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DYNAMIC FEED-MILK RELATIONSHIP AND TECHNOLOGICAL CHANGE IN MILK PRODUCTION

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Feed is the principal input in milk production and it constitutes nearly two-thirds of the total cost of milk production.[1] A number of studies have been undertaken in India to assess the productivity of this input using production function approach.[2] Almost all these are based on static models and do not take care of the fact that the effect of feed is distributed over the length of the lactation period. The milk yield potential in a particular stage of lactation depends on the feed in the current as well as past feedings during preceding lactation stages. Realistic formulation of feed-milk relation thus requires consideration of lagged values of feed as the explanatory variables.[3] Empirical studies available in this country have not incorporated this aspect of reality and have not explored the direct and residual or cumulative effects of feed on milk production. The distributed lag model used in this study helps to generate the cumulative and carryover effects of feed on milk production in addition to the direct feeding effect.

A recent development in dairying is the cross-breeding programme which raises the milk yield potential substantially and makes dairying more profitable.[4] The high-yielding ability of the cross-bred animals can, however, be sustained only if proper feeding is resorted to. The growth in productivity in the dairy sector as a result of cross-breeding programme has given rise to many interesting issues. How much of the growth in milk yield is due to technological change, *i.e.*, breed, and how much of it is due to increased quantity of feeds and fodder? This paper is an attempt to examine these issues and the specific objectives are (1) to establish dynamic feed-milk production functions and estimate the direct, carryover and cumulative effects of feed on milk

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1. R. K. Patel *et al.*: Economics of Cross-bred Cattle (Report of a Survey): A Study of the Cattle Breeding Programme of Indo-Swiss Project, Kerala, National Dairy Research Institute, Karnal, 1976; V. G. Panse *et al.*: Cost of Milk Production (Delhi State), ICAR Report Series No. 6, Indian Council of Agricultural Research (ICAR), New Delhi, 1961.

2. T. Jacob *et al.*, "A Study on Resource Productivity in Milk Production", *Indian Journal of Agricultural Economics*, Vol. XXVI, No. 1, January-March 1971; P. Kumar and K. C. Raut, "Some Factors Influencing the Economy of Milk Production", *Indian Journal of Agricultural Economics*, Vol. XXVI, No. 2, April-June 1971; Ghansham Dass Aul *et al.*, "Milk Production Functions in Ludhiana", *Indian Journal of Dairy Science*, Vol. XXVII, No. 4, 1974; P. Kumar *et al.*, "Economic Response of Feed on Milk Production for Different Breeds of Milch Cows", Brief Communication, *XIX International Dairy Congress*, Vol. IE, 1974; P. Kumar *et al.*, "Lactationwise Production Function and Concentration in Milk Production for Haryana Cows", *Indian Journal of Agricultural Economics*, Vol. XXX, No. 3, July-September 1975; P. L. Sankhayan and A. S. Joshi, "Resource Productivity in Milk Production of Cross-bred and Indigenous Cows in Rural Areas of Ludhiana District (Punjab)", *Indian Journal of Agricultural Economics*, July-September 1975; and Patel *et al.*: *op. cit.*

3. G. W. Dean, "Consideration of Time and Carryover Effects in Milk Production Functions" *Journal of Farm Economics*, Vol. 42, No. 5, December 1960.

4. R. K. Patel and Kulwant Singh, "Dairy Farming with Cross-bred Cows", *Gosamvardhana*, nd Patel *et al.*: *op. cit.*

production and (2) to estimate the contributions of improvement in breed and feed inputs in the total change in milk yield. These objectives are evaluated with cross-section-cum-time-series feed milk data on cross-bred (1976-79) and Sahiwal cows (1968-71) collected from the dairy farm of the Indian Agricultural Research Institute, New Delhi.[5] Direct and carryover effects of feed nutrients in milk production have been examined in the first section and subsequently, the effect of technological change has been analysed.

I

EFFECTS OF FEED ON MILK PRODUCTION

Solution of the carryover problems depends on (1) an experimental design allowing measurement of carryover effects and (2) a method of incorporating this information into conventional economic analysis through econometric models. In the absence of a feasible experimental set-up for this purpose, dynamic milk production function model offers a feasible method for estimating the carryover effects of feed in milk production from period to period.

Dynamic Milk Production Function

A recent version of the milk production function postulates that the current level of milk production depends on current and past levels of feed nutrients, and other factors:

$$M_{i,t} = a + b_0 DCP_{i,t} + b_1 DCP_{i,t-1} + b_2 DCP_{i,t-2} + \dots\dots\dots + C_0 TDN_{i,t} + C_1 TDN_{i,t-1} + C_2 TDN_{i,t-2} + \dots\dots + U_{i,t} \quad \dots(1)$$

$$(i = 1, 2, \dots\dots\dots\dots n);$$

where $M_{i,t}$ represents average milk yield per day in litres for 'i'th cow during 't'th stage of lactation; the stage of lactation being measured as the ordinal number of month (30 days); n is the number of cows; $DCP_{i,t}$ and $TDN_{i,t}$ represent intake of digestible crude protein (DCP) and total digestible nutrients (TDN) in kg. per day for 'i'th cow in the 't' th lactation stage respectively; $U_{i,t}$ is the error term consisting of unspecified explanatory variables. DCP and TDN are the major nutrients recommended by the nutritionists.[6] Therefore, these two feed nutrients have been considered for explaining the feed-milk relationship.

It has been found that the relative value of DCP over TDN was 7.5.[7] Using this prior information ($b_0/c_0 = b_1/c_1 = \dots = 7.5$) the distributed lag model (1) reduced as follows:

$$M_{i,t} = a + b_0 X_{i,t} + b_1 X_{i,t-1} + \dots\dots + U_{i,t} \quad \dots(2)$$

where $X_{i,t} = (DCP_{i,t} + TDN_{i,t}/7.5)$.

5. The replacement of Sahiwal by cross-bred (Friesian ♂ × Sahiwal ♀) cows was initiated in 1970s. Comparable data were available for 1968-71 for Sahiwal breed and for 1976-79 for cross-bred cows.

6. F. B. Morrison: Feeds and Feeding, The Morrison Publishing Co., New York, 1950; and K. C. Sen and S. N. Ray: Nutritive Values of Indian Cattle Feeds and the Feeding of Animals, Research Series No. 25, ICAR, New Delhi, 1964.

7. *ibid.*

Assuming that the effect of feed in milk production declines at a constant proportional rate over time, Koyck's geometric lag scheme gives

$$b_s = b_0 \lambda^s \quad 0 < \lambda < 1$$

where s is the number of lags. We may rewrite the lagged model (2) in the following form:

$$M_t = a + b_0 \sum_{s=0}^{\infty} \lambda^s X_{t-s} + U_t$$

which may be transformed to the autoregressive model

$$M_t = a^* + b_0 X_t + \lambda M_{t-1} + U_t \qquad \ldots.(3)$$

where $a^* = a.(1-\lambda)$ and $X_t = DCP_t + TDN_t/7.5$.
This is the dynamic milk production model which gives the estimates of milk yield in the current period for given levels of feed nutrients (DCP and TDN) and milk yield in the preceding period. Equation (3) was estimated by least squares method for cross-bred and Sahiwal breeds of cattle. The contribution of each explanatory variable has been estimated for examining the relative importance of factors in explaining the milk production.[8] The results are presented in Table I.

TABLE 1—DYNAMIC MILK PRODUCTION FUNCTION AND INCREMENTAL CONTRIBUTION ON DIFFERENT VARIABLES

Explanatory variables	Parameter	Cross-bred cows		Sahiwal cows	
		Regression coefficient	Incremental contribution	Regression coefficient	Incremental contribution
Intercept	a^*	0·3906	—	1·6276	—
Feed nutrients (X_t)	b_0	0·5729* (0·0966)	0·03	0·1284* (0·0375)	0·02
Lagged milk yield (M_{t-1}) ..	λ	0·7788* (0·0302)	0·47	0·7044* (0·0478)	0·26
Multicollinearity effect			0·24		0·30
Total contribution of explanatory variables (R^2)			0·74		0·58

* Significant at 1 per cent. Figures in parentheses are the standard errors of respective regression coefficients. The sum of the incremental contributions of X_t and M_{t-1} is not equal to the total explanatory power of model (R^2) because these variables are not orthogonal. Therefore, the difference between the total contribution (R^2) of all explanatory variables and the sum of the incremental contribution of these variables gives the multicollinearity effect.

The sign of each regression coefficient in Table I is consistent with established principles and facts in dairy nutrition and production economics. The regression coefficients are significant at the 0.01 level of probability. Equation (3) explained 74 per cent of the variation in milk production for the 357 pooled monthly observations from the 18 cross-bred cows involved in the two complete lactation. For Sahiwal breed the production equation explained 58 per cent of the total variation in milk production for 350 pooled

8. For estimation procedure of incremental contribution and multicollinearity effect, see H. Theil: Principles of Econometrics, North-Holland Publishing Company, Amsterdam, 1971, pp. 163-181.

monthly observations of 18 cows in the two successive complete lactation. The incremental contribution of each explanatory variable, namely, feed and lagged milk production revealed that feed nutrients contribute 3 per cent for cross-bred cows and 2 per cent for Sahiwal cows. The lagged milk production contributes 47 per cent and 26 per cent in the total variation in milk yield for cross-bred and Sahiwal cows respectively. These findings reveal that the past milk producing ability of the cow is the major factor for predicting current milk production. The magnitude of the coefficient of lagged milk yield indicates a fairly slow rate of response adjustment of milk production to feed input. This provides an explanation for the relatively small (current) contribution of feed input observed in this analysis.

Direct, Carryover and Cummulative Effects of Feed in Milk Production

The regression coefficient (b_0) of X_t in equation (3) gives the direct (current) effect of a unit change in feed levels. The cumulative effect of a maintained level of feed is given by $b_0/(1-\lambda)$, where λ is the coefficient of M_{t-1} in quation (3). The difference between the cumulatives and direct feed effects gives the carryover (residual) effect of feed nutrients in milk production. While interpreting the results, it is desirable to convert X_t back to the conventional units of DCP and TDN. The results of the feed effects in milk production and elasticities[9] of production for cross-bred and Sahiwal cows are presented in Table II.

TABLE II—FEED EFFECTS AND ELASTICITIES

Particulars	Cross-bred		Sahiwal	
	DCP	TDN	DCP	TDN
Feed effects in milk production (litres/kg.)				
(*a*) Direct effect	0·573	0·076	0·128	0·017
(*b*) Cumulative effect	2·590	0·345	0·434	0·058
(*c*) Carryover effect	2·017	0·269	0·306	0·041
Milk production elasticities				
(*a*) Short run	0·110	0·050	0·037	0·016
(*b*) Long run	0·497	0·227	0·124	0·054

The feed effects given in Table II can be interpreted as the marginal physical product of feed nutrients in milk production. The immediate effect of feed in milk production is only 22 to 29 per cent of the cumulative feed effect on milk yield. A substantial portion of feed effect is due to carryover effect which is distributed over the lactation period in a declining form of geometric progression. This suggests that the proper feeding management

9. The short (E_S) and long run (E_L) elasticities of milk production are given by

$$E_S = b_0 \frac{\bar{X}}{\bar{M}} \quad \text{and} \quad E_L = \frac{b_0}{1-\lambda} \frac{\bar{X}}{\bar{M}}$$

where $\bar{X}$ and $\bar{M}$ are the mean levels of feed and milk yield at which the elasticities are evaluated.

over the entire cycle of milk production is necessary for full exploitation of the milk production potential. The conventional type of milk production functions estimated by researchers[10] do not take care of the residual effect of feed and hence the productivity of feed is under-estimated.[11]

The longrun elasticities of milk production are significantly higher than the shortrun elasticities for both breeds of cattle. For cross-bred cow, the marginal physical product of feed is three to four times higher than that for Sahiwal breed. This clearly reveals the superiority of the cross-bred animals.

II

TECHNOLOGICAL CHANGE

Technological change has traditionally been defined in terms of changes in the parameters of a production function or the creation of new production functions.[12] For any production function, the total change in output is brought about by the shifts in the parameters and by changes in the volume of inputs. The increase in the level of milk yield with new production technology (cross-bred cow) over the old production technology (Sahiwal cow) using the same level of inputs can be attributed to technological change. The decomposition analysis suggested by Bisaliah[13] has been followed to apportion the total change in terms of contributions of changes in the level of feeding and contribution of breed (technology).

Decomposition Model

The specification of the milk production function for Sahiwal and cross-bred cows used in decomposition analysis is:[14]

$$l_n M_1 = l_n A_1 + b_1 l_n DCP_1 + b_2 l_n DNN_1 + U_1 \quad \ldots.(4)$$

$$l_n M_2 = l_n A_2 + b_1 l_n DCP_2 + b_2 l_n DNN_2 + U_2 \quad \ldots.(5)$$

where M is daily milk yield in litres; DCP is digestible crude protein in kg. per day; DNN is digestible non-nitrogenous nutrients in kg. per day; A is the scale parameter and b and c represent milk production elasticities of DCP and DNN inputs respectively; U is a random disturbance term; the subscripts 1 and 2 refer to Sahiwal and cross-bred animals respectively, and l_n is natural log at base 'e'.

10. E. O. Heady *et. al.*, "Milk Production Functions Incorporating Variables for Cow Characteristics and Environment", *Journal of Farm Economics*, Vol. 46, No. 1, February 1964; Parmatma Singh and Dayanatha Jha, "Economic Optima in Milk Production", *Indian Journal of Agricultural Economics*, July-September 1975; Kumar *et al.*, *op. cit.* and Patel *et al.*: *op. cit.*

11. Using static feed-milk model, the same data set revealed that the marginal physical products of milk with respect to DCP and TDN were 1·67 and 0·22 for cross-bred cows, and 0·23 and 0·03 for Sahiwal cows respectively. The productivities of these feed nutrients are much higher in the dynamic model given in Table II.

12. Vernon W. Ruttan, "Research on the Economics of Technological Change in American Agriculture," *Journal of Farm Economics*, Vol. 42, No. 4, November 1960.

13. S. Bisaliah, "Decomposition Analysis of Output Change under New Production Technology in Wheat Farming: Some Implications to Returns on Research Investment", *Indian Journal of Agricultural Economics*, Vol. XXXII, No. 3, July-September 1977.

14. In the specification of the milk production function, using DCP and TDN as the explanatory variables results in a very high degree of multicollinearity and the least squares estimate of the coefficient of DCP turned out with wrong sign and insignificant. Therefore, TDN is replaced by DNN in the analysis which has the identity that DNN = TDN — DCP.

Given these production equations the decomposition equation can be written[15] as

$$l_n\left(\frac{M_2}{M_1}\right)=\left[l_n\left(\frac{A_2}{A_1}\right)\right]+\left[(b_2-b_1).\ l_n DCP_1+(c_2-c_1).\ l_n DNN_1\right]+\left[b_2.\,l_n\frac{DCP_2}{DCP_1}+c_2.\,l_n\frac{DNN_2}{DNN_1}\right]+(U_2-U_1)\ \ldots.(6)$$

The left-hand side of equation (6) is approximately a measure of percentage change in milk yield with the introduction of cross-bred cow in place of Sahiwal cow,[16] the first and second bracketed expressions in equation (6) mesure the contribution of technological change to total change in milk yield; the third bracketed expression in equation (6) measures the contribution of changes in feed levels. The estimated homogeneous Cobb-Douglas type milk production equations of degree one[17] are given in Table III, which also gives the contribution of the above two components in the total change in milk yield.

TABLE III—GEOMETRIC MEANS, COBB-DOUGLAS PRODUCTION FUNCTION ESTIMATES FOR CROSS-BRED AND SAHIWAL COWS AND DECOMPOSITION ANALYSIS OF TOTAL CHANGE IN PRODUCTION

Variables	Geometric mean		Parameters	Elasticity of milk yield	
	Cross-bred	Sahiwal		Cross-bred	Sahiwal
Milk yield (litres)	14·8	7·5			
Intercept			l_n A	1·0179	0·6678
DCP (kg.)	2·7	1·9	b	0·2980 (0·0147)	0·3057 (0·0231)
DNN (kg.)	7·1	5·1	c	0·7020 (0·0148)	0·6943 (0·0239)
R^2				0·77	0·35

Item	Percentage attributable
Total change in milk yield	68·27
Sources of change:	
1. Technological change	35·70
2. Change in feed levels:	
DCP	10·17
DNN	23·79
Total	33·96
Total due to all sources	69·66

Figures in parentheses are the standard errors of estimated parameters.

15. For details, see Bisaliah, *op. cit.*

16. $l_n\left(\frac{M_2}{M_1}\right) = l_n(1+g) \backsimeq g$ for $|g| < 1$ where g is an approximate measure for percentage change in milk yield because the higher order terms in a Taylor expansion are discarded.

17. For estimation procedure, see J. Johnston: Econometric Methods, McGraw-Hill Co., Tokyo, 1960, pp. 155-159.

The contribution of technological change to the total change in milk production is estimated to be 36 per cent, implying that with the same levels of feed nutrients, the milk yield could be increased by 36 per cent with the introduction of cross-bred animals in place of Sahiwal breed. An increased use of feed inputs for cross-bred cow contributes about 34 per cent to the total change in milk yield. Thus, better feeding is an equally important instrument for increasing the milk yield along with genetic development through cross-breeding programme.

III

CONCLUSIONS

1. A major portion of feed effects in milk production was due to the carry-over effect which is distributed over the lactation period. Ignoring this effect leads to serious under-estimation of the productivity of feed inputs in the commonly used static milk production models.
2. The cross-breeding programme made extremely important contribution in increasing the productivity of milch cattle.
3. Proper feeding management over the entire cycle of milk production is essential for full exploitation of the genetic potential.

FEED ECONOMY IN MILK PRODUCTION: A PROBE UNDER NEW DAIRY FARM TECHNOLOGY IN KERALA

T. P. Gangadharan*

The agricultural strategy followed since the mid-1960s has, by and large, left the small farmers behind due to the alleged resource-non-neutral nature of Green Revolution. In the light of this experience, and in view of the present emphasis on social justice in the planning documents, dairy farming, of late, is receiving scrupulous attention. The crucial role of dairying is further highlighted by the ever-increasing demand for milk and milk products and the need to provide a nutrient cover to combat the widely prevailing malnutrition problem. Nothing short of a basic change in the dairy farm technology will, it is asserted, improve the problem of low productivity of Indian cows. Consonant with this, cross-breeding for enhancing milk production is being given a fillip in our milk production system. Against the background of already precarious animal feed situation in the country, the influx of cross-bred cows with the existing stock of native cows draws a picture of scepticism in the dairy sector. This is because feed is a recognized principal input vector governing the potentiality and profit in dairying. Coherent knowledge

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