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Techno-economical analysis of crossbreed cattle milk production in Western Himalayas of India

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Abstract
The study was undertaken to analyse the prospects of crossbreed cattle farming in Himachal Pradesh state India. Himachal Pradesh is a hilly state majorly shadowed with snowfall with predominance of hilly terrain (68.65%) (Anonymous, 2017) [1]. The state is having self sustained balance between supply and demand with structural change i.e., emigrate from traditional farming practices to modern farming practices results in declining of cost of production and hike in profitability and benefit cost ratio. The research has concluded across the three categories such as small, medium and large category of farmers based upon Standard animal unit (SAU). The net return per liter of milk production from crossbred cattle in overall category was Rs 8.59, whereas, at disaggregate level net returns from crossbred cattle were highest for large category farms (Rs 9.70 per liter), followed medium and least for small category farmers i.e., Rs 7.60 and Rs. 6.80 respectively. The cost per liter of milk production was Rs 28.54 for overall category, whereas, and it was least for large category (Rs 27.66 per liter). Among the cost components the total feed cost alone accounted for about 65.67 percent to the gross cost (GC) across the categories. Among feed cost, concentrate constitutes more than 33.50 percent to the GC. The cost of concentrates varied among categories, such as for small category it was 25.50 percent, for medium category 30.24 percent and for large farmers 32.47 percent of the GC. The maximum likelihood estimates for crossbred cattle across the different farm categories. The results clearly indicate that green fodder, dry fodder, concentrate and labour cost are significant at 5 and 10 percent level of significance and positively influences the milk production. However, labour was found negatively associated with milk production in large category. At the disaggregated level, labour coefficient value (-0.34) indicates that 1 percent increase in the labour results in reduction of milk value by 0.34 percent for large category farms which implied excess use of labour. The coefficient of concentrate (0.55) indicates that 1 percent increase in concentrate results in 0.55 percent increase in milk production at 10 percent level of significance. The household size also negatively (0.07) influenced milk production. Green fodder positively influenced milk production as 0.40 percent with 1 percent increase at 10 percent level of significance. However, in small farm category quantity of green fodder, concentrate and labour cost were positively and significantly influenced milk production at 5 percent level of significance. It was found that 1 percent increase in the green fodder, dry fodder and labour cost increased milk production by 0.20, 0.55 and 0.18 percent respectively. In case of medium farms, green fodder, dry fodder and household size were found affecting milk production positively and significantly by 0.19, 0.60 and 0.18 percent respectively.

Keywords: Techno-economical analysis, crossbreed cattle milk production, standard animal unit

Introduction
Himachal Pradesh is a hilly state in the northern part of India positioned in the western Himalayas. The state encompasses predominately mountains of 68.65 percent of total geographical area (Anonymous, 2017) [1]. Livestock sector is also an important source of livelihood in the mountainous terrains of the Himachal Pradesh. Himachal Pradesh comprises total livestock population of 4.41 million in the year 2017, of which 55 percent comprises of bovine and 40.8 percent consists of ovine population to total livestock population (Khalandar *et al* 2022) [8]. Prospects of dairying under hilly conditions would greatly benefit the resource-poor farmers and maximize resource use efficiency. In buffalo upgradation with Murrah bull is being popularized. During 2019-20, three lakh semen straws for buffaloes were produced by sperm stations. During 2019-20, Artificial insemination facility was provided through 3,220 institutions to 2.40 lakh buffaloes.

Poor bargaining power and difficulties in transportation forces the farmers to sell milk at lower prices (Pathania and Sharma, 2016) [10]. The state has one of the weakest organised milk marketing structure (Kale *et al*. 2016) [7] and the lower returns have affected the attitude of farmers towards dairy farming and the farmers are reluctant to sell milk leading to lowest marketed surplus. So, the activity remains non-commercialized in the state (Dogra, 2016) [6]. The dairy processing activities by state owned milk marketing organisations have considerably underperformed (Kumar, 2018) [9] and has limited marketing channels across or outside state (TOI, 2018) [14]. Low performance of state owned dairy co-operatives has given way towards innovative Farmer Producer Organizations (FPOs). The reported evidences of dairy interventions through producer organizations are still very few in India in general and specifically in the state of Himachal Pradesh.

Additionally, this sector can play a key role in encouraging economic redistribution in favour of small and marginal group of farms. The state's economy is heavily reliant on hydropower, tourism, agriculture, and horticulture (Anonymous, 2019) [2]. According to Chand (1995) [5], In the state's number under productive dairy animals is growing while the population of animals that are not productive is decreasing. Due to their better lactation efficiency than domestic and crossbred cattle, Chauhan (1995) further emphasised the significance of buffaloes in the state. Additionally, it was predicted that in the future, there would be more buffalo in the state than cattle. Taking into account all of the aforementioned information, research was done to examine the technical efficacy of various types of farms' milk production processes.

Methodology

Sampling design

Selection of study area

The state was divided into three strata i.e., four districts under each stratum based on milk production. Stratified multistage random design has been employed for selection of households. From each stratum two districts were selected randomly.

Selection of districts

In high milk producing stratum Mandi and Solan districtcs, Hamirpur and Sirmour from Medium stratum and Bilaspur and Chamba from low stratum districts were selected randomly for the collection of primary data.

Selection of blocks and sample

At the second stage, two blocks from each selected district were selected randomly. At third stage five panchayats from each block were selected randomly for the present study. At the final stage of the sampling, six dairy farming households from each selected panchayat were selected randomly to constitute a sample size of 360 for the collection of the primary data.

Stratification of sample households.

For the construction of strata, the cumulative cube root frequency method (Singh and Mangat, 1996) [13] and Standard animal unit method (SAU) Sirohi *et al*. (2019) [12] were used.

Analytical framework

Herd size

The total number of milch animals kept by the sample houses during the study period was taken into account. According to Sirohi *et al*. (2019) [12], the complete herd of cattle on the dairy farm, which consists of adult and young male and female animals, has been transformed into Standard Animal unit (SAU's). SAUs were assigned based upon animal body weight.

Table 1: Standard animal units for hilly region of the India

Types of Animal	Local Cow	Crossbred Cow	Buffalo
Adult Male (≥3 years)	1.48	1.11	1.43
Adult Female (≥3 years)	1.71	1.00	1.70
Young stock male (<1 year)	0.41	0.29	0.35
Young stock female (<1 year)	0.72	0.63	0.63
Young stock male (>1 year)	0.71	0.55	0.73
Young stock female (>1 year)	1.08	0.82	0.94
Heifer	1.24	0.98	1.09

Source: Sirohi *et al*. (2019) [12]

Cube-root cumulative-frequency method

In this study, SAUs was used as the covariate for the post stratification process. Dairy farmer households (360) were categorized into three classes, using the cube-root cumulative-frequency method (Singh and Mangat, 1996; Shyamalie, 2008) [13, 15]. For efficient distribution of households, three class stratification method was performed. Thus, range for Small (0.0-3.0 SAU), Medium (3.1-7 SAU) and Large (>7 SAU) was assigned.

Cumulative cube root frequency method

$$L_i = y_{i-1} + \left(\frac{S_k \div L - S_{i-1}}{\sqrt[3]{f_i}}\right)(y_i - y_{i-1})$$

Where;

L = No. of strata

L_i = Upper limit of *i* th strata

y_{i-1} = Lower limit of the class in which L_I lies

S_k = Cumulative total of $\sqrt[3]{f_i}$

$\sqrt[3]{f_i}$ = Cube root of the frequency of the *i* th class in which L_i lies

S_{i-1} = Cumulative cube root of the frequency of preceding class to the class to which L_i lies

y_i = Upper limit of the class in which L_i lies

y_i-y_{i-1} = Width of the class in which L_i lies

Table 2: Distribution of selected households based on cumulative cube root frequency method

Dairy Farm Category	SAU	Average SAU	Number	Percent	Land Holding (Ha)
Small	Up to 3	2.27	177	49.16	0.49
Medium	3.1 to 7	4.98	119	33.06	0.69
Large	More than 7	15.28	64	17.78	1.44
Overall		5.27	360	100.00	0.71

The distribution of dairy farm categories revealed that 49.16 percent were small dairy farms with an average no of 2.27, whereas, 33.06 were medium category with an average of 4.98 SAUs. The large dairy farms were only 17.78 percent but the average number of SAUs was 15.28.

Cost and returns from milk production

The farmers were surveyed using a dually corrected and pre-tested interview schedule to collect information on various parameters of dairy farming such as value of the animals and investments made in apparatus and cattle shed. Data on outputs like milk and manure were also collected from the sample dairy farmers. Details of inputs like green fodder, dry fodder, concentrates with their amounts and prices, labour engaged with wage details, veterinarian and breeding charges, and miscellaneous expenses were also gathered. The following presumptions were used to estimate and calculate various cost such as Fixed cost, variable cost and depreciation and appreciation.

Functional Analysis

Milk production

Milk production is influenced by several explanatory variables. The production function shows the relationship between milk yiel and explanatory variables used in the production process. Production function analysis was employed to estimate the income from production of milk.

The specification of production function used in the present study for functional analysis is as follows:

$$Y = (X_1, X_2, X_3, X_4, X_5)$$

Where,

Y = Income from milk per animal per day (Rs.)

X_1 = Expenditure on green fodder per animal per day (Rs.)

X_2 = Expenditure on dry fodder per animal per day (Rs.)

X_3 = Expenditure on concentrates per animal per day (Rs.)

X_4 = Value of labour used per animal per day (Rs.)

X_5 = Household size (No.)

Technical efficiency in milk production

To estimate technical efficiency stochastic production function was applied.

$Y_i = f(x_i: \beta) \exp(v_i - u_i)$ i= 1,2,3….n

Where

Y_i denotes the output quantity of the i^{th} farm,

X_j is a (1xJ) vector of input quantities

β is a (J x 1) vector of unknown parameters to be estimated.

V_i are two-sided random variables associated with measurement errors in output and other noise in the data which are beyond the control of firms.

Maximum likelihood estimation methods were used to estimate the stochastic frontier. For the likelihood function the variance term are parameterized as:

$$\sigma^2 = \sigma^2_u + \sigma^2_v$$

$$\gamma = \frac{\sigma^2_u}{\sigma^2_u + \sigma^2_v} \text{ with } 0 \leq \gamma \leq 1 \text{ (Battese and Coelli, 1995)}$$

The technical inefficiency for the i^{th} firm is estimated as the expectation of u_i conditional on the observed value ($v_i - u_i$):

Resource Use Efficiency

The economic efficiency of resource used was determined by using the MVP and MFC ratio. The estimated coefficients were used to compute the MVP and its ratio (r) with MFC. The model used for estimation of r was as follows:

r = MVP/ MFC

r = Efficiency ratio

MVP = Marginal value product of variable inputs

MFC = Marginal factor cost (prices of inputs)

Results and Discussion

Write conclusion in 100-120 following

Costs and returns from crossbred cattle of milk production across the dairy farm categories in Himachal Pradesh

The estimates of cost and returns of milk production of crossbred cattle for different categories are depicted in the Table 3. The findings revealed that the net return per liter of milk production from crossbred cattle in overall category was Rs 8.59, whereas, at disaggregate level net returns from crossbred cattle were highest for large category farms (Rs 9.70 per liter), followed medium and least for small category farmers i.e., Rs 7.60 and Rs6.80 respectively. The cost per liter of milk production was Rs 28.54 for overall category, whereas, and it was least for large category (Rs 27.66 per liter) because the large farmers were technically efficient and the milk productivity of maintained breeds was higher than the breeds with small and medium category farmer. The large farmers were operating in economically high profitable zone compared with others. The large farmers were also having the particular consumers so that they can take risk and feed high quality feed and fodder, whereas, the small and medium category farmers can not able to take higher risk. Large farmers have absolute advantage hence purchase feed and fodder in large quantities. Among the cost components the total feed cost alone accounted for about 65.67 percent to the gross cost (GC) across the categories. Among feed cost, concentrate constitutes more than 33.50 percent to the GC. The cost of concentrates varied among categories, such as for small category it was 25.50 percent, for medium category 30.24 percent and for large farmers 32.47 percent of the GC.

Likewise, green fodder cost accounted for 16.51 percent in all the categories and was highest for small category farmers (17.65%), whereas, for large farmer it was 16.29 percent. The reason for decrease in cost of green fodder was due to positive correlation between herd size and land holding. The large farmers having their own land so they instead of depending entirely on purchase, produced green fodder by them self. In principle the crossbred cows are fed with lower amount of green fodder as compared to concentrate. The labour cost accounted more than 22.97 percent for all the categories with a range of 29.17 to 22.45 percent of gross cost for small and large category farms respectively. The labour cost in case of small farms was higher than the large farms because the large farms were technically efficient and adopted mechanization such as milking machine, grass chopper and water motor for cleaning the mats, but in case of small farms everything was done manually. The result also reveals that there is a positive association between the net returns and herd size. The overall maintenance cost was Rs 183.17 per day per SAU and was highest (Rs 183/day/SAU) as large category farmer and lowest (Rs 182.35/day/SAU) for small

category farmer. These results are similar to the results reported by Bardan *et al.* (2012) who also reported that the cost of maintenance was highest for large farmers and least for small farmers. Khovieo *et al.* (2012) also reported that net returns for crossbred cows were higher for large category farmers as compared to small category farmers.

Resource use and technical efficiency analysis

Stochastic frontier function estimates of milk production for crossbred cattle across the dairy farm categories in Himachal Pradesh

The maximum likelihood estimates for crossbred cattle across the different farm categories are depicted in table 4. The results clearly indicate that green fodder, dry fodder, concentrate and labour cost are significant at 5 and 10 percent level of significance and positively influences the milk production. However, labour was found negatively associated with milk production in large category which implies that dairy farmers are utilizing more of labour for carrying out different operations in dairy enterprise signifying the disguised employment in the dairy farming. At the disaggregated level, labour coefficient value (-0.34) indicates that 1 percent increase in the labour results in reduction of milk value by 0.34 percent for large category farms which implied excess use of labour. The coefficient of concentrate (0.55) indicates that 1 percent increase in concentrate results in 0.55 percent increase in milk production at 10 percent level of significance. The household size also negatively (0.07) influenced milk production. Green fodder positively influenced milk production as 0.40 percent with 1 percent increase at 10 percent level of significance. However, in small farm category quantity of green fodder, concentrate and labour cost were positively and significantly influenced milk production at 5 percent level of significance. It was found that 1 percent increase in the green fodder, dry fodder and labour cost increased milk production by 0.20, 0.55 and 0.18 percent respectively. In case of medium farms, green fodder, dry fodder and household size were found affecting milk production positively and significantly by 0.19, 0.60 and 0.18 percent respectively.

The frontier function reflects the responses of the best and efficiently managed farm. The lambda (λ) which is the ratio of variance of the farm specific production behavior, σ^2 (u) to the variance of the statistical noise σ^2 (v) shows the farm specific variability contributed to the variation in production among dairy farms, which means that the total variation in the output from the frontier is attributable to the technical efficiencies among the dairy farms, which was 0.03 indicating that one-sided error component had dominated relatively to symmetric error component. It implies that 3 percent of the variations in the dairy farms across the categories was mainly due to the differences in technical efficiencies among the farmers. This implied that 97 percent of the variations in the milk value was due to random shocks such as unfavorable weather conditions, untimely availability of quality inputs and other factors which are not under the control of the farmers.

Technical efficiency of crossbred cattle across the dairy farm categories in Himachal Pradesh

The results of farm specific technical efficiency are presented in table 4. The mean technical efficiency (TE) in rearing crossbred cattle across the different dairy farm categories was different. The overall estimated Mean TE was 0.62, which varied between 0.50 to 0.66 among the different dairy farm categories. Further it was observed that if the average dairy farmer in overall category could achieve the TE level of his/her most efficient counterpart he/she would increase output by about 37 percent. Similarly, different category farmers could increase output by 33 to 49 percent. This indicated that there is considerable scope to increase the milk output in crossbred cattle by different dairy farm categories without additional inputs.

Resource use efficiency for crossbred cows across sampled dairy farms in Himachal Pradesh

Given the technology and price, the allocative efficiency refers to achievement of optimum output so as to maximize profit. The optimality condition of price efficiency can be developed in case of single output - multi input production function. The resource use efficiencies of the crossbred cows possessed by the dairy farmers are depicted in the table 4. The resource use efficiency which is measured as the ratio of MVP to MFC of each input to their unit price, indicates how the resources are allocated. This ratio is 1 for perfect competitive market when there is no divergence between their MVP and unit price. The resource use efficiency for overall category indicated that green fodder (1.52) and concentrates (2.65) were underutilized, whereas, dry fodder (-0.26) and labour (-0.001) were over utilized in milk production in crossbred cattle. At disaggregate level, large farms used inputs green fodder (1.70, concentrates (1.03) and dry fodder (2.10) sub-optimally (underutilized) and labour (0.004) was over utilized. It is inferred from results that in order to enhance the milk production the use of labour needs to be increased. The resource use efficiency on medium category farm indicates that green fodder (-0.59), dry fodder (0.31) concentrates (0.75) and labour (-0.26) were over utilized and t need to decrease these inputs to enhance the milk productivity in long run. Whereas, in case of small farms the all the inputs such as green fodder (2.09), dry fodder (1.81) and concentrates (1.83) were underutilized, whereas labour (0.01) was over utilized. The results showed that medium category farmers are using the resources in excess, whereas, small and large farmers are underutilizing resources in dairy farm in the state. These results are in line with Kumari *et al* (2016) [16].

Table 3: Costs and returns from crossbred cattle of milk production across the dairy farm categories in Himachal Pradesh (Rs/Day/SAU)

Particulars	Category			
	Small	Medium	Large	Overall
Green fodder (A)	36.25 (17.65)	34.51 (16.80)	33.66 (16.29)	34.50 (16.51)
Dry fodder (B)	31.92 (15.54)	33.30 (16.21)	33.28 (16.11)	32.93 (15.66)
Concentrate (C)	52.36 (25.50)	62.12 (30.24)	67.09 (32.47)	62.30 (33.50)
Total feed cost (A+B+C)	120.53 (58.71)	129.94 (63.25)	134.04 (64.88)	129.74 (65.67)
Labour (D)	59.90 (29.17)	51.84 (25.23)	46.37 (22.45)	50.94 (22.97)
Miscellaneous (E)	2.76 (1.34)	1.64 (0.80)	2.08 (1.01)	2.17 (1.05)
Total Variable Cost (X= A+B+C+D+E)	183.91 (89.23)	183.43 (89.30)	182.51 (88.35)	182.87 (89.68)
Total Fixed cost (Y)	22.10 (10.76)	22.00 (10.70)	24.00 (11.64)	23.15 (10.32)
Gross cost (GC=X+Y)	205.30 (100)	205.42 (100)	206.58 (100)	206.02 (100)
Returns from dung (VD)	22.94	22.93	22.77	22.85
Net cost (NC=GC-VD)	182.35	182.50	183.80	183.17
Average Milk Production Qty (N)	6.06	6.24	6.64	6.41
Cost per liter (C=NC/N)	30.05	29.21	27.66	28.54
Sale price (P)	36.85	36.80	37.37	36.94
Gross return (GR=P*N)	223.66	229.90	248.25	238.33
Net Return per liter (NR=GR-GC)	6.80	7.60	9.70	8.59

Figures in parenthesis indicates percentage to Gross cost

Table 4: Stochastic frontier estimates of milk production for crossbred across the dairy farm categories in Himachal Pradesh

Particulars	Coefficients			
	Small	Medium	Large	Overall
Green fodder	0.20** (.08)	0.19*** (0.083)	0.40** (0.18)	0.28*** (0.052)
Dry fodder	-0.001 (0.05)	0.60*** (0.19)	0.29 (0.20)	0.089*** (0.005)
Concentrate	0.55*** (0.60)	0.12 (0.09)	0.55*** (0.17)	0.41*** (0.043)
Labour cost	0.183*** (0.04)	0.54 (0.61)	-0.34 (0.22)	0.20*** (0.032)
Household size	0.08 (0.03)	0.18*** (0.07)	-0.07*** (0.03)	-0.003 (0.02)
constant	0.05 (0.26)	-3.31 (3.21)	1.13 (0.62)	-0.38 (0.020)
Insigma v	-3.99*** (0.35)	-3.64*** (0.21)	-5.13*** (0.22)	-3.72*** (0.09)
Insigma u	-4.34*** (0.02)	-13.27 (321.93)	0.001 (0.12)	-0.38 (0.020)
Sigma v (σ_v)	0.13 (0.02)	0.15 (0.01)	0.07 (0.008)	0.155 (0.007)
Sigma u (σ_u)	0.11 (0.76)	0.001 (0.21)	0.001 (0.12)	0.004 (0.18)
Lambda (λ)	0.84 (0.098)	0.008 (0.211)	0.01 0.12	0.03 (0.18)
Log likelihood ratio	67.10	17.45	45.97	100.51

Figures in Parenthesis indicate standard error
* significant at 1 percent level of significance
** significant at 5 percent level of significance
*** significant at 10 percent level of significance

Table 5: Technical efficiency of crossbred cattle across the dairy farm categories in Himachal Pradesh

	Technical efficiency (%)				
Dairy farms	Mean	SD	Min	Max	Mean potential
Small	0.66	0.28	0.01	0.99	0.33
Medium	0.50	0.24	0.01	0.98	0.49
Large	0.58	0.24	0.32	0.99	0.43
Overall	0.62	0.23	0.01	0.98	0.37

Table 6: Resource use efficiency for crossbred cows across sampled dairy farms in Himachal Pradesh

Categories	Allocative efficient coefficients			
	Small	Medium	Large	Overall
Green Fodder	2.09**	-0.59	1.709**	1.552**
Dry Fodder	1.81**	0.31	2.130**	-0.268
Concentrate	1.83**	0.75**	1.033**	2.659**
labour cost	0.01	-0.26**	0.004**	-0.001**

Figures in Parenthesis indicate standard error
* significant at 1 percent level of significance
** significant at 5 percent level of significance
*** significant at 10 percent level of significance

Summary and Conclusion

The share of milk production from buffaloes was declining due to the poor lactating efficiency, less productivity and seasonal breeding in buffaloes. The reasons for this scenario are the majority of the land area of the state is hilly and temperate which leads to scarcity of green fodder throughout the year. Therefore, the Department of Animal Husbandry should make arrangements to purchase feed and fodder from plains and supply them in hilly areas during winters. This will help the individual dairy farmers to purchase feed and fodder at relatively lesser prices. Artificial insemination services in hilly regions need to be extended significantly to improve the milk production. This study has estimated significant quantity of milk surplus for years to come. Therefore, the government should also make arrangements to procure surplus milk and export to other states and convert into milk products. This will help to keep up the demand for milk and thereby the dairy farmers fetch better price for their produce on a sustainable basis. The feed and fodder cost was major component of gross cost, so the govt. should provide the concentrates at affordable prices to lower the cost of milk production.

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