Determinants of Technical Efficiency in Dry Zone Dairy Farming Systems of Sri Lanka

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Introduction

Dairy sector is a vital part of Sri Lanka's rural economy, providing income, employment, and nutrition. Beyond supplying high-quality protein and essential nutrients, livestock also acts as a "living bank" for smallholders, offering financial security in times of hardship. Despite this socio-economic importance, sector's overall contribution to GDP remains modest: agriculture accounted for 8.3% in 2023, with animal production at just 0.8%. With 77% of the population living in rural areas, dairy remains critical for livelihoods.

Sri Lanka's livestock population includes 1.57 million cattle & 0.47 million buffaloes, of which only 37% are milking animals. In 2023, domestic output totaled 370.32 million liters, but the country still imported over 50 million kg of milk powder at a cost of Rs. 63 billion. Productivity is limited by poor feed, breeding, management, & veterinary services, particularly in the Dry Zone, which holds 79% of livestock yet produces only half the milk. Addressing technical efficiency here is crucial for boosting productivity and rural welfare.

Objectives

Main objective of this study is to understand the factors affecting technical efficiency of dairy production in the Dry Zone of Sri Lanka. The specific objectives are: (i) to determine the factors contributing to dairy production efficiency in Dry Zone of Sri Lanka, (ii) to estimate the technical efficiency of dry zone dairy farming systems and (iii) to provide recommendations and policy guidelines to enhance dairy production in the Dry Zone of Sri Lanka through improving the efficiency levels.

Methodology

Technical efficiency reflects the ability to maximize output from given inputs to achchive target output under existing technology which measures how effectively resources are used in production. Stochastic frontier analysis was employed to assess efficiency using data on farming system characteristics collected through key informant interviews and focus group discussions.

The following frontier production function employed to derive technical efficieny:

$$Q_i = f(X_i; u_i)\exp(-u_i) \text{ and } 0 \leq u_i; i = 1, 2, \dots, n \quad (1)$$

Where Qi represents the actual output for the ith unit; Xi is a vector of inputs; and β is a vector of parameters that describe the transformation process; f (.) is the frontier production function and ui is a one-sided (non-negative) residual term. If the production unit is inefficient, its actual output will be less than the potential output. Therefore, we can treat the ratio of the actual output Qi to the potential output f(.) as a measure of the technical efficiency of the production unit, which can be express as follow:

$$TE = Q_i/f(X_i; u_i) = \exp(-u_i) \quad (2)$$

It is noted that u_i is zero if the production unit achieves the potential output with the highest technical efficiency and is greater than zero when production falls below the frontier (less than full TE). A random noise variable v_i (independently and identically distributed normal with mean 0 and variance σ_v^2) can be included in the equation (1) to capture the effect of other omitted variables that may influence the output is given as:

$$Q_i = f(X_i; \beta) \exp(v_i - u_i) \quad (3)$$

Above equaton (3) is known as the individual-specific stochastic production frontier function. In order to estimate this function, a half normal distribution is assumed for u_i (after empirical verification). The likelihood function for this model is:

$$L = -N\ In\ \sigma - constant + \sum[ln\Phi(-\varepsilon_i\lambda/\sigma) - 1/2(\varepsilon_i/\sigma^2] \quad (4)$$

Where, $\lambda = \sigma_u / \sigma_v$, $\sigma^2 = \sigma_v^2 + \sigma^2$, and Φ is the cumulative standard normal distribution function, and $\varepsilon i = (v_i - u_i)$. The maximum likelihood estimation

(MLE) method can used to estimate the stochastic frontier production equation. The individual-specific TE is given by the conditional mean of exp (-ui), based on the distribution of the composite error term, εi.In addition, other important parameters of the model are: σ = √ (σu2+ σv2), λ = σu/σv(>0) and γ= σu2/σ2). A significant σ (and λ) would indicate the significant variations in the output levels. The λ term with value above one would indicate that output variations due to inefficiency are higher than that due to random factors. A zero value of γ would indicate that the deviations from the frontier are due entirely to the noise and, in this case, the ordinary least squares (OLS) estimates of the model are equivalent to the MLE results. A value of one would indicate that all deviations are purely due to differences in TE across farms.

In this model, the empirical strategy consists of two stages adapting transcendental logarithmic (trans log) function and Cobb-Douglas function which is given as follows:

$$logy_i = logx + \sum_{j=1}^{m} \beta_j logx_{ij} + \Sigma_{k=1}^{2} \beta_k D_{kj} + \Sigma_{j=1}^{m} \Sigma_{k=1}^{2} \beta_{jk} D_{kj} logx_{ij} + e_i \quad (5)$$

In this study, the **dependent variable** is monthly milk production (litres). The independent variables are given in the Table 1. A stratified random sampling method was employed to select 216 dairy farmers, including 46 from Jaffna, 60 from Anuradhapura, 65 from Kurunegala's dry zone, and 45 from Hambantota representing four Dry Zone areas in order to capture the diversity of farming practices across the country.

Results and Discussions

Farmers were mainly Sinhala (76%), with aged group of 18 - 88 years while farming experience spanned 1–60 years, with a mean of 13.75 years. This indicates a mix of new entrants and highly experienced farmers. Labour use also varied: some depended entirely on family labour, while others hired additional workers. Accordingly, labour costs were calculated both with and without family contributions. Out of total farmers, 26.4% completed GCE O/L and few had higher qualifications. Dairy farming was the primary occupation for 72.2%, most of them earn Rs. 25,001–100,000 monthly (54.1%) as monthly income while only 1.5% exceeded Rs. 500,000. Out of the total farmers, about 40% are holding less than one acre. Milk yields are

varied by breed and locations. Jersey–Friesian crosses produced about 12 L/day in Kurunegala and Anuradhapura, while Friesians and Jerseys gave 13 L/day and 11 L/day respectively. Buffalo breeds such as Murrah and Nili-Ravi yielded 10–11 L/day, compared with 2–3 L/day from indigenous cattle. Production costs were lowest in Hambantota and Anuradhapura (Rs. 108/L) but highest in Jaffna (Rs. 127/L) due to intensive feeding, with family labour raising costs to Rs. 764/animal/day. Crossbreds and improved buffaloes appear best suited to the Dry Zone, though profitability depends heavily on feed and labour costs.

Table 1: Descriptive Statistics of Variables

Variables	Minimum Value	Maximum Value	Mean Value	Standard Deviation
Milk production litres per month	0	10,500	610	864
No. of milking animals	0	19	4	3.18
Age (HHH)	18	88	51.18	12.07
Experience of cattle farming	1	60	13.75	10.96
Total cost feed (per month) (Rs.)	651	225,000	34876	30,100
No. of animals	1	76	12	10
Labour cost (Rs.)[family labour]	0	105,000	42,524	13,178
Grass land management cost	0	45,000	5,666	7,696
Breeding cost (per month)	0	8,950	431	983.6
Water cost (per month)	100	12,000	1,741	1,965
Disease mgt cost (per month)	0	32,000	4,518	4,812.7
Insurance cost (per month)	0	1,667	14	127.72
Labour cost (Without family labour) (per month)	0	45,000	3,517	10,763
Age of the cattle shed	1	34	7.23	6.14
Cattle shed cost	1,000	3,500,000	264,106	447,883
Cattle shed (per month)	0	10,714	1,804	2,246
Electricity expenses (per month)	0	15,000	2,571	2,279
Machinery expenses (per month)	0	80,000	6,800	12,214
Transport expenses (per month)	0	25,000	7,260	6,199

Source: Survey Data, 2023

Monthly feed expenses ranged from Rs. 651 in low-input systems to Rs. 225,000 in intensive farms, with an average of Rs. 34,876. These findings reveal that there is a diversity among dairy farming in the Dry Zone, from subsistence to commercial operations.

In the production frontier analysis six major independent variables were considered in the maximum likelihood estimation: number of milking animals, concentrate feed, pasture, labour hours, water supply frequency, and total herd size. Results indicated mostly positive relationships between inputs and milk output, except herd size, which showed a negative effect. Inefficiency analysis revealed that farming experience and cattle shed availability enhanced efficiency, whereas farmer education, age, farm society membership, and breeding methods were negatively associated. These findings suggest that practical experience and infrastructure are more critical than formal education for improving dairy productivity in the region.

Table 2: Maximum Likelihood Estimates of the Cobb-Douglas Production Function of the Sampled Farmers

	Coefficients	**Std. Error**	**P – Value**	**95% confident Interval**	
Constant	4.81	0.24	0.000	4.3353	5.291556
No of milking animals	0.816*	0.577	0.000	7035438	0.929764
Concentrate feed per day	0.799*	0.208	0.000	0.039145	0.120725
Pasture per day	0.303	0.308	0.326	0.030152	0.120725
Labour hours per day	0.166	0.560	0.767	0.030152	0.907586
Water supply frequency	0.258**	0.11	0.022	0.093237	0.126468
No. of animals/herd	- 0.012	0.207	0.951	0.4203345	0.394653
Inefficiency model					
Constant	**1.44**	**2.413**	**0.549**	**3.282941**	**6.179626**
Educational Level	- 0.210	0.267	0.429	0.7345503	0.312356
Experience of cattle farming	.267***	0.138	0.054	0.3441286	1.292978
Gender	- 0.474	0.417	0.256	1.747429	0.600849
Age	- 0.573	0.55	0.339	0.8788718	0.394746
Farm Society Member	- 0.001	0.002	0.520	0.0065752	0.003329
Method of breeding	- 0.281	0.372	0.444	1.014003	0.443798
Availability of Cattle shed	0.379	0.282	0.179	0.933746	0.174262

Source: STATA Output, 2023

Stochastic frontier analysis revealed notable variation in technical efficiency among dairy farming systems in Sri Lanka's Dry Zone. The overall mean efficiency was 60.8%, which highlights considerable scope to improve productivity without increasing input use. Across the four farming systems studied, Kurunegala recorded the best results, with an average efficiency of

77.2%. Anuradhapura also performed similarly. Jaffna demonstrated moderate performance with averaging 56.8% efficiency. Hambantota showed the lowest efficiency, averaging 32.9%. These results underline the uneven productivity across systems among milk producing regions in Sri Lanka which influenced by the management practices, resource use, and local conditions.

Conclusion and Policy recommendations

Stochastic frontier analysis revealed significant differences in technical efficiency across dairy farming systems in Sri Lanka's Dry Zone. The overall mean efficiency was 60.8%, suggesting considerable potential to raise productivity without additional inputs. Efficiency values ranged from 15.2% to 92.9%, demonstrating wide variation in farm performance. The study highlights that there is a considerable scope to improve productivity without increasing input use.

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