

DETERMINANTS OF TECHNICAL EFFICIENCY IN COW MILK PRODUCTION IN KURUNEGALA DISTRICT: AN APPLICATION OF DATA ENVELOPMENT ANALYSIS

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D M H Herath
A Thayaparan



Abstract

The aim of this study was to determine the level of technical efficiency scores under the assumptions of both constant returns and variable returns to scales on a sample of 150 cow milk producers in Kurunegala District, Sri Lanka. A structured questionnaire was used to gather the data during 2022 in the study and those data were analysed by Data Envelopment Analysis and Tobit regression model. Results of the data envelopment analysis based on input - oriented reveal that, mean technical efficiency scores estimated for constant returns and variable returns to scales were 0.782 and 0.887, respectively, indicating that substantial inefficiencies occurred in operations among the sample farmers. Further, with respect to returns to scale, out of the 150 dairy farmers, 21 were found to be operating at the constant returns to scale while, 122 and 7 were operating at an increasing return to scale and decreasing returns to scale respectively. Tobit regression model was applied to examine the factors influencing the technical efficiency under the specifications of constant returns to scale, variable returns to scale, and scale effects. The study found that age, sex, family size, credit accessibility, and milking frequency were significantly influence the technical efficiencies in dairy farming. These findings could help to increase the milk production and technical efficiency of cow milk production in the study area.

JEL: D24, O13, Q12, Q13

Keywords: Constant Returns to Scale, Data Envelopment Analysis, Input-oriented Technical Efficiency, Tobit Model, Variable Returns to Scale

D M H Herath (Corresponding Author)

Department of Business Economics, University of Vavuniya, Sri Lanka.

Email: dmharshaniherath@gmail.com, Tel: +94 76 008 4563

 <https://orcid.org/0009-0004-7281-3032>

A Thayaparan

Department of Business Economics, University of Vavuniya, Sri Lanka.

Email: aruppillaihayaparan@yahoo.com, Tel: +94 77 614 3582

 <https://orcid.org/0009-0000-5783-2201>



INTRODUCTION

Dairy farming is an important sector in the rural economy which makes the substantial contributions to the Sri Lankan economy by providing high-value food and employment opportunities for many rural households as well as an important source of income for farm households. Sri Lanka currently produces about 40% of its milk demand domestically and is therefore heavily dependent on imports to meet demand. Dairying is a high potential agro -industry mainly carried out by smallholder farmers in Sri Lanka. (Livestock statistical bulletin,2021). Analysis of cow milk production data for the last five decades showed that milking trends and milk production of cows and buffaloes have increased over the years. There is a great potential to increase milk production from buffaloes in Sri Lanka. Local small-scale dairy processing should be encouraged by promoting the use of products from these local producers when the price of milk products increases in the international market. Cow milk production is the main factor controlling the dairy industry in Sri Lanka. According to government statistics, milk production in 2022 was 506 million liters. (Damunupola, et al, 2022). Livestock plays diverse roles in Sri Lankan agriculture, contributing around 1% to the national Gross Domestic Production (GDP) at present. Primarily, they provide a crucial source of high-quality protein in terms of milk, meat and eggs. However, the dairy sector has been identified as the priority sector for development among other livestock sub-sectors in the country. National Accounts of Sri Lanka (2019) shows that, the contribution of the dairy industry to the GDP in Sri Lanka is 21%. Among different livestock species, cattle and buffaloes are regarded as the major animals that play a momentous role in the dairy industry. Traditionally, these animals are reared for multiple purposes such as to obtain milk for household consumption, as a medium for transportation and draft, and dung as an organic fertilizer and fuel. Presently, it has become one of the major employments for the rural poor which generates a continuous flow of income. (Damunupola, et al, 2022).

Milk production is an important branch of the livestock sector and most of the farmers in the study area are family-based dairy farms producing milk as their main income source. The Government of Sri Lanka is intended to increase milk production since the total import value of milk and milk products was very high and implemented many programs to attained the self-sufficient in milk production. Even though the dairy industry provides substantial benefits, in general, the majority of the small-scale dairy farmers are leaving the industry due to various reasons and facing a number of constraints such as low productivity and efficiency, poor genetic merit of indigenous cattle and a lack of appropriate techniques due to an inadequate extension scheme for technology transfer (Internal Ex-Post Evaluation for Technical Cooperation Project, 2017). A major challenge for the sector is how to improve its profitability and increasing the profitability of the sector can also be possible under the current technologies without changing the production technology. The scope for improving milk production with the existing technology depends on the level of technical efficiency of dairy farmers in the study area.

In this background, this study tries to answer the research questions of what extent dairy farmers are efficient in utilizing the available resources and what factors significantly contributes to attain the technical efficiency in milk production in the study area.

Kurunegala is one of the major districts in Sri Lanka in the milk production which contributes around 15 % to the national milk production. But the annual contribution of the district to the national fresh milk production has been decreasing for past few years. (Hemasiri and Kodithuwakku, 2016).

In this context, estimating the technical efficiency and its determinants among smallholder milk farmers in Sri Lanka is an important aspect. By understanding the constraints and challenges faced by smallholder milk farmers, policymakers, researchers, and other stakeholders can develop effective interventions and policies that can improve the technical efficiency of milk production and enhance the socio-economic status of the dairy farmers in the future.

LITERATURE REVIEW

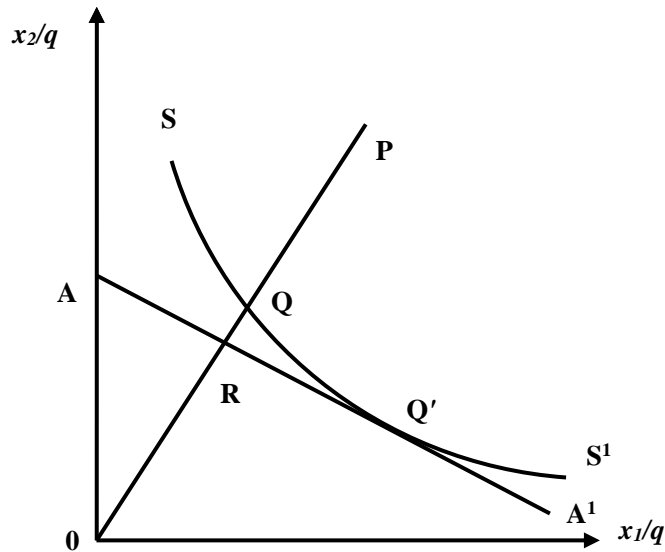
Theoretical Framework for Measuring Technical Efficiency

There are two approaches of measuring production efficiency such as, input-oriented approach and output-oriented. Input-oriented efficiency measures indicate the proportionate reductions in quantities of inputs without any reduction in the output quantity produced and output-oriented efficiency measures indicate the extent to which output quantity can be increased without any change in the quantities of inputs used. Both measures will coincide when the technology exhibits constant returns to scale, but are likely to vary otherwise (Coelli, 2005).

Input Oriented Approach

Farrell (1957) illustrated the idea of input-oriented efficiency using a simple example of a given firm, which uses two factors of production, such as X_1 and X_2 to produce a single output (q). The firm face a production function, $q = f(X_1, X_2)$, under the assumption of constant returns to scale, where the assumption of constant return to scale will help to present all necessary information on a simple isoquant. Input – oriented approach shown in Figure 1 and according to that, isoquant SS^1 represents the various combinations of the two input variables that at least a firm might use to produce a unit of output. This is an isoquant that defines the input per-unit of output ratios associated with the most efficient use of the input to produce the output involved.

Figure 1: Input-Oriented Illustration of Technical Efficiency



Source: Farrell (1957); Coelli et al. (1998)

In an input-oriented measure of efficiency both allocative and technical efficiencies of a firm fall on or above the unit isoquant of the input-per-unit of output space and cannot be below or to the left of it. A departure from the unit isoquant indicates technical inefficiency and the more a firm is far from the unit isoquant the more it is inefficient.

All firms that are located on the unit isoquant SS^1 are technically efficient and all production inputs are optimally used. Departure from the line AA^1 represents the degree of allocative inefficiency (AE) and the value for point Q is given by the ratio RQ/OQ . The distance RQ represents the reduction in production costs that would occur if a firm is to produce at both allocatively and technically efficient point Q' , instead of at the technically efficient, but allocatively inefficient, point Q.

Mathematically, the technical efficiency of a firm operating at P can be represent as follows:

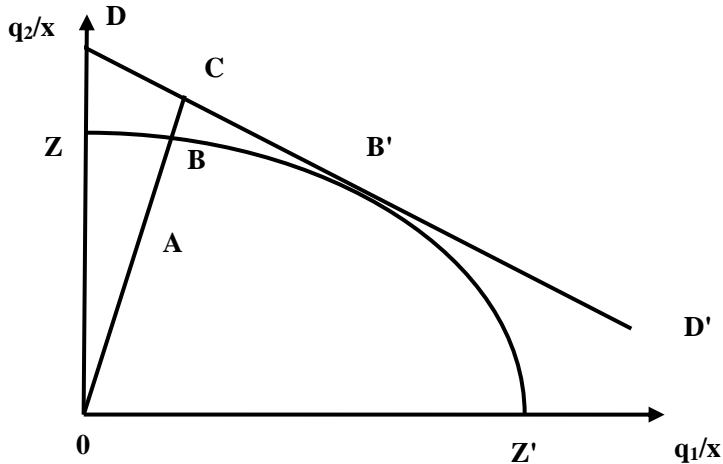
$$TE = OQ/OP \dots\dots\dots (1)$$

Output Oriented Approach

While the input-oriented approach answers the question by how much the input use can be reduced without affecting the level of output, in the output-oriented approach one can alternatively answer the question by how much can output be increased without increasing the amount of inputs used (Coelli et al., 2005). Figure 2 below illustrates the output-oriented approach of efficiency measurement using a production possibility curve

that shows the possible combination of two outputs (q_1 and q_2) one can produce given input X and the level of technology.

Figure 2: Output-Oriented Illustration of Technical Efficiency



Source: Farrell (1957); Coelli et al. (2005)

Given the production possibility curve, a producing unit can then be located either exactly on the production possibility curve or below it. All producers on the curve have attained the maximum combination of q_1 and q_2 that can be produced given the input level and state of technology. But firms located below the curve are said to be inefficient. For instance, given the fixed amount of input and level of technology under constant return to scale firm A is producing lesser amount of both outputs than B. There is a possibility for firm A to increase the level of outputs q_1 and q_2 , without requiring extra inputs. Thus, the technical efficiency of A is given by:

$$TE = OA/OB..... (2)$$

Therefore, it is possible to measure the efficiencies of production using input oriented and or output oriented approaches.

Empirical Studies

In general, two widely used approaches are used to evaluate relative efficiency indices. These are the nonparametric or data envelopment analysis (DEA) and the parametric or stochastic frontier analysis (SFA). In order to estimate the parameters of the production function, SFA establishes a functional link between inputs and outputs. One distinctive quality of the stochastic model specification of SFA, according to Coelli (1995), is that it allows for hypothesis testing. The SFA technique's drawback is that it requires certain assumptions on both the distribution of the error component and the functional form of the frontier. In contrast to SFA, DEA builds a piecewise frontier of the data using techniques from linear programming. Since DEA is deterministic in nature and

nonparametric in nature, it does not need any assumptions about functional form or distribution type and hence blames any departures from the production frontier to inefficiency (Coelli, 1995). The DEA method gives an efficient frontier's form less structure, which is regarded as a notable advantage of nonparametric frontier approaches over parametric measurements.

In this study, constant returns to scale (CRS) and variable returns to scale (VRS) assumptions were used to determine technical efficiency using DEA models. According to Färe et al. (1985), the CRS assumption mandates that any increase in input will result in a corresponding rise in output. This efficiency measure is also known as an overall technical efficiency measure since it will take both controllable and non-controllable sources of inefficiency into account. The projected production frontier of VRS, in contrast to CRS, more tightly encircles the data points since it takes into account scale inefficiencies and the assumption that output won't rise proportionately to an increase in input. This measurement, sometimes referred to as a measure of pure technical efficiency, does not blame inefficiencies on scale disparities (Färe et al., 1985). While the CRS assumption presupposes that farmers are scale-efficient, the VRS assumption argues that not all farms are functioning at their optimal scale. This implies that scale inefficiencies occur if there is a difference in efficiency under both assumptions (CRS & VRS). In this investigation, we expected the return to scale (RTS) to change or be variable, thus we employed the DEA-VRS presented by Banker et al. (1984).

The papers employ either Data Envelopment Analysis (DEA) or Stochastic Frontier Analysis (SFA) in measuring technical efficiency. SFA is a parametric approach that implies a particular functional form, whereas DEA is a non-parametric method that assesses technical efficiency without assuming any functional form. The use of these two methods can lead to different efficiency scores and different determinants of efficiency. Hence, there is a need for comparative studies that examine the differences and similarities between DEA and SFA in measuring technical efficiency in smallholder milk farming. Such studies can provide valuable insights into the methodological issues in measuring technical efficiency in this sector and help identify the best approach for future research.

Data envelopment analysis was used by Hosseinzadeh et al. (2018) to investigate the determine optimal energy consumption in dairy farms in Qazvin, Iran, using data envelopment analysis (DEA). The study employed constant returns to scale (CRS) and variable returns to scale (VRS) models of DEA to measure the technical, pure technical, and scale efficiencies. It also examined the impact of optimal energy consumption on greenhouse gas (GHG) emissions. Results showed that 42.55% and 53.19% of farms were efficient based on CRS and VRS models, respectively. The average technical, purely technical, and scale efficiencies were 0.9, 0.94, and 0.953, respectively. The study also provided insights to enhance energy efficiency and mitigate environmental impacts in dairy farming.

Aldeseit (2013) conducted a study measurement of scale efficiency in dairy farms using data envelopment analysis (DEA) approach. This study aimed at evaluating the performance of sampled dairy farms using farm-level technical and scale input-oriented efficiencies. To achieve the objective of the study Data Envelopment Analysis (DEA) was used to analyse data collected from 120 dairy farms in Jordan. Scale efficiency scores were estimated using constant return to scale and variable return to scale DEA models. The results revealed that the sampled farms were not operating at an optimal size. On average, the scale efficiency is estimated at approximately 0.66, indicating scale inefficiency under both constant returns to scale and variable returns to scale. This inefficiency indicates that the sampled dairy producers were overusing inputs to produce their level of output. To increase scale of operation dairy farmers in Jordan should increase the overall degree of technical efficiency. Extension services can assist in identifying the best management practices on how to improve farms technical efficiency.

Through the use of DEA Gelan and Muriithi (2012) examined the explaining technical efficiency of dairy farms: a case study of smallholder farms in East Africa 371 dairy farms across East African countries. The study utilizes three output and ten input variables to calculate efficiency scores for each farm, employing a two-stage analysis approach. The first stage employs a data envelopment analysis (DEA) using linear programming to measure efficiency scores. The results show that 18 percent of the farms are fully productive, operating at maximum efficiency, while 32 percent have efficiency scores below 0.25, indicating a need for significant expansion in dairy production without increasing inputs. The second stage employs fractional regression to explore the relationship between efficiency scores and various explanatory factors. The findings highlight that the adoption of technology, including improved breeds and innovative feed and fodder practices like growing legumes, positively and significantly impacts efficiency. Additionally, zero-grazing and selling milk to individual consumers or organizations are associated with higher efficiency. While membership in a dairy cooperative has a positive effect, it lacks statistical significance.

These studies utilize data envelopment analysis (DEA) to examine the efficiency and performance of dairy farms in different regions. Hosseinzadeh et al. (2018) focus on optimal energy consumption in Iranian dairy farms, while Aldeseit (2013) evaluates scale efficiency in Jordanian dairy farms. Gelan and Muriithi (2012) investigate technical efficiency in East African smallholder dairy farms. Overall, the studies emphasize the importance of adopting efficient practices, such as optimizing energy consumption, improving scale efficiency, and adopting technology, to enhance the overall performance and sustainability of dairy farming. These findings highlight the need for targeted interventions and best practices to address inefficiencies and promote productivity in the dairy sector. By improving efficiency, farmers can achieve better resource utilization, reduce environmental impacts, and contribute to the long-term viability of the industry.

A stochastic frontier approach was used by Masuku et al. (2014).to investigate the Economic Efficiency of Smallholder Dairy Farmers in Swaziland using Stochastic Profit Frontier Function. This research employed a descriptive and quantitative survey, targeting all registered smallholder dairy farmers with the Swaziland Dairy Board. A sample of 111 respondents was selected using purposive and random sampling techniques. The analysis employed three methods: descriptive statistics, econometric analysis (Stochastic Profit Frontier Function), and gross margin analysis. The results revealed that the mean level of economic efficiency (EE) among the farmers was 79.8%. Several factors were found to influence the level of economic efficiency, including the farm's location, pasture size, soil fertility, water availability, the farmer's experience in dairy farming, membership to dairy farmers' association, and training on dairy farming. The study concludes that smallholder dairy farmers in Swaziland demonstrated economic efficiency and that institutional factors, socioeconomic characteristics, and farm attributes significantly impact their level of efficiency. Additionally, the dairy farming enterprise was found to be profitable.

Ariningsih et.al (2022) focused on the utilization of dairy cattle manure among smallholder dairy farmers in West Java and the factors that hindered its proper management. The study utilized data from 410 dairy farmers in four districts of West Java. The analysis revealed that only 42.8% of smallholder dairy farmers in the region utilized cattle manure for various purposes, such as fertilizer, biogas production, and earthworm raising. Conversely, the majority (57.2%) discharged the manure into their surroundings. The study identified several reasons for the inadequate management of manure, including the difficulty in adopting the technology, high adoption costs, farmers' satisfaction with current practices, limited input availability, land constraints, lack of information on technology, and labour-intensive processes.

Given the environmental impact and the economic potential of dairy waste, the study recommended that the government should provide efficient and practical waste management technologies, along with intensive training and assistance to address the issue effectively. This would contribute to both environmental sustainability and economic benefits for smallholder dairy farmers in West Java. Joseph and Emilian (2022) addressed the importance of production efficiency across sectors in light of the impending threat of food insecurity. The study specifically focused on Tanzanian smallholder farmers and aimed to determine the level of technical efficiency and its associated factors in crop production. The researchers employed a single-step stochastic frontier model assuming a Cobb-Douglas production function. The study utilized the National Sample Census of Agriculture 2019/2020 dataset, focusing on smallholder farmers operating during the long-rainy season. The findings revealed that land size, seeds, and fertilizers were the primary requirements for smallholder farmers to achieve maximum output. The efficiency equation indicated that improved seeds, inorganic fertilizers, and access to extension services decreased technical inefficiency, while household age and cooperative

membership increased inefficiency. The study concluded that the average level of technical efficiency among Tanzanian smallholder farmers was 56.7%, indicating the potential for a 43.2% increase in output using the same inputs. These findings highlighted the importance of addressing technical inefficiencies to enhance productivity and mitigate the threat of food insecurity in Tanzania's agricultural sector.

These three studies reviewed in this summary explore different aspects of efficiency and management in smallholder dairy farming. Masuku et al. (2014) investigate the economic efficiency of dairy farmers in Swaziland and find a mean level of economic efficiency of 79.8%, with various factors influencing efficiency. Ariningsih et al. (2022) focus on the utilization of dairy cattle manure among smallholder farmers in West Java, highlighting the low utilization rate and identifying barriers to proper management. Joseph and Emilian (2022) emphasize the importance of production efficiency among Tanzanian smallholder farmers, identifying key requirements and factors influencing technical efficiency. Overall, these studies stress the significance of efficient practices, such as optimal resource utilization and adoption of appropriate technologies, to enhance the economic and environmental sustainability of smallholder dairy farming and all of these studies employ a stochastic frontier technique to examine the technical effectiveness of smallholder dairy farms in various nations.

METHODOLOGY

Study Area and Method of Data Collection

The study was conducted in Kurunagala district which is located in intermediate zone and it is a part of the coconut triangle in North Western Province of Sri Lanka. From the district, Maho Divisional Secretarial was selected as the study area due to the fact that, this area is more popular for dairy farming in Kurunegala district.

This study involved a purposive sampling and using this method 5 villages such as Balalla, Wilawa, Ambagaswerwa, Thammitagama, and Daladagama were selected based on the relatively high prevalence of smallholder dairy farmers engaging in cow milk production. In the next stage, using a simple random sampling technique 150 farmers were selected from these villages based on the list of dairy farmers who produced milk in the production year 2022. Socio- economic and production of cow milk data were collected using a structured questionnaire from the above selected farmers in the study.

Analytical Procedures for Measuring Technical Efficiency

This study uses a two-step approach and the first step used the data envelopment analysis to determine technical efficiency level among cow milk farmers developed by Cooper et al. (2011) while the second step applied the technical efficiency scores as the dependent variable in the Tobit regression model to determine the determinants of technical efficiency of the milk production in the study.

Data Envelopment Analysis

DEA is a nonparametric method of estimating technical efficiency of farmers and It is a linear programming method proposed by Farrell to calculate the non-parametric boundary, and the efficiency index for a particular farm is obtained by comparing the input and output obtained. It also does not require the assumption of adjacent technologies or distribution inefficiency. Author suggested that efficiency is expressed as the actual production of a farm compared with the maximum output that can be achieved, which is a reference to a production frontier. Therefore, the efficiency of farm production is the average distance measurement's output from the frontier level. Thirty years later, developed such a multi stage methodology and a computer program name as data envelopment analysis program (DEAP) which implements a robust multi-stage model among other options. A ratio of technical efficiency scores obtained from under CRS and VRS assumption measure scale efficiency. According to, DEA model based on the constant returns to scale (CRS) is stated as follows:

$$\begin{aligned}
 & \min_{\theta, \lambda} \theta, \\
 & \text{subject to } -y_i + Y\lambda \geq 0, \\
 & \theta x_i - X\lambda \geq 0, \\
 & \lambda \geq 0 \dots\dots\dots (3)
 \end{aligned}$$

where θ is the scale of technical efficiency for each farm, λ is as $N \times 1$ vector of constants, y_i and x_i is the total output and farm inputs $i, i = 1, 2, \dots, n$. The value of $\theta \leq 1$ indicates the level of production reflects the production frontier and technically efficient farms. The equation (3) has used the assumption that all farms operate at an optimal scale. However, constraints such as finance and imperfect competition that occur at the field cause only part of the farm to operate at that level. Therefore, the above model can be estimated based on the variable returns to scale (VRS), which evaluates the efficiency of farms based on their capabilities. VRS model is formed by inserting the constraints $N1'\lambda = 1$ in equation (4), where $N1$ is $N \times 1$ vector.

$$\begin{aligned}
 & \min_{\theta, \lambda} \theta, \\
 & \text{subject to } -y_i + Y\lambda \geq 0, \\
 & \theta x_i - X\lambda \geq 0, \\
 & N1'\lambda = 1 \\
 & \lambda \geq 0 \dots\dots\dots (4)
 \end{aligned}$$

Constraints of $N1'\lambda = 1$ indicate the inefficiency of a farm evaluated against other farms of similar size. In this way, the efficiency of the farm can be evaluated based on technical and scale efficiency. Technical efficiency describes the ability of farms to achieve maximum production with the use of inputs given while the scale efficiency is the ratio

between CRS and VRS. The differences for both show the levels of scale inefficiency of production of farmers. The output-oriented DEA model based on the VRS is stated as follows:

$$\begin{aligned}
 & \max_{\varphi, \lambda} \varphi \\
 & \text{subject to } -\varphi y_i + Y\lambda \geq 0, \\
 & x_i - X\lambda \geq 0 \\
 & N1'\lambda = 1 \\
 & \lambda \geq 0 \dots\dots\dots (5)
 \end{aligned}$$

where $1 \leq \varphi < \infty$, and $\varphi - 1$ is an increase in the ratio of output that can be achieved by farmers i^{th} , with a given quantity of inputs which is constant. $1/\varphi$ is the technical efficiency which has a value between 0 and 1 in equation (5). The findings also explain scale efficiency. This study uses the program DEAP 2.1 to measure the technical efficiency of the output-based DEA model.

Tobit Regression Model

Technical efficiency scores obtained using the above data envelopment analysis and it was considered as the dependent variable in Tobit model since they were having upper and lower limits between 0 and 1, respectively. Consequently, they were regressed against the technical efficiency scores obtained from DEA approach with the demographic and farm-specific characteristics as independent variables in the model.

As the efficiency index derived from data envelopment analysis is bound between 0 and 1 values, thus it is suitable for use as a simulation analysis to identify the determinant of technical efficiency among farmers. Based on previous studies, the influence of efficiency of farmers by Ordinary Least Square (OLS) has been used by to identify this factor through a regression model. But, some arguments state that the estimation of OLS is inconsistent and inefficient. For this reason, this study used the Tobit Model to replace OLS and according to Tobin (1958), Tobit regression model is specified as:

$$\begin{aligned}
 & y_t^* = x_t^* \beta_0 + \varepsilon_t, \text{ where, } t = 1, 2, 3, \dots, n \dots\dots\dots (6) \\
 & y_i = 0 \text{ if } y_i^* \leq 0 \\
 & y_i = y_t^* \text{ if } y_t^* > 0
 \end{aligned}$$

Where,

y_i is an efficiency index used as a dependent variable, $\varepsilon_t x_t$ is $N(0, \sigma^2)$ and (y_t, x_t) ($t = 1, 2 \dots \dots n$) is a vector of independent variables related to farm-specific attributes, value of c is known. y_t^* is a latent variable. β is an unknown parameter vector associated with

the farm-specific attributes, and ε is an independently distributed error term that is assumed to be normally distributed with zero mean and constant variance, σ^2 .

Using the above general form, the Tobit model used in the study can be specified as:

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \varepsilon \dots \dots \dots (7)$$

Where,

Y_i = Technical efficiency scores measured under constant returns to scale variable returns to scale, and scale efficiency specifications

β_0 = Constant

β_1 to β_5 = coefficients of each explanatory variable

X_1 = Age measured in years

X_2 = Sex coded as 1 for male and 0 for female

X_3 = Number of family members

X_4 = Credit accessibility coded as 1 for yes and 0 for no

X_5 = Milking times per day

ε = Error term

RESULTS AND DISCUSSION

Results of Descriptive Statistics

Table 1: Summary Statistics for Variables

Variable	Minimum	Maximum	Mean	Standard deviation
Milk production per month in Liters	100	800	317.97	159.24
Income in Rs	12000	80000	33282.33	15826.17
Expenditure on animal feed in Rs	500	10000	2890.00	2088.535
Number of lactating cows	1	7	2.49	1.22
Labour hours per day	2	12	5.29	1.88
Expenditure on veterinary in Rs	1000	10000	4136.67	2047.99
CRS technical efficiency (TE _{CRS})	0.40	1.00	0.782	0.133
VRS technical efficiency (TE _{VRS})	0.60	1.00	0.887	0.117
Scale efficiency (SE)	0.52	1.00	0.884	0.114

Source: Aauthor’s calculations

Table 1 presents the descriptive statistics of the variables used in data envelopment analysis (DEA) for the technical efficiency analysis. Milk production per month in Liters considered as an output while income, expenditure on animal feed, Number of lactating cows, labour hours and expenditure on veterinary considered as inputs in the study. The

results showed that the yields from milk is 317.97 liter and they earn the average income per month of Rs 33282/= from milk. The farmers spent an average of Rs 2890/= on animal feed and Rs 4136.67/= on veterinary while they have on average milking cows is 2 with the average labour hours of 5 per day.

The mean technical efficiency scores estimated for the CRS (Overall technical efficiency) and VRS (Pure technical efficiency) were 78% and 88% respectively in the study. 78% of the overall technical efficiency indicates that, on average, milk farmers could reduce their inputs by 22% and still produce the same amount of milk production. The splitting of the technical efficiency measure produced estimates of 12% of pure technical inefficiency and 12% of scale inefficiency. By eliminating scale inefficiency, the milk farmers can increase their average technical efficiency level from 0.78 to 0.88. Scale efficiency indicates whether any efficiency can be obtained by improving the size of the operation and the average of scale efficiency was at 88% indicating that most of the milk farmers are operating near to their optimal size.

Technical Efficiency

The data envelopment analysis program software was developed by Coelli to calculate the DEA scores (1996) and the efficiency scores were measured under CRS and VRS assumptions. The CRS assumption is appropriate when all firms are operating at an optimal scale. However, unfair competition, government regulations, constraints on finance etc., may cause a firm not to operate at optimal scale (Coelli et al., 2005). The use of CRS specification when not all firms are operating at the optimal scale, results in measures of TE that are confounded by scale efficiencies (SE). The use of the VRS specification permits the calculation of TE devoid of these SE effects.

Results of the input-oriented DEA analysis were derived using the computer program DEA 2.1 and its results presented in Table 1 which indicates that, overall technical efficiency (TE_{CRS}) ranges varies from 40% to 100% with an average of 78% and standard deviation of 0.133. Pure technical efficiency (TE_{VRS}) across the 150 milk farmers was, on average 88% ranging from 60% to 100% with a standard deviation of 0.117. The scale efficiency (SE) score for the above samples ranges from 52% to 100% with a sample mean and standard deviation of 88% and 0.114 respectively.

Table 2 presents the results of frequency distribution of technical efficiency scores derived from DEA analysis and its results revealed that under CRS, 28.7% of the farmers achieved the highest efficiency range between 71 - 80% while 53.3% and 52.1% of the farmers attained the efficiency range between 91 - 100 under VRS and scale efficiency respectively.

Table 2: Frequency Distribution of Technical Efficiency Scores Derived From DEA

Efficiency range	TE _{CRS}		TE _{VRS}		SE	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Less than 50	2	1.3
51-60	10	6.7	1	0.7	5	3.3
61-70	36	24.0	10	6.7	11	7.3
71-80	43	28.7	33	22.0	18	12.0
81-90	28	18.7	26	17.3	38	25.3
91-100	31	20.6	80	53.3	78	52.1
Total	150	100.0	150	100.0	150	100.0

Note: TE_{CRS}: – Technical efficiency from constant returns to scale, TE_{VRS}: – Technical efficiency from variable returns to scale, SE: – Scale Efficiency.

Source: Aauthor's calculations

Results of Pearson Correlations

Table 3 gives the correlation statistics between the three technical efficiency scores under three returns to scale which help to determine the relationship between the two efficiency measures. The results showed that, scale efficiency and constant returns to scale were highly positively correlated each other followed by variable returns to scale technical efficiency and constant returns to scale efficiency. But, there is a negative correlation exist between scale efficiency and variable returns to scale technical efficiency at 1% level of significant.

Table 3: Pearson Correlations Between Technical Efficiency Measures

Technical efficiency under different scale	CRS _{TE}	VRS _{TE}	Scale efficiency
Constant returns to scale	1		
Variable returns to scale	.620***	1	
Scale efficiency	.636***	-.203**	1

Note: ** and *** represents the levels of significant at 5% and 1% respectively.

Source: Aauthor's calculations

The minimum, maximum and average values of input slacks were estimated and shown in Table 4. A slack indicates excess of an input where a farmer can reduce his expenditure on an input by the amount of slack without reducing its output. The results show that, income has the highest maximum slack and the labour hours have the lowest maximum slack in the study. The results further explained that, on average income, expenditure on animal feed and expenditure on veterinary could be reduced by Rs 832.747/=, Rs 460.748/= and Rs433.626/= respectively without affecting current output, despite an initial minimization of all inputs farm inputs by 12% in the sample.

Table 4: Estimated Input Slacks from DEA Model

Input	Min slack	Max slack	Mean slack
Income	0.00	11914.89	832.74
Expenditure on animal feed	0.00	5789.24	460.74
Number of lactating cows	0.00	2.75	0.13
Labour hours per day	0.00	2.60	1.17
Expenditure on veterinary	0.00	6000.00	433.62

Source: Aauthor's calculations

Based on the average pure technical efficiency of 88% in the samples, the milk producers were divided into two groups where they have more than 88% of the efficiency belong to efficient producers and who are the producers their efficiency less than 88% belongs to inefficient producers in the study. The results were shown in the following table.

Table 5: Comparison of Average Input Use Between Efficient and Inefficient Farmers

Input use	Income	Expenditure on animal feed	Number of lactating cows	Labour hours	Cost on veterinary	Amount of milk production
Efficient producers	30158.82	2482.35	2.14	4.94	3570.58	306.94
Inefficient producers	37369.23	3423.07	2.93	5.73	4876.92	332.38

Source: Aauthor's calculations

According to the above table, the efficient milk producers used an average of income of Rs 30158/=, Rs 2482/= of expenditure on animal feed, two lactating cows, nearly five hours of labour and Rs 3570/= expenditure on veterinary to produce nearly 307 liters of milk per month. For the inefficient milk producers to move up to the production level of efficient producers, they would have to reduce their income by Rs 7211/=, expenditure on animal feed by Rs 941/=, number of lactating cows by 1, labour hours by 1 hour, expenditure on veterinary by Rs 1306/= in order to become efficient milk producers in the study.

Returns to Scale

Table 6 contains the dairy farmers that were operating at optimal (CRS), sub-optimal (IRS), and super- optimal (DRS) levels. Out of the 150 farmers in this study, 21 (14%) were found to be operating at the optimum scale (CRS) while, 122 (81.3%) and 7 (4.7%) were operating at sub-optimal (IRS) and super-optimal (DRS) scales, respectively.

This means that if the scale of 122 farmers increases and the scale of 7 farmers decreases, efficiency can be increased. Further, this implies that most of the farmers were operating under the sub-optimal conditions, and based on this, they could still produce more output

before arriving at the decreasing returns to scale. This agrees with the results reported by Gul et al. (2009), who found out that 72% of smallholder farmers were operating under the increasing returns to scale, implying that there was room to increase the yield. However, Tipi et al. (2010) reported that only 20% of the rice farmers in Turkey were operating under constant returns to scale.

Table 6: Characteristics of Farms with Respect to Returns to Scale

Characteristics	No. of farmers	Percent of the farmers
Optimal (Constant returns to scale - CRS)	21	14
Sub-Optimal (Increasing returns to scale - IRS)	122	81.3
Super-Optimal (Decreasing returns to scale -DRS)	7	4.7

Source: Aauthor's calculations

Further, Tobit regression model was conducted to identify the determinants of technical efficiency among dairy farmers in the study. In the Tobit model, the score of technical efficiency of constant returns to scale, variable returns to scale and scale efficiency of the farmers are used as the dependent variables, while the independent variables consist of the variables such as age, sex, family size, credit accessibility and time for milking. Thus, three separate Tobit regressions for CRS, VRS and scale efficiency specifications were estimated in the analysis. Since the scores are bounded in between zero to one, the use of the ordinary least-square regression model is not suitable. In such a case, Tobit regression model is more applicable and thus it was employed in the study.

Table 7: Results of Tobit Regression Model and Marginal Effects

Variable	CRS TE		VRS TE		SE TEC	
	β	dy/dx	β	dy/dx	β	dy/dx
Age	0.003*** (0.001)	0.00001	0.006*** (0.001)	3.75e-06	0.0047*** (0.001)	8.63e-06
Sex	0.115*** (0.036)	0.0003	0.129*** (0.048)	0.00007	0.114*** (0.03)	0.0002
Family size	0.042*** (0.013)	0.0001	0.040** (0.017)	0.00002	0.050*** (0.012)	0.00009
Credit	0.060* (0.033)	0.0001	0.083* (0.045)	0.00005	0.041 (0.03)	0.00007
Milking times per day	0.091*** (0.028)	0.0002	0.097** (0.037)	0.00005	0.103*** (0.025)	0.0001

Note: ***, ** and * represents 1%, 5% and 10% levels of significant respectively. Standard errors are in the parentheses.

Source: Aauthor's calculations

Age of the farmer was found to have a positive sign and significant in all three efficiencies revealed that older farmers are found to be more efficient than younger farmers. As age increases by one more year, the probability of technical efficiency in milk production also will be higher in all measures. This can be attributed to the fact that experience in dairy farming of a cattle farmer increases with age as well as resources empowerment which usually lead to increase in technical efficiency. Marginal effect of age for CRS_{TE} shows that elder farmers have 0.001% of more probability to attain technical efficiency in milk production than younger farmers and the probability of attaining technical efficiency under VRS and SE also will be higher in the study. This finding opposes with Mahdi, (2010). The sex of the farmer was highly significant and had a positive effect on the efficiency for milk farmers under all three specifications at 1 per cent significant level indicates that, male farmers are more likely to be efficient than the female dairy farmers. This suggests males are key actors in the business of dairy farming. They may therefore have acquired relatively more technical and managerial expertise on the dairy production than females.

The variable for family size is positively related to technical efficiency and statistically significant at 1% and 5% levels defines that dairy farmers with large family size are more technically efficient than with less members in the family. This is probably because farmers that have large household size tend to endeavour to obtain higher output in order to meet their subsistence necessities. Furthermore, large household size has labour endowment required to implement cattle farm management decisions. The findings are consistent with Bhatt and Bhat (2014).

Coefficient of access to credit is significant at 10% level and positively associated with all specifications of technical efficiencies which suggest that an increase in access to credit increases technical efficiency levels of dairy farmers. According to Desai and Mellor (1993) explained that farm credit boosts diversification of agricultural systems that stabilize and possibly improve farm productivity, if it is appropriately extended, managed and utilized. Maseatile (2011); Butler and Cornaggia (2011) and Tleubayev et al. (2017) reported comparable results in Lesotho, U.S.A. and Kazakhstan, respectively Milking times per day was also found to be significantly affecting the technical efficiency of dairy farm. Specifically, farms milking their cows two times per day were more efficient than those with a milking times of just one time per day. Marginal effects for Milking times reveal that, as the Milking times per day is two times per day the probability of improve the efficiency under CRS and VRS will be higher by 0.02% and 0.005% respectively while the probability of attaining scale efficiency also will be higher by 0.01% in the study. This result agrees with the previous literature. Indeed, Erdman and Varner (1994) reported that daily Milking times of 3 times and 4 times have, respectively, 3.5kg and 4.9 kg of additional milk produced per day per cow. In addition, Dahl et al. (2004) reported that more frequent milking in early lactation stages has been found to

improve milk production efficiency. Cabrera, V. E., et al. (2010) also found that more frequent milking found to improve the efficiency in milk production.

CONCLUSIONS

This paper has estimated the technical efficiency of smallholder dairy farmers in Kurunegala district using data envelopment analysis under the assumptions of input orientation with variable returns to scale, constant returns to scale specifications. The determinant factors that affecting the technical efficiency under the above three specifications were investigated using Tobit regression model in the study. The data were collected through a structured questionnaire during 2022 period and 150 randomly selected dairy farmers were used in the study. The results of data envelopment analysis indicate that CRS and VRS technical efficiency were estimated at 78% and 88% respectively while scale efficiency also was estimated at 88% in the samples. Estimated efficiency of VRS suggesting that dairy farmers in the study could reduce the existing level of inputs by 12% and still achieve the same level of output produced. Input slacks also estimated from DEA model and it suggest that the maximum slack was detected in income and the lowest slack was in the labour hours.

Out of the 150 farmers in this study, 14% of the farmers were found to be operating at the optimum scale (CRS) while, 81.3% and 4.7% of them were operating at sub-optimal (IRS) and super-optimal (DRS) scales, respectively. This implies that most of the farmers were operating under the sub-optimal conditions and based on this, they could still produce more output before arriving at the decreasing returns to scale. Apart from the estimation of technical efficiency scores, Tobit regression also used to investigate the factors that determine the technical efficiency scores under different specifications and its results showed that age, sex, family size, credit accessibility and Milking times per day are the major factors having a significant and positive influence on all three specifications scores of technical efficiencies in dairy farming in the study. Using the major findings of this study, the policymakers will be enabled to utilize them for appropriate implementation of new projects and programs to empower both the dairy producers and the consumers which may enhance the technical efficiency of cow milk production in the future.

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