, the result further revealed that number of crossbreed cows; concentrate, roughage and labour have a significant and positive effect on the average level of milk output. On the contrary, the total number of local breed cows, grazing land, veterinary cost and services were found to be insignificant in influencing milk output. Among farm specific demographic and socioeconomic factors, experience in dairy farming, family size, herd size, extension service, training and market access were found to be negative and significant in determining technical inefficiency except access to the market. Therefore, the findings of the study suggest that policymakers should not stick only to the introduction and dissemination of inputs to the dairy farmers, like crossbreed cows, concentrates but need to give due attention towards improving the existing level of efficiency among farmers.

Key Words: Technical efficiency, Stochastic production frontier, Cobb-Douglas, Input variables, Inefficiency variables.

INTRODUCTION

1.1 Background of the Study

For many developing countries agriculture is the main economic activity. It is the backbone of their economy. In Ethiopia, it is the major source of livelihood for 80% of the population in the country (MoFED, 2010). The livestock sector in particular is a necessary component to sustain the agricultural system which accounts for about 45% of the agricultural GDP (IGAD, 2010) and directly supports the livelihoods of 60-70% of the population (Anteneh, 2008). The livestock sector is an important agricultural sector that contributes to the Ethiopian economy through the dairy sub-sector in both rural and urban areas. It is contributing to food security in the country (Azage et al., 2012).

Taking into consideration the population growth rate of about 2.6% per annum and the likely increase in demand for dairy products especially in the urban areas, milk production is expected to grow in Ethiopia between 3.8% and 4% annually until 2020 (FAO, 2005a). However, the efficiency of the dairy sector or milk production performance in Ethiopia, particularly in the study area is below the expected level and there are a number of factors that accounted for its inefficiency. These include high human and livestock populations (that compete for land and other resources), land shortage, prevalence of animal disease, shortage of livestock feeds both in quantity and quality, poor genetic potential of

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indigenous cattle (Zebu[1]), reduced lactation period and extended calving interval (Yigrem et al., 2008; Ahmed et al., 2010).

Africa contributes to only 5% of the world's milk production. Even in Africa Ethiopia is not among the largest four (Egypt, Kenya, South Africa, Sudan) milk producing countries despite its large livestock population. It is estimated to be 270 liters per cow per lactation versus 498 and 480 liters in neighboring countries of Kenya and Sudan, respectively (FAO, 2010). Also, the per capita consumption of milk in Ethiopia is the lowest in Africa which is about 23 kg per annum, while the per capita milk consumption in Africa, on averages, is 37.2 kg. The sub-Sahara average is below this which is 27.5 kg (Tesfaye et al., 2010).

Despite a number of studies conducted in both urban and peri-urban areas of Ethiopia to examine the potential of the dairy sector, many of these studies focused on technology constraints of the sector including poor genotypes of local breed animals, animal disease, feed availability and input and output market (Asrate, 2013; Ulfina et al., 2013 and Nigusu et al., 2014). Also, most studies on technical efficiency in Ethiopia focused on crop production (Fekadu, 2004; Hailesilasie, 2005; Kinde, 2005). Less emphasis was given to study the technical efficiency of the dairy sector and milk producers. They are unable to achieve why farmers do not achieve the maximum average technical efficiency level. For instance, Fita et al., (2013) and Zewdie et al. (2015) reported that milk producers achieved an average technical efficiency level of 65% and 55%, respectively. So this research tried to fill this gap.

Introduction of new technologies alone regardless of knowing how efficient farmers are in using the existing technologies may result in inefficiency. Theoretically, the introduction of new technology can increase agricultural output. But Tarkamani and Hardarkar (1996) argued that in areas where there is inefficiency, trying to increase a new technology may not have the expected impact if the existing technology is not efficiently used. So there is a need of integrating modern technology with an improved level of efficiency.

The researchers were motivated to conduct this research, because, most farmers in the study (Sululta town) area have dairy farms. Their land is not suitable for agronomic practices because it has a water logging problem. In order to increase milk production regional and town agricultural experts merely disseminate improved dairy breeds, feeds and other technologies without considering the level of technical efficiency.

Accordingly, this study aimed to estimate the level of technical efficiency and identifying determinants of technical inefficiency of smallholder dairy farmers to fill the research gaps in the dairy sub-sector. This provides inputs to policymakers to improve the technical efficiency level of dairy farming in addition to focusing on distribution improved inputs to increase milk production.

LITERATURE REVIEW

2.1 Concepts of efficiency and productivity

The papers by Debreu (1951) and Koopmans (1951) mark the origin of discussion on the measurement of productivity and efficiency in the economic literature. The work of Debreu and Koopmans was first extended by Farrell (1957) to measure productivity and efficiency. The efficiency of a firm is defined as the actual productivity of the firm relative to a maximal potential (also known as best practice frontier) productivity. Measurement of efficiency involves measurement of distance from the observed data point to that frontier. Efficiency has two components: technical efficiency and allocative efficiency (Coelli et al., 1998).

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[1] *Zebu*:-Poor genetic potential indigenous cattle breed commonly found in Ethiopia and Kenya

Allocative efficiency is the ability of a firm to use inputs in optimal proportion, given their respective prices and the production technology (Coelli et al., 1998). Economic efficiency is the product of technical and allocative efficiency. A firm both technically and allocatively efficient is said to be an economically efficient firm (Coelli et al., 1998).

The measure of efficiency is derived by seeing how the performance of individual firms within an industry compares with the industry's frontier function. The efficiency of an individual production unit is measured by its deviation from the frontier function. The concept of production efficiency in general and the distinction between technical and allocative efficiency, in particular, is further explained using two approaches: input-oriented and output-oriented approaches (Coelli et al., 1998).

Input oriented concept of efficiency addresses the question "By how much a production unit can proportionally reduce the quantities of input used to produce a given amount of output?" (Coelli et al., 1998). The value of TE lies between 0 and 1. A firm is technically efficient if it has TE equal to 1. If the value of TE is less than 1, the firm is technically inefficient. But output- oriented concept of efficiency answer the question "By how much can output be increased without increasing the amount of inputs used?"(Coelli et al, 1998). The output oriented measures of efficiency focus on the changes in the output of a firm that may be achieved when using the same quantity of inputs

2.2. Measurement approaches of efficiency

Measures of efficiency could be production functions and frontier models.

2.2.1. Average production function

The production function approach involves the estimation of an average production function by comparing marginal value product (MVP) of each input with its marginal factor cost (MFC). If MVP is not equal to MFC, it indicates that the input is not being used efficiently. The average production function approach has been used extensively in traditional agriculture to measure resource allocative efficiency.

2.2.2 Frontier models

Frontier models are broadly categorized under two frontier methods. These are the parametric frontier model and non-parametric frontier model. The parametric frontier model may further be classified into deterministic frontier model and stochastic frontier model. The parametric models are estimated based on econometric methods and the non-parametric efficiency model, often referred to as data envelopment analysis (DEA), involves the use of a linear programming method to construct a non-parametric 'piecewise' surface (or frontier) over the data. The parametric approach involves a specification of a functional form for the production technology and an assumption about the distribution of the error terms (Battese et al., 2005).

2.2.2.1 Deterministic frontier model

In the deterministic frontier model, the technical efficiency of the farmer is indicated by the factor by which the actual (observed) production deviates from the frontier (maximum possible output). That is, the ratio of the observed output for the i^{th} farm, relative to the potential output, defined by the frontier function, given the input vector, X_i is used to define the technical efficiency of the i^{th} farm: A parametric frontier production model of Cobb-Douglas form may be specified as;

$$\ln y_i = X'_i\beta - u_i i = 1, 2, 3 \ldots N \qquad (2.1)$$

Where: -$\ln y_i$ is output for the i^{th} farmer (log-normalized); X_i inputs used by the i^{th} farmer, β_i, parameters, and u_i is a non-negative random variable associated with technical inefficiency.

The main criticism of the deterministic frontier model is that it rules out the possibility of a deviation from the frontier being caused by measurement error or other noise (such as bad weather) which are beyond the control of farmers and the deterministic approach assumes that all deviations from the frontier are due to (Coelli et al., 1998).

2.2.2.2. Stochastic frontier model

The Stochastic frontier function proposed by Aigner et al. (1977) and Meeusen and van den Broeck (1977) is depicted as follows;

$$\mathbf{ln(y_i) = X'_i\beta + v_i - u_i}, \quad i = 1, 2, \ldots N \qquad (2.2)$$

Where:-i - is the number of farms in the study; $\varepsilon_i = v_i - u_i$,

$\ln(y_i)$ - is the natural log of (scalar) output of the i^{th} farmer;

X'_i - is a (K+1) - logarithms of the K-input quantities used by the i^{th} farmer;

$\beta = (\beta_{0,}\ \beta,\ {}_1\ \beta_{2,}\ \ldots\ldots\ \beta_{k)'}$ is a (K+1) – parameters to be estimated;

v_i- is random error term of the model which can be positive or negative.

u_i - is a non-negative random variable associated with technical inefficiency in production of farms in the industry involved.

Equation (2.2) can be relaxed as;

$$\mathrm{Lny}_i = \beta_0 + \beta_1 \ln x_i + v_i - u_i$$

Or

$$y_i = \exp(\beta_0 + \beta_1 \ln x_i + v_i - u_i)$$

Or

$$yi = \underbrace{\exp(\beta 0 + \beta 1 lnxi)}_{\substack{Deterministic \\ component}} \mathrm{X} \underbrace{\exp(vi)}_{noise}\, x\, \underbrace{\exp(-ui)}_{inefficiency} \qquad (2.3)$$

The random errors, $v_i$is assumed to be independently and identically distributed as N (0, σ^2_v) random variables and independent of the u_i's , which is assumed to be non-negative truncations of the half-normal distribution. Therefore this research applies the stochastic frontier model, since there are factors beyond the control of dairy farming.

2.3 Empirical literature

Mugambi et al. (2010) undertook a study to identify the technical and cost efficiency of dairy cow farmers in Kenya for a sample of 135 randomly selected farmers. The findings of the research showed that the mean farmers' technical and cost efficiency were 83.7% and 1.044, respectively. They found that number of lactating cows, amount of roughages, concentrates and mineral supplements and labour were important in determining milk output. Whereas, Hazneci and Ceyhan (2015) investigated the productive efficiency of 67 randomly selected dairy farms in Turkey. They estimated productive efficiency scores using stochastic frontier analysis. The technical efficiency level of the sampled dairy farm was found to be 78%. They identified the education level of farm operators, feeding frequency, the ratio of Holstein stock and land allocation to fodder crops, better agricultural extension services, farmer training, access to loan affected technical inefficacy negatively and significantly while experience, organizational membership, record keeping, pasture land, credit were statistically insignificant.

Nakanwagi et al. (2015) has done a research to analyze the technical efficiency of milk producers in Uganda. Their finding showed that milk production achieved an average technical efficacy level of 68%. Exotic cows, veterinary cost, herd size, hired labors, land ownership, farm asset, water sources and extension services were found to affect technical efficiency positively and significantly. But, the age of the farmer, education level of the farmer, amount of non-farm income, household size, group membership and distance from town were found to be insignificant.

Nega and Simeon (2006) made a study in the central highlands of Ethiopia to analyze the technical efficiency of smallholder dairy farmers. The result revealed milk production achieved an average technical efficacy level of 79%. The findings of the study showed that cross breed cows, amount of forage, amount of concentrate, and training were significant in determining milk production while local breed cows, sex of the farmer, age of the farmer, family labor, hired labor and access to credit were not significant. Fita et al. (2013) also identified training, dry fodder and concentrate feeds, educational level, labor and experience of the farmers in dairy farming had positive effects on technical efficiency. The finding also showed that the mean technical efficiency of milk production of the peri-urban and urban were 67.47% and 63.06%, respectively and the overall mean of technical efficiency was 65%.

METHODOLOGY

3.1Research Design

Descriptive and explanatory research designs were used to achieve the objectives of the research. As well cross-sectional data was applied. Since the population from which the sample was drawn is finite, the formula provided by Kothari (2004) was employed to determine the sample size. The town consists of 7434 households participating in different economic activities. Out of these households, 2163 households were engaged in dairy farming, so that, 112 smallholder dairy farmers were chosen by systematic random sampling technique from all four *kebeles* of the town. Lists of smallholder dairy farmers were available at the office of development agents working in the *kebele*. The study used both primary and secondary data sources. Primary data was collected from smallholder dairy farmers using a structured questionnaire and secondary data were collected from the Sululta town Agricultural Desk. To analyze the collected data both descriptive and econometrics analysis techniques were used.

3.2 Econometric Models

3.2.1 Specification of Stochastic production frontier model

Since the stochastic production frontier model assumes half normal distribution, Aigner, Lovell and Schmidt (1977) obtained maximum likelihood (ML) estimates under the assumption of v_i- iid N $(0,\sigma_v^2)$, u_i-iidN^+ $(0, \sigma^2_u)$. The model is specified as follows:

$$\ln (y_i) = X_i\beta + v_i - u_i \text{ , } i= 1, 2, \ldots\ldots N \qquad (3.1)$$

Where:

ln: represents the natural logarithm to base "e"

y_i: total milk production in liters per cow per day for the i^{th} farmer.

X_i: is a vector of input for the i^{th} farmer

β: parameters to be estimated.

v_i: is the disturbance error term, independently and identically distributed as $N(0,\sigma_v^2)$ intended to capture events beyond the control of farmers;

u_i: is a non-negative half normal random variable, independently and identically distributed as $N^+(0, \sigma^2_u)$ intended to capture technical inefficiency effects in the production of milk measured as the ratio of observed output to maximum feasible output of the i^{th} farmer.

That is to say, the output oriented technical efficiency of the i^{th}farmer, denoted by TE_i, can be estimated as the ratio of the observed output (y_i) and maximum potential output (y*):

$$\mathbf{TE_i = y_i / y^* = \frac{f(x_{ij;}\ \beta) x \exp (v_i - u_i)}{f(x_{ij;}\ \beta)\ x\exp (vi)} = \exp (-u_i)} \qquad (3.2)$$

Where:

i, j: denote the farmer and input respectively, TE_i: technical efficiency of the i^{th}farmer.

exp $(-u_i)$: expected value of $-u_i$.

Therefore, Cobb-Douglas frontier function is specified as:

$$moutp = (lbcow)^{\beta 1}(cbcow)^{\beta 2}(concrt)^{\beta 3}(rfge)^{\beta 4}(labr)^{\beta 5}(grzl)^{\beta 6}(vcs\ )^{\beta 7}e^{\varepsilon i} \quad (3.3)$$

Taking the natural logarithm of the above specified Cobb-Douglas production function in equation (3.3) we can get the following log linear production function with the definition of variables in Table 3.1.

$\ln(moutp) = \beta_o + \beta_1\ln(lbcow) + \beta_2\ln(cbcow) + \beta_3\ln(concrt) + \beta_4\ln(rfge) + \beta_5\ln(labr) + \beta_6\ln(grzl) + \beta_7\ln(vcs) + v_i - u_i,$ $\varepsilon_i = v_i - u_i$(3.4)

Table 3.1: Definitions and hypothesis of input variables

Variables	Notation	Definition	Hypothesized sign
Milk output	moutp	Total milk production in liters per cow per day	
Local breed cow	lbcow	Number of local breed cows	+
Cross breed cow	cbcow	Number of cross breed cows	+
Concentrate	concrt	Quantity of concentrate feed consumed per cow per day (kg)	+
Roughage	rfge	Quantity of roughage feed consumed per cow per day (kg)	+
Labour	labr	Family and hired labor spent in person day per cow per day	+
Grazing land	grzl	Grazing land in hectare	+
Veterinary costs and services	vcs	expenses for treatment and artificial insemination (AI) in Eth. Birr	+

3.2.2. Specification of technical inefficiency effect model

Farm specific inefficiency effects, u_i's, assuming a half normal distribution $N^+(0, \sigma_u^2)$ is modeled as follows:

$U_i = Z_i\delta + \boldsymbol{\omega}_i i = 1,2,\ldots\ldots N$ (3.5)

Where; U_i - $\mathbf{U}_i$. Is the inefficiency scores for the ith farmer

δ - is a 1xP vector of parameters to be estimated by maximum likelihood estimator

Z_i – is a Px1 vector of explanatory variables associated with farm specific inefficiency effects

$\boldsymbol{\omega}_i$ - is assumed to be normally distributed random variable with mean zero and variance $\delta^2 w$

$U_i = \delta_0 + \delta_1(age) + \delta_2(eprc) + \delta_3(sex) + \delta_4(educ) + \delta_5(fmsz) + \delta_6(hdsz) + \delta_7(exts) + \delta_8(nfmi) + \delta_9(crdt) + \delta_{10}(trng) + \delta_{11}(mrkt) + \omega_i$ (3.6)

Table 3.2:- Definitions and hypothesis of inefficiency variables

Variables	Notation	Definition	Hypo-thesized sign
Age	age-	Age of the household head in years	**+/-**
Experience	eprc	Experience in dairy farming in years	–
Sex	sex	1 if the household head is male, 0 otherwise	**+/_**
Education level	educ	The number of years of formal schooling of the household head.	_
Family size	fmsz	Family size in adult equivalent(AE)	_
Herd size	hdsz	Herd size in total livestock unit(TLU)	**+/_**
Extension contact	exts	1 if a farmer has contact with extension agent, 0 otherwise	_
Non-farm income	nfmi	1 if a farmer participate in non-farm income, 0 otherwise	**+/-**
Credit availability	crdt	1 if a farmer has access to credit, 0 otherwise	**-**
Training on dairying	trng	1 if a farmer has trained on dairy farming, 0 otherwise	**-**
Access to market	mrkt	Distance traveled by farmers to sale milk in kilometer	**-**

***Note**: Negative sign of coefficients indicates positive contribution to efficiency while a positive sign of coefficients indicates negative contribution to efficiency because the dependent variable is inefficiency score.*

The overall model was specified as;

$\ln(moutp) = \beta_o + \beta_1\ln(lbcow) + \beta_2\ln(cbcow) + \beta_3\ln(concrt) + \beta_4\ln(rfge) + \beta_5\ln(labr) + \beta_6\ln(grzl) + \beta_7\ln(vcs) - (\delta_0 + \delta_1(age) + \delta_2(eprc) + \delta_3(sex) + \delta_4(educ) + \delta_5(fmsz) + \delta_6(hdsz) + +\delta_7(exts) + \delta_8(nfmi) + \delta_9(crdt) + \delta_{10}(trng) + \delta_{11}(mrkt) + \omega_i)$
(3.7)

3.3 Predicting farm specific efficiency

The best prediction of farm level efficiency, exp ($-u_i$), can be obtained by

$$E[\exp(-u_i) \,/\, e_i] = \frac{1-\emptyset(\sigma_A+\gamma e_i/\sigma_A)}{1-\emptyset(\gamma e_i/\sigma_A)} \exp(\gamma e_i + \sigma^2/2) \quad (3.8)$$

$$\sigma_A = \sqrt{\gamma(1-\gamma)\sigma_S^2}\ ;\ e_i = \ln(yi) - X_i\beta ; \emptyset(.) \quad (3.9)$$

Where; $\emptyset(.)$ the density function of a standard normal random variable which can be estimated by maximum likelihood once the density function for u_i is specified. The maximum likelihood estimates of the parameters of the frontier model are estimated, such that the variance parameters are expressed in terms of the parameterization as;

$$\sigma^2_s = \sigma^2_v + \sigma_u^2 \text{ and } \gamma = \sigma_u^2 / \sigma^2_s = \sigma_u^2 / \sigma_v^2 + \sigma_u^2 \quad (3.10)$$

Where: the γ parameter has a value between 0 and 1. A value of γ of zero indicates that the deviations from the frontier are due entirely to noise, while a value of one would indicate that all deviations are due to technical inefficiency.

σ_u^2 - is the variance parameter that denotes deviation from the frontier due to inefficiency;

σ^2_v - is the variance parameter that denotes deviation from the frontier due to noise

σ^2_s - is the variance parameter that denotes the total deviation from the frontier.

RESULTS AND DISCUSSIONS

4.1 Descriptive analysis

Although accurate data on inputs of milk production are not easily obtainable in the Ethiopian traditional dairy farming sub-sector in general because of measurement problems, an endeavor was made to reduce the error of margin through schedule methods of data collection by employing development agents working and speaking local language in the sampled kebele. Once data related to demographic, socio-economic and household's resource bases were collected, the following descriptive analysis was made.

Accordingly, the mean age of the respondent was 45.46 years. To evaluate the average milk output between groups of different ages, sample farmers are classified into three age groups (see Table 4.1).

A one way ANOVA test result indicated the mean difference in milk output between the three groups of age is not significantly different from zero (P=0.6890).

The survey result also revealed that 82.14% and 17.86% were male and female headed households, respectively. The average milk output of male headed household farmers was 5572.42 liters per year while 6063.05 liters per year for female headed household farmers.

Table 4.1: Average milk output between different age groups

Age groups	Frequency	Percent	Average milk output(liters)
<30	8	7.14	4932
30 – 64	99	88.39	5696.96
>64	5	4.46	6093.78

Regarding the education level of households, 21.43% have never attended any school, 16.07% were able to read and write and 58.04% were attended formal education from grade 1-12 and the remaining 4.46% were attended above grade12 (Table 4.2).

A one way ANOVA test result showed that the mean milk output difference between groups of level of education of farmers is not statistically significantly different from zero (P=0.237). This implies education is not a key factor in affecting the level of milk output as dairy farming is an aged and common practice for farmers in the study area.

Table 4.2: Education level of household heads and corresponding milk output

Level of education	Frequency	Percentage	Average milk output in liters
Illiterate	24	21.43	4520.69
Read and write	18	16.07	5493
Grade 1-4	24	21.43	5486.84
Grade5-8	31	27.68	6761.03
Grade 9-10	8	7.14	5374.06
Grade11-12	2	1.79	5338.5
>Grade 12	5	4.46	6320.28

The descriptive result also showed that 23.2%, 44.6% and 32.14% of the respondents reported that they got no extension contact, contactless than 48 days and contacted between 48-95days per year, respectively (see Table 4.3). The average milk output of farmers who had no extension contact, <48 days contact and 48-95days contact was 4420.3, 5609.37 and 6625.77 liters per year, respectively. A one way ANOVA test result showed that the mean difference in milk output between these groups was significant (P=0.0045).

Table 4.3: Extension contact and its respective average milk output

Categories	Frequency	Percent Average milk output
No contact	26	23.21 4420.3,
<48 days	50	44.64 5609.37
48-95 days	36	32.14 6625.77
Total	112	100

4.1.1 Milk output and livestock feed

Total milk output produced was 107,766 and 526,154 liters for local and crossbreed cows respectively. The average milk production per cow per year was 615.8 and 2113 liters for local and cross breed cows, respectively. Similarly, the average milk produced per cow per day was 1.69 liters for local cows and 5.79 liters for crossbreed cows (see Table 4.4). This implies cross breed cows give more milk compared to local breed cows.

Table 4.4:- Annual and Daily milk output in liters.

Description	Local breed cows	Crossbreed cows
Total milk produced	107,766	526,154
Average milk/cow/year	615.8	2113
Average milk/cow/day	1.69	5.79

Livestock feed is an important variable that determines the volume of milk produced. As a result, the overall mean consumption of roughage per farmer per year was 3500.04kg whereas the mean consumption of concentrate was 3173.7kg per farmer per year. The average milk output of farmers who feed roughage for milking cows below 3500kg per farmer per year was 4779.52 liters but it was 6751.50 liters for those who feed roughage for milking cows above 3500 kg per year per farmer. Similarly, the average milk output of farmers who feed concentrate for milking cows below 3173.7kg per farmer per year was 3626.34 liters but it was 7622.37 liters for those who feed concentrate for milking cows above 3173.7 kg per year per farm (Table 4.5). This indicates the higher the feed milking cows had, the higher the volume of milk. The t-test result revealed that the mean difference in the milk output of a group of farmers who feed cows below and above or equal the mean consumption of roughage was statistically significant (P=0.0001) and it was also significant for consumption of concentrate (P=0.0000).

Table 4.5: Average consumption of roughage and concentrate for milking cows in kg

Description of Consumption	Local breed cow N=112, AH=1.56	Crossbreed cow N=112, AH=2.22	Overall
Roughage per farmer per year	1270.5	2229.54	3500.04
Roughage per cow per year	814.4	1004.29	1851.87
Roughage per cow per/day	2.23	2.75	5.07
Concentrate per farmer/ year	396.7	2776.98	3173.7
Concentrate per cow /year	254.3	1250.89	1679.2
Concentrate per cow per/day	0.70	3.43	4.6

Note. *N=Sample size, AH=Average holding

4.2 Econometrics analysis results

4.2.1Parameter estimation of SPF models

The stochastic production frontier was estimated by one stage procedure. The maximum-likelihood estimates of the parameters of the frontier functions were presented in Table 4.6 below. Since Cobb-Douglas production function fitted was a log linear model, the coefficients of variables represent elasticity of output with respect to the respective inputs. Variables named number of crossbreed milking cows and concentrate have positive sign coefficient and significant at 1% level while roughage and labour also has positive sign coefficient and significant at 5% probability level (see Table 4.6).

The elasticity of milk output with respect number of crossbreed cows (lncbcow) was 0.3214, meaning that a 1% change in the total number of crossbreed cows would bring about 0.3214 % change in the output of milk production at a 1% level of significance if other covariate held constant. This finding is consistent with the findings of Nega and Simeon (2006), Cabrela et al.(2009) and Mugammbi, et al.(2014).

Concentrate input has an elasticity of 0.2738 implying that a 1% change in the use of concentrate brings about a 0.2738% change in the output of milk production at a 1% level of significant keeping other factors constant. This finding is consistent with Nega and Simeon(2006), Alemder (2010), and Tassew et al. (2013) who used stochastic production frontier with Cobb-Douglas function.

Roughage has also elasticity of 0.127. This implies for a 1% increase in the use of roughage brings about a 0.127% change in the output of milk production at a 5% level of significance, holding other inputs constant. This finding is consistent with Abid and Mushtaq (2008), Mugambiet al. (2014) and Tuna, et al.*(*2010).

Labour has an elasticity of 0.182. This shows for 1% change in labor input in person day; the output of milk changes by 0.182% at a 5% level of significance keeping other factors constant up to the level of optimality (Table 4.6.).

The value of discrepancy ratio (γ) calculated from the maximum likelihood estimation of the full frontier model was 0.9067(see Table 4.6). The coefficient for the parameter γ can be interpreted as about 91% of the variability in milk production among smallholder dairy farmers in the study area in the year 2017/2018 was attributable to technical inefficiency effect (u_i) which are under the control of farmers, while the remaining 9% variation in output was due to the effect of random noise (v_i) which are outside the control of farmers.

The value of lambda (λ)shown in Table 4.6, was about 3.12 which is greater than 1. Such a result according to Ojehomon et al.,(2013)indicated a good fit for the estimated model and the correctness of the distributional assumptions. Lambda value greater than one also indicates that a great part of the residual variation in output is associated with technical inefficiency rather than measurement error associated with uncontrollable factors related to the production process.

Table 4.6:-Maximum likelihood estimates of the Cobb-Douglas Stochastic production frontier in log

Frontier function	Coefficients	Standard error	Z-Value	P-value|
Constant	5.307	0.307	17.28	0.000***
Local breed cow	0.061	0.051	1.19	0.233
Cross breed cow	0.321	0.075	4.27	0.000***
Concentrate	0.273	0.074	3.66	0.000***
Roughage	0.127	0.058	2.16	0.031**
Labour	0.182	0.070	2.58	0.010**
Grazing land	0.007	0.007	0.98	0.328
Veterinary cost	0.005	0.005	0.93	0.352
Sigma v (σ_v)	0.119			
Sigma u (σ_u)	0.371			
$\sigma^2_s = \sigma^2_v + \sigma^2_u$	0.152			
Γ	0.906			
Lambda(λ)	3.118			
LR	7.61***			
Wald chi2(7)	314.56***			

***,** significant at 1% and 5% level

4.2.2 Estimation of farm level technical efficiency

The mean score of technical efficiency of smallholder dairy farmers was 81%, with the minimum and maximum efficiency levels of 27% and 95%, respectively. The mean score of technical efficiency tells us that the level of milk output of the sample respondents can be increased on an average by about 19%. This can be interpreted as dairy farmers could decrease their quantity of input with a ratio by 19% without making any reduction in milk production by increasing their technical efficiency level or farmers can increase milk production by 19% without decreasing the existing input but by only improving technical efficiency level in the short run. A close result to this research finding was reported by Nega and Simeon (2006) with mean TE=79%, Hazneci and Ceyhan (2015) with mean TE=78% and Mugambi et al,(2010) with mean TE= 84%.

4.2.3 Determinants of technical inefficiency

Demographic and socio-economic variables which determine technical inefficiency among farmers were estimated using a one-stage estimation procedure.

Table 4.7:- Maximum-likelihood estimates of the inefficiency variables.

Variables	Coefficients	Standard error	Z-value	p>|z|
Constant	-2.439	2.046	-1.19	0.233
Age of household head	-0.013	0.029	-0.46	0.646
Sex	0.432	0.535	0.81	0.419
Education level	-0.006	0.170	-0.04	0.968
Experience	-0. 827	0.349	-2.39	0.012**
Family Size	-0.527	0.149	-3.53	0.048**
Herd Size	-0.121	0.068	-1.77	0.076*
Extension Service	-0.352	0.177	-1.99	0.046**
Non-farm income	-0.220	0.390	-0.57	0.572
Credit	-0.639	0.642	-0.99	0.320
Training	-0.929	0.513	-1.81	0.070*
Access to Market	0.519	0.249	2.08	0.037**

**, * significant at 5% and 10% level

Inefficiency variables experience in dairy farming, herd size, extension contact, training, access to market and family size have the expected sign which are statistically significant in affecting technical inefficiency. Whereas, age, sex, education, non- farm income and credit are found to be statistically insignificant.

Experience in dairy farming

Experience in dairy farming affects inefficiency negatively (affect positively the level of technical efficiency) in milk production at a 5% level of significance. This could be due to the fact that farmers learn more from their previous experiences of milk production and improve their technical efficiency of milk production (see Table 4.7).

Family size

Family size has a negative sign as expected and significant (see Table 4.7). This implies that family size determines inefficiency negatively (determine efficiency positively).To compare TE differences among different family size groups, sample farmers were classified into two groups considering mean family size as a reference. Households that have ≥4 family sizes have the mean efficiency level of 0.81, but families that have less than 4 family size scores a mean efficiency level of 0.76. The t-test result also indicates that there is a statistically significant difference in the mean TE score between the two groups at a 5% level of significance (P=0.0460). This finding is supported by the findings of Amlaku(2012), and Raham et al.(2013) who used Cobb-Douglas production functional form.

Herd size

The econometric result showed that herd size affects technical inefficiency negatively at a 10% level of significance (see Table 4.7). The mean level of technical efficiency score of sampled respondents having average herd size < 9.59 in terms of TLU was 0.78 but those respondents having average herd size ≥ 9.59 in terms of TLU was 0.83 (see Table 4.8).

The t-test result also revealed that the mean technical efficiency score difference among the two groups of farmers who have total livestock greater than or equal to the average holding and those who have less than the average holding was statistically significant at 5%level (P=0.0259). This finding is consistent with the findings of Demircan et al.(2010) and Nakanwagi et al. (2015).

Table 4.8:Mean technical efficiency and herd size

Herd size	N	Mean TE	Standard deviation
<9.59	50	0.78	0.128
≥9.59	62	0.83	0.118

Extension service

Extension contact determines the inefficiency level of farmers negatively and significantly or efficiency level positively (see Table4.7). A one way ANOVA test result indicates that there is a significant difference in the mean level of technical efficiency scores between groups of extension contact at 1% (P=0.000). This implies farmers with more extension contact have a higher mean level of technical efficiency compared to other groups as extension contact helps farmers adopt new technologies which able to increase the level of milk output. (see Table 4.9).

Table 4.9: Extension contact per year and mean level of technical efficiency

Extension contact	N	Mean TE	Standard deviation
No contact	26	0.71	0.157
<48 days	50	0.81	0.093
48-95 days	36	0.86	0.1003

Training on dairying

Training determined inefficiency negatively and significantly at 10% level (see Table 4.7). The mean level of technical efficiency of farmers who took training in the study area was 0.85 while it was 0.79 for those who did not take training (Table 4.10). This is because training improves the technical and managerial skills of farmers. The t-test result illustrates the mean technical efficiency difference of trained and non-trained farmers was significant at 5% (P=0.0151).

Table 4.10: Training and mean technical efficiency of farmers

Training	N	Mean TE	Standard deviation
Yes	40	0.85	0.098
No	72	0.79	0.133

Access to market

Considering the socio-economic characteristics of the study area, data on access to the market was collected by asking farmers how far they travel to sell milk and milk products. As a result, the distance travelled by farmers was categorized into those who travelled less 1Km, 1-5Km, 6-10Km and greater than 10Km. Consequently, the econometric result in Table 4.7 shows that access to market has the expected sign and statistically significant at 5% level. The mean level of technical efficiency of farmers who travelled less than 1kilometer, travelled 1-5 km,6-10 km and greater than 10 km was 0.83, 0.79, 0.76 and 0.84, respectively to reach a market place to sale their milk output (see Table 4.11). This implies farmers who were close to market were technically more efficient than those relatively far from the market except those farmers who travelled greater than 10 km. Their mean technical efficiency was higher than all other groups. This exception arises due to the fact that these farmers sell their milk output at Addis Ababa market on average 15.75 birr as compared to those who sold at the farm get and milk collection center on average birr 12.08 and 12.40 birr, respectively. This higher selling price at Addis Ababa market may give farmers market incentives and could encourage farmers to produce more. The t-test result indicates that the mean TE difference between farmers who travelled less than 1km and 1-5km is statistically significant (P=0.0970) at a 10% level of significance. Moreover, the t-test result showed the mean TE difference between farmers who travelled less than 1km and 6-10 km is statistically significant (P=0.0564) at a 10% level of significance. But the t-test result that the mean TE difference between farmers who traveled less than 1km and greater than 10 km was not statistically significant(P=0.8091).

Table 4.11: Mean level of technical efficiency and access to market

Access to market	N	Mean TE	Standard deviation
<1km	50	0.83	0.1217
1-5km	39	0.79	0.1075
6-10km	15	0.76	0.1761
>10 km	8	0.84	0.0691

CONCLUSION

Estimated stochastic production frontier model indicates that the number of crossbreed milking cows, amount of concentrate and roughage consumed and labour used in person day were significant in determining milk output. The positive coefficient of these variables indicates that increased use of these inputs increases the production of milk.

The estimated inefficiency model revealed that experience in dairy farming, family size, herd size and extension contact, training related to dairying and access to the market were found to determine technical inefficiency negatively(technical efficiency positively).

About 91% of the residual variation in the SPF was due to technical inefficiency and the remaining 9% residual variation was due to noise. This implies that there is room for improvement through better technical efficiency. The estimated Cobb-Douglas stochastic production frontier showed that the mean technical efficiency score was 81% with a minimum of 27% and a maximum of 95% indicates that production can be increased by 19% without decreasing the existing input supply but by only improving technical efficiency level in the short run.

Therefore, dairy farming is one field of agriculture that recently is getting attention in Ethiopia because it plays a great role in reducing poverty and as a source of food for both urban and rural areas of the country, especially for poor households. Hence, policymakers should give emphasis to improve the milk output of the dairy sub-sector through the provision of sufficient feed, training, health and extension contact of dairy farms. The result suggests, in addition to focusing on the introduction and dissemination of improved breeds and feed, especially cross breed cows policymakers need to give due attention towards improving the existing level of efficiency. This is because the result of improvement in milk output by the use of inputs or technologies is high if it is coupled with improvement in technical efficiency.

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