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Profit Efficiency among Dairy Farmers in Southern India: An Application of Stochastic Frontier Profit Function

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ABSTRACT

Background: Dairy farming has emerged as an important profitable enterprise in India as it is a source of income, especially for small and marginal farmers;the study aims to understand the reasons for increased profit of dairy farmers of South Indian states.

Methods: The present study was undertaken in Southern Indian states during 2020-21 to estimate the profit efficiency of milk producers across different herd-size categories.

Result: Maximum likelihood estimates (MLE) of specified profit function revealed that overall, prices of green fodder (0.1873), prices of concentrate (0.1072), veterinary service rate (0.0569) and herd size (0.7545), had a positive and significant impact on normalized profits, whereas prices of dry fodder (-0.0277) and labour wages (-0.1652) had a negative and significant impact on normalized profits, respectively. Overall, the mean profit efficiency of dairy farmers was found to be 58.65 per cent indicating 41.35 per cent of profit efficiency was lost due to technical and allocative inefficiencies in milk production. Results from the profit inefficiency model revealed that overall, education, herd size, herd composition and experience in dairy farming had a negative and significant impact on profit inefficiency.

Key words: Boxplot analysis, Dairy farmers, Inefficiency model, Profit efficiency, Stochastic profit frontier.

INTRODUCTION

Self-sufficiency in milk Production has been one of the critical issues in South Indian states due to insufficient multi-cut green fodder crops in time and a lack of knowledge about unconventional fodder sources.The study area's dairy farmers successfully selected an optimal set of livestock inputs consistent with relative dairy product prices. Although necessary, technical efficiency studies are insufficient to explain why dairy farmers exit the dairy sector (Bahta *et al.*, 2021).

Small dairy farms in Andhra Pradesh confront different production risks due to increasing dependence on external fodder suppliers, which usually undermines the farm's profitability (Drews *et al.,* 2020). The profitability and resource efficiency of dairy farms depends on various aspects such as the quality of fodder, adoption of technology *etc.* (Toma *et al.,* 2013). This scenario provides little understanding of the profit efficiency elements in the study area and suggests the need for additional research, particularly on revenue components (Adenuga *et al.,* 2018). The hypothesis in the present study is that optimal use of inputs could contribute to improvements in dairy productivity and efficiency in profit. Due to this, the present study was carried out to gain insight into the performance efficiency of dairy farmers in Southern India, for which the profit efficiency of dairy farmers across different herd size categories in the study area was estimated,and an inefficiency model to identify socio-economic factors that affect variations in profit efficiency was constructed.

MATERIALS AND METHODS

The research was carried out at Dr Rajendra Prasad Central Agricultural University, Pusa, Samastipur Bihar, during 2019-21 as a part of Doctoral research by the first author. The study area was the Southern Indian states of Andhra Pradesh (623 gm/day), Karnataka (344 gm/day), and Tamil Nadu (322 gm/day),which were selected on the basis of the highest per capita availability of milk during 2020-21 (Fig 1). One district per state was selected based on cattle population; thus,Chittoor, Belgaum and Villupuram districts were selected from Andhra Pradesh, Karnataka and Tamil Nadu, respectively. One mandal and two villages from each mandal were randomly selected from each district.Further, 240 respondents, i.e. eighty from each state,were selected (Table1). The chosen respondents were post-stratified into three herd-size categories, namely Small (1-3 milch animals), Medium (4-6 milch animals), and Large (7 and

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above milch animals) using the Cumulative Square Root Frequency Method.

To the study, there are many factors which influence the profit efficiency of dairy farms. But, major factors like farmer's practices, dairy breeds, fodder, feeding system, veterinary services, market size, distance to town, education of farmers and age of farmers were thought to influence the profit efficiency of dairy farms in the study area. Conceptual framework on factors influencing profit efficiency of dairy farmer was shown in the Fig 2.

The Stochastic Profit Frontier Function

Two aspects of production efficiency that are typically examined are technical and allocative efficiency.Any faults in production choice are supposed to convert into decreased profits or revenue for producers under the profit function method, which blends technical and allocative efficiency ideas in the profit relationship (Ali *et al.*, 1994). As a result, profit efficiency refers to a farm's ability to generate the most profit possible given the pricing of variable inputs and the quantities of fixed elements on that farm. The loss of profit from not operating on the frontier means "profit inefficiency"(Ali & John, 1989). The inefficiency effects might be described as a linear function of explanatory factors, indicating farm-specific characteristics (Battese and Coelli, 1995). The benefit of this model is that it enables a single-stage estimation technique that can estimate efficiency scores particular to farms as well as the factors causing efficiency differences amongst dairy farmers. The Battese and Coelli (1995) model is used to obtain profit inefficiencies by postulating a profit function approach that is assumed to act in a manner consistent with the stochastic frontier idea. We used the OLS method in the second stage to regress profit inefficiencies obtained in stochastic frontier profit function on socio-economic factors. The definition of the stochastic profit function is:

$$\pi_i = f\,(P_{ij},\ Z_{ik}).\exp\,(\xi_i)$$

where,

π_i = Normalized profit of the i-th farm defined as gross revenue less variable cost, divided by farm-specific output price.

P_{ij}= Price of j-th variable input faced by the i th farm divided by the output price.

Z_{ik} = Level of the k-th fixed factor on the i th farm.

ξ_i = Error term.

i =1,..,n, number of farms in the sample.

The error term $\hat{\imath}_i$ is assumed to behave in a manner consistent with the frontier concept, *i.e.*,

$$\xi_i = v_i - u_i$$

Where,

v_is = Assumed to be independently and identically distributed N (O, σ_v^2) two-sided error terms and independent of u_is.

u_is = Non-negative random variables associated with the inefficiency in production.

The profit efficiency of farm 'i' in the context of the stochastic frontier profit function is:

$$EFF_i = E\,[\exp\,(-u_i)\mid \xi_i] = E\left[\exp\left(-\delta_0 - \sum_{d=1}^{D} \delta_d W_{di}\right) \mid \xi_i\right]$$

Where,

E = Expectation operator.

The unknown parameters were estimated using maximum likelihood, and the stochastic frontier and inefficiency impact functions were also evaluated at the same time.The likelihood function was expressed in terms of the variance parameters, $\sigma^2 = \sigma^2 + \sigma^2$ and $\gamma = \sigma^2 / \sigma^2$.

The Cobb- Douglas functional form of stochastic frontier profit function was expressed as,

$$\ln\pi^* = \beta_0 + \ln\,\beta_{1i}P_{1i} + \ln\,\beta_{2i}P_{2i} + \beta_{3i}P_{3i} + \beta_{4i}P_{4i} + \beta_{5i}P_{5i} + \ln Z_{zi} + v_i - u_i$$

Where,

π^* = Normalized profit (`).

P_1 = Normalized price of green fodder (`).

P_2 = Normalized price of dry fodder (`).

P_3 = Normalized price of concentrate (`).

P_4 = Normalized wage of labour (`).

P_5 = Normalized fee of veterinary services (`).

Z_1 = Herd size (number).

Z_2 = Farm cost used (`).

Now, the inefficiency model u_i is defined as:

$$\mu_i = \delta_0 + \sum_{d=1}^{6} \delta_{di} W_{di}$$

Where,

W_1 = Age of the dairy farm head (years).

W_2 = Education of the dairy farm head

W_3 = Family labour (in numbers).

W_4 = Herd size (in numbers).

W_5 = Herd composition (ratio).

W_6 = Experience in dairy farming (in years).

Herd composition implies the ratio ofthe total number of crossbred cows to the total herd size.

Estimation

FRONTIER 4.1 (Coelli, 1996) software was used to obtain maximum likelihood estimates of the stochastic Cobb-Douglas frontier profit function and profit inefficiency model.

RESULTS AND DISCUSSION

a) Profit Efficiency Model

Maximum Likelihood Estimates of Parameters of Stochastic Profit Frontier Function

As evident from Table 2, overall, prices of green fodder(0.1873), concentrate (0.1072), veterinary service rate (0.0569), and herd size (0.7545) had a positive and significant impact on profits.At the same time, dry fodder price (-0.0277) and labour wage (-0.1652) negatively and significantly impacted profit. Finally, it was observed that a positive effect of green fodder and concentrate is reasonable when their prices increase; farmers will only feed the required quantity of green fodder and concentrate to their cattle so that overall cost decreases, thereby increasing profits. It is possible to increase the milk yield of animals by feeding them with green fodder and concentrate.Meena *et al.* (2012), Kumari and Malhotra (2018) and Acharya *et al.* (2021) all reported similar findings, indicating that feeding concentrate to animals increases milk yield, implying higher profits. Farmers' milk yields are reduced when they use dry fodder, resulting in lower profits (Aquino *et al.*, 2020; Kumari *et al.,* 2020; Acharya *et al.,*2021). Hence, profit has a negative relationship with dry fodder. Profit was negatively associated with labour wages because increased labour hours raise labour costs, lowering profits. This is consistent with previous research by Kumari *et al.* (2020) and Acharya *et al.* (2021). Gamma must be a positive integer between 0 and 1. If ϒ=0, inefficiency is absent, and ϒ=1 random noise is absent. The estimated gamma value was close to one in all farmer herd size categories. It significantly differed from 0, implying that there were inefficiencies among the dairy farmers. Overall, the value was 0.7581, indicating that 75.81 per cent of the variation in actual profit from the frontier profit was caused by differences in the farmer's practices in milk production rather than random noise, whereas it was 99.99 per cent, 90.19 percent, and 93.43 percent, respectively, in the small, medium, and large herd size categories. Ngangaet *al.* (2010), Bardhan and Sharma (2013), Kaka *et al.* (2016), Kumari *et al.* (2020), Lal *et al.* (2020),Singh *et al.* (2012) and Acharya *et al.* (2021) all reported similar findings. The specified distributional assumptions of the composite error term's fitness and accuracy are shown by the value of estimated σ^2 which was found to be significant in all dairy farmer categories, *i.e.*small (0.3223), medium (0.1986), large (0.1061) and overall (0.1390).

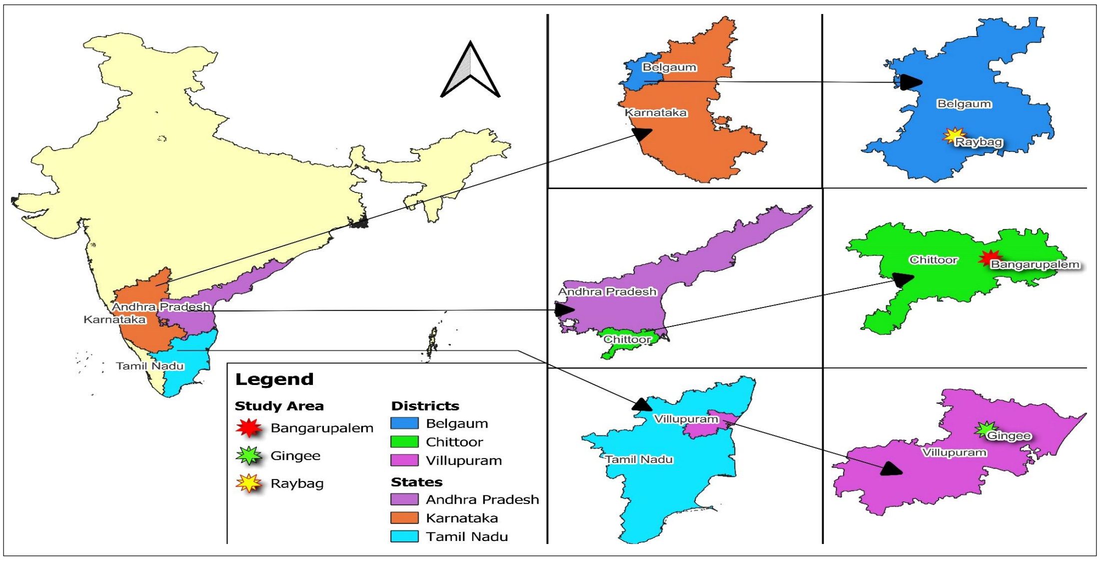

Fig 1: Map showing the location of study area.

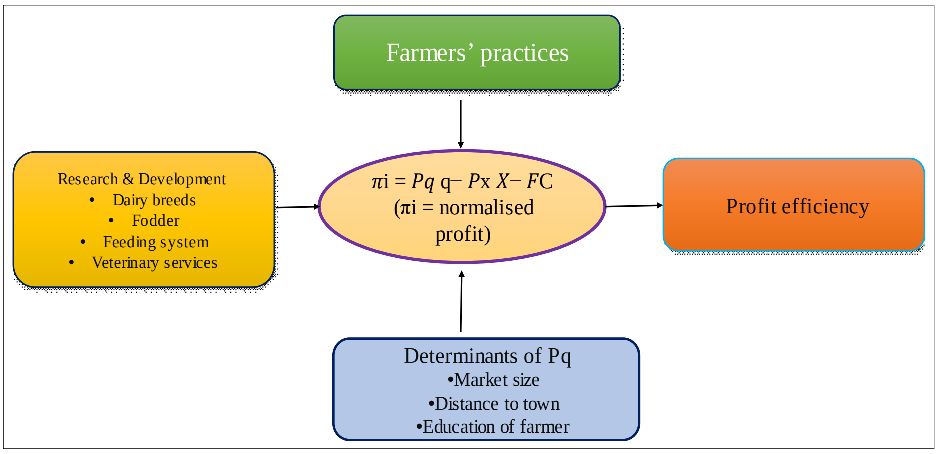

Fig 2: Conceptual framework on factors influencing profit efficiency of dairy farmer.

Frequency Distribution of Profit Efficiency of Dairy Farmers

A perusal of Table 3 revealed that in the case of the small herd size category, profit efficiencies ranged between 36.11 to 90.66 per cent, with a mean profit efficiency of 59.42 per cent, respectively. While in the case of the medium herd size category, profit efficiencies ranged from 58.51 to 99.98 per cent, with a mean profit efficiency of 79.06 per cent, respectively. In the large herd size category, profit efficiencies ranged from 68.37 to 97.74 per cent, with a mean profit efficiency of 88.91 per centrespectively.

Overall, the mean profit efficiency was found to be 58.65 per cent, which varied between 32.50 to 89.61 per cent respectively. This implies that 40.58 per cent, 20.94 per cent, 11.09 per cent and 41.35 per cent of profit efficiency in the case of small, medium, large and overall dairy farmers was lost because of economic inefficiency. Farmers can fill this gap by improving technical and allocative efficiency (Nganga *et al.,* 2010). It was also observed that mean profit efficiency increased as herd size increased. This resulted from the fact that as herd size increased, milk output also increased, thereby increasing the profitability of dairy farms. This is in agreement with the findings of Kumari *et al.* (2020) and Acharya *et al.* (2021). Overall, most dairy farmers in the study area had profit efficiencies ranging from 50 to 60 per cent (70).The maximum number of dairy farmers had their profit efficiencies in the range of 50 to 60 per cent in case of small, 70 to 80 per cent in case of medium and 90 to 100 per cent in case of large dairy farmers, with the numbers being 34, 21 and 29, respectively.

Table 1: Sample distribution of households in study area.

State	District	Taluk	Village	Small	Medium	Large	Total
Andhra Pradesh	Chittoor	Bangarupalem	Ragimanipenta	17	13	10	40
			Mothagunta	19	12	9	40
Karnataka	Belgaum	Raybag	Handigund	12	17	11	40
			Hidakal	28	7	5	40
Tamil Nadu	Villupuram	Gingee	Alampoondi	20	12	8	40
			Kariyamangalam	26	9	5	40
Southern India				122	70	48	240

Table 2: MLE of parameters of stochastic Cobb-Douglas profit frontier function.

Variables	Small	Medium	Large	Overall
Constant	3.1368***	2.6041***	1.6928***	3.1011***
	(0.3522)	(0.3953)	(0.5215)	(0.2201)
Price of green fodder	0.2384**	0.2114***	-0.1596***	0.1873***
	(0.1086)	(0.0511)	(0.0410)	(0.0579)
Price of dry fodder	-0.1438*	0.0263***	0.0411	-0.0277**
	(0.0737)	(0.0089)	(0.0424)	(0.0126)
Price of concentrate	0.0072	0.0354	-0.0786	0.1072**
	(0.0496)	(0.0346)	(0.0608)	(0.0502)
Labour wage	0.0386	-0.0944*	0.0655*	-0.1652***
	(0.0911)	(0.0572)	(0.0336)	(0.0394)
Veterinary services rate	0.0010	-0.0939**	-0.1086*	0.0569*
	(0.0643)	(0.0477)	(0.0616)	(0.0356)
Herd size	0.7082***	1.0351***	1.5337***	0.7545***
	(0.0651)	(0.3194)	(0.1756)	(0.0504)
Farm capital	0.0519	0.0354	-0.0534	0.0457
	(0.0376)	(0.0381)	(0.0691)	(0.0290)
$\sigma^2 = \sigma_u^2 + \sigma_v^2$	0.3223***	0.1986***	0.1061***	0.1390**
	(0.0595)	(0.0499)	(0.0245)	(0.0654)
$\gamma = \sigma_u^2 / \sigma^2$	0.9999***	0.9019***	0.9343***	0.7581***
	(0.0104)	(0.0790)	(0.0286)	(0.1329)
log likelihood	40.3069	64.0283	29.0427	84.4511
LR test of one-sided error	67.6598	37.9464	44.9099	112.4372

(Figures in parenthesis are standard errors).

***, ** and * significant at 1, 5 and 10 per cent levels.

Note: Small (1-3 animals); Medium (4-6 animals); Large (7 and above animals).

Box and Whisker plot analysis

We conducted a box and whisker plot analysis of the profit efficiency of dairy farms by herd size categories (Fig.3).Overall, the median was 57.67, which was highest for the large category (93.65), followed by medium (79.08) and least for small herd size category (56.70). It was also found that overall, the inter-quartile range (IQR) was 16.85, which varied from 10.89 for the large category, 16.52 for the medium category, to 17.28 for the small category respectively. The vertical length of the Box and whisker was found to be highest for the small category, followed by the medium category and least for the large herd size category, respectively, indicating that dairy farms of the small herd size category experienced the highest variation in efficiency score, followed by medium category and least in case of large category. Similar findings were reported by Acharya *et al.* (2021). The mean profit efficiency in the case of medium and large herd size categories ranges from 80 to 90 per cent, but it was around 60 per cent in the case of small herd size categories. It can thus be inferred that most dairy farmers of all categories have profit efficiency in the range of 45 to 90 per cent.

b) Profit Inefficiency Model

Profit inefficiency values obtained from stochastic frontier profit function were regressed on factors like age, education, family labour, herd size, herd composition and experience in dairy farming using the OLS method to determine their influence on profit inefficiency (Table 4).Table 4 shows that age had a negative sign in all categories butwas significant only for the medium herd size category. This implies that as age increases, the risk-bearing capacity of farmers decreases, thereby increasing efficiency (Adamu and Bakari, 2015; Acharya *et al.,* 2021).

Education had a negative and significant impact on profit inefficiency in case of small (-0.0176), medium (-0.0198), large (-0.0177) and overall (-0.0175) categories of farmers, respectively. Improving farmers' education helps to enhance profit efficiency. Nganga *et al.* (2010), Ogunniyi (2011), Kaka *et al.* (2016), Kumari *et al.* (2020) and Acharya *et al.* (2021) all reported similar findings.

Herd size and herd composition had a negative and significant impact on profit inefficiency in case of small (-0.0441 and -0.4019); medium (-0.7702 and -0.2986); large (-0.0350 and -1.0381) and overall (-0.0130 and -0.2494)

Table 3: Frequency distribution of profit efficiency of dairy farmers across herd size categories.

Efficiency estimates (%)	Small	Medium	Large	Overall
30-40	5	0	0	10
40-50	28	0	0	60
50-60	34	2	0	70
60-70	29	16	3	51
70-80	13	21	5	33
80-90	7	19	11	13
90-100	6	12	29	3
Minimum (%)	36.11	58.51	68.37	32.50
Maximum (%)	90.66	99.98	97.74	89.61
Mean (%)	59.42	79.06	88.91	58.65
Total number of farms	122	70	48	240

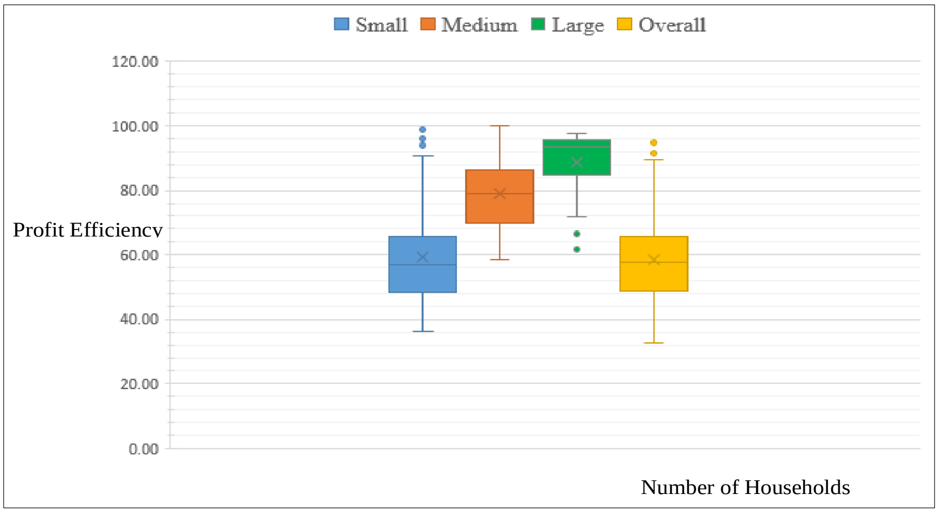

Fig 3: Box plot of frequency distribution of households by herd size and profit efficiency.

Table 4: Determinants of profit inefficiency across herd size categories.

Variables	Small	Medium	Large	Overall
Intercept	0.7928***	0.6145***	1.9980*	0.7505***
	(0.1453)	(0.2326)	(1.0472)	(0.0959)
Age	-0.0016	-0.1910*	-0.0165	-0.0052
	(0.0056)	(0.1113)	(0.0147)	(0.0036)
Education	-0.0176*	-0.0198*	-0.0177*	-0.0175***
	(0.0102)	(0.0141)	(0.0091)	(0.0059)
Family labour	0.0224	-0.0135	-0.1476	0.0050
	(0.0280)	(0.0087)	(0.0994)	(0.0075)
Herd size	-0.0441***	-0.7702**	-0.0350***	-0.0130***
	(0.0143)	(0.3927)	(0.0128)	(0.0033)
Herd composition	-0.4019***	-0.2986***	-1.0381*	-0.2494***
	(0.0335)	(0.0534)	(0.5462)	(0.0232)
Experience in dairy farming	-0.2835***	-0.3884***	0.0041	-0.0220**
	(0.0321)	(0.0930)	(0.0036)	(0.0092)
R^2	0.6897	0.7591	0.7134	0.6971
Number of observations	122	70	48	240

(Figures in parenthesis are standard errors).

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

Note: Small (1-3 animals); Medium (4-6 animals); Large (7 and above animals).

categories of dairy farmers, respectively. This shows that by increasing the number of crossbred cows in a herd leads to increased milk yield and profits.These were similar to the findings Nganga *et al.* (2010), Kumari *et al.* (2020), Yilmaz *et al.* (2020) and Acharya *et al.* (2021).

Experience in dairy farming had a negative and significant impact on inefficiency incase of small (-0.2835), medium (-0.3884) and overall (-0.0220) categories of farmers, while the same was positive and non-significant in case of a large herd size category. It means that profit efficiency will be higher for highly experienced farmers because of their efficient usage, resource allocation, and adoption of new technologies.Rahman (2003), Nganga *et al.* (2010), Ogunniyi (2011), Sharafat (2013), Kaka *et al.* (2016), Kumari *et al.* (2020), Yilmaz *et al.* (2020) and Acharya *et al.* (2021) reported similar results.

CONCLUSION

The findings above reveal that farmers in the study area feed their cattle with green fodder and concentrate on increasing the milk yield of animals, thereby increasing profits.There is a need to enhance access to dairy production inputs and services (feed, veterinary, breeding, training, and credit services) for dairy farmers. Overall, the value of Υ was 0.7581, indicating that 75.81 per cent of the variation in actual profit from frontier profit occurred due to differences in farmers' practices in milk production rather than random noise. Dairy farms with the small herd size category experienced the highest variation in efficiency score, followed by the medium category. They were least in the case of the large herd size category. Farmers with higher levels of education, large farm size, greater number of crossbred cows and more experience in dairying tend to have more profit efficiency. Age, education, herd size and experience in dairy farming were important variables that indirectly influenced profit inefficiency. These findings imply that encouraging new farmers, particularly young farmers, to raise dairy cows by adopting better milk-yielding breeds will increase their productivity and, as a result, their profitability. Therefore, policy initiatives aimed at increasing farmers' market participation rates through training on profitable dairying, better technology and practices to enhance their knowledge and skills, as well as by providing information and other market-related support services; provision of quality feed with subsidies will significantly contribute to profit efficiency and thereby improve the performance of dairy farms.

Conflict of interest: None.

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