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process to avail of the hire-purchase facilities offered by the government to the farmers since 1960. Farmers in the majority of the cases do not get the benefit of government tractor services. The co-operative mechanical cultivation society is also not working too well to facilitate the spread of mechanical cultivation. There is no doubt that mechanization can be speeded up, and can be made available to even an ordinary farmer, if both government and the co-operative society can organize themselves properly.

At the local tractor selling agencies (which are functioning for Massey Fergusson and Russian tractors) there is no report of non-availability of tractors from whole-salers, though Massey Fergusson tractors are not always available in accordance with the demand. The servicing facilities provided by them to their customers are not unsatisfactory in the Dharwar district at least.

On the whole, Dharwar district in particular and India in general have a long way to go to derive full benefits from the modern technology such as mechanization.

THE RATE OF TECHNOLOGICAL CHANGE IN INDIAN AGRICULTURE DURING THE PERIOD 1920-21 TO 1960-61

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It is now accepted in theory that the major contribution to economic growth comes from scientific innovations, that is technological change. In order to understand the forces that bring about this change the measurement of contribution of technological change to growth of production has become necessary. To meet this vital need attempts have been made to evolve different measures. Measures available so far have not proved satisfactory from the point of accuracy of measurement. In this paper we try two alternative measures to study technological change in agriculture in India over a period of time, 1920-21 to 1960-61. Our major objective is to obtain a measure of technological improvement in Indian agriculture. We employ two measures to obtain a better idea regarding the magnitude of change rather than assessing the relative merits of the two approaches.

The two measures adopted are :

(i) Study of the ratio of output to input, both suitably aggregated.

(ii) Solow's approach of isolating technological change based on aggregate production function.[1]

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1. Robert Solow, "Technological Change and the Aggregate Production Function," *Review of Economics and Statistics*, August, 1956.

RATIO OF OUTPUT TO INPUT

A study of the ratio of output to inputs is only an approximation of the measure of the technological change. In the first place we are aggregating both inputs and products to get denominator and nominator. Over a period of time weights are likely to change. Hence this involves an index number problem both for nominator and denominator. Further, as the practice obtains (and we have not departed from it) the products are aggregated by additions, using value weights but inputs are aggregated by taking their shares in the total expenses. It so happens that shares are coefficients of a logarithmic function. In production function of logarithmic form the inputs (with their coefficients) are multiplied, whereas we have aggregated them by additions using their shares in total expenses as weights.

The major limitation of the ratio of output to input is that, a change in it may be the result of a conglomeration of causes such as (i) changes in the quality of inputs and or output, (ii) institutional changes, (iii) change resulting from product as well as factor combination (the index number problem already referred to) as a result of change in relative prices reflecting changes in relative supply position in case of inputs and relative demand position in case of product. (We can therefore add change in derived demand consequent upon change in demand for products as one of the factors), and (iv) change in technology. Thus a change in the ratio of output-input would not precisely indicate how much of it is due to real technological change. This limitation is, however, not so serious for a limited objective.

In an under-developed economy such as ours, we are in the first place interested in finding out whether relation of output to input has remained sticky or has altered. Identification of causes may be taken up later ; most of the institutional changes are deliberately introduced and are not induced in such an economy. Further on input side, a high degree of complementarity can be assumed to prevail making index number problem a less disturbing factor. Changes in demand pattern are few since preferences seldom change and income rises slowly and imperceptibly. The pattern of demand for farm products can be assumed, therefore, as remaining unaltered over a fairly long period.

OUTPUT-INPUT APPROACH

Before we study the change in ratio of output-input during the period under consideration we may examine, in brief, individual long-term trends in production and factors of production—land, labour and capital—of which total inputs are the component. The relevant indexes[2] are given in table I.

We do not go into the details here as to how these indexes are constructed. They are elaborately explained in the source from which they are quoted here. Suffice it to say that they are evolved after all possible statistical adjustments arising out of inaccuracies or gaps or lack of comparability in the data. They are expressed in terms of constant prices. Output index refers to crop production only and is constructed on the basis of three-year averages centered round the

2. These indexes are quoted from Tara Shukla : Capital Formation in Indian Agriculture, Vora & Co. Publishers Private Ltd., Bombay. 1965, p. 115.

TABLE I

(1950-51 = 100)

Years	Indexes of			
	Output	Land	Labour	Capital
1920-21	92.92	97.65	74.75	82.14
1925-26	93.70	97.65	77.91	83.26
1930-31	94.72	98.74	81.40	86.70
1935-36	94.28	98.34	86.37	88.55
1940-41	97.38	99.64	91.93	92.01
1945-46	97.24	100.60	95.80	93.94
1950-51	98.44	100.00	100.00	100.00
1955-56	117.50	102.89	109.91	108.66
1960-61	139.10	105.72	120.82	126.97

quinquennial years given in the table. Land index is based on acreage of cultivated land, *i.e.*, total of net sown area and current fallow land. Index of labour input is based on rural population as reported in the decennial Population Censuses duly adjusted for inter-censal periods. The assumption involved in adopting rural population as indicator of work force in agriculture is that the ratio of work force to population has remained constant over time. In view of lack of comparability of work force data as available from Population Censuses this was the only possible way in which the labour series could be constructed. Capital measured for the above table includes irrigation, bullocks, implements and machinery.

It will be observed from the table that production as well as all the factors of production have recorded increase, more steeply during the last decade. The magnitude of increase is, however, different for different indexes, it being the least in case of land. Capital increased by 22 per cent during 1920-21 to 1950-51 and by as much as 33 per cent during 1950-51 and 1960-61, the annual (simple) rate of increase being nearly three times during the last decade compared to the earlier three decades. Labour increased by 34 per cent between 1920-21 and 1950-51 but its rate of increase was slow—28 per cent—during 1950-51 to 1960-61 compared to the same in capital. As against this, the increase in output was only 8 per cent during 1920-21 and 1950-51 but as much as 42 per cent during 1950-51 and 1960-61. All these taken together suggest that in an under-developed agriculture where land is slow to increase and labour increases autonomously the major burden of increase in output, if any, has to be borne by capital. The fact that increase in output is slow suggests that little, if any, technological change has taken place in Indian agriculture except during the 'fifties.

The index of output-input ratio is given below. It gives a better insight of the aggregate picture. The series of inputs are constructed on the basis of data regarding shares[3] of each of the three inputs in the total expenditure as given in the Farm Management Studies carried out in various States during 1954-55 to 1956-57. These weights are kept constant while constructing the inputs series. Table II gives ratio and index of crop output-input.

3. Weights are : Land 0.2685, Labour 0.3010, Capital 0.4304.

TABLE II

Years	Total Crop	Output-Input	
	Ratio	Index (1920-21=100)	Percentage change over the quinquennium
1920-21	1.105	100.00	—
1925-26	1.096	99.19	— 0.81
1930-31	1.062	95.90	— 3.34
1935-36	1.042	94.09	— 1.89
1940-41	1.036	93.55	— 0.58
1945-46	1.010	91.20	— 2.52
1950-51	0.984	88.86	— 2.57
1955-56	1.092	98.60	+11.09
1960-61	1.164	105.34	+ 6.83

It will be seen that there is little technological change in agriculture over the entire period, the movement of ratio of output-input suggesting first a deterioration and later (during the last decade) a slight recovery in the technological relationship. If one wants to take account of the bias which was considered in favour of stickiness of production estimates, one can observe that the change in the ratio of output-input would have been less than is indicated above. Besides during the post-war period it is alleged that there was a tendency to under-report production. If so, much of the recovery of the ratio of output-input would be statistical. Despite this, one can observe that in the post 1950-51 period and particularly post-1955-56 period there may be some genuine increase in output for given inputs considered in the index, partly because output may be now free from movements in reporting bias. Besides, the price sensitivity of output index may not be much of a problem since relative prices of food and non-food did not change much during 1949-50 and 1960-61. However, on the input side the use of certain inputs like fertilizers not included in the index has increased in quantity during the recent period. But the importance of this input in the total input is very small and hence would not affect the index of input as constructed here substantially.

SOLOW APPROACH

Solow approaches the problem of measurement of the technological change from the side of the capital. All the limitations cited above regarding the ratio of output-inputs apply to this approach except one, *viz.*, index number problem arising from a change in the factor combination. His main approach is to isolate increase in labour productivity resulting from increased capital intensity, the remainder being the effect of the technological change. It is necessary for his construct to assume, as he does, that the technological change is neutral. This is an additional limitation of Solow approach, unlike the approach of ratio of output-input.

Solow approach can be described as under :—

$$\frac{Y_1 - Y_0}{Y_0} = \frac{Y_1 - Y_i}{Y_0} + \frac{Y_i - Y_0}{Y_0} \quad \text{.....(1)}$$

where Y_1 and Y_0 are average labour productivity observed at two points of time and Y_i is labour productivity resulting in time t, solely as a consequence of increased capital intensity. Hence we can write

$$\frac{Y_1 - Y_0}{Y_0} = \frac{\triangle A}{A} + \frac{Y_i - Y_0}{Y_0} \quad \ldots\ldots\ldots(2)$$

where $\frac{\triangle A}{A}$ is technological change. Now $\frac{Y_i - Y_0}{Y_0}$ is the increase in labour productivity resulting from increased capital intensity. If we write increased capital intensity as $\frac{\triangle K}{K}$ and share of capital (or capital and land) as rp, the equation (2) can be rewritten as :

$$\frac{Y_1 - Y_0}{Y_0} = \frac{\triangle A}{A} + rp \frac{\triangle K}{K}.$$

If we have the values of $\frac{Y_1 - Y_0}{Y_0}$ and rp and $\frac{\triangle K}{K}$, we can estimate by simple subtraction of $rp \frac{\triangle K}{K}$ from $\frac{Y_1 - Y_0}{Y_0}$ $\left(\text{or} \frac{\triangle Y}{Y}\right)$ to get the value of $\frac{\triangle A}{A}$.

One of the limitations of our data is that we have value of rp only at one point of time. But if we assume it to have been derived from Cobb-Douglas type of production function we can safely infer it to be constant. We have pleaded reliability of the ratio of output-input assuming that inputs are highly complementary; Cobb-Douglas form of production function cannot, therefore, be validly applied. To this extent the two approaches conflict. Acknowledging this conflict we build up the following estimates of the technological change. Data contained in Table III give values of

$$\frac{\triangle Y}{Y}, \frac{\triangle K}{K}, \frac{\triangle A}{A}.$$

Land and capital taken together per labour have declined, throughout the entire period of 1920-21 to 1960-61, at the rate of 3 to 5 per cent during different quinquennia. But the labour productivity tended to decline upto 1950 and increased thereafter. This is mainly because during 1950-1961 the increase in production has been the result of improved technology. What is of significance to note is that, in the context of our economy improved technology has not been associated with increased capital intensity. This is rather of a neutral nature.[4]

4. This observation is subject to the limitation that we have evaluated land at market value and aggregated it with the value of other productive assets. In an under-developed economy, rarely do we find a situation in which increased capital would keep pace with increased labour supply in agriculture in such a way as to compensate for static supply of land.

TABLE III—LABOUR PRODUCTIVITY, CAPITAL INTENSITY AND TECHNOLOGICAL CHANGE IN INDIAN AGRICULTURE: 1920-21 TO 1960-61

Period	Percentage change in net value added per worker	Percentage change in capital (plus land) intensity	Technological change in per cent
	$\frac{\triangle Y}{Y}$	$\frac{\triangle K}{K}$	$\frac{\triangle A}{A}$
1920-21 to 1925-26	— 3.20	— 3.81	— 0.54
1925-26 to 1930-31	— 3.31	— 2.65	— 1.46
1930-31 to 1935-36	— 6.15	— 5.67	— 2.19
1935-36 to 1940-41	— 2.91	— 4.36	+ 0.14
1940-41 to 1945-46	— 4.32	— 2.93	— 1.28
1945-46 to 1950-51	— 2.94	— 3.41	— 0.56
1950-51 to 1955-56	+ 8.48	— 5.27	+ 4.74
1955-56 to 1960-61	+ 7.82	— 3.51	+ 5.37
	rp = 0.6989		

The results regarding the technological change in Table III compare broadly with the technological change indicated by earlier approach, data for which are given in Table II. Both show that upto 1950-51 technology of production deteriorated and between 1951-61 it improved. The similarity ends here. On the whole, we find that both improvement and deterioration as indicated by Solow approach are lower compared to that indicated by the change in the ratio of output-input. During last 10 years the increase measured by the Solow approach is little more than half of that measured by the Ratio method. This difference may probably be attributed to the index number problem involved as a result of the changing factor combination as seen from Table III. This index number problem may tend to exaggerate both increases and decreases given by the change in the ratio of output-input.

A special note needs to be taken of the deterioration of the technique of cultivation of crops. This is difficult to explain unless we believe that nutrients removed from land far outweighed nutrients supplied by manure then used. Or else, it would be a reflection on the quality of data. The recent efforts to improve production technique and the results as shown by both the tables (II and III) would suggest probably the lack of nutrients in the soil in the earlier period. If we believe the production increases in recent past being genuine to the fullest extent we should conclude that the technological relationship has improved of late.

OVERALL RATE OF TECHNOLOGICAL CHANGE

To measure precisely the overall rate of technological change linear trends were fitted to (1) ratio of output-input, (2) percentage change in the ratio of output-input, (3) Solow's measure of technological change. The results are as under :

Type of Data (for 1920-21 to 1960-61)	Trend	Standard error	t value	R^2
Ratio of output-input	0.000018	0.0018	0.972 (N.S.)	0.0000081
Percentage change in ratio of output-input	0.2849	0.1311	2.1729 (N.S.)	0.4402
Solow's measure of technological change ..	0.1910	0.0562	3.396 significant (at 5 per cent level)	0.6574

The trend in ratio of output-input is not significantly different from zero as judged by the values of coefficients of trend fitted to output-input ratio and the percentage change in the ratio over every quinquennium. This implies that over the period of nearly forty years the production method in Indian agriculture in terms of relation of total input to total output remained unchanged.

When we judge the technological change in terms of the production related to capital intensity per worker we find some improvement of about 7.6 per cent over 40 years. This would mean that productivity of capital has improved. But this small improvement is, however, not reflected in relation to total input to output. This raises the problem of relative superiority of the two tools of measurement, a bigger problem that cannot be dealt with here. Suffice it to say, one observes in both the cases gain to be during the last decade only. We can, therefore, attribute the overall technological change primarily to the recent efforts in the Plan provided the production data are accepted.

CONCLUSIONS

Two conclusions emerge from this discussion. The technological change in Indian agriculture has been, by and large, conspicuous by its absence and if at all some improvement seems to have taken place in the technical relations between output and input during the last decade. Again it was only during the last decade that large increases have taken place in the stock of durable physical assets in agriculture whose composition is still predominantly of traditional type. This gives ground to believe that the modest improvement in technical relationship has been closely associated with rapid increases in the stock of traditional capital. That means rapid increases in the stock of capital are required, other things remaining the same, to bring about slight improvement in the technology which is surely "less than a modest reward for a major effort" as Domar[5] puts it.

5. E. D. Domar, "On Measurement of Technological Change," *The Economic Journal*, Vol. LXIXI, 1961, p. 719.