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DECOMPOSITION OF GROWTH TRENDS AND CERTAIN RELATED ISSUES

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I

Decomposition of growth trends was an interesting development in the analysis of agricultural growth. Although some attempts were made earlier to explain agricultural growth in terms of the area and yield components,¹ the first systematic study came from Minhas and Vaidyanathan.² Their analysis includes, besides area and yield components, a component on cropping pattern and a residual component showing an interaction between cropping pattern and yield. Discussing the usefulness of their additive scheme of decomposition, the authors state, "... our way of decomposing the agricultural output growth can provide a framework for reflective speculation on some meaningful policy alternatives." They describe the analytical design at the back of their decomposition as: "... component elements are so chosen that their contributions to output growth are determined by more or less independent set of factors. Each of these sets of factors can be separately analysed and these analyses should provide building blocks for the construction of output projections."

The scheme decomposes absolute change in the value of gross agricultural output,

$$Q_t - Q_0 = A_t \sum_c a_{ct} y_{ct} p_c - A_0 \sum_c a_{co} y_{co} p_c$$

as

$$Q_t - Q_0 = (A_t - A_0) \sum_c a_{co} y_{co} p_c + A_t \sum_c (a_{ct} - a_{co}) y_{ct} p_c \\ + A_t \sum_c a_{co} (y_{ct} - y_{co}) p_c + A_t \sum_c (a_{ct} - a_{co}) (y_{ct} - y_{co}) p_c \dots (1)$$

where

Q_t = value of gross agricultural output at constant prices (p_c) during period-t,

A_t = gross cropped area during period-t,

a_{ct} = (A_{ct}/A_t) = proportion of area under crop-c (A_{ct}) to the gross cropped area during period-t.

y_{ct} = physical output per acre of crop-c during period-t.

The first three components of the above scheme represent respectively the contribution of change in area, yield and cropping pattern in absolute change in the value of gross agricultural output. The last term shows the interaction effect of changes in yield and cropping pattern in the growth of output.

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1. A. V. K. Sastri, "Relative Contribution of Area and Yield to Increased Production of Wheat during the First Plan", *Agricultural Situation in India*, Vol. XV, No. 5, August 1960, pp. 481-486.

2. B. S. Minhas and A. Vaidyanathan, "Growth of Crop Output in India, 1951-54 to 1958-61: An Analysis by Component Elements", *Journal of the Indian Society of Agricultural Statistics*, Vol. XVII, No. 2, December 1965, pp. 230-252.

The word interaction here need not be confounded with the term used in the statistical analysis of 'experimental design'. It indicates the impact of joint movements in the two factors on overall production increase. It has a resemblance to 'covariance' between the two. A positive interaction would imply that the crop structure has shifted in favour of those crops which show higher growth of yield. The pure cropping effect, if positive, would show a shift in favour of high initial productivity crops.

Later Minhas gave a seven-component version³ of his additive scheme which was subsequently used by Misra,⁴ and Sondhi and Singh.⁵ In this version Minhas further decomposes the yield, cropping pattern and the interaction components as

$$A_t \sum_c a_{co} (y_{ct} - y_{co}) p_c = A_0 \sum_c a_{co} (y_{ct} - y_{co}) p_c + (A_t - A_0) \sum_c a_{co} (y_{ct} - y_{co}) p_c$$

$$A_t \sum_c (a_{ct} - a_{co}) p_c = A_0 \sum_c (a_{ct} - a_{co}) y_{co} p_c + (A_t - A_0) \sum_c (a_{ct} - a_{co}) y_{co} p_c$$

and,

$$A_t \sum_c (a_{ct} - a_{co}) (y_{ct} - y_{co}) p_c = A_t \sum_c (a_{ct} - a_{co}) (y_{ct} - y_{co}) p_c + (A_t - A_0) \sum_c (a_{ct} - a_{co}) (y_{ct} - y_{co}) p_c \dots (2)$$

The interaction of the pure components as well as the interaction between yield and cropping pattern does not differ from the one explained earlier except that the base period area is now associated with the three components. But the interaction between a gross level factor, *viz.*, area and crop-structural components, cropping pattern and yield structure do not fit into the covariance concept. Nor does it fit into the conventional concept of an interaction. A positive area-cropping pattern interaction indicates an increase in gross crop area in favour of high base period productivity crops. A positive area-cropping pattern-yield component similarly suggests increase in area in favour of crops showing higher growth of productivity. This does not add to the interpretative significance of the pure cropping pattern component and its interaction with yield respectively.

Interpretation of interaction between components of the same order is more meaningful. Vidya Sagar⁶ has decomposed the change in the value of gross agricultural output at prevalent prices into three gross components: area, productivity and price and their interactions as

$$\begin{aligned} Q_t - Q_0 &= A_t Y_t P_{0t} - A_0 Y_0 P_{00} \\ &= (A_t - A_0) Y_0 P_{00} + A_0 (Y_t - Y_0) P_{00} + A_0 Y_0 (P_{0t} - P_{00}) + \\ &\quad (A_t - A_0) (Y_t - Y_0) P_{00} + (A_t - A_0) Y_0 (P_{0t} - P_{00}) + \\ &\quad A_0 (Y_t - Y_0) (P_{0t} - P_{00}) + \\ &\quad (A_t - A_0) (Y_t - Y_0) (P_{0t} - P_{00}) \dots (3) \end{aligned}$$

3. B. S. Minhas, "Rapporteur's Report on Measurement of Agricultural Growth", *Indian Journal of Agricultural Economics*, Vol. XXI, No. 4, October-December 1966.

4. V. N. Misra, "Growth of Crop Output in Gujarat: A Component Analysis", *Anvesak*, Vol. I, No. 1, June 1971, pp. 1-15.

5. Rajinder Sondhi and Karam Singh, "Component Analysis of Food Grain Economy of India," *Journal of Social and Economic Studies*, Vol. III, No. 2, September 1975.

6. Vidya Sagar, "A Component Analysis of the Growth of Agricultural Productivity in Rajasthan: 1956-61 to 1969-74", *Indian Journal of Agricultural Economics*, Vol. XXXII, No. 1, January-March 1977.

where

$$\begin{aligned}
 Q_t &= A_t \sum_c a_{ct} y_{ct} p_{ctr} \\
 &= A_t \left(\sum_c a_{ct} y_{ct} (p_{ctr}/P_{0t}) \right) P_{0t} \\
 &= A_t Y_t P_{0t} \text{ is the value of gross agricultural output during period-t} \\
 &\quad \text{at prevalent prices } (p_{ctr}), \\
 P_{0t} &= \left(\sum_c Q_{co} p_{ctr} / \sum_c Q_{co} p_{cor} \right) \text{ is Laspayer's index of agricultural prices} \\
 &\quad \text{during period-t, } Q_{co} \text{ being the physical output of crop-c during} \\
 &\quad \text{the base period, and} \\
 Y_t &= \sum_c a_{ct} y_{ct} p_{ct} \text{ is gross agricultural productivity at deflated current} \\
 &\quad \text{prices } p_{ct} (= p_{ctr}/P_{0t}).
 \end{aligned}$$

The area component of the above scheme is the same as the one given by Minhas. The price component measures the effect of inflation on the growth in the value of output. The productivity component is a composite of crop-structural components, *viz.*, cropping pattern, price structure and yield structure, and their interactions, and is given as

$$\begin{aligned}
 Y_t - Y_0 &= \sum_c (a_{ct} - a_{co}) y_{co} p_{co} + \sum_c a_{co} (y_{ct} - y_{co}) p_{co} + \\
 &\quad \sum_c a_{co} y_{co} (p_{ct} - p_{co}) + \sum_c (a_{ct} - a_{co}) (y_{ct} - y_{co}) p_{co} + \\
 &\quad \sum_c (a_{ct} - a_{co}) y_{co} (p_{ct} - p_{co}) + \sum_c a_{co} (y_{ct} - y_{co}) (p_{ct} - p_{co}) + \\
 &\quad \sum_c (a_{ct} - a_{co}) (y_{ct} - y_{co}) (p_{ct} - p_{co}) \dots (4)
 \end{aligned}$$

The interaction between gross area and productivity is conceptually the same as the residual component of Parikh's multiplicative scheme discussed below. It incorporates the effect of extension in area on productivity, and hence on output net of its contribution if one-to-one correspondence between area and output is maintained. The interactions involving price component may not be of any interest *per se*. But if other sectors of the farm economy such as poultry and livestock are included in the analyses, the price interactions may throw some hypotheses on terms of trade between sectors and its effect on sectoral growth.

The relative price component of the productivity growth is designed to have a negligible pure effect. But the time-series of observations at the individual crop level would show trends in relative prices and its interaction with yield and cropping pattern would provide a framework for hypotheses on relative price-yield and relative price-cropping pattern relationships.

Another important contribution to the Minhas-Vaidyanathan scheme was the introduction of another crop-structural component, *viz.*, the locational component. Dharm Narain⁷ further decomposed the pure yield component of productivity as

7. Dharm Narain, "Growth of Productivity in Indian Agriculture", *Indian Journal of Agricultural Economics*, Vol. XXXII, No. 1, January-March 1977, pp. 1-44.

$$\begin{aligned} \sum_c a_{co} (y_{ct} - y_{co}) P_c &= \sum_c a_{co} \sum_i (d_{ict} - d_{ico}) y_{ico} P_c + \\ &\quad \sum_c a_{co} \sum_i d_{ico} (y_{ict} - y_{ico}) P_c + \\ &\quad \sum_c a_{co} \sum_i (d_{ict} - d_{ico}) (y_{ict} - y_{ico}) P_c \quad \dots (5) \end{aligned}$$

where d_{ict} and y_{ict} represent respectively the proportion of total area under crop-c in the i th crop region and the crop yield of this region.

The first component of the above scheme shows the change in the yield of a crop caused by a shift in crop locations. A positive locational component implies a shift in crop locations from low productivity regions to high productivity regions. A positive interaction will (third component) similarly show a shift in favour of locations with higher growth in crop yield.

Dharm Narain observed that locational shifts have contributed significantly in the growth of crop yield of rice during 1953-61 and that of wheat and rice during the period 1962-73. On the whole, the contribution of the two locational components in the growth of gross agricultural productivity was 33.8 per cent.⁸ During 1962-73 locational shifts contributed only 8.33 per cent to the agricultural productivity of India. In the overall, he says, "the real gain in productivity resulting from locational shifts is rather small, thus reflecting on the limited play of the market forces in bringing about interregional specialisation in the production of crops."⁹ In concluding the aforementioned article, Dharm Narain says "that the base period of the index of productivity being what it is, it imparts an asymmetry to the manner in which interaction effects bear on the growth of productivity in the two periods and this asymmetry imparts an upward bias to the growth rate of productivity. We have thus shown that the substantive step-up in the growth rate for productivity of the 1960s over that for the 1950s has been significantly larger than what the present index of productivity reveals."¹⁰

A close scrutiny of facts with a little mathematical manipulation in his index number would reveal that the above hypothesis is not correct.¹¹

II

The decomposition models of Minhas-Vaidyanathan type help us in establishing certain general hypotheses on growth pattern vis-a-vis its components and their interactions. Besides providing estimates of growth contributed by these components, the analysis may also help us in deducing hypotheses on causes and effects of a specific growth pattern. A general decomposition model that takes care of all the three components (area, productivity and price) of the output growth is discussed here. The model is described in several steps.

8. This is only partially correct. In fact this contribution is of the pure locational component. Together with the negative interaction total locational effect contributes 5.9 per cent only. See Vidya Sagar "Growth of Productivity in Indian Agriculture: A Comment", *Indian Journal of Agricultural Economics*, Vol. XXXV, No. 1, January-March 1980.

9. Dharm Narain, *op. cit.*, p. 21.

10. Dharm Narain, *op. cit.*, pp. 20 and 32.

11. For details, see Vidya Sagar, *Indian Journal of Agricultural Economics*, January-March 1980, *op. cit.*

The value of gross agricultural output at current prices during a time point-t can be written as

$$Q^t = \sum_c A_c^t y_c^t p_c^t \quad \dots (6)$$

where Q^t is the value of gross agricultural output during time point-t and A_c^t , y_c^t and p_c^t are respectively the area, yield rate (physical output per hectare) and current price of crop-c during the time point-t. We have

$$\begin{aligned} Q^t &= \sum_s \sum_{c \in s} A_{sc}^t y_{sc}^t p_{sc}^t \\ &= \sum_s A_s^t \left(\sum_{c \in s} a_{sc}^t y_{sc}^t p_{sc}^{dt} \right) P_s^t \\ &= \sum_s A_s^t Y_s^t P_s^t \quad \dots (7) \end{aligned}$$

where A_{sc}^t , y_{sc}^t and p_{sc}^t represent respectively area, yield rate and price of crop-c in the sth crop season¹² ($s = rabi, kharif, etc.$) of the period-t,

$a_{sc}^t = (A_{sc}^t/A_s^t)$ is the proportion of the gross crop of sth season under crop-c,

$p_{sc}^{dt} = (p_{sc}^t/P_s^t)$ is the deflated price of crop-c of sth season, the deflator P_s^t being the index number of crop prices of sth season and given as,

$P_s^t = \left(\sum_{c \in s} p_{sc}^t Q_{sc}^0 / \sum_{c \in s} P_{sc}^0 Q_{sc}^0 \right)$ and,

$Y_s^t = \sum_{c \in s} a_{sc}^t y_{sc}^t p_{sc}^{dt}$ is the gross agricultural productivity of sth season

at the constant overall seasonal prices.

Identity (7) can be written as,

$$Q^t = A^t \left(\sum_s b_s^t Y_s^t P_s^{dt} \right) \quad P_0^t = A^t Y^t P_0^t \quad \dots (8)$$

where

$A^t =$ gross cropped area,

$Y^t =$ gross agricultural productivity at constant overall prices,

$P_0^t = \left(\sum_s \sum_c Q_{sc}^0 P_{sc}^t / \sum_s \sum_c Q_{sc}^0 P_{sc}^0 \right)$ is the index number of agricultural prices,

$P_s^{dt} = (P_s^t/P_0^t)$ is the price index of sth season relative to the overall index,

$b_s^t =$ share of sth season in the gross cropped area and

$Q_{sc}^t = A_{sc}^t y_{sc}^t$ is the physical output of crop-c of sth season.

Identity (8) describes output in terms of macro components, *viz.*, gross cropped area, gross agricultural productivity and the overall level of agricultural prices. An increase in the value of gross agricultural output from the base period-0 can be given as

$$\begin{aligned} Q^t - Q^0 &= \Delta A \quad Y^0 P^0 + A^0 \Delta Y \quad P^0 + A^0 Y^0 \Delta P \\ &+ \Delta A \quad \Delta Y \quad P^0 + \Delta A \quad Y^0 \quad \Delta P + A^0 \Delta Y \quad \Delta P \\ &+ \Delta A \quad \Delta Y \quad \Delta P \quad \dots (9) \end{aligned}$$

12. Instead of seasonal decomposition, the above scheme can also be attempted in terms of crop groups (*e.g.*, cereals, pulses, oilseeds and cash crops, etc.), in which case it would distinguish structural adjustments between and within different crop groups.

where Δ is the difference operator, so that $\Delta A = A^t - A^0$, etc.

The first three components of the above decomposition show respectively the increase in the value of output contributed by the growth in agricultural area, the growth in agricultural productivity and the general inflation effect. Others are interactions between these components.

The increase in gross agricultural productivity can be similarly decomposed as

$$\begin{aligned} Y^t - Y^0 &= \sum_s \Delta b_s y_s^0 p_s^{d0} + \sum_s b_s^0 \Delta y_s p_s^{d0} + \sum_s b_s^0 y_s^0 \Delta p_s^d \\ &+ \sum_s \Delta b_s \Delta y_s p_s^{d0} + \sum_s \Delta b_s y_s^0 \Delta p_s^d + \sum_s b_s^0 \Delta y_s \Delta p_s^d \\ &+ \sum_s \Delta b_s \Delta y_s \Delta p_s^d \quad \dots (10) \end{aligned}$$

This decomposition gives the contribution of shifts in the distribution of gross cropped area in different seasons (seasonal pattern), growth in seasonal crop productivities and relative change in seasonal price structure. The magnitude of the third component is likely to be very small generally. But the interaction between this (price) component and other components may be of some interest. A positive interaction between price and seasonal pattern of area may imply, for example, a shift in seasonal pattern of area in favour of the season observing higher increase in its crop prices. A positive interaction between seasonal productivity and seasonal pattern may, similarly, indicate a shift in area in favour of higher productivity growth seasons. These implications might be more useful if the decomposition is attempted in terms of crop groups rather than seasons.¹³

The seasonal growth in productivity $\Delta Y_s (= Y_s^t - Y_s^0)$ is decomposed as

$$\begin{aligned} Y_s^t - Y_s^0 &= \sum_c \Delta a_{sc} y_{sc}^0 p_{sc}^{d0} + \sum_c a_{sc}^0 \Delta y_{sc} p_{sc}^{d0} + \sum_c a_{sc}^0 y_{sc}^0 \Delta p_{sc}^d \\ &+ \sum_c \Delta a_{sc} \Delta y_{sc} p_{sc}^{d0} + \sum_c \Delta a_{sc} y_{sc}^0 \Delta p_{sc}^d + \sum_c a_{sc}^0 \Delta y_{sc} \Delta p_{sc}^d \\ &+ \sum_c \Delta a_{sc} \Delta y_{sc} \Delta p_{sc}^d \quad \dots (11) \end{aligned}$$

The growth in crop productivity $\Delta y_{sc} (= y_{sc}^t - y_{sc}^0)$ may be further decomposed in terms of locational adjustment.¹⁴

We have

$$y_{sc}^t = \left(\frac{\sum_i A_{sci}^t y_{sci}^t}{\sum_i A_{sci}^t} \right) = \sum_i d_{sci}^t y_{sci}^t$$

where A_{sci}^t and y_{sci}^t are respectively the area under crop-c and the corresponding yield rate in the i th crop region; $d_{sci}^t = A_{sci}^t / A_{sc}^t$ is the ratio of A_{sci}^t to the area under crop-c (A_{sc}^t) so that $\sum_i d_{sci}^t = 1$. Thus,

$$y_{sc}^t - y_{sc}^0 = \sum_i \Delta d_{sci} y_{sci}^0 + \sum_i d_{sci}^0 \Delta y_{sci} + \sum_i \Delta d_{sci} \Delta y_{sci} \quad \dots (12)$$

The first component of the above identity shows the increase in the yield rate of crop-c contributed by pure increases in crop yields at different regions

13. While such factors as increase in the demand for foodgrain as a result of population pressure or government and private investment in land reclamation and irrigation extension have a say in the overall growth of crop area, relative area shifts are influenced by price and yield factors.

14. Dharm Narain, *op. cit.*

(crop locations) while the second component shows the growth in crop yield contributed by locational shifts in crop area. Thus a positive component of locational shift would indicate that the crop area has shifted in favour of those locations which had higher initial crop productivity. A positive interaction would indicate area shifts in favour of higher growth locations.

Substituting from (12) the value of $\Delta y_{sc}^t (= y_{sc}^t - y_{sc}^0)$ in the pure yield component of (11) and rearranging the terms,¹⁵

$$\begin{aligned} Y_s^t - Y_s^0 &= \sum_c \Delta a_{sc} y_{sc}^0 p_{sc}^{d0} + \sum_c \sum_i a_{sc}^0 \Delta d_{sci} y_{sci}^0 p_{sc}^{d0} \\ &+ \sum_c \sum_i a_{sc}^0 d_{sci}^0 \Delta y_{sci} p_{sc}^{d0} + \sum_c a_{sc}^0 y_{sc}^0 \Delta p_{sc}^d \\ &+ \sum_c \sum_i \Delta a_{sc} \Delta y_{sc} p_{sc}^{d0} + \sum_c \Delta a_{sc} y_{sc}^0 \Delta p_{sc}^d \\ &+ \sum_c \sum_i a_{sc}^0 \Delta d_{sci} \Delta y_{sci} p_{sc}^{d0} + \sum_c a_{sc}^0 \Delta y_{sc} \Delta p_{sc}^d \\ &+ \sum_c \Delta a_{sc} \Delta y_{sc} \Delta p_{sc}^d \end{aligned} \quad \dots(13)$$

The first four terms of the above decomposition now show the growth in seasonal productivity contributed respectively by changes in cropping pattern, shifts in crop locations, pure increase in crop yields and change in price structure.

The four zero-order interactions show respectively the increase in seasonal productivity contributed by (i) shift in crop location in favour of crops of higher

15. In the above scheme of decomposition price variation across regions is not considered (see Dharm Narain, *op.cit.*, p. 22, footnote). If this is also included in the scheme the two stages of decomposition would have to be altered. We will then have,

$$Y_s^t = \sum_c a_{sc}^t v_{sc}^{dt}$$

where

$$v_{sc}^{dt} = y_{sc}^t p_{sc}^{dt} = \left(\sum_i d_{sci}^t y_{sci}^t \right) \left(\sum_i d_{sci}^t y_{sci}^t p_{sci}^{dt} / \sum_i d_{sci}^t y_{sci}^t \right) = \sum_i d_{sci}^t y_{sci}^t p_{sci}^{dt}$$

is the value of output per hectare of crop-c at the constant overall price level.

We then have

$$Y_s^t - Y_s^0 = \sum_c \Delta a_{sc} v_{sc}^{d0} + \sum_c a_{sc}^0 \Delta v_{sc}^d + \sum_c \Delta a_{sc} \Delta v_{sc}^d \quad \dots(12a)$$

and,

$$\begin{aligned} v_{sc}^{dt} - v_{sc}^{d0} &= \sum_i \Delta d_{sci}^0 y_{sci}^0 p_{sci}^{d0} + \sum_i d_{sci}^0 \Delta y_{sci} p_{sci}^{d0} \\ &+ \sum_i d_{sci}^0 y_{sci}^0 \Delta p_{sci}^d + \sum_i \Delta d_{sci} \Delta y_{sci} p_{sci}^{d0} \\ &+ \sum_i \Delta d_{sci} y_{sci}^0 \Delta p_{sci}^d + \sum_i d_{sci}^0 \Delta y_{sci} \Delta p_{sci}^d \\ &+ \sum_i \Delta d_{sci} \Delta y_{sci} \Delta p_{sci}^d \end{aligned} \quad \dots(11a)$$

Combining (11a) and (12a) we get the complete decomposition of growth in seasonal productivity when crop prices also vary across regions.

productivity growth,¹⁶ (ii) shift in cropping pattern in favour of crops showing an increase in relative prices,¹⁷ (iii) locational shift in favour of areas of higher growth in crop yields and (iv) change in yield structure corresponding to a change in price structure.

Further decomposition of the increase in regional crop yields, *viz.*, Δy_{sci} ($= y_{sci}^t - y_{sci}^0$) can be attempted in terms of strategic inputs as irrigation, plant nutrients, high-yielding varieties (HYVs) and plant protection measures, etc. The growth in the use of these inputs is, to a great extent, responsible for the growth of productivity in the crops which dominate the pure yield component in the growth of agricultural productivity during the last 15 years.¹⁸

III

Some of the important studies on the decomposition of agricultural growth have employed multiplicative schemes in their analyses. Unlike additive schemes which decompose absolute increase and hence linear growth rate of output, the multiplicative scheme explains its compound rate of growth in terms of the component growth rates.

Parikh¹⁹ used the identity

$$\frac{A_t \sum_c a_{ct} y_{ct} p_{co}}{A_0 \sum_c a_{co} y_{co} p_{co}} = \frac{A_t}{A_0} \cdot \frac{\sum_c a_{ct} y_{ct} p_{co}}{\sum_c a_{co} y_{ct} p_{co}} \cdot \frac{\sum_c a_{co} y_{ct} p_{co}}{\sum_c a_{co} y_{co} p_{co}} \dots (14)$$

to express the index number of output as a multiple respectively of the index numbers of area, change in cropping pattern and change in crop yields. Fitting exponential time-trend to each series of index numbers, he gets an additive scheme for growth

$$g = g_A + g_a + g_y \dots (15)$$

16. This effect can be further broken into contribution of cropping pattern through change in favour of (i) crops showing higher yield growth $\left(\sum_c \sum_i \Delta a_{sc} \Delta y_{sci}^0 d_{sci} p_{sc}^{d0} \right)$, (ii) crops showing shift in area in favour of higher initial yield locations $\left(\sum_c \sum_i \Delta a_{sc} \Delta d_{sci} y_{sci}^0 p_{sc}^{d0} \right)$ and (iii) crops showing shift in area in favour of locations of higher yield growth $\left(\sum_c \sum_i \Delta a_{sc} \Delta d_{sci} \Delta y_{sci}^0 p_{sc}^{d0} \right)$.

17. In the alternative scheme with variable regional prices, we have a component which would similarly show the influence of regional price variation on locational shifts.

These implications of interactions between price and other components might have serious objections because past prices are more likely to influence the allocation of area and other inputs. However, since both the variables are in relative terms such an interaction may capture the long-term effect of changes in price structure if the time points for comparison are fairly wide. Besides, this is only a preliminary analysis of the data. These interactions help in the postulation of certain relevant hypotheses in an integrated set-up and do not provide a proof of these hypotheses.

18. Dharm Narain, *op. cit.*, p. 30.

19. Ashok Parikh, "Statewise Growth-Rate in Agricultural Output—An Econometric Analysis", *Artha Vijnana*, Vol. VIII, No. 1, March 1966, pp. 1-52.

where g , g_A , g_a and g_y represent growth rates respectively of gross agricultural output, gross cropped area, contribution of changes in cropping pattern and crop yields.²⁰

He introduces a residual component in his scheme in order to do away with one-to-one correspondence between growth in crop area and its production. He extends (15) as

$$g = w g_A + (1 - w) g_A + g_a + g_y \quad \dots (16)$$

where w , the weight assigned to the growth rate of area is to be obtained by regressing $\text{Log} (A_t \sum_c a_{co} y_{ct} p_{co} / A_0 \sum_c a_{co} y_{co} p_{co})$ on $\text{Log} (A_t / A_0)$. The coefficient w of $\text{Log} (A_t / A_0)$ in the above regression shows the effect of change in gross area on gross output (at constant cropping pattern). It follows that $(1-w)$ gives the effect of growth in crop area on productivity. A value of w more than unity implies growth in area on superior agricultural land. To the extent growth in output has occurred because of growth in crop area on superior land, it should be merged with the area component. Thus the real contribution of area and productivity should be

$$g_y (\text{real}) = g_y + (1 - w) g_A$$

$$g_A (\text{real}) = g_A - (1 - w) g_A = w g_A$$

Thus while $w g_A$ is the real contribution of growth in area, the yield effect has now two components g_y and $(1 - w) g_A$. Conceptually, $(1 - w) g_A$ is the same as the interaction effect between gross area and gross productivity of Vidya Sagar's scheme. The manner in which w is computed by Parikh, however, raises doubt on the validity of his estimates. These estimates for different States of India vary between 0.32 (Tamil Nadu) to 3.02 (Bihar). The specification of his regression equation shows that w is capturing not only the interaction effect but also the effect of factors influencing yield such as weather, irrigation and fertilizers.

In fact the effect of weather must be eliminated from w . A weather component, in howsoever crude form, would have improved the results.²¹ Also, the effect of irrigation and fertilizers is to be included in the yield component and so to that extent the estimate of w will be further affected. In the case of additive scheme this problem of a weather component is partially eliminated by taking wider time points for the computation of growth.

Dayal²² in an independent study used the same multiplicative scheme. But he uses only the end points information for his decomposition exercise. Minhas gave his multiplicative scheme as an improvement over Parikh-Dayal version. He extends the identity (14) as

20. Venkateswarulu earlier used a two-component multiple decomposition for his analysis of agricultural growth in Andhra Pradesh. See V. Venkateswarulu, "Growth of Agricultural Output in Andhra Pradesh during the period 1952-3 to 1961-2", *Arthaniti*, Vol. VIII, No. 2, July 1965, pp. 157-170.

21. Parikh mentions about weather while discussing the limitations of his exercise. He argues that rainfall alone is not a satisfactory measure of weather in general. Rainfall alone will not throw meaningful results.

22. R. Dayal, "Agricultural Growth Rates and Their Components", *Indian Journal of Agricultural Economics*, Vol XXI, No. 4, October-December 1966, pp. 227-237.

$$\frac{A_t \sum_c a_{ct} Y_{ct} P_c}{A_0 \sum_c a_{co} Y_{co} P_c} = \frac{A_t}{A_0} \left(\frac{\sum_c a_{co} Y_{ct} P_c}{\sum_c a_{co} Y_{co} P_c} \right) \left(\frac{\sum_c a_{ct} Y_{co} P_c}{\sum_c a_{co} Y_{co} P_c} \right) \left(\frac{\sum_c a_{ct} Y_{ct} P_c}{\sum_c a_{co} Y_{co} P_c} \frac{\sum_c a_{co} Y_{co} P_c}{\sum_c a_{co} Y_{ct} P_c} \right) \dots (17)$$

in order to measure the cropping pattern effect at base period yields and in the process introduces a residual component.

The residual is ratio of the product of tth period productivity and base period productivity to the product of tth period productivities obtained by changing the crop pattern and by growth in crop yields respectively. This implies square of the ratio of mean change in productivity to mean change caused by the two components individually when the other is held constant. Therefore, it measures the joint effect of the two components net of their individual effects. This is the same as the interaction between cropping pattern and yield components.

In a recent study Bhalla and Alagh²³ have used the Minhas' version of the multiplicative scheme.

IV

Most of the studies on decomposition have computed growth in output (or productivity) and its components by comparing the end points of the series. To reduce the effect of short-term weather-induced fluctuations three- to five-year end points are generally considered. Studies which base their decomposition on the entire time-series of observations have been conducted at the aggregate level (Minhas and Dharm Narain at the all-India level and Parikh at the State level). At the aggregate level a series of observations is more likely to show a smooth trend. As is demonstrated by Minhas in the context of a multiplicative scheme, the results obtained by the end points method do not differ from the one obtained by using the entire time-series. In his case the component growth rates are additive. But even in the case of Dharm Narain's additive scheme where component growth rates are not additive, their sum differs only marginally from the growth rate of total productivity. However, the magnitude of growth differs by nearly 15 per cent when computed by the two methods. In contrast, except for a highly stable agriculture, time-series at the disaggregated level (*e.g.*, a district) will show wide fluctuations around trend.

The use of point-to-point method of measuring growth in such circumstances may lead to seriously biased estimates of growth unless care is taken in selecting the points for comparison.

Often three-year time points are considered to adjust for the short run fluctuations arising from the vagaries of weather. In view of the increased variability at the disaggregated level and because of the fact that this variability has increased during the recent past,²⁴ even this practice may fail to provide representative time points.

23. G. S. Bhalla and Y. K. Alagh: Performance of Indian Agriculture: A Districtwise Study, Planning Commission, Government of India; Sterling Publishers Pvt. Ltd., New Delhi, 1979.

24. C. H. Hanumantha Rao: Technological Change and Distribution of Gains in Indian Agriculture, The Macmillan Company of India Ltd., Delhi, 1975.

This is evident from the Bhalla-Alagh study which depicts a very rosy picture of agricultural growth in Rajasthan particularly in the case of the semi-desert districts of Barmer, Jalore, Jodhpur and Pali.²⁵

A comparison of growth rates of productivity obtained by fitting geometric growth curves to the time-series of index numbers of agricultural productivity for the same period (1962-63 to 1972-73),²⁶ with those given in the study for the high growth districts (districts having more than 4.5 per cent growth rate of agricultural production according to the study) would clearly indicate this bias²⁷ (see Table I).

TABLE I—GROWTH RATES OF AGRICULTURAL PRODUCTIVITY* (1962-63 TO 1972-73)

Region/district	Coefficient of variation (1961-62 to 1975-76)	Growth rates**	
		A	B
Western Rajasthan			
Barmer	71	-0.8	6.3
Jalore	42	0.3	6.4
Jodhpur	67	-1.0	8.8
Pali	32	1.7	5.3
Sirohi	29	0.8	2.7
North Rajasthan			
Ganganagar	33	4.0	6.4
Eastern Rajasthan			
Alwar	27	4.4	5.1
Bharatpur	22	5.0	4.0
Jaipur	13	1.9	2.8
South-eastern Rajasthan			
Bundi	30	4.6	3.2
Kota	29	5.5	3.5
South Rajasthan			
Chittorgarh	20	4.4	4.2

* Districts of Rajasthan showing more than 4.5 per cent rate of growth in agricultural production (according to Bhalla-Alagh study) are shown.

** Growth rates-A have been obtained by fitting the growth curve $Y = ab^t$ to the index numbers of agricultural productivity. Growth rates-B are obtained from Bhalla-Alagh study.

As a result of this bias, not only a desert district of the State, *viz.*, Jodhpur leads all other Indian districts in the growth of productivity, but also the State enjoys a pride position of leading all other States of India, with six out of a total of 16 Indian districts having more than 5 per cent growth rate. These six districts include the above-mentioned semi-desert districts also.

As against an 8.8 per cent rate of growth of agricultural productivity obtained by Bhalla-Alagh, the growth rate computed by fitting a growth curve is -1.0 per cent in the case of Jodhpur. The situation in other districts is no better. It is clearly indicated by the above comparison that the effi-

25. Bhalla and Alagh: *op. cit.*

26. While during the first triennium of the study, *viz.*, 1962-63 to 1964-65, and around it the temporal variation is mild, wide variation is observed in most of the districts of the State around the second triennium. The bulk of growth observed during the second triennium is due to the inclusion of year 1970-71, an unprecedented crop year, the productivity level of which could not be matched even in the following five years.

27. *Kharif* pulses occupy an important position in the cropping pattern of the western desert districts of the State. Exclusion of pulses in the Bhalla-Alagh study, therefore, may vitiate the above comparison. The results do not alter significantly, however, even if pulses are ignored while computing the index numbers of agricultural productivity in these districts.

ciency of the point-to-point method of computing growth is varying inversely as the increase in the coefficient of variation.

Preliminary analysis on the nature and amplitude of fluctuations might be attempted in such cases. It would be safer to take time points as wide as short-term agricultural cycle, particularly in the regions of high annual fluctuations. Otherwise, those time points can be taken which fall on the fitted growth curves (with time-series of individual years or with time-series of three-year moving averages).

V

An attempt is made here to describe the relationship between strategic inputs and increase in crop yields by deriving mean response to the use of fertilizers (both in terms of increase per hectare at the mean level of nutrient use and in terms of increase per kg. of nutrient use), HYVs and irrigation for the important cereals in different agricultural regions of Rajasthan.

The response to the use of strategic inputs is derived from the cross-section data of 'Intensive Agricultural Area Programme' (IAAP) survey.²⁸ In all, six districts of the four non-desert agricultural regions of the State are analysed for wheat. In maize five districts of the most important crop areas of the State (south and south-eastern Rajasthan) and in bajra three districts of eastern Rajasthan are analysed. In the absence of desired data in the largest jowar region, *viz.*, south-eastern Rajasthan, Bhilwara district of south Rajasthan is analysed to get the yield response coefficients.²⁹

In all, four-years' data (1971-72 to 1974-75) for wheat and three years' data (1972-73 to 1974-75) for *kharif* crops are analysed. Responses are obtained for individual years and then averaged over the given period.

Methodology

Response coefficients are obtained by the method of regression analysis. Dummy variables, corresponding to each of the inputs, instead of their quantitative magnitudes are employed to explain the cross-sectional variability in the crop yield of relevant crops. The coefficient of a factor dummy is interpreted as the yield response coefficient of the corresponding factor. Following regression equation is used for the fields of local and HYVs separately.³⁰

28. This survey is conducted by the Directorate of Agriculture, Rajasthan under technical guidance from the Indian Agricultural Statistics Research Institute (ICAR). In all, eleven districts for wheat, six districts for bajra, five districts for maize and two districts for jowar are covered by the survey.

29. Ganganagar, the most important agricultural region of the State in regard to the use of these inputs in wheat, is ignored because of nearly perfect complementarity in the use of these factors. In bajra insignificant responses to these inputs were observed.

30. Initially, the equation was run for the entire set of data pooled together. Dummy variables corresponding to the HYVs and for plant protection measures were added to the list of explanatory variables. This scheme was discarded because of (a) possible differences in the response pattern of factors across regions, and (b) possible differences in the response to local and HYVs. Dummy variables corresponding to the use of farmyard manure and plant protection measures were used for the sake of complete specification. The variable corresponding to plant protection measures was dropped because of an insignificant proportion of fields using this input.

$$Y_{ic} = a_{0c} + a_{1c} I_{ic} + a_{2c} M_{ic} + a_{3c} F_{ic}$$

where

Y_{ic} = yield per hectare of crop-c in ith field,

I_{ic} = 1, if the field is irrigated,

= 0 otherwise,

M_{ic} = 1, if the field is manured,

= 0 otherwise,

F_{ic} = 1, if the field is fertilized,

= 0 otherwise.

The difference between the intercept terms of the two estimated equations (corresponding to the fields of local and HYVs of a given district) is taken as the yield response of HYVs.³¹

The rate of fertilizer application in terms of nutrients ($N + P_2O_5 + K_2O$) is also obtained from the survey data in order to find the fertilizer response in terms of yield increase per kg. of fertilizer use.

Results

Table II shows districtwise mean values of the response coefficients. Fertilizer yardsticks in terms of yield response per kg. use of nutrients are computed in Table III.

TABLE II—MEAN VALUES OF RESPONSE COEFFICIENTS OF TECHNOLOGICAL INPUTS
(*quintal per hectare*)

Crop/Region	District	HYV	Irrigation		Manures		Fertilizers	
			HYV	Local varieties	HYV	Local varieties	HYV	Local varieties
<i>Wheat</i>								
Ajmer-Sirohi strip	Pali	1.70	—	—	1.88	1.34	3.52	1.14
Eastern Rajasthan	Alwar	4.63	—	—	2.59	1.40	2.96	1.24
	Bharatpur	4.31	—	—	1.30	1.13	3.69	1.63
	Jaipur	3.19	—	—	-0.43	Neg.	4.71	1.79
	Overall	4.04	—	—	1.15	0.83	3.78	1.55
Southern Rajasthan	Chittor	3.72	—	—	0.39	2.27	3.95	2.77
South-eastern Rajasthan	Kota	3.08	—	3.80	2.96	2.50	5.06	2.20
<i>Bajra</i>								
Eastern Rajasthan	Alwar	1.81	2.90	1.68	1.94	1.95	1.88	1.84
	Bharatpur	1.69	1.98	1.58	1.54	1.05	3.71	3.42
	Jaipur	1.66	2.67	1.63	2.25	1.68	3.10	1.83
	Overall	1.72	2.50	1.63	1.91	1.56	2.89	2.36
<i>Maize</i>								
Southern Rajasthan	Bhilwara	0.63	3.52	3.52	1.91	1.42	3.29	3.06
	Chittor	2.30	7.14	5.98	1.58	1.39	4.85	3.71
	Udaipur	0.16	3.09	1.91	3.10	1.62	4.42	2.68
	Overall	1.03	4.58	3.80	1.86	1.48	4.19	3.15
South-eastern Rajasthan	Kota + Jhalawar	2.66	3.55	3.68	1.09	0.64	4.85	3.50
<i>Jowar</i>								
Southern Rajasthan	Bhilwara	2.95	2.30	—	0.98	—	2.56	1.36

31. The estimate of the standard error of the yield response of HYVs is derived from the estimated standard errors of the two intercept terms as

$$\text{Est. S.E. (H)} = \sqrt{(\text{S.E. (a}_{0h}))^2 + (\text{S.E. (a}_{0i}))^2}$$

TABLE III—ESTIMATES OF FERTILIZER YARDSTICKS

Crop/Region	District	HYVs				Local varieties		
		Per cent area under HYY*	Per cent area fertilized	Rate of application	Yardstick	Per cent area fertilized	Rate of application	Yardstick
<i>Wheat</i>								
Eastern Rajasthan	Alwar	60	84	68	4.4	57	43	3.3
	Bharatpur	49	71	66	5.5	40	46	3.6
	Jaipur	57	79	75	6.2	52	47	3.8
	Overall	55	79	70	5.4	42	45	3.6
Ajmer-Sirohi strip	Pali	24	68	76	4.6	43	62	2.0
Southern Rajasthan	Chittor	41	75	82	4.8	43	55	5.0
South-eastern Rajasthan	Kota	45	89	93	6.9	42	66	3.2
<i>Bajra</i>								
Eastern Rajasthan	Alwar	27	50	43	4.2	4	29	8.0
	Bharatpur	31	46	46	8.3	11	26	13.7
	Jaipur	12	45	51	6.3	16	36	6.2
	Overall	21	48	47	6.3	13	32	8.7
<i>Maize</i>								
Southern Rajasthan	Bhilwara	3	68	68	4.7	37	41	7.2
	Chittor	7	75	83	6.0	52	57	6.9
	Udaipur	3	51	74	6.0	38	39	7.1
	Overall	4	66	75	5.6	44	46	7.1
<i>Jowar</i>								
South-eastern Rajasthan	Kota + Jhalawar	2	52	95	5.2	25	64	6.1
<i>Jowar</i>								
Southern Rajasthan	Bhilwara	15	33	53	4.7	5	25	5.1

Wheat

The annual values of responses to fertilizer in HYV and to high-yielding varieties³² were mostly significant at 5 per cent or better level of significance. The frequency of insignificant fertilizer response coefficients in the case of local varieties was nearly 50 per cent. The coefficient of irrigation was insignificant in 1973-74 (Kota district).

The response pattern of strategic inputs differs in general over different regions. The mean response to HYV varies between 1.7 quintals per hectare in Pali (Ajmer-Sirohi strip) and 4.04 quintals in eastern Rajasthan. Due to lack of observations on irrigated fields, the irrigation response coefficient could be worked out for the local variety fields of Kota (south-eastern Rajasthan) only. The four years' average of the irrigation responses is 3.8 quintals per hectare. This value of the irrigation response is less than the one suggested

32. In Pali the coefficient of HYV was significant only in 1974-75. In Jaipur and Bharatpur it was insignificant during 1973-74 and in Kota it was insignificant during 1972-73 (at 5 per cent).

by Panse *et al.*³³ Their estimates based on the experimental data of Uttar Pradesh place this value between 5 and 7 quintals while their estimates based on the crop cutting surveys vary between 2 quintals in Uttar Pradesh and 5 quintals in Punjab.³⁴ The estimates of Krishnan *et al.*³⁵ based on the IADP evaluation survey of the four wheat districts vary between 0.8 quintal in Shahabad (Bihar) to 4.3 quintals in Jammu.

Our estimates of fertilizer response in terms of yield increase per kg. use of nutrients are smaller than the estimates of Panse *et al.* and Krishnan *et al.* The fertilizer coefficient in terms of yield increase per hectare varied between 3.52 quintals (Pali) and 5.30 quintals (Kota) for HYVs and between 1.14 quintal (Pali) and 2.77 quintals (Chittor) for local varieties.

Because of higher rate of fertilizer application, however, these moderately high estimates turn smaller when computed in terms of response per kg. of nutrient use (yardsticks). The estimates of Krishnan *et al.* of fertilizer yardstick vary between 8 and 15 kg. in irrigated fields at the mean rate of application varying between 32 kg. and 55 kg. per hectare. The estimate of Panse *et al.* for Rajasthan places its value at 9.8 kg. at an application rate of 22.4 kg. and at 7.9 kg. when the rate of application is increased to 44.8 kg.³⁶ At an average rate of application varying between 66 kg. and 93 kg. in HYV and between 45 kg. and 66 kg. in local varieties, our estimates of fertilizer yardsticks are less than 6 kg. in all the regions both for HYVs and local varieties (Table III).

The lower fertilizer response ratio on farmers' fields (our estimates) vis-a-vis Simple Fertilizer Trial (SFT) estimates of Panse *et al.* justifies Vaidyanathan that the fertilizer response under the conditions of mass application may be lower than what SFT data suggest.³⁷

This, however, should not contest the validity of another point emerging from the foregoing analysis. Three average response points for the State (two based on SFT data and one of the present analysis) indicate a declining average response curve on the scale of fertilizer application. Fertilizer response of the present analysis with a relatively higher rate of application

33. V. G. Panse, T. P. Abraham and C. R. Leelavati: Yardsticks of Additional Production of Certain Foodgrains, Commercial and Oilseed Crops, Institute of Agricultural Research Statistics, New Delhi, 1964, pp. 17-18.

34. *ibid.*, pp. 24-25.

35. K. S. Krishnan, P. N. Soni and V. S. Rustogi, "A Study on Irrigation and Fertiliser Responses of Rice in I.A.D.P. Districts", *Fertiliser News*, Vol. XVI, No. 3, March 1971, pp. 33-42, and "Irrigation and Fertiliser Responses of Wheat, Maize, Jowar and Gram in I.A.D.P. Districts", *Fertiliser News*, Vol. XVII, No. 9, September 1972, pp. 50-55.

36. Panse *et al.*'s estimates of fertilizer yardstick mentioned here refer only to the use of nitrogen. Their estimates of yield response to phosphatic fertilizers are 7.5 and 6.5 kg. at the rate of application of 22.4 and 44.8 kg. respectively. The overall estimate of the yardstick should, therefore, be less than the value mentioned here.

37. "Although the SFT is designed to test the yield response to varietal change and fertilizer use (keeping all other practices of the sample farmer unchanged), the sample plots do have the benefit of expert knowledge on the mode and timing of applying fertilizers. To the extent that responses are affected by these factors and farmers using fertilizers on their own are not aware of the right practices in this regard, the latter's response could be lower than SFT." A. Vaidyanathan, "HYV and Fertilizers: Synergy or Substitution? A Comment", *Economic and Political Weekly*, Vol. XIII, No. 25, June 24, 1978, p. 1033. Also see A. Vaidyanathan, "Performance and Prospects of Crop Production in India", *Economic and Political Weekly*, Vol. XII, Nos. 33 and 34, Special Number, August 1977, and Kirit S. Parikh, "HYV and Fertilizers: Synergy or Substitution", *Economic and Political Weekly*, Vol. XII, No. 12, March 25, 1978, pp. A-2-A-8.

lies lowest on the average response curve. Even if the nitrogen response ratio of SFT estimate of Panse *et al.* is lowered to allow for the lower phosphatic response ratio (see footnote 36) and the upward bias of SFT estimates, the pooled mean response ratio for local varieties at a rate of application of 58 kg. should be lower than the estimate of Panse *et al.* at 44.8 kg. rate of application. Farmers in Rajasthan, thus, might be applying uneconomical doses of fertilizers.³⁸

Another important point emerging out of the present investigation is that whatever the level of response there is a significant difference between the fertilizer response ratio of HYVs and local varieties of wheat. The higher response ratio of HYVs even at a higher rate of fertilizer application clearly indicates the presence of interaction effect between fertilizer and HYVs.³⁹

Kharif Crops—Bajra

Irrigation in *kharif* crops is more a protective measure than productive. Sufficient number of irrigated observations were available in bajra only for the crop years 1972-73 and 1974-75, the years of poor rainfall. During 1973-74, a year of good rainfall as well as a very good *kharif* harvest, the irrigation coefficient in Jaipur is negative (—2.31 quintals per hectare, significant at 5 per cent probability level).

Since the data for this crop are analysed for one agricultural region only, there are not much inter-district differences in the mean irrigation coefficient. The mean response to irrigation in the three eastern districts is 2.5 quintals and 1.6 quintals respectively for HYVs and local varieties. The response coefficient of improved varieties is 1.72 quintals per hectare. Fertilizer yardsticks are relatively high at 6.7 kg. and 8.7 kg. respectively for HYVs and local varieties, at 47 kg. and 32 kg. rate of application.

In most of the cases the response coefficient corresponding to HYVs as well as of HYVs itself was found to be statistically significant. In the case of local varieties, however, both irrigation and fertilizer response ratios were found to be insignificant during 1973-74 in Bharatpur and Jaipur districts. The response coefficient corresponding to farmyard manure was mostly significant.

Maize

South Rajasthan is predominantly a maize growing region. Three districts of this region, *viz.*, Chittor, Udaipur and Bhilwara and one district of south-eastern Rajasthan, *viz.*, Kota, are analysed for this crop. Amongst the districts of south Rajasthan, only Chittor shows statistically significant positive coefficient of improved varieties at an average value of 2.30 quintals per hectare. In other districts the response coefficient of HYVs fluctuates

38. An economic analysis recently conducted in several districts of Madhya Pradesh suggests similar findings. The results of the data collected from Indore, Nimar and Khandwa districts of the State conclude that the net returns per rupee invested in fertilizers were 58 to 65 paise at the use-level of 30 kg. per hectare whereas the benefit slumped down to 21 and 43 paise only when the fertilizer consumption was doubled. V. K. Shrivastava, "Imbalances in Fertilizer Consumption", *Indian Express*, June 13, 1978.

39. As will be seen in the following lines, there is no such interaction effect in *kharif* crops. In most of the *kharif* cases the fertilizer response ratio is less for HYVs.

marginally around zero. The overall estimate for this region is, therefore, low at 1.03 quintal per hectare against the corresponding estimate of south-eastern Rajasthan at 2.66 quintals. While an interaction between HYVs and irrigation is clearly visible, no such effect is reflected by the response coefficient of fertilizers for local and HYVs. Like bajra, on the contrary, in maize also the fertilizer yardstick is higher for local varieties. There is a marginal difference in the fertilizer yardstick of hybrid maize in the two regions while the corresponding value for local varieties is higher in south Rajasthan.

Jowar

Due to scanty use of improved seed in this crop only few observations were available. The mean value of fertilizer yardstick in Bhilwara district of south Rajasthan is 4.7 and 5.1 kg. respectively. The response coefficient of improved seed is highest amongst the three *khari*f crops at 2.95 quintals per hectare. Only the response to fertilizer in HYVs and the response to HYVs is significant.

VI

The decomposition in terms of strategic inputs involves not only the level of their use but also the response to the use of these inputs. The variable response pattern of these inputs may have a bearing on the heterogeneous use of these inputs and may, therefore, explain locational shifts to some extent.

Distribution of Inputs into Crops

While cropwise annual estimates of area under high-yielding varieties and irrigation might be easily available, the distribution of plant nutrients and plant protection measures might be difficult to obtain. This distribution is to be estimated either on certain *a priori* assumptions⁴⁰ or by using the yield estimation surveys' data collected in all the States of the country. In some cases these surveys may not be able to provide information on the rate of application and other technicalities which enable us to derive the exact nutrient content. Estimates on these variables can be drawn from alternative sources.⁴¹

The gross increase in the irrigated area under a crop is to be decomposed into area and yield components and only the yield component of irrigation increase is to be retained for the decomposition of yield growth. The yield component is nothing but change in irrigated area under a crop with more than a proportionate change in gross area under it. This can be given as

$$\Delta I_c(y) = I_c^t - I_c^0 (A_c^t/A_c^0) \quad \dots (18)$$

for a given region. Here $\Delta I_c(y)$ implies the yield component of irrigation increase in the crop-c, I_c^t is the irrigated area and A_c^t is the total area under crop-c during the period-t ($t = 0, t$).

40. N. K. Nair, "Contribution of Fertilizers to Foodgrain Production in India: Some Estimates", *Productivity*, Vol. XVII, No. 1, April-June 1976.

41. See Vidya Sagar, "Contribution of Individual Technological Factors in Agricultural Growth", *Economic and Political Weekly*, Vol. XIII, No. 25, June 24, 1978, pp. A-63-A-69.

Yardsticks of Factor Inputs

Yardsticks or factor response coefficients can be obtained from cross-section data. Fertilizer and irrigation yardsticks obtained from controlled (experimental) and partially controlled (simple fertilizer trials on farmers' fields) are available for different agro-climatic regions of India.⁴² However, the use of these yardsticks is likely to cause an upward bias in the contribution of these factors.⁴³ These yardsticks should, therefore, be adjusted for the bias before using them in the analysis.

Not much is available on the yardsticks of factor inputs obtained from actual farm conditions⁴⁴ even though crop estimation surveys conducted in different States can provide rich source of information for their computation.

The set of technological factors would under-explain or over-explain the actual yield growth in a year (or during a period) depending upon the role played by agro-climatic factors.

The influence of rainfall, a major climatic factor can be isolated separately and placed as yet another component of yield growth which can then be expressed as

$$\Delta Y_{sci} = (\Delta F_{sci})b_F + (\Delta I_{sci})b_I + (\Delta H_{sci})b_H + (\Delta W_{sci})b_W + \text{Res.} \dots (19)$$

where ΔF_{sci} and b_F represent respectively the change in fertilizer consumption of crop-c in the region-i, and its yardstick. Similar is the interpretation of the next three components on the right hand side of equation (19). The last component shows the yield change caused by the left out factors and obtained by subtracting from the total increase in yield, the yield increase contributed by the first four factors.

The pure yield component of growth in gross agricultural productivity can now be expressed as

$$\begin{aligned} Y(\text{yield}) &= \sum_s \sum_c \sum_i b_s^0 a_{sc}^0 d_{sci}^0 \Delta Y_{sci} p_{sc}^{d0} \\ &= \sum_s \sum_c \sum_i b_s^0 a_{sc}^0 d_{sci}^0 \Delta Y_{sci}(F) p_{sc}^{d0} \\ &+ \sum_s \sum_c \sum_i b_s^0 a_{sc}^0 d_{sci}^0 \Delta Y_{sci}(I) p_{sc}^{d0} \\ &+ \sum_s \sum_c \sum_i b_s^0 a_{sc}^0 d_{sci}^0 \Delta Y_{sci}(H) p_{sc}^{d0} \\ &+ \sum_s \sum_c \sum_i b_s^0 a_{sc}^0 d_{sci}^0 \Delta Y_{sci}(W) p_{sc}^{d0} \\ &+ \sum_s \sum_c \sum_i b_s^0 a_{sc}^0 d_{sci}^0 \Delta Y_{sci}(\text{Res.}) p_{sc}^{d0} \dots (20) \end{aligned}$$

where ΔY (yield) implies the yield component of the growth in gross agricultural productivity and $\Delta Y_{sci}(F) = (\Delta F_{sci}) b_F$, etc., show the contribution of strategic and climatic factors in the growth of crop yields.

42. For controlled observations, see Annual Reports of All India Co-ordinated Agronomic Experiments Scheme, Indian Council of Agricultural Research, New Delhi. For partially controlled observations on yardsticks, see Panse, Abraham and Leclavati: *op. cit.* and Kirit Parikh, T. N. Srinivasan *et al.*: Optimum Requirement of Fertilisers for the Fifth Plan Period, Indian Statistical Institute, Planning Unit, New Delhi, 1974 (mimeo.).

43. See Vaidyanathan, *Economic and Political Weekly*, June 24, 1978, *op. cit.*, p. 1033 and section V of this paper.

44. See K. S. Krishnan, P. N. Soni and V. S. Rustogi, "Irrigation and Fertiliser Responses of Wheat, Maize, Jowar and Gram in I.A.D.P. Districts", *Fertiliser News*, Vol. XVII, No. 9, September 1972, pp. 50-55 and Vidya Sagar, *Economic and Political Weekly*, June 24, 1978, *op. cit.*