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Factors Affecting Technical Efficiency of Urban Dairy Farming: The Case of Nekemte City, Oromia, Ethiopia

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ABSTRACT

Background: Urban Dairy farming is a vital sector in Ethiopia, contributing to urban food security and rural livelihoods. However, inefficiencies in resource use and management practices often limit productivity of the sector. Therefore, this study was intended to measure and identify factors affecting technical efficiency of dairy farmers in Nekemte City.

Methods: Data was collected from both primary and secondary sources. Primary data was collected from 135 sample dairy farm business owners. For data analysis, descriptive statistics, stochastic frontier analysis (SFA) was used to model the production function and identify inputs driving milk output and a Tobit regression model assessed the impact of managerial factors on technical efficiency.

Result: The SFA results revealed that concentrate feed and fodder were statistically significant inputs influencing milk production. The Tobit regression model further showed that training, education, and work experience of farm owners/managers significantly explained variations in technical efficiency. To improve dairy productivity in Nekemte City, government and non-governmental institutions should prioritize training programs to enhance farmers' skills in feed management and modern practices. Strengthening access to education and promoting institutional support, such as subsidies for high-quality feed, could reduce inefficiencies and optimize resource use.

Key words: Cobb douglass, Dairy farm, SFA, Tobit regression.

INTRODUCTION

Ethiopia holds the largest cattle population from Africa which has estimated to be about 70 million heads of cattle. Out of total cattle population, the female cattles constitute about 56 per cent and the remaining 44 per cent are males (CSA, 2021). About 97.4% of the total cattle in the country are local breeds. The remaining are hybrid and exotic breeds that accounted for about 2.3 per cent and 0.31 per cent, respectively and the number of milking cows are about 15.04 million heads (CSA, 2021). In 2020/21, about 4.96 billion liters of cow milk was produced in the country (CSA, 2021).

In Ethiopia, urban dairy farming is performed in Peri-urban and urban. In urban areas, population has been increasing and the agricultural land is scare. With better management and bread improvement, there is a possibility of increasing supply of dairy products. However, pure exotic animals are limited to commercial or government farms (Metekia and Nezif, 2017).

However, due to inadequate access and high price of inputs such as feed, animal-health service, water shortage and lack of adequate capital are the major bottlenecks in dairy farm business in the study areas/target town (Teshome, 2024). This resulted in per capita consumption of milk is approximately 19 kg per year in Ethiopia which is very low as compared to other countries. In Africa, dairy per capita consumption was 45 kg per year in 2021 and in Europe 283 kg per year while in Asia 94 kgs per capita per year on average (IDF, 2022).

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Nekemte city, a significant urban hub located in the Western part of Oromia Region of Ethiopia, thrives mainly due to its agriculture-centered economy. The city is surrounded by fertile farmlands, green areas and grazing lands. In order to make urban households to be more food secure, the Ethiopian government has been actively promoting and supporting urban agricultural initiatives to address various challenges and harness the potential of urban areas for food production. Owing to this, a number of dairy farm businesses have been established in the town.

Dairy Farming plays an important role in the Ethiopian agricultural sector and the national economy (Tegegne *et al.,* 2013). The main source of milk production in Ethiopia is mainly from cow, but small quantities of milk have been obtained from goats and camels in some regions particularly in pastoralist areas. Dairy production systems in Ethiopia can also categorize to rural, peri-urban and

urban in Ethiopia (Mohamed *et al.,* 2004). The sector is a source of livelihoods for a vast majority of the rural and urban population in terms of consumption, income and employment. The CSA (2013) indicated that 2.8 billion liters of milk was produced in 2012/2013, out of which 42.3% was used for household consumption. This shows that dairy production is an important agricultural activity in the country and provides livelihood for significant proportion of smallholders.

Since the early 1990s, Ethiopia has embarked on a policy reform that aims to bring about a market-oriented economic system. Subsequently, several macro and sectarian economic policy changes were implemented. For instance, the Ethiopian government launched a national development strategy namely; Agricultural Development Led Industrialization (ADLI), a Plan for Accelerated and Sustained Development to End Poverty (PASDEP), Growth and transformation plan I and II and the Pathway to Prosperity Ten Years Perspective Development Plan 2030. These strategies seek to bring about an improvement in the livestock sector by enhancing the quality and quantity of feed and improved extension services, increasing livestock health services and improved productivity of local cows by artificial insemination while preserving the indigenous breeds (Mohamed *et al.,* 2004).

Peri-urban and urban dairy production system is becoming an important supplier of milk products to urban centers, where the demand for dairy milk products is remarkably high. Because of this, urban dairy farming business is being intensified with cross breed dairy cows, purchased and conserved feeds. These production systems are favored due to the proximity of the production sites to centers of high fresh milk demand, easy access to agro-industrial by-products, veterinary services and supplies (Azage *et al.,* 2005). On the other hand, modern dairy farming practices cover a range of intensive management practices and zero grazing. This production system also involves the use of exotic crossbreed genotypes that give high yield as compared to the traditional dairy farms. Both practices are confronted with the problem of competing for scarce resources. Nonetheless, these resources have to be optimally and efficiently utilized on the bases of their marginal value productivity in order to get maximum income from dairy enterprises. Therefore, efficient milk production is a key to sustainable development of dairy farm.

Peri-urban dairy production systems are mainly located at the edge of the town areas which have comparatively better access to urban centers in which dairy cattle products are extremely wanted (Alemu and Minale, 2019). Most of the dairy cattle producers depend on hybrid cows and they practiced supplementary concentrate feeding (Gebreselassie, 2019). It possesses animal types ranging from 50% crosses to high grade Friesian in small to large sized farms and contributed only 2% of the total milk production of in Ethiopia. This sector owns most of the country‘s improved dairy stock (Gobena, 2016). Their main source of animal feed is home produced hay for some and pastured hay for other with or without additional supplemental feed. The animals they keep range from 50% cross breeds to high grade Friesians. This sector controls most of the country’s improved dairy stock (Getabalew *et al.,* 2019).

Urban milk productions the most market-oriented production system compared to other production systems (Bekele *et al.,* 2015; Asrat *et al.,* 2016). Urban areas producers use crossbred, as well as high grade, dairy animals. However, only 1% of the dairy cattle from the total population of dairy cattle of the country are kept under urban dairy cattle production system (Gezu and Zelalem, 2018). Concentrates, roughages and non-conventional feeds are the main feed resources which are used in urban dairy cattle production system. Moreover, roadside grazing, fruits of plants and wastes also used in urban dairy cattle production system (Asrat *et al.,* 2016). According to Kiros *et al.* (2018), the average number of hybrid dairy cattle were greater in urban than that of peri-urban dairy cattle production system. Grass, hay, crop residues and concentrates were regularly used dairy cattle feeds in both urban and peri-urban areas.

Smallholder dairy producers dominate the dairy industry at the production and are the users of the extension services provided by various development partners. Different players are linked and interact with smallholder dairy producers at various levels based on the type of ongoing joint venture activities. The actors are: extension agents, various non-governmental and international development collaborates mainly Food and Agricultural Organization (FAO), Netherlands Development Organization (SNV), Land O’Lakes, Self Help, Hunde (in the central highlands), cooperatives and research and higher education institutions (Yilma *et al.,* 2011). Smallholder producers, however, lack the required technological, organizational, as well as institutional capacities. Tesfaye *et al.* (2008) reported them to be less organized and distant from market outlets, lack economies of scale and institutions for risk management and face higher transaction costs. Urban and peri-urban smallholder producers are the main suppliers of raw milk-to-milk processors of different scales.

This day, due to high rate of urbanization and improved income in some segments of the society, demand for milk and milk products has been increasing. There are a number of researches that were done on dairy farm in Ethiopia. For instance, Tadesse and Mengistie (2016) and Getabalew *et al.* (2019) did on the Challenges, Opportunities and Prospects of Dairy Farming in Ethiopia. Tadesse *et al.* (2017) also conducted on the Importance dairy farm in Ethiopia. However, research on technical efficiency of dairy farm is scanty. Therefore, in order to ensure sustained improvement in urban dairy farming, this study digs out factors affecting the level of technical efficiency of dairy farms in Nekemte city.

Accordingly, the general objective of this study is to identify factors influencing technical efficiency levels of dairy farms in Nekemte city.

Theoretical review

Production is a process of transforming inputs (*e.g.* labor, capital and raw materials) to output (which can be in the form of intermediate goods, final goods or services). This transformation of inputs to outputs can be represented in production function. It shows the maximum level of output that can be produced from a given production technology and level of input (Aigner *et al.,* 1977; Kumbhakar *et al.,* 2015).

Efficiency is defined as the maximum level of output produced with the inputs, which is actually employed, or whether that output is produced at minimum cost. Efficiency is categorized to technical efficiency and allocative efficiency which together gives overall efficiency. Technical efficiency relates observed level of output and ideal or potential level of output. In the other word, it measures the maximum attainable level of output that can be resulted from best practice and optimal combinations of inputs. In principle, technical efficiency implies maximizing level of output produced with given the level of cost production. Allocative efficiency on the other hand shows producer's success in choosing optimal set of inputs consistent with relative factor prices. In principle, it implies minimizing cost of production from the given the level output produced (Farrell, 1957 and Greene, 2008).

In many studies of technical efficiency, the results are used to estimate the effects of various factors on inefficiency. These may be estimated using a two-step process in which the production frontier is first estimated and the technical efficiency of each farm is derived afterward. These are subsequently regressed against a set of variables which are hypothesized to influence the farm's efficiency. This approach has been adopted in a range of studies (FAO, 2000).

The measurement of technical efficiency of a farm indicates that if a farm is successful in converting all the physical inputs into outputs and the efficiency of converting is equal to the frontier production function, then it is said to be an efficient farm and if a farm falls short of this requirement, then the farm is termed as technically inefficient farm (Reddy *et al*., 2008).

In microeconomic theory, the primal transformation function or production frontier, describes the maximum output that may be obtained given inputs and technology. Some inputs may be varied at the discretion of the decision maker, while the other inputs are exogenously fixed, acting as constraints to the production process. Any deviation from the maximal output is typically considered technical inefficiency (Coelli *et al.,* 2005). Farrell (1957) proposed that the economic efficiency consists of two components. Technical efficiency, which is measured as the ratio between the observed output and the maximum output, under the assumption of fixed input, or, alternatively, as the ratio between the observed input and the minimum input under the assumption of fixed output (Porcelli, 2009). Allocative efficiency measures the ability of a farmer to use inputs in optimal proportions given their respective prices and the production technology. Allocative inefficiency arises when inputs of production are used in proportions that do not minimize the costs of producing a given level of output. Economic efficiency is the product of technical efficiency and allocative efficiency.

MATERIALS AND METHODS

This study was conducted in Nekemte town (Fig 1). Nekemte town is located in western Oromia National Regional State, in East Wallaga Zone, at a Distance of 331 Km from Addis

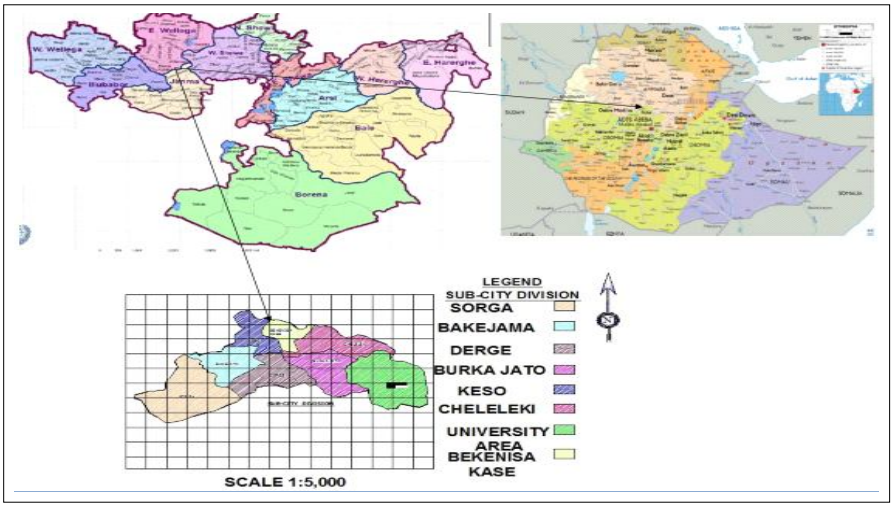


Fig 1: Map of nekemte town.

Ababa (Finfinnee), 110 km North East of Gimbi, the principal town of West Wallaga and 250 km North West of Jima zone in Oromia regional state or the town is boundary by Guto Gida district of the North, South and in West side and also Wayu Tuka Woreda of the zone surrounds the Nekemte town in east side. Its astronomical location is 9°04′ North Latitude and 36°30′ East Longitude. The total land area estimated to be 5480 hectare. Administratively, it is divided into seven sub towns or Ganda. A towns altitude ranges from 1960 to 2170 m.s.l.

In this study, both qualitative and quantitative data type by using primary and secondary data sources. The primary source of data for this study were collected through direct observation of the study area and sample survey whereas, secondary data source for this study were collected from central statistical agency of Ethiopia (CSA), different written documents, published researches, books and other related sources.

A multistage sampling procedure was employed for this study. In the first stage, from the total seven kebeles of Nekemte town, 4 kebeles, namely, Sorga, Bake Jama, Chelalaki and Darge Kebele's were selected as purposive sampling based on the population of households engaged on dairy farming production activity.

Simple random sampling (SRS) technique was employed to select the final sample respondents. The sample size for this study were determined through Kothari formula which is based on approach of precision rate and confidence level, the researcher has specified the precision that he wants in respect of his estimates concerning the population parameters. This approach is capable of giving the mathematical solution and as such a frequently used technique of determining 'n'. Accordingly, the formula to find out the sample size (n) of finite population is.

$$n = \frac{N.p.q}{(N-1)\,e^2 + z^2.p.q}$$

Where,

N = Population.

n = Sample size.

z = Value of standard variation at a given confidence level and to be worked out from table showing area under normal curve.

p = Sample proportion.

q = 1-p.

e = Given precision rate or acceptable error (Kothari, 2004). In this study, N = 207, z= 1.96, p= 0.5, q= 1-0.5= 0.5, e = 0.05.

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

$$= \frac{1.96^2 * 0.5 * 0.5 * 207}{0.05^2\,(207-1) + 1.96^2 * 0.5 * 0.5} = \frac{198.8028}{1.4754} = 135$$

Therefore, sample size for this study is 135.

Model specification

The functional form we employed to specify the stochastic production is the Cobb Douglas function. The Cob-Douglas functional form is chosen because the small number of observations makes it impossible to estimate a model with fully flexible functional forms. It is also broadly applied in farm efficiency analysis for both developing and developed countries (Sristy, 2024).

Transforming given input in to outputs is the main concern of the concept of efficiency. The primary and secondary data collected were summarized to describe households and farms characteristics. In addition, data on quantities of inputs, in milk production and amount of milk produced and return obtained from milk and milk by-products will be summarized to compute values of input parameters needed for production function model.

$$Yi = \beta_0\, X1i^{\beta 1}\, X2i^{\beta 2}\, X6i^{\beta 3}\, X6i^{\beta 4}\, e^{\varepsilon i} \quad \text{....(1)}$$

Transformed of the equation (1) is.

$$\ln Yi = \beta_0 + \beta_1 \ln X2i + \beta_2 \ln X2i + \beta_3 \ln X3i + \beta_4 \ln X4i + \varepsilon_i \quad \text{....(2)}$$

$$\ln (milk) = \beta_0 + \beta_1 (Lncows) + \beta 2\ (Lnshed) + \beta 3\ (Lnfodder) + \beta 4\ (Inconcrte) + \varepsilon_i \quad \text{....(3)}$$

After technical efficiency score at farm level is estimated , to identify factor that affect technical efficiency level of dairy farmers Tobit regression model was applied. Factors affecting Technical efficiency of urban and peri-urban dairy farmer were specified as follows.

$$TE\,(u_i) - \beta_0 + \beta_1\, Age + \beta_2\, familysize + \beta_3 EDUCL + \beta_4 FARMEXP + \beta_5\, ditroad + \beta_6 TRAIG + \beta_7 vetraid + \varepsilon_i \quad \text{....(4)}$$

Where,

TE (u_i) = i^{th} farmer's technical inefficiency.

Age = Age of owner/manager.

Family size = Number of family size of the owner or the anger.

EDUCL = Educational attainment of the owner or the manger.

FARMEXP = Dairy farm experience in years.

Ditroad = Distance to nearby asphalt road.

TRAIG = Received training.

Table 1: Summary of descriptive statistics for continuous variables.

Variables	Observation	Mean	Std. dev.	Minimum	Maximum
Age of the owner/manager	135	43.126	7.178	28	58
Family size of the owner/manager	135	5.578	2.478	2	11
Education level	135	9.193	3.149	2	13
Work experience	135	4.941	3.528	1	18
Distance from road	135	536.741	441.067	0	2000

Source: Computed from own survey data (2023).

Vetraid = Received veterinary aid.
ε_i = Error term.

RESULTS AND DISCUSSION

Descriptive statistics

Age

Age is one of the important factors which determine management experience of the milk producing households. Therefore, it is important to discuss an age structure of household heads within the sample. The survey result showed that the average age of sample dairy farm owners was 43.126 years with a standard deviation of 7.178 years ranging from 28 to 58 years, implying that the majority of the milk producers are in their middle ages.

Table 2: Summary of descriptive statistics for categorical variables.

Variables	Frequency	Per cent
Gender		
Female	37	27.41
Male	98	72.59
Total	135	100
Training		
Yes	131	97.02
No	4	2.96
Total	135	100
Veterinary aid		
Yes	131	97.04
No	4	2.96
Total	135	100

Source: Computed from own survey data (2023).

Family size

Having more family can be used as a proxy for labour availability. The sample households have mean family size of 5.578 persons per household with standard deviation of 2.478 ranging from 2 to 11 families.

Education level

Education helps farmers to acquire and understand information about agricultural inputs and newly discovered breeds and to calculate appropriate input quantities in a modernizing or rapidly changing environment. Improved attitudes, beliefs and habits may lead to greater willingness to accept risk, adopt innovations, save for investment and generally to embrace productive practices. The result obtained from Table 1 indicates that the average of educational level of farm owner is 9.193 grades with standard deviation of 3.149 grades in years of schooling. This implies that the education level of many farm owners is secondary school and above.

Work experience

Experience usually helps urban dairy farmers to accumulate essential skills and broaden their market networks and shares**.** The average of farm owner's experience is 4.941 years with standard deviation 3.528 years ranging from 1 to 18 years. This indicates that minimum of experience of farm owner is 1 year and maximum experience is 18 years.

Distance from the nearest market

Markets have clearly played a role in determining the economic viability of dairy development. With regard to the distance from the nearest market, the average distance of the sample household from the nearest market was 536.741 meter with standard deviation of 441.067 meter.

Table 3: Estimation of stochastic production **f**rontier.

Input variables	Coef.	Std. Err.	z	P>z
Ln of number of lactating cows	-0.00025	0.00216	-0.11	0.909
Ln of shed size m^2	0.00155	0.00224	0.69	0.487
Ln of fodder	0.96592	0.01949	49.56	0.000
Ln of concentrate	0.07279	0.02072	3.51	0.000
Constant term	-1.73170	0.02457	-70.47	0.000
/mu	-13.80433	15.75649	-0.88	0.381
/lnsigma2	-1.99851	1.10458	-1.81	0.07
/lgtgamma	6.71153	1.13600	5.91	0.000
sigma2	0.13554	0.14971		
Gamma	0.99878	0.00138		
sigma_u2	0.13537	0.14971		
sigma_v2	0.00016	0.00004		
Wald $chi^2(4)$ = 66951.31				
Log likelihood = 367.3849				
Prob > chi^2 = 0.0000				
AIC= -718.7698				
BIC = -695.5276				

Source: Computed from own survey data (2023).

Sex of household head

As indicated in Table 2 below the survey result showed that out of the total 135 sampled households, 98% (72.59%) male headed and 37 (27.41%) female headed were participated in dairy farm production in Nekemte city.

Training

The study result in Table 2 showed that 97.04% of the sample households received training services while 2.96% had not received it. The majority of the sampled households were obtained training services.

Veterinary aid

The study result in Table 2 showed that 97.04% of the sample households used veterinary aid services while 2.96% had not used it. The majority of the sampled households were obtained veterinary aid services.

Econometric analysis

The maximum likelihood estimation results of the parameters using the SFPF equation specified and presented in Table 3 were obtained using STATA 15 computer program. The value of σ2 for the frontier of milk output was 0.13554 which were significantly different from zero and significant at 1% level of significance. The significant value of the sigma square indicates the goodness of fit and correctness of the specified assumption of the composite error terms distribution. The Gamma (γ) statistic, which is a measure of the overall is highly significant indicating the presence of a high systematic inefficiency which explains about 99.9% of the variation in milk output.

The results of the model showed that two of the input variables in the production function: *i.e.* fodder and concentrate had a positive significant effect on the level of dairy milk productivity (Table 3). Hence, the increase in these inputs would increase productivity of milk significantly as expected. The coefficients of the production function are interpreted as elasticity. The highest coefficient of output to fodder (0.96592) indicated that fodder is the main determinant of milk production in the study area.

The major interest behind measuring technical efficiency is to know what factors determine the efficiency level of individual farm owner and to come up with development and policy recommendations that improve their efficiency. The technical efficiency scores derived from the model were regressed on socioeconomic, farm owner and institutional variables that explain variations in efficiency across farm households using the Tobit regression model. The estimation of the Tobit regression model showed that Sex, education level, training service, experience and distance from road were found to be statistically significant in explaining the variation in the level of technical efficiency. Detail discussions of the results from the Tobit model are presented in Table 4.

Age of farm owner

The estimated coefficient of age for technical efficiency was negative and insignificant influence on milk production and technical efficiency, which was not in line with the hypotheses made. This indicates no relationship between the age of the farm owner and milk production of milk.

Family size of the owner

The estimated coefficient of family sizes of the owner for technical efficiency was negative and insignificant influence on milk production and technical efficiency. This indicates that no relationship between the family size of the farm owner and milk production of milk.

Education level of the owner

Education had significant effect on technical efficiency with expected sign. It is positive and significant at 1% level of significance. As education increases by one year, milk technical efficiecy of increases by 0.000457. The significant effect of education on technical efficiencies confirms the importance of education in increasing the efficiency of milk production. This result was consistent with Adane *et al.* (2016); Al-Sharafat (2013) and Binam *et al.* (2004).

Table 4: Results of tobit regression.

Independent variables	Coef.	St.Err.	t-value	p-value
Age of the owner/manager	-0.0000511	8.64E-05	-0.59	0.555
Family size of the owner/manager	-0.0000946	0.000202	-0.47	0.641
Education level of the owner/manager	0.000457	0.000166	2.76	0.007
Work experience of the owner/manager	0.0008268	0.000157	5.28	0.000
Distance from road	-3.42E-06	1.73E-06	-1.98	0.05
Received training	0.0144424	0.003201	4.51	0.000
Veterinary aid	0.0004565	0.001145	0.40	0.691
Constant	0.9639402	0.005994	160.82	0.000
var€	0.0000346	9.73E-06		

Source: Computed from own survey data (2023).

Experience of owner

The result of estimation on experience of the farm owner for technical efficiency indicated positive and significant at 1% level of significance. As experience increases by one year, milk technical efficiecy of production would increase by 0.0008268. This implies technical efficiency of the farms reflecting that higher experience will end in higher TE due to more efficient use of input. This result was consistent with Al-Sharafat (2013).

Distance from the road

This variable was indicates a negative relationship with milk production and it was a significant at 10% level of significance. As distance from the road increases by one kilometer, milk production efficiency decreases by 0.00036. However, there was consistent regarding the relationship between distances from the country and milk production because the sign was expected. This implies it affects the level of milk production negatively. This keeps the findings of Adane *et al.* (2016).

Received training

Training on dairy farming refers to the training given to farmers on some improved dairy husbandry practices or protecting animals from disease *etc.* Farm owners who received regular training by extension workers, government and non-government organizations appear to be more technical efficient. The coefficient for the access to training had statistically significant and positive relationship with TE at 1% level of significance. As training services increases by one in unit, milk production efficiency would increase by 0.0144424. This result was consistent with Lemma *et al.* (2013).

CONCLUSION

This research paper study were conducted on dairy farm milk production to estimate technical efficiency and identify factors affecting efficiency among dairy milk producer on Nekemte administrative town, Sorga, Bake Jama, Chelalaki and Darge Kebele's of Nekemte city. In the study, it adopted both descriptive and casual designs based on the collected a cross sectional data to find out the technical efficiency of the sampled farm areas. Both primary and secondary data were used for the study. Simple random sampling techniques were used to select sample survey of 135 dairy milk producers' in the city.

The technical efficiency of the selected sample dairy milk producer farms were analysis in econometric analysis system using the Cobb-Douglas Frontier and Tobit regression models. The result of the stochastic production frontier model indicated that fodder and concentrate were significant determinants of technical efficiency level of the sampled dairy farm. The Tobit regression model revealed that education level, received training, distance from road and experience were found to be statistically significant in explaining the variation in the level of technical efficiency of dairy milk producers in the study area.

Therefore, based on the findings of this study, policy implications are made to enhance resource use efficiency and increase dairy farm efficiency in the study area.

- ✓ Feed volume had an impact on dairy farm milk producers' technical efficiency. Government should therefore use the available technology to more effectively plan the input supply.
- ✓ Technical efficiency of dairy farm milk producers was impacted by training. Government should therefore provide dairy producers with training.

Ethics approval and consent to participate

Not applicable.

Consent for publication

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Availability of data and material

Data will be made available upon request of the author.

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Authors' contributions

- First author Gemechu Mulatu Kerorsa has contributed data validation, software and supervision.
- Second author Kashula Gadisa Suki has contributed as conception, design, data collection, analysis, interpretation, writing and revision.

Conflict of interest

The author declare that there is no competing interests.

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