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Technical efficiency of dairy farmers in Bihar, India: status and determinants

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Abstract Bihar's share of the total milk produced in India rose from 3.2% in 2001–02 to 5.2% in 2018–19, but the productivity of its dairy sector is lower than the national average. The low economies of scale, lack of institutional support, and dominance of small and marginal farmers have constrained the sector's efficiency. The technical efficiency of dairy farmers—determined by a farmer's herd size, the size of their holding of cultivated land, education, and experience— would be improved by skills development and technology transfer.

Keywords Dairy farmers, small farmers, technical efficiency, determinants, market access

JEL codes C01, Q12, Q13

India is the largest producer of milk in the world; its dairy subsector is an essential part of its agricultural economy. Milk production has grown so significantly that it now contributes more than any other farm commodity to the national economy. Small and marginal farmers, and landless labourers, substantially depend on dairying for their livelihoods; they make up more than 80% of the country's milk producers and produce about 70% of the milk (Birthal 2008). In the state of Bihar, too, milk production is a significant source of income among small and marginal farmers. Smallholder dairy farmers produce around 80% of the total milk. Bihar's share of the total milk in India rose from 3.2% in 2001–02 to 5.2% in 2018–19 (Department of Animal Husbandry, Dairying and Fisheries 2006, 2019). Milk production increased consistently in the past two decades due to the conducive policy environment (breed improvement and the development of milk marketing channels). The indigenous cow population has been declining in the state while the crossbred population has been increasing rapidly, and the buffalo population has been growing marginally, and the productivity of all types of animals has marginally increased.

However, milk productivity in the state is only 4.5 litres, much less than the national average of 5.1 litres (Department of Animal Husbandry, Dairying and Fisheries 2019), and it varies by the source of milk. The yield from crossbred cows is 17% less than the national average and from buffaloes 22% less, but the yield from nondescript cows is 11% more than the national average (Department of Animal Husbandry, Dairying and Fisheries 2019). Across districts, the spatial distribution of milk production is unequal. It could be due to the unequal increase or decrease in the population of crossbred cows, nondescript cows, and buffaloes in the districts. The technical efficiency of dairy farmers has been measured (Kumar 2012), but not by the type of dairy farmer or market access. This paper uses primary data to understand the efficiency of the different types of dairy farmers and access to the market in three districts of Bihar. It also examines the determinants of efficiency in milk production.

Data

This study is based on primary data collected from dairy farmers of three districts—Samastipur, Katihar, and Nawada—in Bihar, India. The selection of the districts is guided by the intensity of dairying activity and the type of milk disposal channels. Based on soil character, rainfall, temperature, and terrain, each of these districts represent a different agroclimatic zone. Samastipur falls in agroclimatic zone 1 (northern west), Katihar in agroclimatic zone 2 (northern east) and Nawada in agroclimatic zone 3 (southern east and west).

At the next stage of sampling, we randomly selected two blocks from each district, two villages from each block, and 20 dairy farm households from each village; the sample totalled 240 respondents (dairy farmers or households, used interchangeably). Using the direct questionnaire method, we surveyed the respondents between January and February in 2013. We tested the survey instruments before undertaking the survey.

Method

To calculate the economics of milk production, we collected data on the quantity of dry fodder, green fodder, and concentrate fed to the dairy animals per day, and the purchase price per unit. In addition, we collected the village-level unit price of hired labour and used it to impute the cost of family labour. We also collected the data from the dairy farmers on their expenditure on veterinary and health care services. The milk price is the actual price received by the dairy farmers from the sale of milk.

The milk output of two types of milch animals (cows and buffaloes) was converted into 4% fat corrected milk following the methodology and specifications provided by Hemme et al. (2003). We assumed the actual fat content 3.5%, for crossbred cows, 4.5% for nondescript cows, and 6% for buffaloes and corrected the fat content in terms of 4% fat corrected milk level. The net revenue (earnings to dairy farmers) was estimated as the difference between the realized price of the fat corrected milk and cost of production.

Using Stata 13, we employed stochastic frontier analysis to estimate the technical efficiency of dairy farmers. The production frontier provides the upper boundary of production possibilities, and the input-output combinations of each producer are located on or beneath the production frontier. We followed a production function approach to measure productivity and technical efficiency. To estimate farmers' average production and productivity, we used ordinary least squares (OLS) to fit a log-linear Cobb-Douglas production function to the observations. The output interacted by a district dummy (Nawada = 1 and 0 otherwise, Samastipur = 1 and 0 otherwise) is obtained in an additive form for the intercept. The specific Cobb-Douglas production fitted is

$$\ln Q = \alpha + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \varepsilon \quad \ldots(1)$$

Where, Q = milk production (kg), α = the intercept, X_1 = dry fodder (kg), X_2 = green fodder (kg), X_3 = concentrate (kg), X_4 = labour (hours), X_5 = district dummy.

The stochastic production frontier function fitted is

$$\ln y_i = \alpha_0 + \sum_{i=1}^{6} \beta_i \ln x_i + \beta_5 x_5 + v_i + u_i \quad \ldots(2)$$

where, all variables are defined in the equation and v_i is the two-sided 'noise' component and u_i is the non-negative technical inefficient component of the error term. The noise component v_i is assumed to be symmetric and distributed independent of u_i. Thus, the error term in the stochastic production frontier becomes $\varepsilon = v + u$. The maximum likelihood method of estimation enables us to obtain the maximum possible output function. These require that the density function for random variables v_i and u_i are given. It is assumed that u_i follows a half-normal distribution due to the nature of definition and follows a conventional normal distribution (Kalirajan and Shand 1994).

Using the half-normal and exponential maximum likelihood methods to measure technical efficiency yields similar results. This study follows the half-normal method because it is slightly tighter than the exponential (Kumbhakar and Tsionas 2006). With the estimated coefficients, we can evaluate crop- and farm-specific outputs for individual sample farmers. This has been achieved by multiplying the full technical efficiency coefficients with the corresponding actual level of inputs and adding the constant term of the frontier for each sample farmer. There is a difference between the log value of the frontier output of these farmers and the log value of actual output, and it is due to the compared variable of the inefficiency of the sample farmers and random statistical factors.

The technical efficiency is assumed to depend on factors that determine an individual's technical knowledge and understanding and on the socio-economic environment in which the individual works (Kalirajan and Shand 1994; Kalirajan 1990). The factors affecting the efficiency of the sample dairy farmers can be classified into two groups—those associated with technical knowledge and those related to socio-economic variables. We used a simple OLS regression analysis to identify the determinants of technical efficiency:

$$Y_i = \alpha + \beta X_i + \mu_i \qquad \ldots(3)$$

where, Y_i is the estimated technical efficiency score of the dairy farmers/producers, and X_i are the explanatory variables, which include characteristics like the age of the household head, the education of the household head, labour availability, number of dairy animals, cultivated land, and district dummy; α and β are the estimated parameters, while ìi is the error term.

Results and discussion

General characteristics of dairy farming households

Across the sample districts, the head of the dairy farming households is aged around 50 years on average (Table 1), and most have completed primary schooling only. Most dairy farmers are small landholders, and the cultivated area averages one to two acres. Fodder cultivation is low in these three sample districts, which represent the three agroclimatic zones in Bihar in terms of the incidence of rainfall and floods and the availability of common land for open grazing. Dairy farmers in Samastipur district cultivate green fodder because there is less common land for open grazing, the rainfall is sufficient, and seasonal floods do not occur. That is why a larger proportion of cultivable land is used to cultivate green fodder in Samastipur than in districts in the other agroclimatic zones in Bihar. Nearly 70% of the dairy farming households own a single dairy animal, but the other 30% own at least two animals, and some of them own three or more, and so the mean ownership of dairy animals is two.

The economics of milk production

We collected data to estimate the cost of milk production and the share of each input in the total cost of rearing the dairy animals and milk prices (Table 2). In our estimation, we attempted to account for the fact

Table 1 General characteristics of the dairy farming households by district, 2013

Characteristics	Nawada	Katihar	Samastipur	All
Average age of the household head (no. of years)	50	48	50	49
Average education of the household head (no. of years)	6	4	5	5
Average number of members in the age group (15–59 years)	4.9	4.6	3.9	4.4
Percentage distribution of households by landholding				
Landless (0 acre)	11.3	25.0	13.8	16.7
Small (0.01 to 2 acre)	55.0	63.8	67.5	62.1
Medium (2 to 4 acre)	23.8	8.8	12.5	15.0
Large (>4 acre)	10.0	2.5	6.3	6.3
Average area cultivated (acres)	2.0	1.1	1.5	1.5
Percentage area under fodder crop	1.5	5.0	9.4	4.9
Percentage distribution of households by herd size				
Small (only 1 animal)	73.8	68.8	68.8	70.4
Medium (2 to 3 animal)	15.0	20.0	23.8	19.6
Large (more than 3 animal)	11.3	11.3	7.5	10.0
Average number of livestock in (TLU)				
Dairy animals	1.9	2.0	1.9	2.0
In milk	1.2	1.4	1.5	1.4
Dry	0.8	0.6	0.4	0.6

Field survey.

TLU stands for Tropical Livestock Unit.

Table 2 Economics of milk production (Rs./litre) by district, 2013

Head of expenditure	Nawada	Katihar	Samastipur	All
Dry fodder	9.8	7.5	5.8	7.2
	(54.17)	(36.93)	(31.08)	(38.36)
Green fodder	0.8	2.2	1.7	1.6
	(4.31)	(10.81)	(9.05)	(8.50)
Concentrate	3.9	3.7	7.7	5.8
	(21.76)	(18.27)	(41.04)	(31.01)
Family labour	3.1	6.0	2.8	3.4
	(17.01)	(29.39)	(14.81)	(18.25)
Hired labour	0.1	0.3	0.1	0.1
	(0.45)	(1.28)	(0.52)	(0.67)
Veterinary charges	0.4	0.7	0.7	0.6
	(2.31)	(3.33)	(3.49)	(3.21)
Total	18.0	20.3	18.7	18.7
Milk price	21.8	18.5	19.2	19.5
Net revenue	3.8	-1.8	0.6	0.8
Return to family labour	6.8	4.2	3.3	4.2

Field survey.
Figures in parentheses are share of different expenditures.

that small-scale milk production involves, mainly, family labour. The cost of milk production in Katihar is highest among the three districts, at INR 20.3 per litre, but its market price is the lowest at INR 18.5 per litre. Katihar is flood-prone, and it is inundated for at least three to four months during the monsoon season. Therefore, farmers need to buy green fodder, and the cost of production rises. Cash is limited, and farmers make several trips to the fodder market to buy dry fodder in small quantities. The cost of time and transport is reflected in the higher cost of family labour in Katihar.

In Nawada, the cost is INR 18.0 per litre, the lowest among the districts, but the market price is the highest at INR 21.8 per litre. The cost of milk production is low because expenditure on green fodder is low—common lands are available for open grazing—and the animals need less of concentrate feed. The price of milk is higher because the marketable surplus is low, and milk marketing intermediaries are few. We analyse the share of the cost of each input in the total cost of milk production, and we find that the share of dry fodder is high in both Nawada and Katihar.

In Samastipur, the cost of milk is INR 18.70 per litre, and the price is INR 19.20 per litre. The price of milk is low because production and supply are high. The share of the cost of concentrate feed, and dry fodder, in the total feed cost, is higher in Samastipur than in the other districts. The return on family labour is highest in Nawada, at INR 6.80 per litre, followed by Katihar at INR 4.20 per litre and Samastipur at INR 3.3 per litre. The net revenue is negative in Katihar and high in Nawada.

Technical efficiency

This section discusses the farm-specific production performance of our sample dairy farmers with the feasible or best performance. We use maximum likelihood estimation and the Cobb-Douglas production function to obtain the best practical performance output. Our analysis implicitly assumes that the technical change is Hicks-neutral; that is, it does not affect the capital-labour balance in the production function.

The empirical results of the half-normal maximum likelihood estimation of the best performance production of farmers indicate that out of six independent variables, four influence the total output achieved by the dairy farmers (Table 3). The coefficients of dry fodder, green fodder, and concentrate feed positively and significantly influence

Table 3 Production function of milk, 2013

Milk production (litre/day)	Coefficient	Standard error
Dry fodder (dm/kg/day)	0.54***	0.09
Green fodder (dm/kg/day)	0.15**	0.06
Concentrates (dm/kg/day)	0.10**	0.05
Labour (hrs/day)	0.07	0.11
Nawada=1, otherwise=0	0.14	0.13
Samastipur=1, otherwise=0	0.64***	0.12
Constant	0.28	0.22
/lnsig2v	-1.39***	0.34
/lnsig2u	-0.29	0.37
sigma_v	0.50	0.09
sigma_u	0.87	0.16
sigma2	1.00	0.21
Lambda	1.73	0.24
Log likelihood	-259.80	
Wald chi2(6)	116.54	
Number of observations	240	

Estimated by author based on field survey.
*** $p < .01$, ** $p < .05$ and *$p < .1$.
dm denotes the dry matter.

the total output (milk production). The value of the coefficient indicates that using the same composition of inputs, farmers in Samastipur are likely to produce more milk than in the other districts. This study did not find any significant impact of labour days on milk production. This could be because the feeding of concentrate does not require much labour and contributes to high yield.

There is a marginal variation in farm-level technical efficiency between districts and types of livestock holding (Table 4). The mean efficiency is 56% in Nawada, 55% in Samastipur, and 54% in Katihar; farmers in Nawada are more efficient than farmers in Samastipur and Katihar, but not significantly so. This contradicts our hypothesis that farmers in Samastipur would be more efficient than farmers in other districts.

The results (Table 4) allow us to examine the technical efficiency by sizes of livestock holding: it is higher for farmers who own more than two dairy animals (64%) than those who own less than two (52%). This pattern is uniform across districts. The technical efficiency improves significantly as the herd size increases from one to two, and it rises even more significantly as the herd size increases beyond two.

Determinants of technical efficiency

To explain the variations in milk production efficiency among the sample farmers, we conduct regressions that identify the contributions of the selected variables (Table 5). The results indicate that efficiency can rise with an increase in a farmer's age and education level. Farmers who use more family labour are technically inefficient. Farmers can raise their technical efficiency if they increase their ownership of total livestock units. The coefficient of landholding size indicates that higher the landholding, higher the efficiency, as large landholdings provide farmers with enough crop residue and green fodder for their livestock. Our study did not find any significant regional impact on milk production, as technical efficiency does not vary much by the district.

Table 4 Average technical efficiency across districts and dairy animals in total livestock unit (TLU), 2013

Districts	<= 1 animal	1–2 animals	> 2 animals	All
Nawada	$0.47^{a}\pm0.03$	$0.55^{b}\pm0.03$	$0.64^{c}\pm0.03$	$0.56^{d}\pm0.02$
	(0.14)	(0.14)	(0.14)	(0.15)
Katihar	$0.47^{a}\pm0.03$	$0.52^{a}\pm0.03$	$0.66^{b}\pm0.04$	$0.54^{d}\pm0.02$
	(0.15)	(0.17)	(0.16)	(0.17)
Samastipur	$0.49^{a}\pm0.19$	$0.52^{a}\pm0.03$	$0.62^{c}\pm0.03$	$0.55^{d}\pm0.02$
	(0.26)	(0.19)	(0.15)	(0.18)
All	$0.47^{a}\pm0.02$	$0.52^{b}\pm0.02$	$0.64^{c}\pm0.02$	0.55 ± 0.02
	(0.15)	(0.17)	(0.15)	(0.17)

Estimated by author based on field survey data.
Values bearing different superscripts ^{a,b,c,d} differ significantly ($P<0.05$); Figures in parentheses are standard deviations (SD).

Table 5 Determinants of technical efficiency, 2013

Technical efficiency	Coefficient	Std. Err.
Age of head (no. of years)	0.01	0.00
Education of head (no. of years)	0.01	0.00
Family labour (hrs/day)	-0.01*	0.02
Dairy animals (TLU)	0.05***	0.01
Cultivated land (acre)	0.02**	0.01
Nawada=1, otherwise=0	-0.01*	0.03
Samastipur=1, otherwise=0	-0.01*	0.03
Constant	0.47***	0.00
R^2	0.89	
Number of observations	240	

Estimated by author based on field survey data.
*** p <.01, ** p <.05 and *p <.1.

Conclusions

This study analysed the economics of milk production, technical efficiency, and determinants of technical efficiency in three districts of Bihar. It finds that technical efficiency is higher for farmers who own more than two dairy animals (64%) than farmers who own fewer than two (52%). Technical efficiency also rises with a farmer's education and experience (age), herd size, and the size of cultivated land. There is enough scope to enhance milk production in Bihar with the current level of technology. From the policy and programme perspective, it may be useful to focus on skills development and transfer of relevant technologies/knowledge for improving the technical efficiency of dairy farmers.

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