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Technical Efficiency of Dairy Farms in Developing Countries: A Case Study of Haryana State, India

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I

INTRODUCTION

Milk is one of the most important tradable commodity as is evident from India being the world's top milk producer accounting for about 13 per cent of total world milk production. But India has very little experience in the international trade of dairy products. The potential reform in the international agricultural policy arena is on the cards and the World Trade Organisation policy initiatives on the agenda will serve to increase the world access to the markets of developing countries. This can have a very big impact on the welfare of millions of dairy farmers. Hence, assessing the technical efficiency of dairy farms in developing countries could be an important measure to understand the competitiveness of smallholder dairying.

Low productivity has been a major problem of Indian dairying for a long time. It is important to know what policies, and steps need to be taken for productivity enhancement before investing scarce capital in certain factors which affect productivity. The problem is a complex systems problem. Hence, it firsts needs to be recognised whether the problem is due to efficiency of the farm or due to lack of technology or input use. This will enable us to focus on the scarce capital and get better results in a short time. The present study seeks to measure how efficient the small holder dairy farms are.

II

DESCRIPTION OF STUDY AREA

The state of Haryana has been selected for the present study considering both the importance of dairying for Haryana's economy and the significance of this study to serve as a model to be replicated in other regions of the country. Haryana is divided into three major agro-climatic zones, namely, arid, semi-arid and dry sub-humid with tropical to sub-tropical climatic conditions (Gupta *et al.*, 1989). The districts of Yamunanagar, Bhiwani and Gurgaon were purposively selected for this study based

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on the variations in agro-climatic features, cropping pattern, irrigation intensity, dairy and other livestock enterprises and socio-economic characteristics.

From the three selected districts of Yamunanagar, Bhiwani and Gurgaon, the blocks of Radaur, Dadri and Sohna, respectively, were purposively selected. From each of the selected block, two villages were selected in such a way that one village is within the periphery of the town/city and the other away from it in the same block. The villages selected near and away from town were Bendi and Antawa from Yamunanagar, Mehra and Dokhaharia from Bhiwani, and Alipur and Berka from Gurgaon district.

A complete enumeration of all the households in the selected villages were done to identify the dairy farming systems existing in the region. After removing outliers; cluster analysis of all the households from each of the two agro-climatic zones separately, was done on selected variables, viz., total milk production in the farm/day in the month of survey (most frequent yield), herd size, total number of lactating animals species wise, operational holdings and area under fodder crops. Eight dairy farming systems were identified, four from each of the two agro-climatic zones in Haryana. A total of 60 farm households per block were selected from the dairy farming systems identified on the basis of probability proportional to size subject to a minimum of five from each dairy farming system identified (Table 1).

TABLE 1 SELECTION OF SAMPLE HOUSEHOLDS FROM THE STUDY AREA.

Sr. No. (1)	District (2)	Block (3)	Village (4)	Number of households (5)	Number of sample households (6)
1.	Yamunanagar	Radaur	Bendi	203	28
			Antawa	158	32
2.	Bhiwani	Dadri	Mehra	350	34
			Dokhaharia	472	28
3.	Gurgaon	Sohna	Alipur	340	29
			Berka	178	29

This included 35 households from the irrigated landless dairy farming system (IL-2), 8 from the irrigated marginal (IM-2), 12 from the small irrigated (IS-3) and 5 from large irrigated (IL-4) systems in the irrigated zone. From the rainfed zone, 23 households were selected from the landless rainfed system (RLL-2), 37 from the marginal rainfed (RM-2), 51 from the small rainfed (RS-3) and 9 households from the large rainfed system (RL-3). Thus the total number of sample households was 180 from the three selected districts. The detailed data on parameters relating to the socio-economic characteristics and input-output parameters of crop and dairy enterprises was collected from the selected 180 sample households for the year 2000-01 using a well structured and field tested schedule. The data was collected through household surveys, personal interviews and group discussion for three seasons, namely, *kharif*, *rabi* and summer. The information on prices, infrastructural facilities and demographic characteristics of the study area was collected through various secondary sources.

III

METHODOLOGY

Functional analysis to understand milk production relationships has mostly concentrated on resource use efficiency, technical and technological change to improve productivity. Studies to evaluate efficiency of dairy farming systems have been mostly neglected except a few studies carried out by Srivastava (1995) and Chand (1998) wherein they used deterministic approach to efficiency estimation of commercial dairy farms. They fitted different functions separately for best practiced and poorly managed farms. The causative factors responsible for the gaps were suggested as technological efficiency and differences in input use. Dixit (1999) conducted a study to estimate the technical efficiencies of dairy farming systems under village conditions using Corrected Ordinary Least Square (COLS) method of stochastic frontier analysis. However, determination of efficiency using maximum-likelihood estimation (MLE) method of stochastic frontier analysis, which gives better and reliable estimates than COLS method has not been attempted under Indian conditions.

The stochastic frontier model permits the estimation of standard errors and tests of hypothesis using traditional maximum-likelihood methods, which was not possible with the earlier deterministic models because of the violation of certain Maximum likelihood regularity conditions (Schmidt, 1976). Thus, the various identified dairy farming systems were evaluated in terms of efficiency of milk production by the farm households across each one of them using stochastic frontier production function approach.

Hence, in the present analysis, the technical efficiency was determined by considering the stochastic frontier translog and Cobb Douglas production function approach. The input variables specified for the frontier milk production function at the farm household level were green fodder, dry fodder, concentrates, machinery, buildings, veterinary expenses, labour, miscellaneous expenses per animal unit per year. Different functions were fitted for different species of milch animals. To take care of variations in the type of fodder fed at different times and the mixture of fodder fed; the feed inputs were standardised to nutrition units in terms of a feed index developed from standard Digestible Crude Protein (DCP) and total digestible nutrients (TDN) content in the feeds and fodder. Further, the examination of correlation matrices suggested that some variables (various forms of feeds and fodders and forms of labour) tended to move together rather significantly, hence to avoid the problem of multi-correlation, the indexes of feed and fodder and labour units were used for specification of the model. The labour was considered in man-days and depreciation on machinery and building, veterinary expenses, miscellaneous expenses in rupees, as no substitute of physical terms was available. The output variable was taken as fat corrected milk production per standard animal unit per lactation in litres based on the following formula.

FCM milk = (milk production*fat in %*0.15)+(milk production*0.4)[1] .... (1)

Some of the important variables such as herd size, order of lactation of milch animals, stage of lactation of milch animals have been purposively eliminated as the purpose of the model was estimation of efficiency of milk production at the farm household level, and the difficulty in incorporating these information at an aggregated milk production function. Hence it was assumed that the eliminated variables were not significantly varying between farm households in the dairy farming systems. Though there were a number of outputs, which are produced along with milk, it was very difficult to quantify them in a specific scale of measure of production in the production function analysis approach. Hence only milk production was considered as the output of the farm.

Cobb Douglas form of function was estimated with the specification

$$\text{Log } Y_{kl} = \alpha + \sum_{i=1}^{8} \beta_{il} \log X_{ikl} + \varepsilon_{ikl} \quad \text{.... (2)}$$

$$\varepsilon_{ikl} = u_{ikl} + v_{ikl}; \; u \leq 0 \quad \text{.... (3)}$$

The specification of translog milk production function for stochastic frontier approach can be stated as under

$$\text{Log } Y_k = \beta_0 + \sum_{i=1}^{8} \beta_i \log X_{ik} + \tfrac{1}{2} \sum_{i=1}^{8} \sum_{j=1}^{8} \gamma_{ij} \log X_{ik} X_{jk} + \varepsilon_{ik} \quad \text{.... (4)}$$

$$\varepsilon_{ikl} = u_{ik} + v_{ik} \; ; \; u_{ik} \leq 0 \quad \text{.... (5)}$$

The description of various variables used in the models is stated as under:

i,j = independent input variables used in the model (1, 2,…8);

k = sampled 180 farms of the study area (1, 2, …, 180);

ε_{ik} is a stochastic error term consisting of two independent elements. The symmetric component 'v_{ik}' takes care of measurement error and random variation in output due to factors outside the control of one farm, such as weather, unexpected incidences and diseases together with the combined effects of unspecified input variables in the production function. Aigner *et al.* (1977) assumed that v_i's were independent and identically distributed (i.i.d.) normal random variables with mean zero and constant variance, σ_v^2, independent of the u_{ikl}^s, which were assumed to be i.i.d. exponential or half-normal random variables.

Y_k = total milk produced in k-th farm per standard animal unit per annum,

X_{1k} = Index for green fodder used in k-th farm per standard animal unit per annum,

X_{2k} = Index for dry fodder used in k-th farm per standard animal unit per annum,

X_{3k} = Index for concentrate used in k-th farm per standard animal unit per annum,

X_{4k} = hired labour used in k-th farm for dairy management activities (number of man-days) per standard animal unit per annum,

X_{5k} = unpaid family labour used in k-th farm for dairy management activities (number of man days) per standard animal unit per annum,

X_{6k} = depreciation and interest on fixed assets (Rs.) per standard animal unit per annum,

X_{7k} = variable cost of veterinary expenses (Rs.) per standard animal unit per annum,

X_{8k} = variable cost of miscellaneous expenses (Rs.) per standard animal unit per annum,

γ_{ij} = total variations in output from the frontier which is attributable to technical inefficiencies, i.e., $\gamma = (\delta_i^2 / \delta_j^2)$; $0 \leq \gamma \leq 1$,

β_i = Parameters of regression coefficients of the i-th variable.

The standard animal unit[2] was derived to standardise output of different farms with different species of dairy animals.

The total milk produced per annum per standard animal unit was derived on the basis of data collected for three seasons (summer, rainy, winter) for each of the species of dairy animal per day multiplied by the number of days per season (summer: 125 days; rainy: 120 days; winter: 120 days).

The quantity of feeds and fodder per standard animal unit was derived on the basis of data collected for three seasons based on the quantity of feed and fodder fed to each of the milch unit per day multiplied by the number of days per season.

The family and hired labour per standard animal unit was derived on the basis of data collected on labour used per day for all the dairy operations multiplied by the number of days in a year.

The quantity of feeds and fodder fed were converted to DCP and TDN equivalents using the standardised conversion units of different types of Indian feed and fodder as per the standards given by Sen and Ray (1971). The estimates of feed index were worked out for the feeds and fodder for the individual farms using the formulae DCP + (TDN/7.5) given by Kumar and Singh (1980).

The mathematical expectation of the technical efficiency of the i-th farm is given as,

$$TE_i = \exp(-u_i) \quad \text{.... (6)}$$

This involves the technical inefficiency effect, u_i, which is unobservable. Even if the true value of the parameter vector, β, in the stochastic frontier model (1) were known, only the difference, $e_i \equiv v_i - u_i$ could be observed. The best predictor for u_i is the conditional expectation of u_i, given the value of $v_i - u_i$.

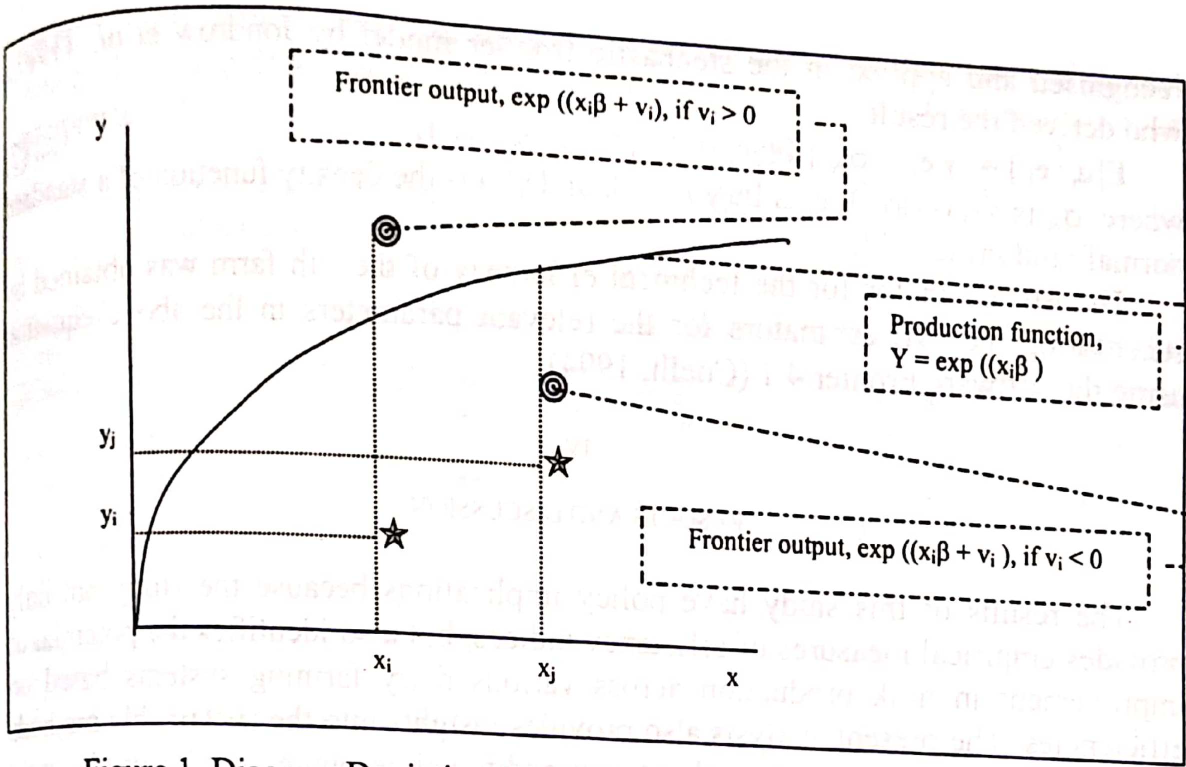

Figure 1. Diagram Depicting Stochastic Frontier and Observed Output.

The model defined by equation (2) and (4) is called the stochastic frontier production function because the output values are bounded above by the stochastic (random) variable, $\exp(x_i\beta + v_i)$. The random error v_i can be positive or negative and so the stochastic frontier outputs may vary about the deterministic part of the frontier model, $\exp(x,\beta)$. The basic features of the stochastic frontier model are illustrated through two-dimensional diagram given in above figure.

The inputs are represented on the horizontal axis and the outputs on the vertical axis. The deterministic component of the frontier model, $y = \exp(x\beta)$, is drawn assuming diminishing returns to scale apply. The observed input-output value is indicated by the point marked with ★ above the value of x_i representing x_i input required to produce y_i output. The value of the stochastic frontier output, $y_i^* \equiv \exp(y_i + u_i) \equiv \exp(x_i\beta + v_i)$ is marked by the point ◎ above the production function because the random error v_i is positive. Similarly, the j-th farm uses the levels of inputs, x_j and produces the output, y_j. However, the frontier output, $y_j^* \equiv \exp(y_j + u_j) \equiv \exp(x_j\beta + v_j)$ is below the production function because the random error, v_j is negative. Of course the stochastic frontier outputs, y_i^* and y_j^* are not observed because the random errors v_i and v_j are not observable. However, the deterministic part of the stochastic frontier model is seen to lie between the stochastic frontier outputs. The observed outputs may be greater than the deterministic part of the frontier if the corresponding random errors are greater than the corresponding inefficiency effects, i.e., $y_i > \exp(x_i\beta)$ if $v_i > u_i$. The parameters of the stochastic frontier production function, defined by the equation (7) can be estimated using either the maximum-likelihood method (ML) method or using COLS method. The result was first recognised and applied in the stochastic frontier model by Jondrow *et al.*, (1982), who derived the result

$$E[u_i | e_i] = -\gamma e_i + \sigma_A \{\Phi(\gamma e_i / \sigma_A) / (1 - \Phi(\gamma e_i / \sigma_A))\} \quad \text{....(7)}$$

where, σ_A is $\sqrt{\gamma(1-\gamma)\sigma_s^2}$; e_i is $In(y_i) - x_i\beta$; and $\phi(.)$ is the density function of a standard normal random variable.

The ML estimator for the technical efficiency of the i-th farm was obtained by substituting the ML estimators for the relevant parameters in the above equation using the software Fronter 4.1 (Coelli, 1994).

IV

RESULTS AND DISCUSSION

The results of this study have policy implications because the study not only provides empirical measures of efficiency indices, but also identifies the potential of improvement in milk production across various dairy farming systems based on efficiencies. The present analysis also provides insights into the sustainable methods of productivity improvement without any additional resources unlike productivity improvement through change in inputs or technological change, which requires additional resources. The results have been presented in two sections: fitting of frontier model and thereafter technical efficiencies have been estimated.

The estimation of technical efficiency and its interpretation has been done on the basis of the estimation of the stochastic production frontier using Cobb-Douglas and translog models as specified in methodology. In this regard it is pertinent to mention that only a few studies in agriculture have been carried out using stochastic frontier functions under Indian conditions, e.g., Kalirajan and Flinn (1984) for crop farming and Sharma and Sharma (2002) for dairying. A few deterministic frontier estimation studies have been carried out for commercial herds by Srivastava (1995) and Chand (1998). An attempt has, therefore, been made in this section to analyse the efficiencies of dairy farming systems using stochastic frontier function.

4.1 *Frontier Functional Analysis for Milk Production*

The objective of the present investigation was to estimate the efficiencies of the farm household in milk production; therefore, it was very important to consider the effect of various species of bovine animals kept by the farm households. Thus, standard animal units of the bovine stock were derived for each of the farm households as per the methodology stated earlier. The milk production by the farm household was also standardised to fat corrected milk as per the equation (1) given in the methodology.

Based on the model discussed in methodology, ordinary least squares (OLS) and maximum likelihood estimation (MLE) techniques were employed to estimate the parameters of the Cobb-Douglas and Translog production function using Frontier version 4.1 software package. Based on the calculated value of Likelihood Ratio statistic, translog model was not found to be an adequate representation of the data. Hence, the Cobb-Douglas frontier function was used for further calculation and interpretations. The results of the same have been presented in Table 2.

TABLE 2. OLS AND MLE ESTIMATES OF STOCHASTIC COBB-DOUGLAS FRONTIER MILK PRODUCTION FUNCTION OF STANDARD ANIMAL UNIT OF FARM HOUSEHOLDS IN THE STUDY AREA

Variables (1)	OLS estimates (2)	Standard errors (3)	MLE estimates (4)	Standard errors (5)
Constant term	1.563**	0.262	1.726**	0.257
Green fodder index	0.172*	0.086	0.186*	0.081
Dry fodder index	0.127	0.095	0.106	0.093
Concentrate index	0.218**	0.076	0.193**	0.073
Hired labour	0.012	0.019	0.013	0.018
Family labour	0.103**	0.043	0.078*	0.043
Depreciation	0.039	0.053	0.047	0.050
Veterinary expenses	-0.039	0.065	-0.002	0.064
Miscellaneous costs	0.045	0.053	0.028	0.050
Variance parameter				
$\sigma^2 = s^2v + s^2u$	0.012		0.021**	0.004
$\gamma = s^2u / s^2s$			0.723**	0.113
LR test of the one-sided error			4.810	
Log-likelihood function	149.203		151.608	

* Significant ($P < 0.05$) and ** Significant ($P < 0.01$).

The generalised likelihood ratio statistic for testing the null hypothesis for the absence of inefficiency effects in the Cobb-Douglas stochastic frontier production was estimated to be 4.81. If the null hypothesis is true, the generalised likelihood-ratio statistic has a mixed chi-square distribution with 7 degrees of freedom. Using a probability of type 1 error of 0.05, the critical value for the test statistic is 6.35, which was obtained from table of percentage points of the chi-square distribution. The calculated value of the LR test statistic of 4.81 was not found to be statistically significant at 5 per cent level. Though the tests of significance are frequently conducted at a much smaller value of a type 1 error, there is some basis for considering a higher probability level for a preliminary testing procedure. Therefore, the null hypothesis that there were no technical inefficiency effects in the Cobb-Douglas stochastic frontier production function was rejected at 10 per cent probability level for the sample data in the present study. Accordingly, the Cobb-Douglas OLS model or the average response function was not considered to be an adequate representation of data.

The estimate of the gamma values of 0.723 was found to be significant at 1 per cent level, which showed that the frontier model was significantly different from the OLS model or the deterministic frontier, in which there were no random errors in the production function. Thus, it can be inferred that there are random errors as well as inefficiency errors in the model.

The OLS function provided the estimates of the 'average' production function, while the ML model provided estimates of the stochastic production frontier. The dissimilarities of the coefficient parameters across equations confirm that the frontier function does not represent a neutral upward shift of the average production function. The higher constant value in the case of MLE clearly indicated higher frontier output. The relatively lower value of the significant input parameters in the case of concentrates, family labour and higher significant value of green fodder coefficients in the case of MLE may be interpreted as the increasing role of green fodder than concentrates or family labour in determining the efficiency of the farm.

The elasticities of milk production for dry fodder; hired labour and depreciation were not significant in both the OLS and MLE models suggesting that these variables did not have significant impact on average or frontier levels of milk production. The elasiticites of milk production with respect to concentrates and family labour were found to be positive and significant at 1 per cent level of significance and green fodder at 5 per cent level. Thus, it could be concluded that concentrates, family labour management and green fodder has a significant impact in increasing milk productivity at the overall farm household level.

4.2 *Estimation of Technical Efficiency*

An important component of frontier production function is the estimation of the technical efficiency of individual farms (Annexure I). In order to analyse how efficient are the dairy farms in the study area, technical efficiency of milk production by the farm households were determined to assess the efficiency of individual farms. To determine the technical efficiency of the identified systems, the mean of the technical efficiency indices of the milk production for different sample farms across each dairy farming system were obtained. The indices of mean technical efficiency of farm households are presented in Table 3.

TABLE 3. MEAN TECHNICAL EFFICIENCY ESTIMATES AND INCREASING EFFICIENCY POTENTIAL OF DAIRY FARMING SYSTEMS IN THE STUDY AREA

(per cent)

Dairy farming system (1)	Mean technical efficiency (2)	Mean potential to increase efficiency (3)	Potential of least efficient farms (4)
Irrigated dairy farming systems	91.2	5.2	16.9
Irrigated landless (ILL-2)	92.5±3.9	4.6	14.4
Irrigated marginal (IM-2)	86.8±6.2	7.7	18.1
Irrigated small (IS-3)	92.2±6.0	4.9	22.7
Irrigated large (IL-4)	86.6±6.8	5.9	18.5
Rainfed dairy farming systems	91.1	5.7	20.3
Rainfed landless (RLL-2)	90.5±4.8	5.7	24.0
Rainfed marginal (RM-2)	90.5±0.1	5.7	18.8
Rainfed small (RS-3)	91.7±4.3	5.5	19.6
Rainfed large (RL-3)	91.1±5.7	7.0	20.4
Overall	91.1±4.7	7.1	25.5

A close perusal of Table 3 shows that in the irrigated zone, the mean efficiency estimates ranged from 86.6 per cent in the irrigated large systems (IL-4) to 92.5 per cent in the irrigated landless systems (ILL-2). The mean efficiency estimate of the landless systems was found to be better than the large systems in the irrigated zone. This could be attributed to dairying being the main source of farm income for the landless farm households, which compels them to take better care of animals to ensure higher efficiency unlike the marginal or large systems. The mean efficiency estimate of the irrigated small systems (IS-3) was found to be 92.2 per cent, however, with a higher value of standard deviation of 6.0. The irrigated large systems were found to have the least technical efficiency in the irrigated zone. The mean efficiency estimate of the marginal system (IM-2) was relatively lower at 86.8 per cent. On the whole, the irrigated landless system (ILL-2) was found to be the most technical efficient system with a lower value of standard deviation. The results clearly indicated that there is relatively more scope for improvement of technical efficiency in the case of the marginal and the large dairy farming systems in the irrigated zone.

In the rainfed zone, the mean technical efficiency estimates closely ranged from 90.5 per cent in the rainfed landless system (RLL-2) and rainfed marginal system (RM-2) to 91.7 per cent in the rainfed small systems (RS-3). The value of standard deviation associated with technical efficiency showed that technical efficiency estimates were found to vary more in the rainfed large systems than in the rainfed marginal systems. The most technically efficient dairy farming system in the rainfed zone was the rainfed small (RS-3) system while the least efficient system were the rainfed landless (RLL-2) and the rainfed marginal (RM-2).

In the nutshell, the irrigated landless systems (ILL-2) was the most technically efficient while the irrigated large system (IL-4) was the least efficient dairy farming system in the study area. The variation in mean efficiency estimates was found to be more in the irrigated zone than in the rainfed zone. However mean efficiency estimates were nearly similar in both the zones at 91 per cent, signifying not much role of agro-climatic conditions on technical efficiency of milk production. Similar results were also found by Sharma and Sharma (2002) wherein the majority of the farmers were in the efficiency range of 80-90 per cent and above 90 per cent.

4.3 *Potential of Technical Efficiency Improvement of the Dairy Farming Systems*

Productivity enhancement in milk production is one of the most important goals of Indian dairying. The present analysis of data has focused on the issues of productivity enhancement through improvement in technical efficiencies of the dairy farming systems with the existing resources and technology.

Based on the technical efficiency of the most efficient farm in each of the dairy farming system, the average potential to increase milk production of the dairy farming systems was determined using the following formula:

Potential for increasing milk production per milch animal = [1 – (mean technical efficiency of the system/maximum technical efficiency of the system)] * 100.

The average potential of increasing milk production through technical efficiency improvement across various dairy farming systems are presented in Table 3.

A close perusal of Table 3 revealed that in the irrigated zone, the potential for technical efficiency improvement of milk production of standard animal unit across systems varied from 4.6 per cent in the irrigated landless system to 7.7 per cent in the irrigated marginal system. A further perusal of the Table revealed that in the rainfed zone, the potential for technical efficiency improvement of milk production in case of standard animal unit across systems varied from 5.5 per cent in the rainfed small system to 7.0 per cent in the rainfed large system. In case of buffaloes it varied from 5.2 per cent in the marginal system to 7.3 per cent in the large system.

The potential for improvement in technical efficiency of the least technical efficient farms in each of the dairy farming systems is presented in Table 3. A close perusal of Table 3 revealed that for the least efficient farms in the irrigated zone, the maximum potential for efficiency improvement in terms of reducing milk production costs varied from 18.1 per cent in the marginal system to 22.7 per cent in case of small system for standard animal unit. In the rainfed zone, the potential for reducing the milk production costs for the least efficient farms varied from 18.8 per cent in rainfed marginal systems to 24 per cent in rainfed landless systems.

The mean technical efficiency (TE) indices for SAU in the overall category ranged from 73 to 98 per cent across the farm households in the sample, with an average of 91.1 per cent (Table 3). If the average farmer in the sample was to achieve the TE level of its most efficient counterpart, then the average farmer would realise an 7.08 per cent cost savings [1- (91.06/98)]. A similar calculation for the most technically inefficient farmer revealed a cost saving of 25.5 per cent [1 - (73/98)].

V

SUMMARY AND CONCLUSIONS

Green fodder, feed and farm family labour are still the most important factors affecting milk production. The mean technical efficiency of milk production in the study area was found to be around 91 per cent signifying high overall efficiency of milk production in the study area. This signifies that the farmers did not have much scope to increase productivity through technical efficiency. The potential increase in milk production per household using existing resources ranged from 4.6 per cent in the irrigated landless systems (ILL-2) to 7.0 per cent in the irrigated marginal systems (IM-2) by improving technical efficiency. The potential for improvement in milk productivity for the least technically efficient farm households was however much higher ranging from 14.4 to 24 per cent.

The use of stochastic frontier analysis enabled the ranking of the farm households based on efficiency of milk production thereby identifying the most efficient and the most inefficient farms across various dairy farming systems in the region. Thus suitable interventions targeting these inefficient farms need to be made to bring about significant increase in the farm income for these households in both the zones. The most efficient farms identified within each of the dairy farming systems can serve as model farm for improving efficiency of milk production in the study area. The significant results of the data indicate that the landless dairy farmers in the irrigated zone are more efficient than their counterpart large farmers. Hence, suitable development efforts for these landless farmers are essential to further increase their income and productivity. Further research on non-parametric factors to identify the inefficient farms and quality of milk needs to be carried out to take advantage of the liberalised markets.

NOTES

1. Hemme (2000).
2. Standardisation of herd size of the farm households were done using the standards given by Patel *et al.* (1982)

Milch buffalo	1.30
Milch crossbred cow	1.40
Milch local cow	1.00

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