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Stochastic frontier model to assess technical inefficiency of dairy farms in Kerala: A study

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Abstract

The present study was conducted to determine the level of technical inefficiency of dairy farms in Kerala by applying the stochastic production frontier (SPF) methodology. Technical efficiency estimates were generated for 100 dairy farms selected from two districts. The shortfall in the output among the dairy farmers from the two districts in Kerala was observed by the frontier output model due to the factors fixed costs, recurring costs, milk prices and labour costs per animal, access to credit and location of farm households. The negative and significant coefficients of recurring costs, labour costs and access to credit were observed while estimating the inefficiency. This implied these factors would increase the efficiency of the dairy farmers. Moreover, predicted coefficient of district effect of the farmers was positive and significant for the Wayanad district; implied inefficiency was more in Wayanad as compared to Palakkad. Moreover the inefficiency was less for the overall borrower farmers from both Palakkad and Wayanad districts. Borrower farmers from the Wayanad district were more efficient than the borrower farmers from Palakkad. Study had explained that the non- borrower farmers of Palakkad had a higher technical inefficiency percentage as compared to the borrower dairy farmers in the same district. The non- borrower farmers of Wayanad had a higher technical inefficiency per cent age as compared to the borrower dairy farmers in the same district. The borrower farmers from Wayanad district were comparatively more efficient than that of borrower farmers of Palakkad. The results suggested that the borrower dairy farmers are technically more efficient than that of the non-borrower farmers. The need to involve farmers more in the extension process itself should be encouraged. This highlighted the strong extension activities at the grass root level to ensure more awareness among the farmers for optimum use of resources to have sustainable regular income.

Keywords: Stochastic frontier model, dairy farms, technical inefficiency, maximum likelihood estimates

Introduction

Agriculture and livestock production have been intrinsically intermingled and both are very crucial for the overall food security for any country (Chavas *et al.* 2022) ^[6]. Livestock sector has been proved as an important subsector of the agriculture for number of countries in the world (Batha *et al.* 2020) ^[2]. This sector has been established as the livelihood activity for most of the farmers, support agriculture by sparing crucial inputs, directly supports the health and nutrition of the households, to supplement incomes, offer employment opportunities etc (Yu *et al.* 2023) ^[21]. The dairy sector played an essential role in the national economy as well as for promoting the long-term and stable development of animal husbandry, the food industry, and the consumer economy, regulating people's nutritional patterns, enhancing physical health, and raising their living standards. However, the productivity of the dairy sector in the area is low. An improvement in the productivity level will augment the profitability of the dairy farmers depended on this sector. The possible increase in the profitability of the sector would be anticipated by employing the current technologies. The scope for improving milk production with the existing technology depends on the level of technical efficiency of dairy farmers. Broadly, there are two main streams of

research on milk production efficiency. The first is the evaluation and decomposition of production efficiency (Switlyk *et al.* 2021) ^[16]. Production efficiency can be measured by total factor productivity (TFP) or technical efficiency (TE), which can find the source of efficiency difference while evaluating the efficiency of decisions and provide directions for the efficiency improvement (Madau *et al.* 2017) ^[13]. The second stream of research focuses on the influencing factors of production efficiency. Analyzing influencing factors is the key to define the path for efficiency (Yilmaz *et al.* 2020a) ^[19]. The limitation of resources with farmers cause to think about the reallocation of existing resources to have more output with given level of input combinations or to produce a prescribed level of output with the minimum cost to achieve the required production efficiency (Coelli, 1995; Yilmaz *et al.* 2020b) ^[7, 20]. In many other developing countries the efficient use of inputs is not fully understood by the concerned farmers. On the other hand, the measurement of the productive efficiency in dairy production is an important issue because it gives pertinent information for making appropriate management decisions particularly in resources allocation (Priyanka *et al.* 2020) ^[15].

The dairy sector has been influenced by structural changes,

including the geographical relocation of milk production or the introduction of an intensive production system (Cabrera *et al.* 2010) [4]. These changes may affect farm efficiency, farm profitability, or the sector's sustainability in traditional milk-producing areas. There are two most prominent and widely applied methods Stochastic Frontier Analysis (SFA) and the Data Envelopment Approach (DEA) have been used for measuring efficiency (Theodoridis & Psychoudakis, 2008; Náglová & Rudinskaya, 2021) [17, 14]. The function in SFA model involves a composite error term which accounts both for the statistical noise in the data as well as the inefficiency in production which is one of its strength while DEA uses linear programming function which does not decompose stochastic disturbance from inefficiency effect in production (Kroupová Žáková & Trnková, 2020) [12]. In the present study SFA is used owing to its advantage in decomposing the error term into inefficiency and noise (stochastic) term (Belete, 2020) [3]. Many types of research have specifically applied Stochastic Frontier Analysis (SFA) for the measurement of technical efficiency in the dairy sector (Čechura *et al.* 2021) [5]. SFA entails the simultaneous estimation of the frontier production function and an inefficiency model. Usefully, inefficiency effects are specified as a function of other variables (Haile, 2019) [8]. It effectively specifies the relationship between output and input levels and decomposes the error term into separate components representing random errors and inefficiency.

Methodology

Kerala is a model state for financial institutions as every household had access to at least one bank account. The performance of Kerala's dairy sector lags behind, even though 94% of total cattle population in the state is exotic/crossbred cattle (*Economic Review*, 2020). About 5 lakh out of 70 lakh families in Kerala are dependent solely on livestock sector for their livelihood, while another 5 lakh depends on livestock as a subsidiary means for supporting their livelihood. The state was divided into two strata based on amount of institutional credit disbursed viz. High and Low institutional credit disbursed districts. One district will be selected randomly from the stratum of high and one from low institutional credit disbursed districts. Total of two districts had been selected from the state. From each selected district, two blocks were selected and from each block, 25 borrowers and 25 non-borrowers of institutional credit were considered from the earmarked villages after the consultation with staff of prevailing banks in the study area. The Cobb-Douglas functional form has been preferred for assessing the technical efficiency because of its ability to indicate output elasticity by the coefficients. Its purpose is to show what output of a given product will be achieved by efficient combination of the factors. However, it is possible to estimate the stochastic frontier using Maximum Likelihood Estimation Method (Kostlivý & Fuksová, 2019) [10]. In the present study, estimation of efficiency levels of individual farms using Stochastic Frontier production function of the Cobb- Douglas type had been used (Kovács & Szücs, 2020) [11]. The study attempted to measure the technical inefficiency in the dairy farms for both borrower and non borrower farm house holds. The empirical model was as stated below

$$Y_i = \beta_0 + \sum_{j=1}^J \beta_j X_{ij} + D_i X_{ij} + v_i - u_i$$

where,

Y_i = output of i^{th} farm

X_{ij} = Explanatory variables

(X_{ij} = No. of milch animals, milk yield, Income from dairy, Land holdings, capital investment, education, per capita expenditure on food, dairy products etc.)

D_i = Dummy for institutional credit (1 if borrower, 0 otherwise)

v_i represents independently and identically distributed random errors $N(0, \sigma_v^2)$. These are factors outside the control of the firm.

u_i represents non-negative random variables which are independently and identically distributed as $N(0, \sigma_u^2)$ i.e. the distribution of u_i is half normal.

$|u_i| > 0$ reflects the technical efficiency relative to the frontier production function.

$|u_i| = 0$ for a farm whose production lies on the frontier

$|u_i| > 0$ for a farm whose production lies below the frontier

$$\text{Potential Output, } Y_i = f(X_i) e^{v_i - u_i} \quad i = 1, 2, \dots, N_j$$

Technical efficiency of the dairy farms will be estimated as the ratio of potential output to actual output. T.E lies between 0 to 1

$$T.E_i = \frac{Y_i}{f_i(X_i) e^{v_i}} = e^{-u_i}$$

$$u \geq 0, \quad 0 \leq e^{-u} < 1$$

The lower value would represent the higher side of inefficiency and vice versa by the higher value as the technical inefficiency was calculated as $1 - e^{-u}$. In order to supplement the farm-level information and estimate the gap in efficiency analysis studies on dairy farming, the study focused on measuring productive efficiency and the factors influencing inefficiency.

Results and Discussion

The maximum likelihood estimates of the stochastic frontier production function are given in Table 1. By the estimation of stochastic frontier production function it was possible to comprehend whether the deviation in technical efficiencies from the frontier output was due to farm specific factors or due to external random factors. The different explanatory variables used in the model were cost of green fodder, dry fodder, concentrate and number of milch animals. For the convenience of technical efficiency analysis, the respondents were categorized in to two groups based on the number of milch animals. Farmers with 1-10 milch animals were classified in to Group I and 11- 38 were classified in to group II. Approximately 65.50 per cent of farmers were of group I and rest (34.50%) was classified under the Group II. The kernel density graph of milch animals in the study area was depicted in Figure 1. The average herd size found in the area was of 10 milch animals per farm.

All the explanatory variables of the model had expressed positive and significant effects (Table 1). The value of inputs and number of milch animals had positive effect on the value of milk production. The values in table 1 revealed

that majority of the inputs played an important role in the milk productivity as of the factors was judged by more of their contribution. The findings are in conformity of the fact that proper nutritional balance has played an important for the production efficiency (Hazneci & Ceyhan, 2015) ^[9]. The value of gamma (0.829) was significant at 95 per cent level of confidence indicated that 82 per cent of the differences between observed and maximum production frontier output were due to differences in farmer's technical inefficiency in the adoption of better management practices and remaining 18 per cent were due to random errors. Moreover the estimated value of γ implied the dairy farmers would be able to reduce 28 percent of their inputs if operate at full efficiency level by without any reduction in the level of output and with the existing technology.

The technical inefficiency effect model of dairy farmers from both the districts in Kerala had expressed the shortfalls in output from the frontier function due to the factors within the control of the farmers (Alem *et al.* 2019) ^[1]. These factors were fixed costs, recurring costs, milk prices and labour costs per animal, access to the credit source and location of the farm households. The results of the inefficiency effect showed that the coefficients of the recurring costs, labour costs and access to credit were

negative and significant. This expressed that the efficiency of the farmers would be increased these factors. The predicted coefficient of the district factor for Wayanad district was positive and significant had implied that the inefficiency was more as compared to Palakkad.

Figure 2 had exhibited the inefficiency per cent of borrower and non- borrower farmers from both Palakkad and Wayanad districts in Kerala. It was evident that inefficiency was less for the overall borrower farmers from both the studied districts. However, the borrower farmers from the Wayanad district were more efficient in comparison to the borrower farmers from Palakkad as reflected by Priyanka *et al.* 2020 ^[15].

Perusal of Table 3 explained that, the non- borrower farmers of Palakkad had a higher technical inefficiency percentage (11.02) as compared to the borrower dairy farmers in the same district (10.63). The non- borrower farmers of Wayanad had a higher technical inefficiency percentage (10.76) as compared to the borrower dairy farmers in the same district (9.34) as mentioned by Yu *et al.* 2023 ^[21]. More over the borrower farmers from Wayanad district were more efficient than of Palakkad farmers. The overall technical inefficiency of the dairy farmers from both the districts was found to be 10.44 per cent.

Table 1: Maximum likelihood estimates of Stochastic Frontier Production function

Particulars	Coefficients	Standard Error	P Value
Green fodder (Rs)	0.212***	0.051	0.000
Dry fodder (Rs)	0.104**	0.042	0.013
Concentrate (Rs)	0.088*	0.047	0.065
1.No of milch animals (Group I=0, Group II =1)	0.115***	0.013	0.000
constant	0.599	0.196	0.002
σ_v	0.050		
σ_u	0.110		
σ^2	0.015		
$\gamma = \sigma_u^2 / \sigma^2$	0.829		
lambda	2.219		
LR Test	3.910		
Log Likelihood Function	218.47		
No of observations	200		

* Significant at 10 per cent level, ** Significant at 5 per cent level, *** Significant at 1 per cent level

Table 2: Factors affecting the technical inefficiency of farm households

Particulars	Coefficient	Standard Error	P Value
Fixed cost (Rs)	0.059	0.121	0.628
Recurring cost (Rs)	-0.535***	0.083	0.000
Milk price (Rs)	0.335	1.726	0.846
Labor cost (Rs)	-2.539***	0.116	0.000
1. Access to credit (N.B=0, B=1)	-2.810***	0.139	0.000
District (Wayanad)	0.265**	0.114	0.021
_Constant	24.982	6.426	0.000

** Significant at 5 per cent level, *** Significant at 1 per cent level

Table 3: District wise inefficiency percentage of sample respondents

Particulars	District	Farmers	Technical inefficiency (%)	Standard deviation
Non- Borrower Households	Palakkad	50	11.02	1.66
	Wayanad	50	10.76	1.54
	Overall	100	10.89	1.60
Borrower Households	Palakkad	50	10.63	2.21
	Wayanad	50	9.34	1.00
	Overall	100	9.98	1.83
Total		200	10.44	1.77

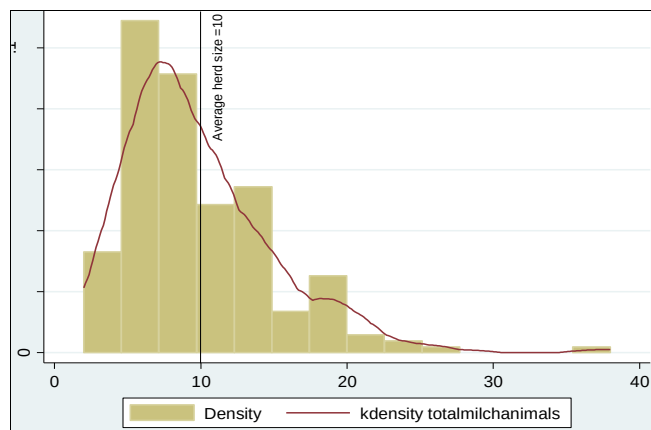


Fig 1: Kernel density graph of milch animals

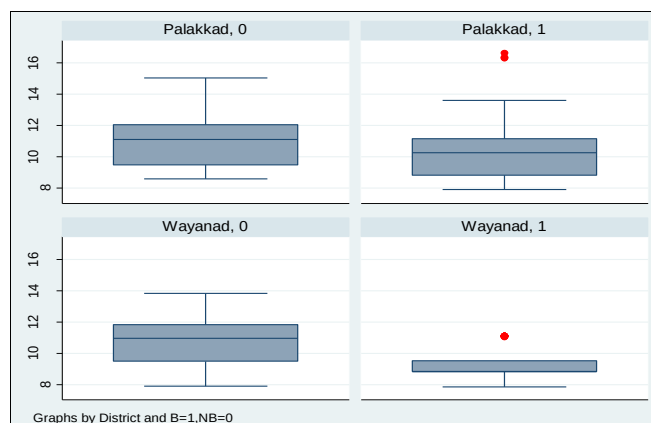


Fig 2: District wise inefficiency percentage of sample respondents

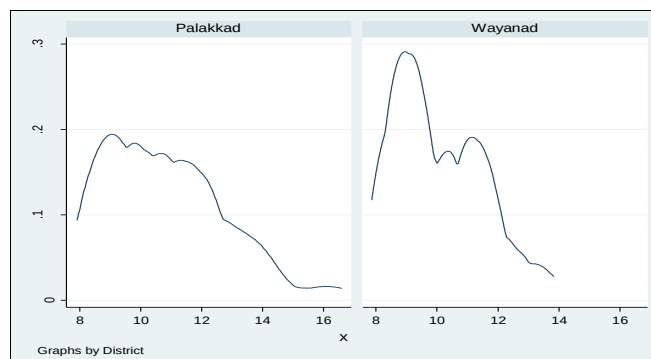


Fig 3: District wise kernel density graphs showing inefficiency percentage of sample respondents

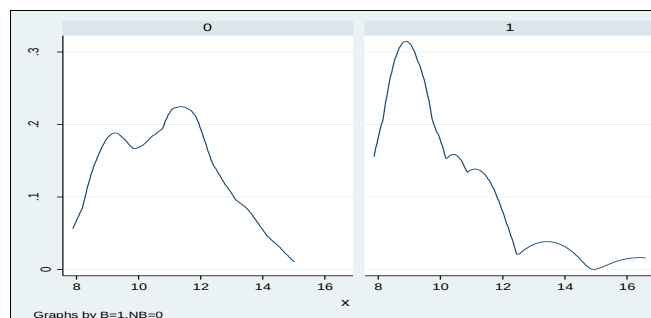


Fig 4: Kernel density graphs showing inefficiency percentage of non-borrower and borrower sample respondents

Conclusion

The technical inefficiency effect model of dairy farmers

from both the districts in Kerala showed the shortfalls in output from the frontier output were due to the factors within the control of the farmers. The coefficients of recurring costs, labour costs and access to credit were negative and significant to increase the efficiency of the dairy farmers. The predicted coefficient of district of farmers was positive and significant for Wayanad district, implying that the inefficiency was more in Wayanad comparing to Palakkad. Inefficiency was less for the overall borrower farmers from both Palakkad and Wayanad districts. Borrower farmers from the Wayanad district were more efficient than the borrower farmers from Palakkad. The borrower farmers from Wayanad district were comparatively more efficient than that of borrower farmers of Palakkad. The results suggest that the borrower dairy farmers are technically more efficient than that of the non-borrower farmers. Stochastic frontier analysis showed the variance parameters of the model were statistically significant indicated that a deterministic production function is not an adequate representation of the data values. The results of the likelihood-ratio (LR) test revealed that the production function was stochastic. It meant that technical inefficiency had an influence on the milk production of dairy farmers in the study area. According to the maximum-likelihood estimates, the signs of the variables were expected in the stochastic production frontier.

Conflicts of Interest

The authors declare no conflict of interest.

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