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A Pricing Model for Milk Based on Cost of Production

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ABSTRACT. *Pricing policy is very important for any organized enterprises. Two axis pricing system is followed in dairy business centers of Tamil Nadu. Though it is scientifically rational, this pricing system ignores the input prices, technology and government policies. Since the economic reforms have been taken for achieving an annual average growth of 7 - 8 % in the next five years and dairying is practiced as a component of mixed farming systems, it becomes imperative to take into account the interrelationship among the enterprises and general economic factors. So, the study made an attempt to develop the price model based on cost of production and projected different price scenarios of milk for forthcoming years. To achieve the above issues, the present study was undertaken in the Tamil Nadu state with the specific objective to determine the cost and price models for milk. The primary data were collected for the year 2002-03 and normalized restricted quadratic profit function analysis and price determination models were used. To maintain constant returns to the production cost of milk, the milk price would need an upward adjustment of 10.45%, whereas to provide constant net monetary income, the milk price would need an upward adjustment by 11.79%. Considering 2002-03 as the base year, the cost of milk production per litre of milk would be Indian Rs.15.58 during the year 2009-10. With the assumption of 10% increase in all the variable inputs prices, the estimated price for milk per litre is expected to be Indian Rs.18.65 at constant monetary income and Indian Rs.17.14 at constant return to production cost in the year 2009-10.*

INTRODUCTION

At present, livestock sector is emerging as a driving force in the growth as well as economic symbiosis of agricultural sector of India. In India, 27% GDP of Agriculture and allied sector contributed by this sector in 2005-06 (Economic Survey, 2005-06). Milk production alone involves more than 30 million small producers, each raising one or two cows or buffaloes. With 97.1million tons of milk output, India is sustaining the status of global leader in milk production (Economic Survey, 2005-06). It accounts for more than 65 percent of the total value of livestock output. Though, India is the world's top milk producer, but the per capita milk availability remains low at 241 g/day (Economic Survey, 2005-06), which is lower than the minimum recommended requirement of 250 g/ day as recommended by Indian Council of Medical Research (ICMR). The demand for milk is estimated to 191.3 million tons by 2020 assuming the growth rate of the economy at 5% per annum. Milk supply projections indicated a deficit of 52.7 million tons by 2020 (Kumar, 1998).

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The fast growth in human population and the liberalization of dairy trade as a consequence of economic development, lead to a strong pressure on demand for milk, which needs to be met by its matching supply. Thus, there is a need of reliable empirical knowledge with regard to the degree of responsiveness of demand and supply of milk, and associated inputs to fluctuations in their relative prices. However, the degree of responsiveness will not be same in all the regions and for all the periods. Therefore, development of suitable dynamic cost and price models for milk for major species of milk animals in various seasons is essential to workout cost and price structure, thereby helping in fixation of milk prices in advance. In India, such type of price policy for milk and other livestock products has not yet been adopted by the government and the same is being handled by middleman, individual traders and vendors. Previous studies conducted by Ray (1978) and Gandhi (2002) with respect to milk pricing policy and concluded that two axis pricing policy was suitable for milk and milk producers also not affected by this policy. However, Patel (1975), Raut and Singh (1979) and Pundir (1996) concluded that the cost of milk production, seasonal variation and general market trend should be taken into account for pricing of milk. Keeping above in mind, the study made an attempt to develop price model based on cost of production and project different price scenarios of milk in future.

METHODOLOGY

Sampling framework and data collection

The state of Tamil Nadu has been purposively selected. It has emerged as the ninth largest milk producer state of the country with a milk production of 4.75 million tons accounting for 5.40% to the total milk production in the country and the second largest milk producer in the southern region (CSO, 2004). In order to achieve the objectives of the present study, a multi-stage stratified random sampling technique was adopted to select the sample households. Erode and Trichy districts of Tamil Nadu were purposively selected for the study. Two blocks were selected randomly from each of the two districts. In order to select sample households, a complete enumeration of all households in the selected villages was carried out. A sample of 20 households from each village was randomly selected and thus totally, 160 sample households were selected. The data for the investigation consisted of both primary data for two seasons, namely, flush (August to February) and lean (March to July) for the year 2002-03 through a well structured, pre-tested proforma by personal interview method and secondary data obtained from published sources.

Existing milk pricing system

The basic purpose of this study has been to apply methodology for determination of product price to milk output in the study area. The milk price is set to cover production costs, including remuneration of family and a normal profit rate, and to follow the general evolution of market prices. Normally, in India, the price of milk is determined in cooperatives by two ways (Ray, 1978 and Gandhi, 2002), viz., (1) bulk line cost method, which is that level of cost which covers / reflects bulk line (i.e., 85^{th} percentile) of milk production, (2) two axis pricing policy (i.e., considering both fat and SNF), fat is estimated by Gerber method (BIS, 1981), lactometer reading and modified Richmond’s formula is used to estimate SNF in milk. But there is no uniform pattern followed throughout the country to give weightage to SNF-Fat value, and bulk line costing method, while fixing the price of milk. Generally, the dairy plants fix their own SNF-fat weight, fat rates to attract higher milk procurement. These pricing policies completely ignore the factor allocation, yield levels and income, which are very much affected by movements of relative prices. In such situations, it is important to take into account the interrelationships of milk on both the factor and product market sides for determining the price of milk.

Price determination model for milk

Kumar (1984) and Kumar and Mruthyunjaya (1989) developed and used the methodology for factor and product price determination taking into account product interrelationships through price and non-price factors, which measure the adjustments needed in product price in relation to factor price, inflation, infrastructure development and technological change. They proposed price model based on cost of production. This price model requires information on growth in cost of production and net income. The growth equations of cost of production and net income can be obtained by using the elasticities of normalized restricted quadratic profit equation model.

Price model based on cost of production

The price of milk ought to be at level, which covers production cost and leaves sufficient margin of profit to induce farmers to improve the productivity of milk animals by adopting modern technology. The milk output price under different income policies for farmers (Kumar, 1984) can be determined as follows:

At specific rate of return:

$$P_t = \tilde{C}_t \; (1 + \Pi_t) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\; 1$$

At constant rate of return:

$$P_t = P_{t-1}\,(1 + \dot{\tilde{C}}_t) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\; 2$$

At constant monetary net income:

$$P_t = P_{t-1}\,(1 + (\dot{P})_{dI=0}) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\; 3$$

Where,

P_t is the price per litre of milk in year 't', Π_t is the rate of return to production cost in year 't', $\tilde{C}_t$ is the cost of production of milk in year 't' and $(\dot{P})_{dI=0}$ is the growth in milk price corresponding to constant net income. Thus, price model requires information on growth in cost of production and net income. In the subsequent section cost of milk production and net income models have been amply elaborated.

Model for cost of production of milk

Consider the milk production function:

$$Q = F\,(X, Z, T) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\; 4$$

Where,

Q is the milk yield per milk animal, X is a vector of 'm' inputs whose demand is variable with prices (variable inputs), Z is a vector of k inputs whose demand is fixed in short-run (fixed inputs) and T is technology. The factor demand for variable inputs is given as:

$$X_D = X\,(p/P, Z, T) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 5$$

The cost of production per milk animal is :

$$C = p.\, X'_D + g \cdot Z' \qquad \text{…………………..6}$$

Where,

C is total cost per milk animal and g is a vector of prices of fixed inputs Z.

By substituting X_D from (5) we get :

$$C = p \cdot X' \,(p/P, Z, T) + g \cdot Z' \qquad \text{………………….7}$$

Taking total differentials of (7) and writing in terms of relative changes and elasticities, we get :

$$\dot{C} = E_C^P \cdot \dot{P} + \sum_{i=1}^{m} E_C^{p_i} \cdot \dot{p}_i + \sum_{i=1}^{k} E_C^{g_i} \cdot \dot{g}_i + \sum_{i=1}^{k} E_C^{Z_i} \cdot \dot{Z}_i + E_C^T \cdot \dot{T}$$

$$\text{…………………..8}$$

Where,

$$\dot{C} = \frac{dC}{C}, \quad E_C^P = \frac{dC}{dP} \cdot \frac{P}{C} \quad \text{and so on.}$$

These elasticities are, in turn, equal to:

$$E_C^P = -\sum_{j=1}^{m} \frac{p_j X_j}{C} \cdot \sum_{i=1}^{m} E_{X_j}^{p_i/P}$$

$$E_C^{p_i} = \frac{p_i X_i}{C} + \sum_{j=1}^{m} \frac{p_j X_j}{C} \cdot E_{X_j}^{p_i/P}$$

i = 1, …., m; j = 1, …., m

where p_i – price of i^{th} input, P- price of milk and X_i – quantity of i^{th} input.

$$E_C^{g_i} = \frac{g_j \cdot Z_i}{C}$$

i = 1, …., k

$$E_C^{Z_i} = \sum_{i=1}^{k} \frac{p_i X_i}{C} \, E_{X_j}^{Z_i} + E_C^{g_i}$$

j = 1, …., k

$$E_C^T = \sum_{i=1}^{m} \frac{p_i X_i}{C} \cdot E_{X_i}^T$$

The milk supply function is :

$$Q = Q\,(P, p, Z, T) \qquad \text{………………… 9}$$

Based on milk supply function (9), the milk supply growth model in terms of elasticities and relative changes is estimated as:

$$\dot{Q} = E_Q^{P}\,.\,\dot{P} + \sum_{i=1}^{m} E_Q^{p_i}\,.\,\dot{p}_i + \sum_{j=1}^{k} E_Q^{Z_j}\,.\,\dot{Z}_j + E_Q^{T}\,.\,\dot{T} \qquad \ldots\ldots\ldots\ldots\ldots 10$$

Where, (.) denotes the growth of respective parameter.

Let, $\underset{\sim}{C} = C / Q$ be the production cost per litre of milk, the growth in production cost per litre of milk can then be derived as :

$$\dot{\underset{\sim}{C}} = \dot{C} - \dot{Q} \qquad \ldots\ldots\ldots\ldots\ldots\ldots 11$$

Substituting (8) and (10) into (11) and the cost of milk production model to inflation will be as :

$$\dot{\underset{\sim}{C}} = (E_C^{P} - E_Q^{P})\,\dot{P} + \sum_{i=1}^{m} (E_C^{p_i} - E_Q^{p_i})\,\dot{p}_i + \sum_{j=1}^{k} E_C^{g_i}\,.\,\dot{g}_i + \sum_{j=1}^{k} (E_C^{Z_j} - E_Q^{Z_j})\,\dot{Z}_j + (E_C^{T} - E_Q^{T})\,\dot{T} \qquad \ldots.\ 12$$

At break-even point :

$$\underset{\sim}{C} = P \ \text{(or)}\ \dot{\underset{\sim}{C}} = \dot{P}$$

Therefore, model (12) reduces to:

$$\dot{\underset{\sim}{C}} = \frac{1}{(1 - E_C^{P} + E_Q^{P})}\,.\left[\sum_{i=1}^{m} (E_C^{p_i} - E_Q^{p_i})\,\dot{p}_i + E_C^{g_i}\,.\,\dot{g}_i + \sum_{j=1}^{k} (E_C^{Z_j} - E_Q^{Z_j})\,\dot{Z}_j + (E_C^{T} - E_Q^{T})\,\dot{T}\right] \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 13$$

Model (13) measures the growth in production cost per litre of milk with regard to observed changes in factor prices, production cost per litre of milk for any time period can then be projected as :

$$\underset{\sim}{C}_t = \underset{\sim}{C}_{t-1}\,(1 + \dot{\underset{\sim}{C}}_t) \qquad \ldots\ldots\ldots\ldots\ldots\ldots 14$$

Where, $\underset{\sim}{C}_t$ is the cost of production per litre of milk in year 't' and $\dot{\underset{\sim}{C}}_t$ is the growth in the same period. Once, the production cost is known for one year (based on survey data), the production cost for subsequent time periods can be generated by making use of equation (14) and be used for determining the price of milk.

c) Income Model for Milk Producers

If the net income is positive and larger, the milk producers will be induced to produce more milk by adopting new technologies. On the other hand, if it is negative, milk producers will quit from the dairy enterprise at long run. The price of milk should be fixed in the limit of income elasticity between zero and one, where the milk producers will get reasonable net income. Therefore, the estimation of net income elasticities is very important to fix the price.

Net income (I) from milk is :

$$I = P \cdot Q\,(P, p, Z, T) - p \cdot X'\,(p / P, Z, T) - g \cdot Z' \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ 15$$

The growth in net income from milk in terms of elasticities can be written as

$$\dot{I} = E_I^{P} \cdot \dot{P} + \sum E_I^{p_i} \cdot \dot{p}_i + \sum E_I^{g_i} \cdot \dot{g}_i + \sum E_I^{Z_i} \cdot \dot{Z}_i + E_I^{T} \cdot \dot{T} \qquad \ldots\ldots\ldots\ldots\ldots\ldots 16$$

Where,

$$\dot{I} = \frac{dI}{I}, \quad E_I^{P} = \frac{\partial I}{\partial P} \cdot \frac{P}{I} \quad \text{and so on.}$$

These derived elasticities of income with respect to prices are given by:

$$E_I^{P} = \frac{P \cdot Q}{I}\left(1 - \sum_{i=1}^{m} E_Q^{p_i/P}\right) + \sum_{j=1}^{k} \frac{p_j\, X_j}{I} \sum_{i=1}^{m} E_{Xj}^{p_i/P}$$

$$E_I^{pi} = \frac{P \cdot Q}{I}\, E_Q^{p_i/P} - \frac{p_i\, X_i}{I} - \sum_{j=1}^{m} \frac{p_j \cdot X_j}{I}\, E_{Xj}^{p_i/P}$$

$$E_I^{gi} = -\frac{g_i\, Z_i}{I}$$

$i = 1, \ldots, m$

$$E_I^{Zi} = \frac{P \cdot Q}{I} \cdot E_Q^{Zi} - \sum_{j=1}^{m} \frac{p_j \cdot X_j}{I} E_I^{Zi} + E_I^{gi}$$

$$E_I^{T} = \frac{P \cdot Q}{I} \cdot E_Q^{T} - \sum_{i=1}^{m} \frac{p_i \cdot X_i}{I}\, E_{Xi}^{T}$$

From the above model, the equation (16) measures the growth in net income of dairy farmers.

The growth models of cost of production and net income can be obtained by using the elasticities for output supply and factor demand for milk derived from the estimated parameters of normalized restricted quadratic profit equation model give in Annexure-1

(Evenson and Biswanger, 1980, and Pundir, 1996) and the cost and return structure of milk based on survey data. Further the profit function and factor demand functions were jointly estimated by Zellners' seemingly unrelated regression equations (SURE) to overcome the demerit of OLS method (Zellner's, 1962). (i.e. Estimation of OLS would result inefficiency, as it would ignore the correlation of error terms across equations, Greene,1997). Using the elasticities of output supply and factor demand for milk output (Annexure-4) derived from the estimated parameters of normalized restricted quadratic profit equation and the cost and returns structure of milk output based on survey data (Annexure-5), the parameters of growth models of cost of production and net income for milk were derived.

RESULTS AND DISCUSSION

The price determination model based on cost of production was developed for milk and the results thereon are presented in the following sections.

Cost of production model

The growth model for cost of milk production during the current year with respect to realized changes in price and non-price factors were worked out from the following model 17*.

$$C = 0.13\, \dot{p}_1 + 0.18\, \dot{p}_2 + 0.026\, \dot{p}_3 + 0.03\, \dot{p}_4 - 0.26\, Z_1 - 0.27\, Z_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..17$$

* The econometric procedure for deriving the models 17* is:

Where, p_1, p_2, p_3 and p_4 represent the growth in prices of green fodder, dry fodder, concentrate and wage rate, respectively; Z_1 is the veterinary and miscellaneous cost and Z_2 is the fixed cost.

It was observed from model 17 that the elasticities of growth of cost of production with respect to prices of variable inputs were positive and less than one. The elasticities of fixed inputs Z_1 and Z_2 were negative for crossbred cows during the year. It implied that the increase in both fixed resources like veterinary and miscellaneous cost and interest and depreciation on fixed assets would improve the productivity of milk and reduce the cost of milk production. The prices of green fodder and dry fodder had the major impact in raising the cost of milk production for crossbred cows which implied one percent increase in these prices would increase the cost of milk production by 0.13 and 0.18%, respectively.

Net income model

The growth model for net income from milk with respect to observed changes in price and non-price factors during the current year can be worked out from the following model 18*

$$\dot{I} = 6.35\, \dot{P} - 0.73\, \dot{p}_1 - 1.21\, \dot{p}_2 - 0.01\, \dot{p}_3 - 0.98\, \dot{p}_4 + 1.29\, \dot{Z}_1 + 2.59\, \dot{Z}_2 \quad \ldots\ldots 18$$

* The econometric procedure for deriving the models 18 is:

The signs of net income elasticities with respect to the prices of green fodder, dry fodder, concentrate and wage rate were observed to be negative, which was anticipated with the theoretical framework. It was found that the elasticity estimates were less than unity in both the equations except for dry fodder price in the model 18, which was elastic. The net income elasticity with respect to the fixed inputs (Z_1, Z_2) was found to be positive and elastic. With respect to milk price, the net income elasticity showed more responsiveness, i.e., one percent increase in milk price would raise the income at 6.35 percent for crossbred cows during the year.

Under the assumption that there are no changes in the fixed factors, viz., veterinary and miscellaneous cost (Z_1) and interest and depreciation on fixed inputs (Z_2) and that factor price inflation in prices of green fodder, dry fodder, concentrate and wage rate will continue to rise in future at a rate of 10 percent, the growth equations of cost of production and net income for crossbred cow milk be as reduced as follows:

$$\dot{C} = 0.1045, \quad \dot{I} = 6.35\,\dot{P} - 0.7486$$

The extent of ten percent increase in the level of price of factors used in milk production for crossbred cows will be 10.45 percent. Thus, if the objective of the policy makers is to maintain constant returns to the production cost of milk production during the year, the price of milk needs to be adjusted upwards at a rate equal to the magnitude of cost-push inflation. For maintaining constant monetary net income (I = 0) to the milk producers, the adjustment in milk price for crossbred cows would be $\dot{P} = 0.1179$ during the year.

Projected estimates of cost of production of milk and prices of milk at constant monetary net income (dI = 0) and at constant return to production cost based on the model developed in the study. Considering 2002-03 as the base year, cost of milk production, and prices of milk at constant monetary net income (I = 0) as well as at constant returns to production cost were estimated for crossbred cows during the year and overall up to 2010 A.D. The projected estimates are depicted in Table 1.

A perusal of Table 1 revealed that the estimated overall cost of production per litre of crossbred cow milk would be Rs.15.58 respectively during the year 2009-10. And, the estimated price for crossbred cow milk is expected to be Rs.18.65 and Rs.17.14, respectively, at constant monetary income (I = 0) and constant return to production cost during the year 2009-10 based on the price determination model with the assumption of 10 percent increase in all the variable inputs prices every year.

Table 1. Estimated production cost and price of milk, based on the cost and price model for crossbred cow farms.

Year	Cost of Milk Production (Rs./L)	Milk Price (Rs./L)	
		At Constant Monetary Net Income ($\dot{I} = 0$)	At Constant Return to Production Cost
2002-03	7.77	8.55	8.55
2003-04	8.58	9.56	9.44
2004-05	9.48	10.68	10.43
2005-06	10.47	11.94	11.52

2006-07	11.56	13.35	12.72
2007-08	12.77	14.93	14.05
2008-09	14.11	16.69	15.52
2009-10	15.58	18.65	17.14

Note: * Based on survey data.

Technological change allows productivity growth to compensate for cost-push inflation, while maintaining product price and rate of profit to be constant. However, productivity change itself is conditioned by the rate of profit on investment in dairying. Hence, there is a need to set the limits of milk price at the existing cost-push inflation. Net income from milk for both the species during the year will face negative growth, if the milk price is adjusted below the level at which net income elasticity with respect to milk price is negative. This would act as disincentive to the milk producers in context of adoption of improved technology. On the other hand, the price adjustment above the limit, where net income elasticity is positive and elastic, will leave the milk producers with high profit rates. So, the milk price is adjusted within the range of where net income elasticity floats between zero and one; it may provide fair income to milk producers, so as to induce them towards the adoption of improved milk production technology. Further, keeping in view, the competition among the farm enterprises, constraints in rapid adoption of new technology, general economic condition and scenario of the international market, the prices are required to be adjusted. The changes in net income and elasticity of net income for corresponding changes in milk prices for crossbred cows during the year were calculated and presented in Table 2.

Table 2. Changes in net income elasticity and net income due to change incorresponding price of milk of Crossbred cow farms

Changes in Net Income Elasticity (E_I^P)	Change in Net Income ($\dot{I}$)	Changes in Milk Price ($\dot{P}$)
$-\alpha$ to 0	-0.75 to 0.00	0.00 to 0.1179
0 to 1	0.00 to 0.1399	0.1179 to 0.1399
> 1	> 0.1399	> 0.1399

It is evident from the same table that the growth in milk price will compensate for the cost-push inflation if it lies between 11.79 to 13.99 percent during the year. The adjustment of milk price below 11.79 percent per annum will generate a negative growth in net income and may not provide enough incentive to the milk producers for the adoption of improved technology. Price adjustment above 13.99 percent will give high rate of profit to the middle producers which may led to specialization of dairy farms. The results obtained in the present study were in conformity with the findings of Pundir (1996) who obtained similar results for crossbred cow milk production in Himachal Pradesh.

CONCLUSIONS AND POLICY IMPLICATIONS

The Pricing model for milk based on cost of production revealed that the price of green fodder, dry fodder and concentrate played a significant role in raising the cost of milk production and the fixed factors influenced negatively in order to reducing the cost. The growth of net income of milk with respect to milk price was also positively influenced. These results indicating that the price of inputs and fixed factors were significantly influencing the cost of milk production. These results were in conformity with the findings of the Pundir (1996) who obtained similar results for crossbred cow milk production in Himachal Pradesh and the results of Patel (1975) and Raut and Singh (1979). The study concluded that the price of feeds are important factors in determining the cost of milk production, therefore, in order to have a rational price policy of milk, the price and non-price factors like technology should be considered for taking up the appropriate decisions. The price model based on cost of production developed in the study used to project the future price of milk by taking into account of cost of inputs, technology and general economic conditions. The calculated parameters of the model are to be treated with caution in as much as they are based on the reference year for the milk. The results of the paper are illustrative of the utility approach in generating consistent price sets for milk in response to alternative policy interventions.

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ANNEXURE 1

Empirical estimation of normalized quadratic restricted (NRQP) profit function model

The specification of the model in actual variables used in the present investigation is given as under. The normalized quadratic profit function and factor demand functions for green fodder, dry fodder, concentrate and human labour are given as follows:

$$\Pi^* = a_0 + a_1 q_1 + a_2 q_2 + a_3 q_3 + a_4 q_4 + ½ [a_{11} q_1^2 + a_{22} q_2^2 + a_{33} q_3^2 + a_{44} q_4^2] + a_{12} q_1 q_2 + a_{13} q_1 q_3 + a_{14} q_1 q_4 + a_{23} q_2 q_3 + a_{24} q_2 q_4 + a_{34} q_3 q_4 + r_{11} q_1 Z_1 + r_{12} q_1 Z_2 + r_{21} q_2 Z_1 + r_{22} q_2 Z_2 + r_{31} q_3 Z_1 + r_{32} q_3 Z_2 + r_{41} q_4 Z_1 + r_{42} q_4 Z_2 + b_1 Z_1 + b_2 Z_2 + ½ [b_{11} Z_1^2 + b_{22} Z_2^2] + b_{12} Z_1 Z_2 \quad \ldots\ 1$$

$$X_1^* = -[a'_1 + a'_{11} q_1 + a'_{12} q_2 + a'_{13} q_3 + a'_{14} q_4 + r'_{11} Z_1 + r'_{12} Z_2] \quad \ldots\ 2$$

$$X_2^* = -[a'_2 + a'_{21} q_1 + a'_{22} q_2 + a'_{23} q_3 + a'_{24} q_4 + r'_{21} Z_1 + r'_{22} Z_2] \quad \ldots\ 3$$

$$X_3^* = -[a'_3 + a'_{31} q_1 + a'_{32} q_2 + a'_{33} q_3 + a'_{34} q_4 + r'_{31} Z_1 + r'_{32} Z_2] \quad \ldots\ 4$$

$$X_4^* = -[a'_4 + a'_{41} q_1 + a'_{42} q_2 + a'_{43} q_3 + a'_{44} q_4 + r'_{41} Z_1 + r'_{42} Z_2] \quad \ldots\ 5$$

Where,

Π^*, q_1, q_2, q_3 and q_4 are the normalized profit, normalized green fodder price, normalized dry fodder price, normalized concentrate price and normalized wage rate, respectively. Z_1 is veterinary cost and miscellaneous cost. Though veterinary cost is a variable cost, it is very difficult to quantify the optimal quantities of veterinary medicines and services. Therefore, it is taken as a fixed input for the profit function analysis and Z_2 is interest and depreciation on fixed capital and assets.

The system comprising normalized restricted quadratic profit (NRQP) and factor demand equations (Equations 1 to 5 in the Annexure 1) were estimated with symmetry and equality restrictions using Zellner's SURE method (1962). The NRQP model for both flush and lean season were estimated by econometric models and tested statistically given in Annexure 2 and 3. The goodness of fit (i.e. Adj. R^2) of NRQP models for flush and lean seasons were 85 and 82 percent, respectively. Majority of parameter estimates found to be statistically significant at 1 percent ($P<0.01$). The elasticity estimates for flush and lean seasons were calculated only from the significant coefficients and aggregated* these two seasons elasticities for the overall year (Annexure 4). The value of elasticities in the models 17 and 18 were not directly estimated but worked out by using elasticities during the year (Annexure 4), and price and cost indices (Annexure 5) which were elaborately discussed in the methodology part.

* The season-wise estimates were aggregated as :

$$\eta_{iP} = \sum_{j=1}^{2} \eta_{iP.j} \, (x_{ij} \mid x_i),$$

Where,

$$x_i = \sum_{j=1}^{2} x_{ij},$$

$\eta_{iP.j}$ = The elasticity of i^{th} factor with respect to variable P for the j^{th} species,

x_{ij} = The demand for i^{th} factor for j^{th} species, and

x_i = The aggregate demand for i^{th} factor for all species in the same season or period.

ANNXEURE 2

Parameter estimates of normalized restricted quadratic profit (NRQP) function, factor demand and supply functions for milk of crossbred cows during flush season.

Type of Function	Constant term	Green Fodder Price (q_1)	Dry Fodder Price (q_2)	Concentrate Price (q_3)	Wage Rate (q_4)	Veterinary and Miscellaneous Cost (Z_1)	Interest and Depreciation on Fixed Assets (Z_2)
Normalized Quadratic Profit Function :							
NQ function (Π*)	8.9070	-10.1890***	-7.9250***	-9.3170***	-0.2206***	1.1390***	-0.1345
		½ q_1^2	**½ q_2^2**	**½ q_3^2**	**½ q_4^2**	**q_1q_2**	**q_1q_3**
		25.8980***	4.0790	10.8620***	0.0058	-5.4080***	-4.1570
		q_1q_4	**q_2q_3**	**q_2q_4**	**q_3q_4**	**q_1Z_1**	**q_1Z_2**
		0.1119	-1.0770***	-0.1780***	0.0140***	-0.0004	-0.0765
		q_2Z_1	**q_2Z_2**	**q_3Z_1**	**q_3Z_2**	**q_4Z_1**	**q_4Z_2**
		-0.0464	0.0729	0.0006	-0.0008***	-0.0523**	0.0013
		½ Z_1^2	**½ Z_2^2**	**Z_1Z_2**			**Adj.R^2**
		-0.1796**	0.0012***	0.0010			0.8500
Factor Demand Function :							
		q_1	**q_2**	**q_3**	**q_4**	**Z_1**	**Z_2**
Green fodder (X_1^*)	10.1890***	-25.8980***	5.4080***	4.1570	-0.1119	0.0004	0.0765
Dry fodder (X_2^*)	7.9250***	5.4080***	-4.0790	1.0770***	0.1780***	-0.0464	0.0729
Concentrate (X_3^*)	9.3170***	4.1570***	1.0770***	-10.8620***	-0.0140**	-0.0006	0.0008***
Human labour (X_4^*)	0.2206***	-0.1119	0.1778***	-0.0140**	-0.0058	0.0523**	-0.0013
Output Supply Function :							
		-½ q_1^2	**-½ q_2^2**	**-½ q_3^2**	**-½ q_4^2**	**$-q_1q_2$**	**$-q_1q_3$**
Milk supply function (Y*)	8.9070	-25.8980***	-4.0790	-10.8620***	-0.0058	5.4080***	4.1570
		$-q_1q_4$	**$-q_2q_3$**	**$-q_2q_4$**	**$-q_3q_4$**	**Z_1**	**Z_2**
		-0.1119	1.0770***	0.1780***	-0.0140***	1.1390***	-0.1345
		½ Z_1^2	**½ Z_2^2**	**Z_1Z_2**			
		-0.1796**	0.0012***	0.0010			

Note: *** Significant (P<0.01); ** Significant (P<0.05).

ANNXEURE 3

Parameter estimates of normalized restricted quadratic profit (NRQP) function, factor demand and supply functions for milk of crossbred cows during lean season.

Type of Function	Constant term	Green Fodder Price (q_1)	Dry Fodder Price (q_2)	Concentrate Price (q_3)	Wage Rate (q_4)	Veterinary and Miscellaneous Cost (Z_1)	Interest and Depreciation on Fixed Assets (Z_2)
Normalized Quadratic Profit Function :							
NQ function (Π*)	4.6615*	-4.3169***	-11.9700***	-5.9820***	-0.1940***	0.5838***	0.0245***
		$\frac{1}{2} q_1^2$	**$\frac{1}{2} q_2^2$**	**$\frac{1}{2} q_3^2$**	**$\frac{1}{2} q_4^2$**	**q_1q_2**	**q_1q_3**
		18.8140***	10.5968***	8.7100***	0.0166***	0.0944*	-2.8248***
		q_1q_4	**q_2q_3**	**q_2q_4**	**q_3q_4**	**q_1Z_1**	**q_1Z_2**
		-0.1298***	-0.0384***	-0.1020***	-0.0076**	-0.0021**	-0.0308
		q_2Z_1	**q_2Z_2**	**q_3Z_1**	**q_3Z_2**	**q_4Z_1**	**q_4Z_2**
		-0.0459	-0.0772***	-0.0270***	-0.0087***	-0.0189***	-0.0015***
		$\frac{1}{2} Z_1^2$	**$\frac{1}{2} Z_2^2$**	**Z_1Z_2**			**Adj. R^2**
		0.1716**	-0.0002**	0.0238**			0.8198
Factor Demand Function :							
		q_1	**q_2**	**q_3**	**q_4**	**Z_1**	**Z_2**
Green fodder (X_1^*)	4.3169*	-18.8140***	-0.0944	2.8248***	0.1298***	0.0021*	0.0308
Dry fodder (X_2^*)	11.9700*	-0.0944	-10.5968***	0.0384***	0.1020***	0.0459	0.0772
Concentrate (X_3^*)	5.9820*	2.8248***	0.0384***	-8.7100***	0.0076**	0.0270***	0.0087 ***
Human labour (X_4^*)	0.1940*	0.1298***	0.1020***	0.0076*	-0.0166***	0.0189	0.0015
Output Supply Function :							
		$-\frac{1}{2} q_1^2$	**$-\frac{1}{2} q_2^2$**	**$-\frac{1}{2} q_3^2$**	**$-\frac{1}{2} q_4^2$**	**$-q_1q_2$**	**$-q_1q_3$**
Milk supply function (Y*)	4.6615*	-18.8140***	-10.5968***	-8.7100***	-0.0166***	-0.0944*	2.8248***
		$-q_1q_4$	**$-q_2q_3$**	**$-q_2q_4$**	**$-q_3q_4$**	**Z_1**	**Z_2**
		0.1298	0.0384***	0.1020***	0.0076*	0.5838***	0.0245***
		$\frac{1}{2} Z_1^2$	**$\frac{1}{2} Z_2^2$**	**Z_1Z_2**			
		0.1716**	-0.0002**	0.0238**			

Note: *** Significant (P<0.01); ** Significant (P<0.05); * Significant (P<0.1).

ANNEXURE 4

Factor demand and output supply aggregated elasticity estimates of crossbred cows for milk production during the year

Demand Function	Price of Green Fodder (q_1)	Price of Dry Fodder (q_2)	Price of Concentrate (q_3)	Wage Rate (q_4)	Veterinary and Miscellaneous Cost (Z_1)	Interest and Depreciation on Fixed Cost (Z_2)	Price of Milk (P_Y)
Green fodder (X_1^*)	-0.4974	0.0378	0.1963	0.0967	0.0003	0.0456	0.1054
Dry fodder (X_2^*)	0.0581	-0.1307	0.0578	-0.0090	0.0105	-0.0144	0.0241
Concentrate (X_3^*)	0.1766	0.0576	-1.5858	-0.0096	0.0048	0.0091	1.4557
Human labour (X_4^*)	0.0329	-0.0020	-0.0115	-0.5078	0.4788	0.0135	0.4755
Milk supply (Y^*)	0.0355	-0.0001	-0.2386	-0.0695	0.2605	0.3515	0.3287

ANNEXURE 5

Cost and returns structure of milk production

Sl. No.	Particulars	Description	Rs./day/milch animal
1.	Green fodder cost	X_1p_1	8.55
2.	Dry fodder cost	X_2p_2	6.92
3.	Concentrate cost	X_3p_3	20.48
4.	Total labour cost	X_4p_4	8.05
5.	Veterinary and Miscellaneous cost	Z_1	1.61
6.	Total fixed cost	Z_2	5.85
7.	Gross cost	Cost C	51.46
8.	Milk production	Q	6.47

	(litres/day)		
9.	Per litre cost of milk production (Rs/Lit.)	C	7.77
10.	Net Income	I	3.77