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# TECHNOLOGICAL CHANGE IN INDIA'S DAIRY FARMING SECTOR: DISTRIBUTION AND DECOMPOSITION OF OUTPUT GAINS

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## I

## THE PROBLEM

The shift in dairy technology, conceived as a shift from buffalo to crossbred cow (case I) and from indigenous to crossbred cow (case II), is said to have raised the country's milk output by realising the higher lactation of the crossbred cattle. This expectation is also built into the policy of the Government of India on crossbreeding of the indigenous cattle. Our empirical estimates on the geometric mean levels of milk yield for different types of bovines (Table II) also confirm this expectation. But the higher mean milk yield of the crossbred cattle is not necessarily a technological improvement over the existing dairy technology, based upon the indigenous cattle and buffalo. It may so happen that the entire gain in milk yield, consequent upon the shift in dairy technology from buffalo and indigenous cattle to the crossbred cattle, may occur due to the increased input use. The gains of pure technological efficiency may elude the dairy producers. The principal objective of this paper is, therefore, to decompose the output gain in milk yield occurring as a result of shift in dairy technology, as defined above, into its causative factors. The decomposition analysis is carried out at the aggregate sample level and by farm size in order to know if the gains of technological shift are uniformally distributed across all cross-sections of dairy farmers in the project area.

## II

## ANALYTICAL APPROACH

The Cobb-Douglas milk production function (1), with milk yield ($Y_i$) as the dependent variable and the feeding levels of green fodder ($G_i$), dry fodder ($D_i$) and concentrates ($C_i$) and labour use ($N_i$) as the independent variables, were estimated independently for three samples (j = 1, ..., 3) representing respectively the buffalo, crossbred cattle and indigenous cow:

$$Y_{ij} = A_j \quad G_{ij}^{a_j} \quad D_{ij}^{b_j} \quad C_{ij}^{k_j} \quad N_{ij}^{r_j} \quad e^{U_{ij}} \qquad \text{.... (1)}$$

where $a_j$, $b_j$, $k_j$ and $r_j$ denoted under the jth technology the partial output elasticities with respect to green fodder, dry fodder, concentrates and labour respectively; and $A_j$ denoted the intercept term under the jth technology. The error term ($U_{ij}$) was assumed to follow the assumptions of the Linear Stochastic Regression Model (for details, see Goldberger, 1964, pp. 171-172). It was further assumed that the explanatory variables in our Linear Stochastic Regression Model were not perfectly linearly correlated and were free from the aggregation error (see Koutsoyiannis, 1977, pp. 57-58). The model was, besides, assumed to be free from the identification and specification bias.

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If crossbred cattle were an improvement in dairy technology, its effect in terms of the gain in milk yield should have occurred in two stages. Initially, more output is made available from the existing resource base under the new production technology (in our case the crossbred cow). This is the efficiency component, reflected in the shift in the production function. Second, an adjustment component of technological change is evident in the movement along the new production function. This movement along the new production function follows from the efforts of the firms to adjust to disequilibrium caused by the new level of efficiency (Bisaliah, 1975). It was worthwhile, therefore, to decompose the total difference in milk output into its causative factors of the differences in the levels of input use and technological efficiency. The neutral and non-neutral variants of technological efficiency were explored separately.

For accomplishing the task, the homogeneity of the milk production function was constrained to unity which in the framework of the Cobb-Douglas milk production function meant restricting the sum total of the partial output elasticities with respect to the included variables to unity, such that:

$$a_j + b_j + k_j + r_j = 1 \qquad .... (2)$$

To decompose the total difference in milk yield, consequent upon the shift in dairy technology, into its causative factors of the difference in the levels of technological efficiency and input use, the Cobb-Douglas milk production function (3) expressed in natural logarithms and homogeneous of degree one:

$$Log_n Y_{ij} = Log_n A_j + a_j Log_n G_{ij} + b_j Log_n D_{ij} + k_j Log_n C_{ij} + r_j Log_n N_{ij} + U_{ij} \qquad .... (3)$$

was differentiated totally to give (4):

$$\begin{aligned}[dY_{ij}/Y_{ij}] &= [dA_j/A_j] + [(da_j)Log_n G_{ij} + (db_j)Log_n D_{ij} \\ &+ (dk_j)Log_n C_{ij} + (dr_j)Log_n N_{ij}] + [a_j(dG_{ij}/G_{ij}) \\ &+ b_j(dD_{ij}/D_{ij}) + k_j(dC_{ij}/C_{ij}) + r_j(dN_{ij}/N_{ij})] \qquad .... (4)\end{aligned}$$

The derivatives when replaced with discrete values, for instance, $[\Delta Y_{ij}/Y_{ij}]$ defined the difference between the geometric mean levels of milk yield associated with the new (crossbred cattle) and old (buffalo/indigenous cow) dairy technologies. A similar interpretation was accorded to the terms $\Delta D_{ij}$, $\Delta C_{ij}$, $\Delta G_{ij}$ and $\Delta N_{ij}$. Likewise, $\Delta a_j$ defined the difference in the partial output elasticities with respect to green fodder between the one associated with the crossbred cattle and the other associated with the buffalo/indigenous cow. The terms $\Delta b_j$, $\Delta k_j$ and $\Delta r_j$ were similarly defined. The term $\Delta A_j$ stood for the difference in the intercept terms. The rest of the terms in the decomposition equation (4) were taken at the levels of old milk production technology (buffalo under case I and indigenous cow under case II of the shift in dairy technology).

On the left hand side of the equation (4), the term $[\Delta Y_{ij}/Y_{ij}]$ measured the proportionate change in milk output, consequent upon the shift in dairy technology. On its right hand side, the first two bracketed expressions, summed up, measured the joint contribution of the component of technological efficiency and individually measured the contribution of the neutral and non-neutral variants of technological efficiency respectively. By neutral variation in efficiency is meant only the increased efficiency that increases the amount obtainable from a given input combination proportionately for all factor proportions. In other words, the isoquant determined by an input combination is not changed by increased efficiency; its quant is just raised and the same input combination as before lies along it. For the Cobb-Douglas production function, this means that only the constant term varies from firm to firm, but not the elasticity of output with respect to various inputs (Nerlove, 1975). The shift in the partial output elasticities with respect to included variables jointly measured the effect of the non-neutral technological efficiency. The last of the bracketed expressions measured the contribution of the component of the difference in the levels of input use.

The empirical results based upon the decomposition equation (4) revealed sizable deviation of the estimated from the observed total proportionate change in milk output, as is evident in Table IV. Consequently, an alternative scheme, following Bisaliah (1975), was adopted. The Cobb-Douglas milk production functions, homogeneous of degree one, were estimated separately under three variants (j=1 if buffalo, j=2 if crossbred cattle and j=3 if indigenous cow) of dairy technology. Buffalo milk production function was deducted from crossbred cattle milk production function under case I of the shift in dairy technology. By simultaneously adding and subtracting from the resultant equation the terms $a_2 Log_e G_{i1}$, $b_2 Log_e D_{i1}$, $k_2 Log_e C_{i1}$ and $r_2 Log_e N_{i1}$, we got the estimating decomposition equation (5):

$$
\begin{aligned}
[Log_e(Y_{i2}/Y_{i1})] = {} & [Log_e(A_2/A_1)] + [(a_2-a_1)Log_e G_{i1} + (b_2-b_1)Log_e D_{i1} \\
& + (k_2-k_1)Log_e C_{i1} + (r_2-r_1)Log_e N_{i1}] \\
& + [a_2 Log_e(G_{i2}/G_{i1}) + b_2 Log_e(D_{i2}/D_{i1}) \\
& + k_2 Log_e(C_{i2}/c_{i1}) + r_2 Log_e(N_{i2}/N_{i1})] \\
& + [U_{i2}-U_{i1}] \qquad \text{.... (5)}
\end{aligned}
$$

that helped in decomposing the total per cent[1] difference in milk yield $[Log_e(Y_{i2}/Y_{i1})]$ into the components of neutral and non-neutral (first and second bracketed expressions on the right hand side of the equation respectively) technological efficiency and the difference in the levels of input use (third bracketed expression). The last bracketed expression related to the different in the error terms.

In decomposition equation (5), the underlying Cobb-Douglas milk production function followed the restrictive assumptions of unitary elasticity of substitution between all pairs of inputs and the constant returns to scale. The limitation of such assumptions was that while decomposing the observed total per cent change in milk yield into its constituent forces, one may be ascertaining changes in elasticity to changes in technology and to the extent that economies of scale exist, the rate of technological progress will be over-estimated in the production function studies which constrain the homogeneity of the function to unity. The only offset to this is that some economies may be of a technological nature (Kennedy and Thirlwall, 1972).

## III

## THE DATA

For the empirical estimation of milk production functions, the input-output data for the reference period 1979-80, collected under the aegis of the ongoing Operation Research Project (ORP) of the National Dairy Research Institute (NDkI), Karnal, were utilised. The project covered all the 5,805 rural households in its 30 villages, as on June

1980, of which six villages with 1,391 rural households were purposively selected as the first stage of sampling. A total of 104 rural households from amongst these 1,391 households (7.5 per cent), selected randomly, formed the core sample. Although nearly 48 per cent of the total households in the six sample villages belonged to the landless category, only 27 per cent (28 among 104 households) of our sample consisted of them. And the rest 73 per cent, *i.e.*, 76 households were selected randomly amongst the cultivating households, classified into five farm size categories,[2] in accordance with the probability proportional to the number of households in a sample village. The inclusion of at least one household in each farm size category in each village too was ensured. The final distribution of the 104 sample households by farm size is presented in Table I.

TABLE I. DISTRIBUTION OF TOTAL AND SAMPLE HOUSEHOLDS IN VILLAGES

| Sr. No. | Farm size/No. of households | | Villages: Sanghoa | Shamgarh | Dadupur | Bhaini-Khurd | Samora | Janesron | Total |
|---|---|---|---|---|---|---|---|---|---|
| | (1) | | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| I | Landless | Total | 225 | 248 | 34 | 75 | 48 | 44 | 674 |
| | | Sample | 8 | 7 | 2 | 4 | 3 | 4 | 28 |
| II | Marginal | Total | 48 | 79 | 7 | 20 | 28 | 6 | 188 |
| | | Sample | 3 | 4 | 3 | 2 | 1 | 3 | 16 |
| III | Small | Total | 59 | 75 | 18 | 37 | 17 | 9 | 215 |
| | | Sample | 3 | 6 | 3 | 4 | 2 | 1 | 19 |
| IV | Lower Medium | Total | 52 | 52 | 17 | 32 | 11 | 7 | 171 |
| | | Sample | 3 | 3 | 2 | 4 | 2 | 3 | 17 |
| V | Upper Medium | Total | 14 | 11 | 7 | 19 | 1 | 4 | 66 |
| | | Sample | 2 | 2 | 4 | 1 | 1 | 2 | 12 |
| VI | Large | Total | 25 | 19 | 5 | 11 | 9 | 8 | 77 |
| | | Sample | 3 | 1 | 3 | 3 | 1 | 1 | 12 |
| VII | Aggregate | Total | 423 | 484 | 98 | 194 | 114 | 78 | 1,391 |
| | | Sample | 22 | 23 | 17 | 18 | 10 | 14 | 104 |

*Notes*:- (1) Marginal land holding: upto one hectare.
(2) Small land holding: exceeding 1.0 and upto 2.0 hectares.
(3) Lower Medium land holding: exceeding 2.0 and upto 4.0 hectares.
(4) Upper Medium land holding: exceeding 4.0 and upto 8.0 hectares.
(5) Large land holding: exceeding 8.0 hectares.

A total of 238 milch bovines, of which 206 were found actually in milk, comprising 124 buffaloes, 48 crossbred cattle and 34 indigenous cows, were reared by the 104 sample households during the reference year. Since the statistical enquiry covered each in-milk bovine once every month from July 1979 to June 1980, it was possible to utilise 12 monthly observations on a single milch bovine. However, the dry period of a milch bovine forced dropping out of some monthly observations in the estimation of milk production functions. Finally, a total of 804, 290 and 209 monthly observations on buffalo, crossbred cattle and indigenous cow were utilised for empirical research. However, this way of treating one single animal for repeated measurement might have led to the problem of autocorrelation. The problem of autocorrelation might have been solved if enough number of animals were available so that these were used only once to maintain independence in observation. Our resources did not allow consideration of animals only once for measurement and therefore the error term might have violated the assumption of being a normally independent random variable.

In order to avoid the problem of degrees of freedom in the estimation of production functions at the individual farm size level, the marginal and small farm sizes, on the one hand, and lower and upper medium farm sizes, on the other hand, were amalgamated to form the small and medium farm size categories respectively.

## IV

## THE MEASUREMENT OF VARIABLES

The milk yield ($Y_{ij}$) per animal per day, drawn in pail, and the feeding levels of green fodder ($G_{ij}$), dry fodder ($D_{ij}$) and concentrates ($C_{ij}$) were weighed in kg. and recorded once every month on the day of visit to the household.

For apportioning 'the total labour use on dairy and allied activities' among different members in a bovine herd, most farm management studies in India customarily assigned the weights of 1.0, 0.50 and 0.25 to bovine adult, heifer and calf respectively. Following the practices adopted in U.S.A. and Great Britain, Gadgil (1948, p. 184) used animal unit weights of 1.0, 0.5 and 0.14 for adult male and female buffalo, buffalo heifer and buffalo youngstock respectively. For cattle, he used the weights of 1.0, 0.7, 0.4 and 0.14 for working bullock, adult cow, heifer and youngstock respectively. Buffalo and cattle bulls were considered equal to 0.5 and 0.6 animal units respectively. Prabhakaran and Raut (1981) assigned the weights of 1.6, 0.8, 1.0 and 0.6 to in-milk buffalo, dry buffalo, in-milk indigenous cattle and dry indigenous cattle respectively (see also Patel, 1981). The Central Statistical Organisation (CSO) (Government of India, 1961) used 1.33, 1.0 and 0.50 weights for buffalo in-milk, dry buffalo and buffalo youngstock respectively. For cattle, the weights of 1.0, 0.5 and 0.33 were used for in-milk cattle, dry cow and youngstock respectively (also see Raut *et al.*, 1978). Patel *et al.* (1980) used the weights of 1.4, 1.0, 1.3, 1.0, 0.8, 0.5, 0.4 and 1.0 for in-milk buffalo, dry buffalo, in-milk crossbred cattle, dry crossbred cattle, in-milk indigenous cow, dry indigenous cow, youngstock and working bovine respectively. Usha Rani (1983) assigned the weights of 1.2 for in-milk buffalo and crossbred cattle, 1.0 to 1.2 for dry buffalo and crossbred cattle depending upon the stage of pregnancy, 1.0 and 0.8 for indigenous in-milk and dry cow, 0.7 to 1.0 for heifers of different animals and 0.5 to 0.6 for the youngstock of different bovines.

Lalwani (1987, pp. 104-106) adopted the following approach (see also its use in Mishra). The ORP survey, as described earlier, recorded labour use on dairy and allied activities separately once every quarter of the reference year, 1979-80. The quarter's total labour use was first divided by 90 days to arrive at the per day total labour use on the household's entire bovine herd. For further apportioning the day's total labour use, it was essential to standardise the bovine herd. For doing so, Lalwani (1987) assigned per day total labour use spent by a household on its entire herd to each in-milk bovine reared by the household. This procedure was repeated for all households. Different households exhibited different stocking rates of milch animals of different types and surely if the labour use on different types of animals differed sizably, it should reflect itself in the mean levels of labour use on the three types of animals considered in this study. The geometric mean levels of labour use for the three types of animals were worked out and used to form the relative weights, the geometric mean level of per day total labour use on cattle being taken as the base (1.0). In-milk buffalo and crossbred cattle were assigned the weights of 1.26 and 1.19 cattle units respectively. Dry breeding female, heifer and youngstock were assumed to constitute 0.8, 0.55 and 0.4 parts of their in-milk partner respectively. For instance, dry buffalo constituting 0.8 part of its in-milk counterpart

(1.26 cattle unit) became 1.01 standard cattle unit. Both buffalo bull and cattle ox were given equal weight of 1.26. No cattle bulls and working buffalo males were found in the project area.

Using the weights so defined, the household's entire bovine herd was first standardised in terms of the standard cattle units. In order to know the average per day labour use on a standard cattle unit, we divided the day's total labour use on the entire herd by the herd size, expressed in standard cattle units. For determining the labour use for a particular class of in-milk bovine, for instance, on in-milk buffalo, the average labour use on a standard cattle unit was multiplied by the weight of an in-milk buffalo, *i.e.*, 1.26. The procedure was extended to all types of milch bovines to arrive at labour input ($N_{ij}$) in the estimation of milk production functions, described above.

## V

## STABILITY TEST FOR IDENTIFYING STRUCTURAL BREAKTHROUGH

To test, if the shift from buffalo (j=1) or indigenous cow (j=3) to crossbred cattle (j=2) led to structural breakthrough in milk production processes, the Chow-test (Chow, 1960), utilising the Ordinary Least Squares (OLS) estimates of milk production functions (Table III), was applied. The null and alternative hypotheses set out under the test are:

*Case I: Buffalo vis-a-vis Crossbred Cattle*

$H_o$: $A_1=A_2$; $a_1=a_2$; $b_1=b_2$; $k_1=k_2$; $r_1=r_2$;

$H_a$: $A_1\neq A_2$; $a_1\neq a_2$; $b_1\neq b_2$; $k_1\neq k_2$; $r_1\neq r_2$;

*Case II: Indigenous Cow vis-a-vis Crossbred Cattle*

$H_o$: $A_3=A_2$; $a_3=a_2$; $b_3=b_2$; $k_3=k_2$; $r_3=r_2$;

$H_a$: $A_3\neq A_2$; $a_3\neq a_2$; $b_3\neq b_2$; $k_3\neq k_2$; $r_3\neq r_2$;

The null hypothesis under both cases was rejected, as the observed F-ratio exceeded its critical value even at one per cent level of significance. This implied that population structures defining the competing technologies, as discussed in Section II, were different and that the adoption of crossbred cattle either in the place of buffalo or indigenous cow led to structural breakthrough in the processes of milk production.

## VI

## THE EMPIRICAL RESULTS

The empirical use of decomposition equation (5) utilised the parametric estimates (Table III) of milk production functions, homogeneous of degree one, and the geometric mean levels of input use and milk output (Table II), estimated independently under the three variants of dairy technology. The OLS estimates bear the expected signs except the one related to dry fodder ($D_{ij}$) in the medium farm size for indigenous cow (j=3), where it was found negative but insignificant. The estimates were found statistically significant.

### *Distribution of Total Difference in Milk Yield*

The adoption of new dairy technology (j=2), *i.e.*, crossbred cattle in the place of the prevailing dairy technology (j=1 or j=3), *i.e.*, buffalo or indigeneous cow led to higher per day milk yield (Table II). Consequently, the shift in dairy technology, either from buffalo (Case I) or indigenous cow (Case II) to crossbred cattle, brought about a sizable total percentage gain in milk yield, represented in decomposition equation (5) by the bracketed term on its left hand side. The total percentage gain in milk yield increased with the increase in the farm size under both cases of the shift in dairy technology. For instance, the total gain in milk yield of 30.46 and 54.43 per cent observed under Case I and Case II respectively at the small farm size level rose to 48.32 and 61.41 per cent at the medium farm size level and further to 66.84 and 80.20 per cent at the large farm size level (Table V). The landless dairy producers enjoyed a slightly higher total gain of 33.40 and 60.62 per cent in milk yield under Case I and Case II of the shift in dairy technology respectively, as compared to the gains realised by the small farm size-group of dairy producers.

TABLE II. GEOMETRIC MEAN LEVELS OF MILK YIELD AND INPUT USE BY FARM SIZE PER DAY

| Sr. No | Farm size/Bovine | $Y_{ij}$ | $G_{ij}$ (kg.) | $D_{ij}$ | $C_{ij}$ (10 grams) | $N_{ij}$ (minutes) |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| I | Aggregate | | | | | |
| 1. | Buffalo | 4.708 | 24.34 | 5.15 | 4.13 | 57.75 |
| 2. | Crossbred cattle | 7.456 | 27.11 | 6.36 | 6.70 | 99.01 |
| 3. | Indigenous cow | 3.933 | 24.45 | 4.38 | 3.33 | 48.57 |
| II | Landless | | | | | |
| 1. | Buffalo | 4.453 | 20.87 | 5.30 | 2.04 | 74.82 |
| 2. | Crossbred cattle | 6.219 | 22.70 | 5.64 | 5.68 | 110.47 |
| 3. | Indigenous cow | 3.392 | 16.38 | 5.04 | 1.19 | 45.11 |
| III | Small(upto 2 ha.) | | | | | 67.89 |
| 1. | Buffalo | 4.668 | 23.48 | 5.27 | 2.77 | 90.05 |
| 2. | Crossbred cattle | 6.330 | 22.39 | 6.07 | 3.85 | 62.65 |
| 3. | Indigenous cow | 3.670 | 19.44 | 4.46 | 2.23 | |
| IV | Medium(2.01 to 8.0) | | | | | |
| 1. | Buffalo | 4.600 | 24.80 | 5.14 | 4.20 | 55.20 |
| 2. | Crossbred cattle | 7.457 | 29.05 | 5.23 | 6.65 | 94.28 |
| 3. | Indigenous cow | 4.035 | 23.16 | 3.99 | 4.27 | 50.46 |
| V | Large(exceeding 8.0) | | | | | |
| 1. | Buffalo | 4.991 | 29.60 | 5.50 | 6.74 | 50.41 |
| 2. | Crossbred cattle | 9.738 | 31.84 | 7.78 | 9.62 | 81.88 |
| 3. | Indigenous cow | 4.367 | 27.22 | 4.08 | 6.13 | 38.35 |

*Note*:- $Y_{ij}$ = Milk yield under jth animal; $G_{ij}$ = Green fodder use;
$D_{ij}$ = Dry fodder use; $C_{ij}$ = Concentrates use; $N_{ij}$ = Labour use.

But the higher total percentage gain in milk yield, consequent upon the shift in dairy technology, as the farm size increased, might not necessarily be suggestive of higher economic efficiency of the medium and large farm size-group of dairy producers over their counterparts in the small farm size-group. For, much of the increase in milk yield might occur due to reasons unrelated to the improved levels of technological efficiency. It might, for instance, occur predominantly due to the increased levels of input use, as was evident with regard to the project farmers in our sample. It became essential, therefore, to decompose the total gain in milk yield into its causative factors of the difference in the level of technological efficiency and in the levels of input use.

TABLE III. OLS ESTIMATES OF MILK PRODUCTION FUNCTION, HOMOGENEOUS OF DEGREE ONE

| Sr. No. | Farm size/Bovine | OLS estimates | | | | | F | $\bar{R}^2$ | Sample size |
|---|---|---|---|---|---|---|---|---|---|
| | | $A_j$ | $G_{ij}$ | $D_{ij}$ | $C_{ij}$ | $N_{ij}$ | | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| I | Aggregate sample | | | | | | | | |
| 1. | Buffalo | 0.2368 | 0.3044 | 0.1920* | 0.1285* | 0.3751* | 157.6 | 0.37 | 804 |
| 2. | Crossbred cattle | 0.3869 | 0.1989* | 0.3457* | 0.1596* | 0.2957* | 244.4 | 0.73 | 290 |
| 3. | Indigenous cow | 0.2427 | 0.3557* | 0.1168* | 0.2002* | 0.3273* | 67.8 | 0.51 | 209 |
| II | Landless farmers | | | | | | | | |
| 1. | Buffalo | 0.4216 | 0.2795* | 0.3891* | 0.1586* | 0.1728* | 51.4 | 0.73 | 74 |
| 2. | Crossbred cattle | 0.4809 | 0.2042 | 0.4683* | 0.1443* | 0.1832* | 39.3 | 0.87 | 38 |
| 3. | Indigenous cow | 0.3996 | 0.0606 | 0.6054* | 0.0774 | 0.2566* | 11.4 | 0.71 | 27 |
| III | Small farmers | | | | | | | | |
| 1. | Buffalo | 0.2892 | 0.2784* | 0.2313* | 0.1719* | 0.3185* | 26.9 | 0.34 | 166 |
| 2. | Crossbred cattle | 0.3403 | 0.3566* | 0.2127 | 0.1609* | 0.2698** | 35.7 | 0.68 | 64 |
| 3. | Indigenous cow | 0.2560 | 0.3378* | 0.1612* | 0.1967* | 0.3043 | 26.9 | 0.34 | 66 |
| IV | Medium farmers | | | | | | | | |
| 1. | Buffalo | 0.1909 | 0.3237* | 0.1842* | 0.0515 | 0.4406* | 48.2 | 0.30 | 335 |
| 2. | Crossbred cattle | 0.3943 | 0.0610* | 0.1684* | 0.3950* | 0.3756 | 119.4 | 0.97 | 123 |
| 3. | Indigenous cow | 0.2420 | 0.5348 | -0.0281 | 0.3086 | 0.1846 | 35.7 | 0.64 | 46 |
| V | Large farmers | | | | | | | | |
| 1. | Buffalo | 0.3011 | 0.3560 | 0.3949* | 0.0239 | 0.2253 | 135.6 | 0.64 | 229 |
| 2. | Crossbred cattle | 0.6997 | 0.0985* | 0.6220* | 0.1005 | 0.1789* | 47.7 | 0.70 | 65 |
| 3. | Indigenous cow | 0.2956 | 0.2309 | 0.0871 | 0.3706* | 0.3115* | 11.4 | 0.38 | 70 |

*Note*:- $A_j$, $G_{ij}$, $D_{ij}$, $C_{ij}$ and $N_{ij}$ stand respectively for intercept, green fodder, dry fodder, concentrates and labour.

* and ** indicate 99 and 95 per cent level of significance respectively.

## *Decomposition of the Total Difference in Milk Yield*

*(i) Aggregate sample:* Under Case I of the shift in dairy technology, *i.e.*, from buffalo to crossbred cattle, nearly three-fourths of the total gain in per day milk yield occurred due to the component of difference in input use and the rest (one-fourth of the total) occurred due to the difference in the levels of technological efficiency. Within the component of difference in the levels of input use, labour, concentrates and dry fodder, in that order, contributed sizably to the total gain of 46 per cent in milk yield. As regards

the contribution of neutral (shift in the intercept term) and non-neutral (sum of the shift in slope elasticities) variants of technological efficiency, the former contributed positively by 49 per cent to the total gain in contrast to a negative contribution of 36 per cent in the case of the latter (Table V). The adoption of milch crossbred cattle, thus, brought about an immediate upward shift in the threshold level of milk yield, enabling the farmers to get more milk at the existing levels of input use. However, as was evident by the negative contribution of non-neutral variant of technological efficiency, the project's dairy farmers failed in consolidating such technological gains as they were unable to adjust to the new requirements of the crossbred dairy technology.

TABLE IV. DECOMPOSITION† OF GROWTH IN MILK YIELD BY FARM SIZE: SCHEME I (EQUATION 4)

| Sr. No. | Farm size/Case | Total gain (per cent) | Sources of change (per cent) | | | | | | | | Total estimated (per cent) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Technological efficiency | | | Input use | | | | | |
| | | | NTE | NNTE | Total | $G_i$ | $D_i$ | $C_i$ | $N_i$ | Total | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) |
| I | Aggregate | | | | | | | | | | |
| 1. | Case I* | 58.37 | 63.39 | -36.28 | 27.11 | 3.46 | 4.51 | 8.00 | 26.80 | 42.77 | 69.88 |
| 2. | Case II** | 89.58 | 59.41 | -33.47 | 25.94 | 3.87 | 5.28 | 20.26 | 33.99 | 63.40 | 89.34 |
| II | Landless | | | | | | | | | | |
| 1. | Case I | 39.66 | 14.07 | - 6.20 | 7.87 | 2.45 | 2.50 | 28.30 | 8.23 | 41.48 | 49.35 |
| 2. | Case II | 83.34 | 20.35 | - 8.82 | 11.53 | 2.34 | 7.21 | 29.20 | 37.18 | 75.93 | 87.46 |
| III | Small | | | | | | | | | | |
| 1. | Case I | 35.60 | 17.67 | - 0.07 | 17.60 | -1.28 | 3.51 | 6.70 | 10.40 | 19.33 | 36.93 |
| 2. | Case II | 72.48 | 32.93 | - 3.57 | 29.18 | 5.13 | 5.34 | 14.29 | 13.31 | 38.07 | 67.25 |
| IV | Medium | | | | | | | | | | |
| 1. | Case I | 62.11 | 106.55 | -63.71 | 42.84 | 5.55 | 0.32 | 3.00 | 31.19 | 40.06 | 82.90 |
| 2. | Case II | 84.78 | 62.93 | -34.26 | 28.67 | 13.60 | -0.87 | 17.20 | 16.03 | 45.96 | 74.63 |
| V | Large | | | | | | | | | | |
| 1. | Case I | 95.11 | 132.38 | -52.10 | 80.28 | 2.69 | 16.37 | 1.01 | 14.04 | 34.12 | 114.40 |
| 2. | Case II | 122.99 | 136.71 | -65.86 | 70.85 | 3.92 | 7.90 | 21.10 | 35.36 | 68.28 | 139.13 |

*Notes:-* (1) † Based on OLS estimates (Table III) and geometric mean levels (Table II).
(2) NTE and NNTE denote neutral and non-neutral technological efficiency respectively.
(3) $G_i$, $D_i$, $C_i$, and $N_i$, denote respectively green fodder, dry fodder, concentrates and labour inputs.
(4) * and ** denote shift from buffalo to crossbred cattle and from indigenous to crossbred cattle respectively.

A similar pattern of empirical results emerged under Case II of the shift in dairy technology. The two components of the difference in the levels of input use and technological efficiency continued to contribute about three-fourths and one-fourth respectively to the total estimated gain of 60 per cent in milk yield (Table V), consequent upon the shift in dairy technology. The neutral and non-neutral variants of technological efficiency continued to contribute positively and negatively respectively to the total gain.

TABLE V. DECOMPOSITION † OF TOTAL GAIN IN MILK YIELD BY FARM SIZE: SCHEME II (EQUATION 5)

| Sr. No. | Farm size/Case | Total gain (per cent) | Sources of change (per cent) | | | | | | | | Total estimated (per cent) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Technological efficiency | | | Input use | | | | | |
| | | | NTE | NNTE | Total | $G_i$ | $D_i$ | $C_i$ | $N_i$ | Total | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) |
| I | Aggregate | | | | | | | | | | |
| 1. | Case I* | 45.98 | 49.10 | -36.28 | 12.82 | 2.14 | 7.30 | 7.72 | 15.94 | 33.10 | 45.92 |
| 2. | Case II** | 63.96 | 46.63 | -33.47 | 13.16 | 2.05 | 12.89 | 11.16 | 21.06 | 47.17 | 60.33 |
| II | Landless | | | | | | | | | | |
| 1. | Case I | 33.40 | 13.16 | - 6.22 | 6.94 | 1.72 | 2.85 | 14.75 | 7.14 | 26.46 | 33.40 |
| 2. | Case II | 60.62 | 18.52 | -11.75 | 6.77 | 6.66 | -4.73 | 22.55 | 16.41 | 40.89 | 47.66 |
| III | Small | | | | | | | | | | |
| 1. | Case I | 30.46 | 16.27 | - 0.07 | 16.20 | -1.70 | 3.02 | 5.29 | 7.62 | 14.23 | 30.43 |
| 2. | Case II | 54.43 | 28.47 | - 3.76 | 24.71 | 5.04 | 6.09 | 8.80 | 9.79 | 29.72 | 54.43 |
| IV | Medium | | | | | | | | | | |
| 1. | Case I | 48.32 | 72.54 | -63.71 | 8.83 | 0.97 | 0.29 | 18.12 | 20.11 | 39.49 | 48.32 |
| 2. | Case II | 61.41 | 48.82 | -34.26 | 14.56 | 1.38 | 4.56 | 17.50 | 23.48 | 46.92 | 61.48 |
| V | Large | | | | | | | | | | |
| 1. | Case I | 66.84 | 84.32 | -52.18 | 32.14 | 0.72 | 21.57 | 3.56 | 8.67 | 34.53 | 66.47 |
| 2. | Case II | 80.20 | 86.16 | -65.86 | 20.30 | 1.54 | 40.15 | 4.32 | 13.57 | 59.58 | 79.88 |

*Notes:-* † Based on OLS estimates (Table III) and geometric mean levels (Table II).
NTE and NNTE denote neutral and non-neutral technological efficiency respectively.
$G_i$, $D_i$, $C_i$, and $N_i$, denote respectively green fodder, dry fodder, concentrates and labour inputs.
* and ** denote shift from buffalo to crossbred cattle and shift from indigenous to crossbred cattle respectively.

*(ii) Farm size analysis:* At disaggregate level, the dairy producers in different farm sizes responded differently to the shift in dairy technology. Between the two components of the difference in the levels of input use and technological efficiency, the contribution of the latter in per cent terms to the total gain in milk yield was the least for the landless class of dairy producers and the highest for the small farm size-group of dairy producers under both cases of the shift in dairy technology. For instance, the dairy producers in the small farm size-group could realise nearly half (16 per cent) of their total gain (30 per cent) in per day milk yield under Case I and slightly more than half of their total gain under Case II of the shift in dairy technology due to the difference in levels of technological efficiency (Table V). In contrast, for the landless class of dairy producers, the technological efficiency component contributed barely one-fifth and one-tenth of the total gain in milk yield under Case I and II respectively. The rest of the total gain, *i.e.*, four-fifths and nine-tenths, occurred as a result of the increased input use under the two cases of the shift in dairy technology respectively.

Among the landed class of dairy producers, the total gain occurring due to the technological efficiency component declined with the increase in the farm size under Case II of the shift in dairy technology. For instance, as compared to barely one-fourth (15 and 20 per cent) of the total (61 and 80 per cent) gain in milk yield occurring due to the technological efficiency component for the medium and large farm size-groups dairy producers respectively, the dairy producers in the small farm size-group achieved nearly half of total gain in milk yield due to this component, consequent upon the shift from indigenous to crossbred cattle. But when the dairy farmers shifted from indigenous to crossbred cattle (Case I), the contribution of the technological efficiency component to the total gain in milk yield showed a mixed trend among the three size-groups of farmers. As compared to a more than half of the total gain occurring due to the technological efficiency component in the small farm size-group, the contribution of this component in the medium farm size-group declined to barely one-fourth (9 per cent) of the total (48 per cent) gain. But it rose to nearly half (32 per cent) of the total (67 per cent) gain in milk yield in the large farm size-group. In general, the gain of pure technological efficiency diminished as the farm size increased, which could be due to differential livestock production management practices, differential importance attached to dairying by the farmers of varying farm sizes, etc. The dairy farmers in the small farm size-group seemed to have adjusted better to the new requirements of crossbred dairy technology, as was evident by the lowest negative contributions of 0.07 and 3.76 per cent of non-neutral variant of the component of technological efficiency to the total gain in milk yield under the two cases of the shift in dairy technology (Table V).

Inversely, therefore, the contribution of the component of difference in input use was found lowest for the dairy producers in the small farm size-group and the largest for the landless dairy producers (Table V). The two classes of dairy farmers, otherwise similarly endowed with family labour, received gains of pure technological efficiency in such diametrically opposite direction that it provides grounds for further empirical research. In our view, the pulls of penury might have forced the landless towards earning agricultural wages and neglect dairying. It might also be related to breed differences in the stocking rates of milch bovines owned by the landed and landless dairy farmers.

## NOTES

1. $\text{Log}_n(Y_{i2}/Y_{i1}) = \text{Log}_n(1+x) \approx x \text{ for } |x| < 1$

where x is a percentage change in output; it is approximately a percentage change because the higher order terms in a Taylor expansion are discarded.

2.

| Sr.No. | Category | Operational Land holding (hectares) |
|---|---|---|
| 1 | Marginal | Upto one hectare. |
| 2 | Small | Exceeding 1.0 and upto 2.0. |
| 3 | Lower Medium | Exceeding 2.0 and upto 4.0. |
| 4 | Upper Medium | Exceeding 4.0 and upto 8.0. |
| 5 | Large | Exceeding 8.0 |

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