Technical efficiency and supply chain practices in dairying: The case of India

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Abstract: The presented paper investigates the technical efficiency of small dairy farmers in India using the stochastic production frontier function approach. The study reveals that building the supply chain can increase the efficiency of dairy farmers, as the milk producers who are part of a cooperative supply chain experienced a higher technical efficiency as compared to those who do not follow the modern supply chain practices. The milk producers in the supply chain are found better crisis managers as their inefficiency is the least attributed to their own decisions. The possession of the crossbred livestock, schooling of the manager and the institutional finance have been found affecting the efficiency of the dairy farmers positively and significantly. The study recommends the expansion in the supply chain network of the cooperative milk societies for enhancing the efficiency and profitability of the dairy sector along with the provision of more crossbred livestock and an easy availability of finance.

Key word: technical efficiency, cooperative milk supply chain, stochastic frontier

Procurement and distribution of milk from villages has been phenomenal since the evolution of the Cooperative Societies in India. The Government of India set up the National Dairy Development Board in 1970 for strengthening the supply chain network in dairy cooperatives throughout the country. The Operation Flood programme not only accelerated the growth of the dairy sector but also helped India to become the world's largest milk producer. The production of milk has increased many times since the Independence, which is mainly due to the increased number of livestock, especially buffaloes The productivity of this sector is low due to its small-scale operations, the mixed farming system, the lack of finance, and hybrid animals etc. Increasing the efficiency in production is a significant factor of the productivity growth and it can be increased by using better technologies along with the better management of all crucial inputs, which are at the disposal of the farmers. A higher level of technical efficiency is essential for a higher profitability and to enhance the competitiveness in the dairying sector. Technical inefficiency connotes the ability of farms to produce the maximum possible output with the given set of resources.

Recent studies have shown that dairy farmers failed to exploit the full potential of technology. Bailey et al. (1989), Fraser and Coridna (1999), Mbaga et al. (2002) and Dalton (2004) have examined the efficiency of the dairy sector in developed as well as in developing countries. Reardon and Barrett (2000), Sartorius and Kristen (2007), Demircan et al. (2010) and Caberera et al. (2010) have found that small dairy farmers are gradually becoming less profitable and loosing their market share due to a tighter alignment of the supply chain producing for international markets. Burki and Khan (2008) analyzed the effects of the supply chain on the productive/technical efficiency and found that building the supply chain management practices has a strong positive effect on the productive efficiency. Sharma and Gulati (2003) and Kumar and Jain (2008) analyzed the farm level efficiency for dairy farmers in India using the stochastic frontier production function approach. Binam et al. (2004) analysed the factors affecting the technical efficiency among smallholder farmers in the slash and burn agriculture zone of Cameroon. However, there seems to be a lack of studies where the technical efficiency of farmers following the modern supply chain management practices has been measured and compared with non-followers of the modern supply chain practices. Further, the influence of some farm and farmers specific characteristics and socio-economic features on the inefficiency has not been examined; which is undoubtedly very significant for policy makers. In this background, the present paper investigates the technical efficiency along with the technical inefficiency effects on milk production of the member and non-member dairy farmers in India.

MATERIAL AND METHODS

Material

The present study uses the farm-level cross section data from small dairy farmers of North India for the year 2009–2010. The sample farms were selected by using a two-stage random sampling technique. In the first stage, one village was selected randomly from each of the five North Indian states (Punjab, Haryana, Himahcal Pradesh, Uttar Pradesh and Jammu & Kashmir). In the second the stage, 40 milk producers from each village were selected randomly by considering them into two strata, i.e., 20 member farmers (supply chain practitioners) and 20 non-members farmers (non- practitioners). In all, a sample comprising of 200 milk producers was selected. Information on a wide range of the socio-economic and business characteristics was also gathered through the structured survey schedule, which includes the number of crossbred animals, the experience and education, the amount of milk produced the expenses on feed and fodder, input and output prices, the membership in the cooperative union of the dairy farmers. These variables have been used by Bravo-Ureta and Rieger (1991) and Battese and Coelli (1996). The experience and education (formal years of education) is measured in years. The value of livestock represents the present value of livestock and it is measured in money terms. The herd size is the average number of animals per farm. The institutional finance ratio is the ratio of loan from the institutional sources to the total loans taken for the purpose of dairying.

Methods

The present study has employed the stochastic frontier production function approach for the measurement of the farm level technical inefficiency. The concept of frontier production was first proposed by Farrell (1957), further, developed by Aigner et al. (1977) and Meeusen and Broeck (1977). Jondrow et al. (1982) have provided the method to estimate technical efficiency for the individual farms. Battese and Coelli (1995) have specified stochastic frontiers and models for the technical inefficiency effects and simultaneously estimating all the parameters involved. In such a specification, output of each farm is bounded above by a frontier, which varies across observations. This technique measures the efficiency of farms relative to their own frontier. In the stochastic frontier production, the disturbance term is composed of two parts; one symmetric, which captures the random effects outside the control of farms and the statistical noise contained in every empirical relationship, and the other one-side, which captures the deviations from the frontier due to the technical inefficiency.

Formally,

$$Y = \mathrm{f}(x)\, e^{Ei}$$

where:

$E_i = V_i - U_i \quad i = (1, 2, \dots n)$

$-\propto \leq vi \leq + \propto$ = the symmetric component

$u_i \geq 0$ = the one-sided component

Since the frontier is stochastic in nature, permitting random variations of the production frontier across observations, the technical inefficiency, which is captured by the one-sided error component, i.e., $u_i \geq 0$, is relative to the stochastic frontier.

Stochastic frontier production function

Technical inefficiency of the individual dairy farm is estimated through the stochastic frontier production function, which is defined as:

$$\mathrm{In}Y_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + V_i - U_i$$

where:

Y_i = milk production in \$[1]

X_1 = value of feed in \$[2]

X_2 = labour hours

X_3 = value of livestock in \$

X_4 = fixed cost in \$[3]

β's = parameters to be estimated

V_i = symmetric error term which is assumed to be in dependently and identically distributed having $N(0, \sigma_v^2)$ distribution

U_i = one sided error term, reflecting technical inefficiency, which is assumed to be independent of V_i, is such that U_i is the non-negative truncation (at zero) of the normal distribution with mean μ and variance σ^2 .

[1]Output is the money value of the total milk production by an animal during its lactation period, multiplied by the market price and the price offered by the cooperative societies which also include the imputed value of home consumption The Cooperative Milk Societies have offered prices ranging from \$ 0.53 to \$ 0.86 per liters based on the content of FAT and SNF. The value of 1 \$ is considered to be 44.70 Indian Rupees.

[2]Value of feed includes the cost of dry fodder, green forage, feed and concentrates etc.

[3]Fixed costs include the costs incurred on depreciation and interest on fixed capital structures.

Inefficiency model

$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5$

where:
Z_1 = crossbreed
Z_2 = experience
Z_3 = education
Z_4 = herd size
Z_5 = institutional finance ratio

The variables, $Z_1, \ldots, Z_5$, are included in the model for the technical inefficiency effects to indicate the possible effects of the farmer specific characteristics on the efficiency of milk production. The β's and δ's are unknown parameters to be estimated together with the other parameters, which are expressed in terms of

$\sigma_s^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2/\sigma_s^2$

where the γ parameter lies between zero and one.

It is worth mentioning here that the above model for the inefficiency effects can only be estimated if the inefficiency effects are stochastic and have a particular distributional specification. Hence, it is interesting to test the following hypotheses:

(1) H_0: $\gamma = \delta_0 = \ldots = \delta_5 = 0$, i.e., inefficiency is absent
(2) H_0: $\gamma = 0$, i.e., inefficiency effects are not stochastic
(3) H_0: $\delta_0 = \ldots = \delta_5 = 0$, i.e., the coefficients of explanatory variables in the models are simultaneously zero
(4) H_0: $\delta_1 = \ldots = \delta_5 = 0$, i.e., the coefficients of the variables in the model for inefficiency effects are zero

The tests of these hypotheses for the parameters of the frontier are conducted using the generalized likelihood ratio statistics, λ defined as;

$\lambda = -2\,[LR_R - LR_U]$

where LR_R is the value of the likelihood function for the frontier model in which parameter restrictions are specified by the null hypothesis and LR_U is the value of the likelihood function for the general linear frontier model. If the null hypothesis is true, then λ has approximately a chi-square (or mixed square) distribution with the degrees of freedom equal to the difference between the parameter estimated under LR_R and LR_U, respectively.

The technical efficiency of the farmer, given the specification of the model, is defined by $TE_i = E(-U_i)$. Thus, the technical efficiency of the farmer lies between zero and one and it is inversely related to the inefficiency model. The parameters of the stochastic frontier production function model are estimated by the method of the maximum likelihood using the Econometric Computer Program FRONTIER Version 4.1XP (Coelli and Battese 1996).

Farm/farmer specific characteristics

To indicate the possible effects of farm specific characteristics on the efficiency of milk production, the variables such as the number of crossbred animals, the experience and education of the manager, the herd size and the institutional finance ratio are included in the model for the technical inefficiency measurement. The number of crossbred animals in the livestock is likely to cast a negative effect on the level of inefficiency. The crossbred animals yield more milk as compared to the traditional ones and thus lead to a higher level of technical efficiency. Hence, the farms having more crossbred livestock tend to be more efficient. Farmers having more experience are expected to be more efficient as they possess more experience in managing their enterprises and they are expected to be better crisis managers. Similarly, the farmer who possesses more formal years of education to his/her credit is expected to be more efficient as he/she tends to be more open to the new methods and technologies and more innovative as compared to others. Similarly, the farm possessing a larger herd size is hypothesized to be more efficient (provided that it possesses adequate resources to manage it). The milk producers having more finance from the institutional sources are again hypothesized to be more efficient as compared to others as they are subjected to the least exploitation and have to pay a lower rate of interests and other charges.

RESULTS AND DISCUSSION

A basic summary of the values of the key variables used in the stochastic frontier production function is presented in Table 1. The average size of the herd per farm turned out to be 4.12 and 3.14 for the members who are following the modern supply chain management practices and the non-member farms, respectively. The value of output per animal per year came out to be \$ 2123.31 and \$ 1786.58, while the cost of feed and fodder per animal per year was \$762.13 and \$ 650.03, respectively, for the member and non-member farms. The human labour hours per 1 animal turn out to be 4860 and 4470 hours, whereas the capital cost per 1 farm per year was \$ 373.28 and \$ 220.36, respectively, for the member

Table 1. Summary statistics of the study variables for dairying in India

Variable	Member farms	Non-member farms
Herd size (per farm)	4.12	3.14
Output ($ per animal per year)	2 123.71	1 786.58
Feed and fodder cost ($ per animal per year)	762.13	650.03
Human labour hours (per animal per year)	4 860	4 470
Capital cost ($ per year)	373.38	220.36
Crossbred animals	116	19
Value of livestock ($ per farm)	2 640.94	2 020.58
Experience of the manager (in years)	15.7	22.6
Education (in years)	10.3	7.9
Institutional finance ratio (per cent)	42.00	23.00

and non-member farms. The member farms have been found possessing 116 crossbred livestock against just 19 in the case of the non-member farms, while the average value of livestock per farm was $ 2640.94 and $ 2020.58, respectively, for the member and non-member farms. The non-member farms mangers have more experience as compared to the member farms, but in terms of education, the case is reverse, and further, the member farms have shown more faith in the institutional source of finance as compared to the non-member ones.

The maximum likelihood estimates for the parameters in the stochastic frontier model are presented in Table 2. The parameters estimated for feed, labour and livestock are found statistically significant at 5% level of significance, whereas the parameter estimate for capital cost turns out to be statistically insignificant, though attached with a negative sign for both categories of farms. The coefficient of the capital cost turns out to be positive but statistically insignificant, which may be due to the low variations in the variable. Both categories of farmers experienced increasing returns to scale, which is more pronounced in the case of the non-member farmers indicating a higher scope of increasing production by increasing the amount of inputs. As a whole, comparing the two models, the maximum likelihood estimates for the parameters are more or less similar for the supply chain practitioners and non-practitioners.

Table 2. Maximum likelihood estimates for parameters of the stochastic frontier for dairying in India

Variable	Parameters	Member farms	Non-member farms
Constant	β_0	3.263 (0.539)	2.549 (1.006)
Feed	β_1	1.858* (0.831)	1.926* (1.026)
Labour hours	β_2	1.053* (0.541)	0.832* (0.431)
Livestock	β_3	1.098* (0.541)	1.949* (0.906)
Capital cost	β_4	0.787 (0.457)	1.169 (0.965)
Returns to scale		4.796	6.656

Figures in the parenthesis represents standard errors
*Statistically significant at 5% level of significance

Parameter estimates of inefficiency model

The estimated coefficients of the explanatory variables in the model for the technical inefficiency effects (Table 3) are of interest and have important implications. The possession of crossbred animals in the livestock was found to have a negative association with technical inefficiency, which indicates that farmers having more crossbred livestock tend to have a lower inefficiency. This could be explained in terms of a high milk yield by the crossbred livestock as compared to the traditional ones, leading to a higher milk production and efficiency of farmers. The coefficient of experience is estimated to be negative but statistically insignificant indicating that inefficiency tends to decline as the number of the years of experience increases for both categories of farms. This appears despite the fact that the non-members farms possess more years of experiences. It may be due to the reason that the experience of farming of the non-member farmers is not associated

Table 3. Maximum likelihood estimates for parameters of inefficiency models for dairying in India

Variable	Parameter	Member farms	Non-member farms
Constant	δ_0	2.237 (0.478)	3.156 (1.536)
Crossbred animals	δ_1	–1.567* (0.795)	–1.549** (0.806)
Experience	δ_2	–1.004 (0.859)	–1.795 (1.954)
Education	δ_3	–2.164* (1.059)	–2.675* (1.154)
Herds size	δ_4	0.864 (0.559)	0.975 (0.854)
Institutional finance ratio	δ_5	–1.596* (0.736)	–2.109* (1.166)
Variance parameters	σ^2	0.945* (0.123)	0.849* (0.406)
	γ	0.698* (0.256)	0.791* (0.256)
Log likelihood function		172.68	196.16

Figures in parentheses represent standard errors
**Statistically significant at 5% level

with education as they possess less education years compared to the member farms. The coefficients of education turn out to be negative and statistically significant for both categories of farms, which reflects that inefficiency tends to decline with the increased years of formal education, as the educated farmers are more innovative and receptive of new technology like crossbreeds, etc. The coefficient of the herd size turns out to be positive but insignificant for both categories. The coefficient of the institutional finance ratio in the model for the inefficiency effects is experienced to be negative and statistically significant and hence it affects inefficiency negatively, and the coefficient is higher in the case of farmers who are not at all following the modern supply chain management practices.

Tests of hypotheses

Tests of various null hypotheses associated with the models were carried out using the likelihood ratio (LR) statistics and the results are presented in Table 4. The first null hypothesis, H_0: $\gamma = \delta_0 = \ldots = \delta_5 = 0$, i.e., that inefficiency is absent from the model, is strongly rejected for both categories of farms at 5% level of significance. It also indicates that the traditional mean response function is not an adequate representation of the data for milk production. The second null hypothesis, H_0: $\gamma = 0$, which specifies that the inefficiency effects are not stochastic, is again rejected for the member and non-member farms at 5% level of significance. So, we do not accept the null hypothesis that there was no technical inefficiency. The parameter γ is estimated to be 0.698, which suggests that 69.8% inefficiency is due to the farm's own decision and the remaining 30.2% are due to the factors outside the control of the farmers for the member farms. On the other hand, the parameter γ is estimated to be 0.79 for the non-members farms indicating that 79% of inefficiency is due to the farm's own decision and the remaining 21% are due to the factors outside the control of the farmers for the non-member farms. In other words, 14.70% of their technical inefficiency (70% of 21% inefficiency) for the member farms is due to their wrong decision which is 26.86% (79% of 34% inefficiency) in case of

Table 4. Likelihood ratio tests of the hypotheses for parameters of the stochastic frontier for dairying in India

Null hypotheses	Farm level	Log likelihood	λ	Critical value	Decision
1. H_0: $\gamma = \delta_0 = \ldots = \delta_5 = 0$	member	146.37	52.62*	14.10	Reject H_0
	non-member	186.27	19.78*	14.10	Reject H_0
2. H_0: $\gamma = 0$	member	148.38	48.60*	7.05#	Reject H_0
	non-member	184.19	23.94*	7.05#	Reject H_0
3. H_0: $\delta_0 = \ldots = \delta_5 = 0$	member	158.27	28.82*	12.59	Reject H_0
	non-member	190.32	11.68**	10.64	Reject H_0
4. H_0: $\delta_1 = \ldots = \delta_5 = 0$	member	152.06	41.24*	11.10	Reject H_0
	non-member	191.18	9.96**	9.23	Reject H_0

#This critical values for the hypotheses are obtained from Table 1 of Kodde and Palm (1986, p. 1246) at $q + 1$ degrees of freedom, where q is the number of parameters to be estimated, whereas the other value in this column represents chi square values.
The Log-Likelihood values in Column No. 3 are compared with the base values of the model in Table 3
* and ** statistically significant at 5 and 10% level, respectively

Table 5. Technical efficiency statistics of dairying in India

Technical efficiency	Member farms	Non-member farms
Below mean efficiency	67	85
Above mean efficiency	33	15
Mean technical efficiency	79%	66%
Maximum	96%	94%
Minimum	43%	29%
Total farms	100	100

the non-member farms. The parameter γ also reflects that the inefficiency effects are highly significant in the analysis of milk production.

The third null hypothesis considered in the model, H_0: $\delta_0 = \ldots = \delta_5 = 0$, i.e., that the coefficients of the explanatory variables in the inefficiency models are simultaneously zero, is also rejected. It indicates that the five explanatory variables taken in the model make a significant contribution in the explanation of the inefficiency effects associated with the value of output for member as well non-member farms. The last null hypothesis considered, H_0: $\delta_1 = \ldots = \delta_5 = 0$, i.e., that the coefficients of the variables in the model for inefficiency effects are zero, is also rejected for both the categories of farmers. It reflects that all the coefficients of the explanatory model are significantly influenced by the number of crossbred animals, the herd size, the education and experience and the institutional finance for the farmers for both the categories of farmers.

Technical efficiency

Estimates of the farm specific technical efficiencies for each category of farmers are presented in Table 5. The mean technical efficiency for the member farms following the modern supply chain management practices turned out to be 79% as compared to the non-member farm (66%). Thus the member dairy farms possess 21 percent technical inefficiency, while the non-member farms have been found possessing 34% technical inefficiency. Further, it is observed that 67% of the member and 85% of the non-member farms are realizing technical efficiency below the mean level, i.e., 79% and 66% level, whereas 33% of the member and 15% non-member farms have the technical efficiency above the mean level. The heterogeneity in management and production practices employed by these farmers may explain the distribution of technical efficiency. The failure of most of the farmers to maximize output while operating in the rational region of production may be due to their failure to adopt appropriate management practices.

Table 6. Estimated potential output and output forgone for dairying in India

Technical efficiency	Member farms	Non-member farms
Actual output ($/farm)	8 749.70	5 609.85
Potential output ($/farm)	11 075.57	8 499.76
Loss due to inefficiency ($/farm)	2 325.87	2 889.91

Potential output and output forgone

The potential output as well as loss of output is estimated by dividing the actual output by the mean technical efficiency whereas the output forgone is the difference between the potential output and the actual output. Table 6 presents an account of the potential as well as the output forgone in dairying in India. These non-member farms in average lose the output worth of $ 2889.91 annually, while the member farms lose the output value of $ 2325.87 only due to the technical inefficiency. This can be regained by way of a better utilization of resources which are at the disposal of farmers.

CONCLUSION

The study is an attempt to analyze the impact of the participation in the modern supply chain management practices formed through the cooperative milk union on dairy farmers in India. It is found from the present analysis that the farmers following the modern supply chain management practices are able to reduce the level of inefficiency. There found a variation in the level of technical efficiency of the member dairy farmer and non-member dairy farmers that turns out to be 79% and 66%, respectively. Thus, the milk production can be increased by 21% and 34% for the actors and non- actor of the supply chain, if this level of inefficiency is removed, without increasing the level of inputs. In other words, dairy farmers can gain considerably higher profits just by increasing the efficiency in their operations. The study also reveals that the impact of wrong own decisions on technical inefficiency was more pronounced in the case of the non-member farmers. The possession of crossbred animals, the experience and education of the managers and the institutional finance ratio affect technical inefficiency negatively and it is statistically significant for the supply chain member as well as non-members. The paper advocates more provisions of the crossbred livestock, provisions of education and improving the institutional access to credit for the farmers engaged in dairying. The study, further, suggests the need to organize training programmes for dairy farmers so that they can be inspired to be a part of some modern value chain practices so as to enhance the efficiency and profitability as well as to equip them with more infrastructural resources for the dairying purpose.

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