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Technical efficiency in milk production in indo-gangetic plain of India: status and determinants

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ABSTRACT

India is the largest milk producer in the world with annual production of about 105 million tonnes in 2007–08. But, milk productivity in India is very low and there is a tremendous scope for its enhancements. The study has measured farm-specific technical efficiency in milk production and has identified its determinants to suggest options for increasing farm level efficiency to strengthen competitiveness of dairy farmers. It has been shown that India has potential to increase milk production by about 25% at the existing level of technological development. However, improvement in technical efficiency in milk production requires adequate and quality veterinary services, augmentation of feed and fodder resources at the farm, integration with formal marketing system, and scaling-up of the dairy enterprise.

Key words: JEL Classification: Q12, Q13,Milk production, Smallholders, Technical efficiency

India is the largest milk producer in the world with annual production of about 105 million tonnes in 2007–08 (DAHD, GoI). But, milk productivity in India is very low and there is a tremendous potential for increase in productivity, which will enhance competitiveness of dairy producers and raise their income. It is important in view of the predominance of smallholders in this enterprise. Further, more than 80% of our milk producers are small and marginal farmers, and landless labourers, whose dependence on dairying for sustenance is substantial. About 70% of milk in India is produced on these farms (Birthal 2008). Improvement in productivity can come through either adoption of new technologies and/or increase in production efficiency. It is also well established that the improvement in efficiency is more cost-effective than introducing new technology, particularly if the producers are not efficient in the use of even the existing technology (Belbase and Grabowski 1985, Shapiro 1983 and Dey *et al.* 2000). In case the producers are reasonably efficient, new inputs and technology would be required to shift the production frontier upward (Ali and Chaudhary 1990, Ali and Byerlee 1991). Available studies have shown that inefficiency in milk production in India is the rule rather than exception (Sharma and Singh 1993, Saha and Jain 2004, Rajendran and Mohanty 2005, Delgado *et al.* 2008). This finding is quite significant because the main consequence of technical inefficiency is the increased production costs, which make dairy farms less competitive and the viability of dairy farming is questioned. A clear understanding of the farm level efficiencies in milk production and identification of their determinants would provide the clue for making this sector competitive and viable. It will also help in suggesting policy options for enhancing the efficiency and competitiveness of the smallholder dairy producers. Therefore, the study was undertaken with the specific objectives to (i) measure farm-specific technical efficiency in milk production, and (ii) to measure the effects of factors, determining technical efficiency.

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MATERIALS AND METHODS

Materials

This study is based on the primary data collected at the farm-level in three states, namely Bihar, Punjab and Uttar Pradesh in the year 2007. These states were selected to capture the geographic and institutional diversities of milk production and marketing. One district was selected from each state purposively. The selected districts have a sizeable milk production and the presence of a variety of milk marketing channels. These were Aligarh in Uttar Pradesh, Patna in Bihar and Rupnagar in Punjab. Administrative blocks (3) were randomly selected from each selected district. From each selected block, three villages were selected randomly. From each block, 75 households were selected for the survey. At the village level, number of selected households was decided in proportion to the village population. Sample households were post-stratified into different categories, viz

landless, marginal, small, medium and large households (landless,without any land; marginal,< 1 ha; small, 1–2 ha; medium, 2–4 ha; large, > 4 ha). Thus, 225 households were selected from each state, making the total sample size of 675 households. The data gathered covered a wide range of information on household, farm and milk production practices.

Methods

Of the various approaches to the estimation of technical efficiency, the stochastic frontier production function (Aigner *et al*. 1977, Meeusen and van den Broeck 1977), and Data envelopment analysis (DEA) (Charnes *et al*. 1978) are the two most popular approaches. A review of the literature suggested that stochastic production function with a composed error-term was more appropriate to estimate the technical efficiency in milk production, particularly in the developing countries, where the probability of data being influenced by measurement errors and the effects of weather conditions, disease, etc. were high (Coelli *et al*. 1998, Kirkley *et al*. 1998, Jaforullah and Devlin 1996, Dey *et al.* 2005). Most of the applications of frontier analysis in the Asian dairy sector have followed this approach (Sharma *et al.* 2003, Saha and Jain 2004, Rajendran and Mohanty 2005).

The frontier production function defines the potential output that can be produced by a farm/firm with the given level of inputs and technology. The empirical model used consists of two stages. At the first stage, farm-specific technical efficiency scores were estimated using stochastic frontier production function following Aigner *et al*. (1977) and Meeusen and van den Broeck (1977). The function was specified as:

$$\ln Y_i = ß_0 + ß_1 \ln (DFOD_i) + ß_2 \ln (GFOD_i) + ß_3 \ln (CONC_i) + ß_4 \ln (FLAB_i) + ß_5 \ln (HLAB_i) + ß_6 \ln (VEXP) + \sum_j \gamma_j STAT + V_i - U_i \quad ... (1)$$

where, subscript i refers to the i^{th} farm, Y is the quantity of milk production (kg/animal/day); DFOD is the amount of dry fodder (kg/animal/day); GFOD is the amount of green fodder (kg/animal/day); FLAB is the family labour used (person/h/animal/day); HLAB is the hired labour used (person/hours/animal/day); VEXP is the expenditure incurred on veterinary medicines and health care (₹/animal/day); $ß_1$, $ß_2$, $ß_3$, $ß_4$, $ß_5$ and $ß_6$ are output elasticities of dry fodder, green fodder, feed concentrate, family labour, hired labour and veterinary expenditures, respectively; STAT represents state dummies, which are included in the model to account for the state-specific influences; V_i is the symmetric random error-term distributed independently and identically [N (0, σ_v^2)] and captures errors beyond the farmer's control; U_i is the one-sided error-term used to denote technical efficiency in production, distributed independently and identically with non-negative truncation of the normal distribution [N (0, σ_v^2)]. If the farm is inefficient (efficient), the actual output is less than (equal to) the potential output. Therefore, the ratio of actual output and potential output can be treated as a measure of technical efficiency. Using, equation (1), the technical efficiency (TE) of the i^{th} farm is derived as: $TE_i = \exp(-U_{i)}$

At the second stage, the influence of socio-economic and farm characteristics was examined on the technical efficiency. A number of variables such as level of education (EDU), experience in dairy farming (EXP), veterinary care (VET), purchase of fodder (PFODD), landholding size (LAND), herd size (HERD), household size (HHS), and proportion of milk sale to formal buyers (SMILK), were considered in the model. A priori, the level of education, experience in dairy farming, veterinary care, proportion of milk sold to formal buyers are expected to have positive influence on technical efficiency. The other variables like purchase of fodder, landholding size, and household size can have either positive or negative influence on the technical efficiency depending on the situation and context. The technical efficiency scores generated by the frontier were regressed on the above variables as per equation(2):

$$TE_i = \alpha_0 + \alpha_1(EXP) + \alpha_2(EDU) + \alpha_3 (VET) + \alpha_4 (PFODD) + \alpha_5 (SMILK) + \alpha_6 (LAND) + \alpha_7 (HERD) + \alpha_8 (HHS) + ei \quad ..... (2)$$

RESULTS AND DISCUSSIONS

Socio-economic profile of households

The socio-economic profile of surveyed farm households is presented in Table 1. The average age of households-head was 50 years while the average years of their schooling were 6.5. The average household size was 8 and the average size of landholding was 1.7 ha. The farmers were reported to have a herd size of 4 livestock units and the milk productivity of milch animals was about 4 litres per day. A little more than one-fourth of the surveyed households were found to be associated with milk co-operative societies. The distribution of surveyed households into different categories indicated that landless, marginal and small farmers together accounted for about 72% of the total sample households. Medium and

Table 1. Socio-economic profile of surveyed milk farmers

Particulars	All
Age of household head (years)	50.3
Education of household head (years)	6.5
Household-size (no.)	8.0
Landholding (ha)	1.7
Herd-size (no.)	4.1
Milk productivity (litre/day/animal)	4.2
Members of dairy co-operatives (%)	26.4
Distribution of households (no.)	
Landless	103
Marginal	260
Small	119
Medium	112
Large	81

Source: Field Survey (2007).

large farmers constitutes 17 and 12 %, respectively of the selected sample households.

Technical efficiency in milk production

The maximum likelihood estimates (MLE) of the parameters in the stochastic production frontier for the milk producers are presented in Table 2. The values of the σ^2, γ, log-likelihood function and test statistic λ and their significance levels indicate that inefficiency effects of a stochastic nature existed in milk production in the study area. All slope coefficients have the expected signs and are significant, except the veterinary expenditure. All the coefficients of input variables are significant at the 1% level of significance, except for the veterinary costs. Of all the input variables, output elasticity was the highest for family labour (0.4101), followed by feed concentrate (0.3495), dry fodder (0.2598), hired labour (0.2564) and green fodder (0.1447). The coefficients for state dummies are not significant, indicating that state level factors do not have any significant influence on the milk production frontier.

To analyse how efficient the dairy farms are in the study area, technical efficiency of milk production by farm households was determined. The frequency distribution of the farm-specific technical efficiency scores is depicted in Table 3. It indicates wide variations in the level of technical efficiency across farms. About 10% farms operate below the technical efficiency (TE) level of 0.5, indicating potential to double the milk production. About 11%dairy farms operate within TE range of 0.5 to 0.6. The % of dairy farms operating within the technical efficiency range of 0.6 to 0.7 is 23%. About one-fifth of the dairy farms operate at TE 0.8 or above.

Table 2. Maximum likelihood estimates of the parameters for milk production frontier

Variable	Coefficients	Standard error
Dry fodder	0.2598*	0.0363
Green fodder	0.1447*	0.0191
Feed concentrate	0.3495*	0.0343
Family labour	0.4101*	0.0592
Hired labour	0.2564*	0.0719
Veterinary expenditure	–0.0001	0.0125
STAT		
Western Uttar Pradesh	–0.0603	0.0638
Punjab	–0.0535	0.0650
_cons	0.4764*	0.1110
s^2_v	0.1193*	0.0294
s^2_u	0.2705*	0.0598
s^2	0.3899*	0.0475
g	0.6938*	
log-likelihood	–358.93	
Wald (Chi^2)	1209.81	
Number of observations	553	

Source: Field survey 2007; Author's own analysis

Table 3. Distribution of dairy farms by level of technical efficiency (per cent)

Technical efficiency status	Farms					
	Landless	Marginal	Small	Medium	Large	Overall
< 0.50	9.5	16.1	9.7	3.8	2.6	9.8
0.5 to 0.6	13.5	13.0	7.8	6.6	12.8	10.8
0.6 to 0.7	24.3	20.8	19.4	26.4	28.2	23.1
0.7 to 0.8	37.8	33.3	38.8	41.5	35.9	36.9
e"0.8	14.9	16.6	24.3	21.7	20.5	19.4

Source: Field survey 2007, Author's own analysis

The modal range, however, lies between 0.7 and 0.8. The distribution of farms as per the level of technical efficiency depicted considerable variations across the categories of farms. For instance, only about 3%of the large farmers operate at TE<0.5, while 16%of the marginal farmers operate at TE below 0.5.

Potential for technical efficiency improvement

Productivity enhancement in milk production by improving technical efficiency is one of the most effective ways to improve competitiveness and enhance income of dairy farmers. An attempt was made to explore the possibilities of milk productivity enhancement through improvement in technical efficiency of dairy farmers with the existing resources and technology. Based on the technical efficiency of the most efficient farms, the average potential to increase milk production per milch animal was estimated by using the following formula:

Potential for increasing milk productivity= [1-(mean technical efficiency/maximum technical efficiency)]*100.

The average potential of increasing milk production through technical efficiency improvement across different categories of farmers in selected states is presented in Table 4. A perusal of Table 4 reveals that the average potential for improvement in technical efficiency in milk production is 25%, if the average farmer in the study area could achieve

Table 4. Average technical efficiency and potential for productivity improvement

Farm-size	Number of farms	Technical efficiency			Average potential to increase efficiency (%)
		Mean	Minimum	Maximum	
Landless	74	0.68	0.30	0.88	26.7
Marginal	192	0.67	0.23	0.92	28.1
Small	103	0.71	0.31	0.89	23.8
Medium	106	0.72	0.37	0.88	22.3
Large	78	0.71	0.37	0.93	23.1
All	553	0.69	0.23	0.93	25.3

Source: Field survey 2007, Author's own analysis

the TE level of its most efficient counterparts. This implies that the average dairy farmers could enhance milk production by 25% with the existing level of technology and resources. The potential for improvement in milk productivity varies from 22% medium farms to 28% in small farms.

Implications of technical efficiency improvement on milk production in India

It is clear from the above discussions that there is a significant scope to increase milk production in India even with the existing technology and without making costly investments. The milk production in India can be enhanced from the existing level of 105 million tonnes to about 131 million tonnes if the observed improvement in TE could be attained. The improvement in TE would bring substantial economic gains and help improve the competitiveness of the dairying sector. The enhanced production in milk is likely to make additional contribution of ₹450 billion (US $10 billion) to the Indian economy. If we are able to achieve the desired improvement in TE, it would be a win-win situation for both consumers as well as producers.

The benefits accruing from TE improvement will have distributional impact and smallholders because of having dominance in milk production, would get a substantial share. The enhanced production will help ease the rising trends of milk prices as milk is a price-sensitive commodity. The tapering of prices helps the consumers, especially the poor consumers. This in turn will improve nutritional security in the country. The increased milk production in India will have implications for the neighbouring countries also. Most of the South Asian and East Asian countries being deficit in milk production, import dairy products in substantial quantities. Since India is now by and large self-sufficient in milk production and is even exporting milk products, the increase in milk production will boost its export potential of dairy products. Several of its neighbouring countries, including Sri Lanka, Bangladesh, Nepal, Bhutan, Maldives, and Bangladesh import milk and milk products from Australia, New Zealand, etc. India can increase its access to these countries and export dairy products competitively if the desired improvements in TE in milk production can be accomplished.

Determinants of technical efficiency

The results of this study as well as others depict significant technical inefficiency in milk production in India. A number of technological and farm-specific features could be responsible for the inefficiency. The effects of such factors are summarized in Table 5. Availability of veterinary care, purchase of fodder, proportion of milk output sold to formal buyers and herd size are found to have significant influence on the technical efficiency in milk production in the area. The coefficient of purchase of fodder is negative and significant at 10% level, indicating that the dependence on purchased fodder reduces the efficiency in milk production. The purchase of green and dry fodder increases the uncertainty in the availability of fodder and thus sometimes adversely affect the efficient management of milk production activities. The availability of veterinary care is observed to have a positive and significant influence on the technical efficiency. Improvement in veterinary care facilities, both prophylactic and curative, is needed for increasing the efficiency in milk production. The association between technical efficiency and herd size is positive and significant, i.e. large dairy farms are comparatively more efficient. This finding is quite significant given the fact that an overwhelming majority of the dairy farms belong to smallholders who may not have adequate capital to invest in the yield enhancing measures. Though in some of the states bigger dairies are coming up particularly on the urban and semi-urban peripheries, smallholders dairying would continue to dominate the milk production system in foreseeable future. These smallholders need policy support in terms of credit, technical advice, extension, etc. to improve their efficiencies in milk production. A higher proportion of sale of output to the formal buyers significantly increases the efficiency in milk production. This indicates that increasing vertical integration with formal milk buyers like co-operatives, private sector corporates, producer associations or companies will be efficiency enhancing measures and should be promoted and strengthened.

Table 5. Impact of farm specific variables on technical efficiency in milk production

Explanatory variables	Coefficients	Standard Error
Experience (years)	0.00000	0.00043
Education (years)	0.00013	0.00118
Veterinary care availability (Yes=1, No=0)	0.02598**	0.01248
Purchasing fodder (Yes=1, No=0)	–0.02155*	0.01209
% Milk sold to formal buyers (%)	0.001514*	0.000161
Size of landholding (ha)	–0.00133	0.00299
Herd size (No.)	0.00587***	0.00170
Household size (No.)	–0.00004	0.00130
Constant	0.65461	0.02785
R^2	0.5190	
Number of observations	553	

***, ** and * show statistical significance at the 1, 5 and 10% levels, respectively.

Source: Field survey 2007, Author's own analysis

The study has shown that India has potential to increase milk production by about 25% at the existing level of technological development. Improvement in technical efficiency will strengthen competitiveness of the farmers as well as their capacity to access high-value markets for better return of their produce. However, improvement in technical efficiency in milk production requires adequate and quality veterinary services, augmentation of feed and fodder

resources at the farms, integration with formal marketing system and scaling up of the dairy enterprise. The technical efficiency has shown a scale-biasness against small farms, which suggests that smallholders need special attention in terms of technological policy and institutional intervention.

The paper has also found that milk production is less efficient with smaller herd size. This may be taken as indicative of equity-efficiency trade-off in the Indian dairying sector. The findings suggest that encouraging milk production by smallholders may lead to declining efficiency in milk production though it may promote equity in the rural economy. It also suggests that increasing herd-size will raise the efficiency in milk production. The government's efforts to improve the technical efficiency of dairy farmers should be diverted more towards small farms, as they operate at lower technical efficiency than of the large farms and therefore present a relatively higher scope for improvement.

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