INVESTMENT, GROWTH AND WEATHER FLUCTUATIONS IN INDIA

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Analysis of growth process in India with the help of variations in factor-use does not yield significant results. The role of exogenous factors like weather resulting in frequent cyclical movements in output, and of inflation causing an erosion of the real value of the financial investment are the two basic factors for the below-target level performance. They are yet to receive the attention of planners.

An effort is made here to explain variations in growth rates of the Indian economy with the help of an elementary growth model incorporating (a) rainfall as a measure of weather along with (b) the ratio of the moving averages of investment to income, and (c) deviations of a national index of rainfall from its normal value.

I

ECONOMICS, PLANNING AND WEATHER

Existing body of empirical literature on Indian economy in the form of macro econometric models contains an explanation of the output levels, in either aggregate or sectoral terms, through the production function approach. Agricultural sector, because of its size and fluctuations in output, assumed importance in many of the research works. Land, capital stock and labour were the factors generally used as the explanatory variables. A few of them even sought to incorporate rainfall as one way or the other as a causal variable. Analysis of the growth pattern with the help of such production functions was an attempt to synchronise the role of supply bottlenecks with demand constraints in an overall Keynesian framework. Surprisingly, while the trend movements in output received considerable attention, there has been no focus on explaining the causes for and role of cyclical fluctuations in the economy. An early attempt to trace the effects of agricultural cycles on the economy in general and implications for monetary policy can be seen in Ramachandra (9).

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The results of this study were first published in a seminar at the Institute of Economic Growth, Delhi, in April 1975 and again with a slight variation at the Delhi School of Economics in December 1980, where cyclostyled copies containing the basic results were distributed. The unusual length of the lag in formalising the study into a research paper (for a number of unavoidable and avoidable reasons) apart, the potential of the theme dealt with in drawing the attention of research workers has proved to be significant in that a few more attempts have recently been publicised.

1. N V A Narasimham, Ramgopal Aggarwala, N K Chowdhary, K Krishnamurthy, Thampy Mammen, Kanta Marwah, V N Pandit, G S Gupta, etc., are only a few of those who dealt with aggregate models of the economy having an analysis of the production sector though with a varying focus—on the determination of nominal income, price level, equilibrium of the monetary sector, etc. Ramgopal Aggarwala and N K Chowdhary were the only two who used some measure of rainfall as an explanatory variable in the agricultural production function.
INVESTMENT, GROWTH AND WEATHER FLUCTUATIONS

With an irrigation system yet to be strengthened to provide continuous support to steadily increase the output of the agricultural sector, the largest component of national income, nature continues to wield the power of arbitrating upon the results of the production efforts in most of the developing countries. The impact of weather fluctuations on growth rates of output is so significant that their non-inclusion as a causal variable in the production function leaves a substantial variation unexplained and cannot be compensated by the use of any spurious variable or sophistication in methodology. The role of savings-income ratio, factors determining its behaviour and interaction with techniques of production in determining the growth process of the Indian economy over the initial Four Plans were analysed cogently in Chakravarty (3). However, one does not find a reference to the fluctuations caused by exogenous factors directly, and indirectly through savings-income ratio on the pattern of growth. Similarly, in an earlier historical analysis of the development process in India over the past century and half by Bhatt (2), one does not find a reference to the role of weather factors. The size and frequency of the agrarian cyclical fluctuations cannot be left aside in any meaningful analysis of the growth problems in India. While Rudra (12) dealt with the statistical problems like measurement of growth rates, Mukherjee (8) presented a discussion on the factoral sources of growth processes in India over long period. But neither of them, the latter makes a casual reference, tried to relate them to anything like weather movements. Ramdas (10) made a worthy attempt in analysing rainfall and agricultural output movements in India over a long period. Among other empirical works, mention can be made of Ueno (15), Ueno and Kinoshita (14), Aggarwalla (1), Chowdhury (4), Cummings, Jr. and Ray (5) and Ray (11). Cummings and Ray (5) estimated cereal yields as a function of rainfall and time trend in linear and quadratic forms for the period 1951-52 to 1966-67 and found a significant non-linear effect of variations in rainfall on yields. The index of rainfall was computed cropwise as a weighted average of the levels of rainfall of 31 weather zones of the country with acreages as the weights. In another work as part of a comprehensive exploratory study for the empirical construction of Indian economy, Ray (11) tried to analyse weather-induced fluctuations in area, yields and production of 19 crops in three groups: foodgrains, oilseeds and cash crops, for 1949-50 to 1970-71. His conclusions generally showed the importance of the adverse effects of both too much and too low rainfall levels for each crop.

This is a preliminary attempt at tracing the effects of rainfall on the growth rate of aggregate real income in the Indian economy during the period 1951-71. The continuing predominance of the agricultural output, its vulnerability to the effects of weather variables like rainfall, temperature, stretch of sunshine, light, moisture, evaporation, wind speed, direction of winds, etc., are known. These dimensions of weather may often have an

2. Agricultural sector's income accounts for 42 per cent of the national income in real terms even today. A 10 per cent decrease in this component results in a direct decline of 4.2 per cent in the aggregate income. Through the linkage effects a further decrease in the output due to an adverse effect on the manufacturing and tertiary sector is expected to be to the extent of 1½ to 2½ per cent. This brings down the total output by a rate equal to or even higher than the planned growth rate. The effects through other channels like shrinkage of the tax base in quantitative terms and the need for financing subsidised wage goods intensify the strain on the econo-
indivisible relationship, in terms of their values, at several places and
this might simplify the number of combinations of their values that one has
to consider for a study.1 Even then the task of constructing a national
composite index of weather over a long period is so immense that it has
prompted the use of rainfall as the only measure of weather. One does not
see any objection to consider those very indivisibilities providing support
to the use of a single dimension of weather. If the other variables offshoot
their associative values in combination with the measures of rainfall, the
resultant effects then will be erroneously analysed. For example, a given
level of rainfall with higher wind speeds or higher evaporation may yield
different results than otherwise.2 Meteorological Department has made
some studies on droughts and floods and their causes. Though systematic
efforts are to be made in arriving at scientific estimates of losses to the
economy as a whole due to adverse weather conditions, the recurring enormous expenditure incurred on explicit grounds of adverse weather speaks out the need for evolving an appropriate method of analysing the role of weather in Economic Planning.

Section II contains a discussion on the specification of a model and of
methodological problems. Section III deals with the main results and their
consequences for policy. A detailed analysis of the agricultural output and
weather cycles in historical perspective and upto 1971-80 is presented in
this section. Some reference to the need for weather planning, not in terms
of conditioning of weather, but in terms of adapting economic planning to
weather is made in section IV.

II

AN ELEMENTARY MODEL SPECIFICATION

Let us first consider a linear proportionate relationship between
real income and capital stock.3

\[ y_t = \beta k_t \]  

\[ y_t \]  

\[ l_t = \Delta k_t \]  

\[ 1 \]  

The inverse of \( \beta \) gives the capital-output ratio value as a constant. On the
assumption of equality of average and marginal capital-output ratios, we
can write

\[ \Delta y_t = \beta l_t \]  

\[ \Delta y_{t-1} = \beta l_{t-1} \]  

\[ \Delta y_{t-1} \]  

\[ y_{t-1} \]  

\[ 1 \]  

\[ 1 \]

3. If we consider the measure of weather as a vector of elements located at a point in an n-dimensional space, the
spread of temporal locations of the vector in the space will be within a narrow bound because the position of these ele-
ments is relative to each other. Climatological tables show the combinations of about 13 components of weather—
stationwise, monthwise—normals and extremals on either side.

4. It is interesting to observe the cycle that the dominant elements of weather go through in different seasons. Tem-
peratures of summer, rains in the season, cold spells in winter followed by summer have a systematic linkage effect
establishing a predictable cyclical pattern over years. This is to say, we find a significant correlation between different
weather dimensions not only of contemporaneous values, but also of the seasonally lagged values of various measures
of weather.

5. This resembles an elementary version of the Harrod-Domar growth model.
\[ g_t = \beta \frac{l_t}{Y_{t-1}} \quad \cdots (4) \]

Capital formation usually has a lagged effect on growth. These gestation lags in development effort with accent on building up the infrastructure will be considerable in length and persistence of effects. Investment-income ratio also fluctuates around a perceptible trend because of variations in market expectations, strategies and goals of public policy and no less due to resource availabilities. Therefore, we take a form of moving averages of the two variables for investment-income ratio resulting in

\[ g_t = \beta \frac{\sum_{t-n}^{t} l_{t-i}}{\sum_{t-n}^{t} Y_{t-i}} \quad \cdots (5) \]

Relaxing the proportionality requirement, we get the form in which \( g \) is estimated as

\[ g_t = \alpha \cdot \beta + \sum_{t-n}^{t} l_{t-i} + \gamma R_t \quad \cdots (6) \]

The ratio of the nominal values of \( l \) and \( Y \), though may be different from the ratio of the real values, is proposed to be used, a decision justifiable on other grounds as well. But investment decisions being made in nominal terms it is justified to use this ratio on the assumption that the difference in the deflator movements is not significant. Further, it is known that expected changes in investment costs are not as yet an element affecting the level of proposed Plan investment expenditures.

That this specification does not explain movements in Indian growth rates being the prime contention, we alter the specification to include rainfall as an explanatory variable

\[ g_t = \alpha + \beta \frac{\sum_{t-n}^{t} l_{t-i}}{\sum_{t-n}^{t} Y_{t-i}} + \gamma R_t \quad \cdots (7) \]

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6. The issue of deflators for investment and income does not arise when we are using the ratio of the values estimated at fixed prices. Investment decisions are made in nominal terms and with a periodicity of more than one year. The use of moving averages over years takes into account to some extent this temporal lumpy nature of the investments though the annual budget allocations define the pattern. Further, investment cost does not figure in these decisions except at the time of estimating the total Plan requirements and interim variations either eat away into the real value or to be compensated by ad hoc and improvised (in the Plan shown) attempts to raise additional financial resources. This problem constitutes an element of the theme of the author's research dissertation on "Monetary Policy, Economic Growth and Price Stability in India" at the University of Delhi.
where $R_t$ is a measure of the national aggregate annual rainfall and represents in some sense, as discussed in section I, the overall weather conditions.

The exact form of relationship between output and rainfall will not be one in their absolute levels nor monotonic. Macro economic variables like output and investment register a trend over time but weather variables do not exhibit any such behaviour. Some long-term cycles are of course traceable in rainfall, temperature, moisture, etc., in addition to the normal short run cyclical (and seasonal) movements. Statistically, no clues can be obtained in analysing the linear relationship between two variables, one with a high trend and the other with only cyclical fluctuations. Further, even to the extent that we consider an increasing or decreasing phase of a rainfall cycle, the relationship will be one of asymmetry for both excess and deficiency of rainfall that will adversely affect growth rates.

To incorporate these improvements in the specification, it is necessary to define three concepts of rainfall — Base, Normal and Optimal. ‘Base’ rainfall may be taken as the level of $R$ in a particular year chosen for its normal conditions in the usual sense of the base year value of an index. The nomenclature ‘normal conditions’ again may be related to the rainfall in the sense of meteorological history or in terms of the general economic conditions, etc., influenced by it directly and indirectly. Without being arbitrary, it is necessary to note that such normal rainfall conditions vary from crop to crop which gets submerged in any aggregation towards a total national index. The concept of Normal rainfall is taken by the Meteorological Department as an arithmetic average measure of the reference period corresponding to past years over a discernible cycle or a sufficiently longer period. Polynomials and filters even are used to smoothen the fluctuations of a number of observations of the variables to obtain a trace of the ‘Normal’ weather. Normalcy has varying connotations in physical systems without weather-conditioning aids in any activity. There are purposewise or functional Normals as opposed to the absolute meteorological Normals which may be Economic Normals, Navigational Normals, Flying Normals, etc., and a number of others relating to controlled scientific experiments. Given the tendency to identify ‘Normal’ as the specification of an average level of performance (unlike human body temperatures), we define the economic concept of ‘Optimal’ rainfall as one that maximizes the rate of growth in national output in all its forms of contribution. Thus we have first

$$g_t = \alpha + \beta \frac{\sum_{i=0}^{n} I_{t-i}}{\sum_{i=0}^{n} Y_{t-i}} + \gamma (R_t - R^*) + \epsilon_t \quad \cdots \cdots \quad (8)$$

which shows that growth rate is related to the deviations of rainfall from its optimal level $R^*$. At times the effect of capital formation may be even fully nullified or compensated by these deviations when there exists an asym-
metric relationship. The adversities of floods and famines are not the same from the common knowledge experience. Hence we introduce a variable

\[ D(R_t - R^*) \text{ where } D = 0 \text{ for } R_t < R^* \text{ and } D = 1 \text{ for } R_t > R^* : \]

\[ g_t = \alpha + \beta \sum_{i=0}^{n} \frac{I_{t-i}}{Y_{t-i}} + \gamma (R_t - R^*) + \delta D (R_t - R^*) + \epsilon_t \quad \cdots \cdots (9) \]

The effect of excess rainfall measured from the regression estimates will be given by \((\gamma + \delta)\) since \(D = 1\) and the effect of deficiency is given by \(\gamma\) since \(D = 0\).

Is the ‘Optimality’ of rainfall independent of the level of investment? Investment-income ratio has been increasing and absorbed by increasing capital intensity as well as larger number of programmes and projects. Rainfall is exogenous to the system. Investment decisions in agriculture are to a significant extent based upon anticipated as well as realized rainfalls at various stages of the production processes. Inventory investment in manufacturing sector is related to the actual availability of inputs determined by the production levels of the corresponding segments in the agricultural sector. A part of the investment cushioning adverse effects of weather—particularly tapping of groundwater sources, building up dams and reservoirs, drainage systems, etc.—cannot be taken as influencing the ‘Optimal’ level of rainfall. At best, it can vary the rate at which growth rate declines for excess and deficient rains around the given ‘Optimal’ level. The relationship thus runs from \(R_t\) to \(\frac{1}{Y}\).

The concepts of Normalcy and Optimality and the Base for Aggregate Rainfall Index are taken to be the same at \(R^* = 100.0\). The relevance of this assumption can be proved as follows: Let us define \(R = 100.0\) as the Normal (as well as Base period) rainfall and the Optimal rainfall be \(X \neq 100.0\). Then we have

\[ g_t = \alpha + \beta \sum_{i=0}^{n} \frac{I_{t-i}}{Y_{t-i}} + \gamma (R_t - R) + \delta D (R_t - X) + \epsilon_t \quad \cdots \cdots (10) \]

With the assumption that \(D = 1\) for \(R > X\) and \(D = 0\) for \(R < X\), we have the growth maximizing level of rainfall (Optimal) at \(X \neq R = 100.0\). For all \(R < R_t < X\), \(g_t\) will be expected to be an increasing function of \(R_t\) and \(R_t > X\) produces adverse effects. An interesting feature of this specification is for \(R_t = R\), rainfall has no adverse effects on \(g_t\) except as acting as a complementary input (or a catalyst). For values \((R_t < R)\) and \((R_t > X)\) the negative effects can be seen. For \((R < R_t < X)\) the larger is the value of
R_t the greater will be the beneficial effect of rainfall. (In such formulation the signs of \( \gamma \) and \( \delta \) may be expected to be opposite.)\(^7\) The assumption that Normal and Optimal rainfalls are different results in the following conclusion. Normal rainfall is one which assumes no direct influence of rains on growth rates except by way of helping to realize the full benefits of investment. In this sense rainfall will be perhaps a mere catalyst. Optimal rainfall is one which maximizes the growth rate by taking into account both the roles of rainfall—one to enable the realization of full benefits of other inputs (complementary), and the other, directly contributing towards the output (compensatory).\(^8\) The value of \( X \) taken to be the growth-maximizing one has to be empirically determined by iteration.

The comparative superiority of the specification over alternatives with those using all the variants—gross and net values, output and income, sectoral and aggregate measures, expected and realised values, absolute levels and proportions, domestic capital and foreign capital and other nonlinear forms—was empirically established before presenting the basic result. "Estimates of Net National Product in India" published by the Central Statistical Organisation provided the source of data for national income (GDP), price level and capital formation. Data for Rainfall Index was obtained from Ray (11). Computed series of Index of Rainfall can be obtained from the author on request.

III

WHEN AND HOW DOES WEATHER MAXIMIZE GROWTH?

Estimated regression equation of the specification approved in the earlier section using the current and two past period values of \( I \) and \( Y \) for investment-income ratio is given by

\[
g_t = 0.0214 + 0.2602 \left( \frac{\sum_{i} I_{t-1}}{0.939} \right) + 0.0035 (R_t - 100.0) + 0.00374 D (R_t - 100.0) \left( \frac{\sum_{i} Y_{t-1}}{6.118} \right) - \frac{0.00374}{(4.614)} \left( R_t - 100.0 \right) \]

\[ R^2 = 0.736 \]

\[ D-W = 2.2302 \]

\[ \text{.....(11)} \]

7. The asymmetric effects can be estimated with the help of a quadratic functional form also. The results of this and other functional forms were discussed for their comparative merits, statistical and otherwise, before arriving at the chosen form. Here we report a result

\[
g_t = 0.00596 + 0.2754 \left( \frac{\sum_{i} I_{t-1}}{0.231} \right) + 0.00177 (R_t - 100) \left( \frac{\sum_{i} Y_{t-1}}{1.868} \right) - 0.000039 (R_t - 100) \left( \frac{\sum_{i} Y_{t-1}}{4.744} \right) \]

\[ R^2 = 0.645, \]

\[ D-W = 2.2776. \]

8. It will be a task to resolve the complications in determining the optimal level of water input in view of its dual role particularly when there is choice about the combination of other inputs. It is known that larger doses of fertilizer also generate larger demand for water. The exogeneity of the input (to a considerable extent) and the costs of streamlining its supplies should be taken note of in the choice of agrarian techniques.
Identifying the coefficients as per the notation used in the earlier section

\[
\alpha = 0.0214 \quad \beta = 0.2602 \quad \gamma = -0.00374
\]

\[D = 1 \text{ for } R \geq 100.0\]
\[= 0 \text{ for } R < 100.0\]

For values of \( R \geq 100.0 \), the net effect of rainfall for each unit increase is given by \((0.0035 - 0.00374) = -0.00024\) as \( D = 1.0 \). This depresses the growth rate induced at any level of investment.

For values of \( R = 100.0 \), the complementarity of rainfall is brought out by directly taking into account only the effect of investment on the growth rate.

For values of \( R < 100.0 \), the negative contribution of each unit decline in rainfall will be given by \(-0.0035\) as \( D = 0 \) and the value of the third variable will be zero. The decline in \( g_t \) is faster for \( R < 100.0 \) than for \( R \geq 100.0 \). The adverse effect of any deviation from \( R_t = 100.0 \) is thus clearly shown to be asymmetric for excess and deficient rainfall levels.

The elasticity of response in the growth rate to a one per cent variation in the investment-income ratio at the average levels of the variables is 0.814, given normal weather conditions. An interpretation of \( g \) as the inverse of (incremental) capital-output ratio would give us a value of the ratio of 3.842 (given by \( 1 / 0.2602 \)). This figure tallies with a number of estimates given by various works including documents on strategy, mid-term appraisals and final performance reports of various Plans. The sign and size of \( \alpha \) and \( \delta \) show that the optimal value of \( R \) is at \( R^* = 100.0 \) that maximizes the growth rate. Statistical significance of the coefficients, high explanatory power in terms of \( R^2 \), and the absence of serial correlation in the residuals as shown by the D-W statistic provide the basis to approve of the equation. Neither the lag structure nor the non-linearities present in the form of ratios create any specific problems for using linear regression method because of the very definition of the variables in that form, and non-reference to any compulsion for using a structural model. A more detailed discussion on this issue is presented in section IV. Growth rates estimated for the period of coverage with the equation, and the actual rates along with the percentage errors are presented in Table I.

The results estimated for 1971-72 to 1979-80 using this equation under a set of assumptions about the weather conditions are presented towards the end of this section.

The predicting ability of the model with an error margin of \(-2/5\) to \(+2/5\) of the actual rates of growth for the period suggests the possibility of improving its performance with the inclusion of other explanatory varia-

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9. Average growth rate and investment-income ratio over the period under consideration are 3.826 and 15.138 respectively. Elasticity is given by \( \beta(1/g) \) (i.e., \( 0.2602 \times \frac{15.138}{3.826} \)) = 0.814.

10. It is to be noted that the specification is obtained on the assumption of equality of average and marginal capital-output ratios.
TABLE I—ACTUAL AND ESTIMATED GROWTH RATES

<table>
<thead>
<tr>
<th>Year</th>
<th>$\dot{G}_{GDP}$</th>
<th>$\hat{G}_{GDP}$</th>
<th>Deviation</th>
<th>Percentage deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1951-52</td>
<td>2.2</td>
<td>2.4</td>
<td>-0.2</td>
<td>-9.80</td>
</tr>
<tr>
<td>1952-53</td>
<td>3.4</td>
<td>2.5</td>
<td>0.9</td>
<td>26.40</td>
</tr>
<tr>
<td>1953-54</td>
<td>6.2</td>
<td>4.3</td>
<td>1.8</td>
<td>42.551</td>
</tr>
<tr>
<td>1954-55</td>
<td>2.7</td>
<td>3.7</td>
<td>-0.9</td>
<td>-25.580</td>
</tr>
<tr>
<td>1955-56</td>
<td>3.6</td>
<td>3.8</td>
<td>-0.2</td>
<td>-6.114</td>
</tr>
<tr>
<td>1956-57</td>
<td>5.3</td>
<td>4.0</td>
<td>1.4</td>
<td>33.848</td>
</tr>
<tr>
<td>1957-58</td>
<td>-0.7</td>
<td>-1.0</td>
<td>0.3</td>
<td>-28.238</td>
</tr>
<tr>
<td>1958-59</td>
<td>7.8</td>
<td>8.7</td>
<td>2.1</td>
<td>37.681</td>
</tr>
<tr>
<td>1959-60</td>
<td>-3.1</td>
<td>5.3</td>
<td>-3.2</td>
<td>-60.890</td>
</tr>
<tr>
<td>1960-61</td>
<td>6.6</td>
<td>8.4</td>
<td>1.2</td>
<td>21.769</td>
</tr>
<tr>
<td>1961-62</td>
<td>3.7</td>
<td>5.8</td>
<td>-2.1</td>
<td>-36.028</td>
</tr>
<tr>
<td>1962-63</td>
<td>2.8</td>
<td>4.9</td>
<td>-2.1</td>
<td>-41.983</td>
</tr>
<tr>
<td>1963-64</td>
<td>5.5</td>
<td>4.1</td>
<td>1.5</td>
<td>35.967</td>
</tr>
<tr>
<td>1964-65</td>
<td>7.4</td>
<td>6.2</td>
<td>1.2</td>
<td>19.808</td>
</tr>
<tr>
<td>1965-66</td>
<td>-5.1</td>
<td>-3.4</td>
<td>-1.7</td>
<td>49.428</td>
</tr>
<tr>
<td>1966-67</td>
<td>1.7</td>
<td>0.6</td>
<td>1.1</td>
<td>187.225</td>
</tr>
<tr>
<td>1967-68</td>
<td>9.1</td>
<td>7.3</td>
<td>1.8</td>
<td>24.691</td>
</tr>
<tr>
<td>1968-69</td>
<td>2.5</td>
<td>1.2</td>
<td>1.3</td>
<td>104.564</td>
</tr>
<tr>
<td>1969-70</td>
<td>5.2</td>
<td>6.6</td>
<td>-1.4</td>
<td>-21.813</td>
</tr>
<tr>
<td>1970-71</td>
<td>4.5</td>
<td>6.5</td>
<td>-2.0</td>
<td>-30.848</td>
</tr>
</tbody>
</table>

bles to further reduce the margin of deviations (only few extreme values lie outside the range of deviations). One might think of labour, technical progress, cultivated area of land, improvement in soil fertility, etc., as the possible direct elements of the unexplained contribution to the growth rates of national income in the economy. (Supply of labour-base in different academic or occupational categories is not a constraint on our planning yet.) While the sacrifice of consumption involved in capital formation proves to be a constraining factor, the large base of population, its rate of growth and increased supplies of educated manpower do not necessarily call for its being considered as a constraining factor. Cultivated area of land is likely to provide an explanation to the residual variation. With an upward trend over the period, the variable may have to be used in terms of its annual incremental values if it were to explain the cyclical pattern observed in error terms. It is to be remembered that the total cultivated area as well as its cropwise allocation affects the growth rates, and the method of constructing the rainfall index has used only the crop composition of the production index.

Whatever may be the growth maximizing level of the rainfall index, there exists two values of $R_t$, one each on its (the growth-maximizing level) either side to nullify the effect of investment and equate $\xi_t$ to zero. The asymmetry built into the function position the pair of values at unequal distance from the optimal value. With increasing investment-income ratio the pair of values move in the same absolute direction, outdistance the earlier one in the severity of natural calamity of excess rainfall and move towards the normal level with shortages of rainfall if the growth effects of higher rates of capital stock creation have to be nullified. This
can be seen from Table II. The values are estimated from the equation for various values of I/Y ratio.\textsuperscript{11}

\begin{center}
\textbf{TABLE II—VALUES OF RAINFALL INDEX TO EQUATE \( g_t \) TO 0.0}
\end{center}

<table>
<thead>
<tr>
<th>I/Y (Percentage)</th>
<th>( R_1 ) (Index value)</th>
<th>( R_2 ) (Index value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>298</td>
<td>79</td>
</tr>
<tr>
<td>15</td>
<td>352</td>
<td>83</td>
</tr>
<tr>
<td>20</td>
<td>406</td>
<td>87</td>
</tr>
<tr>
<td>25</td>
<td>460</td>
<td>91</td>
</tr>
</tbody>
</table>

\( R_1 \) = Measure of excess rainfall.  
\( R_2 \) = Measure of deficient rainfall.

\( R_1 \) on the right hand side and \( R_2 \) on the left hand side of the optimal value show that approximately an increase of 54 points of excess rainfall and a mere 4 points of decrease in rainfall index are required to nullify the effects of an additional 5 per cent of national income allocated towards capital formation. The greater ability of the economy to absorb the adverse impact of excess rainfall than that of its shortage, without severely impairing its productive efforts, is demonstrated by these estimates. An interesting possibility would be unequal differences in rainfall levels on either side of the normal value nullifying the positive effect of a given incremental percentage of national income allocated to capital formation. It can be incorporated only in a more complicated specification and the composition of investment may have to be then taken into account.

That no Planwise behaviour of the error terms could be observed (see Table I) brings out the following conclusions relevant either separately or together: (a) the predominant influence of the selected explanatory variables; (b) validity of the specification for all the successive Plans showing the pervasive force of the perspective planning concept beneath the periodic investment decisions; (c) the inflow of foreign capital considerably during the Second and Third Plans did not prove to be different from capital formation with domestic savings as far as the immediate present and future growth rates were concerned.\textsuperscript{12} This is to say, any strategic role played by the foreign capital in determining the growth process beyond the three-period lag is not taken note of except through any possible effects on subsequent capital formation.

Omission of the Dummy variables results in a linear and monotonically increasing function with an increasing growth rate corresponding to increasing amounts of rainfall therefore and there exists no ‘optimal’ level. Growth rates estimated for different values of \( R_t \) in sequence using the linear function’s parameters increased from 4.71 at \( R_t = 95.0 \) to 5.31 at \( R_t = 100 \) and 5.91 at \( R_t = 105 \), with a 0.12 per cent increase for every one point increase in rainfall index. While the function with provision for asymmetry gives 7.4 as the highest growth rate at \( R = 100.0 \) with a 20

\textsuperscript{11} Problems relating to the estimation of national income from equations with levels of the variables are discussed in the study referred to in footnote 6.

\textsuperscript{12} Assuming a differential impact of I/Y on \( g \) for the period of 1956-57 to 1965-66 with the highest quantum of foreign capital inflows, the function was estimated with a dummy variable but no significance could be found in the resulting equation.
per cent of national income used in capital formation, this function without Dummy gives a growth rate of 5.31 at \( R = 100.0 \) with the same ratio of I/Y which goes on increasing with the value of \( R \). An interesting observation to be made here is that while nature provides the constraint on the amount of rainfall that actually occurs, the function may as well take note of non-asymmetric possibilities. A counter example that is immediate is the occurrence of crop losses within the range of observed past values of excess rainfall that needs to be taken note of. The incongruity of this result is only too obvious to be analysed any further. One might however concede to some extent the argument that the monotonicity of the function for \( R \neq 100.0 \) to be realistic within a narrow range of deviation beyond which the depressive effects of abnormal weather begin to be felt. The explanatory power of the estimated parameters is also substantially lower fortifying the assumption that this specification will not be appropriate.

Earlier we have stated that the optimal level of \( R \) is not only the level that maximizes the growth rate (i.e., economic optimum) for any given level of investment but is also the statistical optimum giving highest value of coefficient of determination with the absence of any significant serial correlation in the residuals. The optimal level cannot be \textit{a priori} taken to be the ‘Base’ value of the index number but has to be obtained from an iterative computation. We take \( R^* \neq X \) where \( R^* \) is the ‘normal’ rainfall and \( X \) is the ‘economic optimum’. The purpose of attempting to locate for the turning point, growth-maximizing level, a value other than the ‘normal’ rainfall level is to look for any possible range within which the growth rate may not be maximized on account of various factors like investment decision, risks and expectations, even availability of specific composition of goods, etc. The specification rules out the location of any such value on the lower side of \( R^* = 100.0 \) (i.e., deficiency in rainfall) for the value of the explanatory variable becomes zero with \( D \) defined to be equal to 0.0. While the effects of a slightly excess rainfall can be cushioned through seepage, evaporation, drainage, evapotranspiration, storage, controlled irrigation system, etc., shortage of rainfall cannot be compensated without considerable immediate additional expenditures on alternative sources of supply like tubewells, pumps, etc. It is however known that except groundwater use through tubewells and pumps, all other forms of irrigation depend upon rains either from season to season or from year to year and at any rate a maximum of two years with shortage of rainfall if the river valley dams have adequate storage facilities and water for that period. In fact, the immediate cushioning factors for rainfall may prove to be beneficial for future growth rate given the lag structure in the relationship.

Let us look at the coefficients of \( \frac{\Sigma_{t-i}}{\Sigma Y_{t-j}} \) for the iterative values of \( X \) in order to find out if there exists such consistent value. The value of \( 1/\beta = 3.84 \) at \( X = 100.0 \) moved upto 3.89 at \( X = 102.0 \) and subsequently slid down to 3.66 at \( X = 112.0 \) to get stabilised at that level for subsequent iterations. Table III shows the values of \( X \) and corresponding \( 1/\beta \).
## Table III—Iterative Values of X and Estimated Equations

<table>
<thead>
<tr>
<th>X</th>
<th>α</th>
<th>β</th>
<th>γ</th>
<th>δ</th>
<th>ΔK/Δo</th>
<th>r*</th>
<th>D-W</th>
</tr>
</thead>
<tbody>
<tr>
<td>101</td>
<td>0.0197</td>
<td>0.2552</td>
<td>0.0033</td>
<td>-0.0036</td>
<td>3.92</td>
<td>0.732</td>
<td>2.231</td>
</tr>
<tr>
<td></td>
<td>(0.863)</td>
<td>(1.800)</td>
<td>(6.085)</td>
<td>(4.557)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>102</td>
<td>0.0180</td>
<td>0.2505</td>
<td>0.0032</td>
<td>-0.0035</td>
<td>3.99</td>
<td>0.726</td>
<td>2.215</td>
</tr>
<tr>
<td></td>
<td>(0.783)</td>
<td>(1.747)</td>
<td>(6.016)</td>
<td>(4.372)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>105</td>
<td>0.0099</td>
<td>0.2621</td>
<td>0.0028</td>
<td>-0.0032</td>
<td>3.81</td>
<td>0.683</td>
<td>2.114</td>
</tr>
<tr>
<td></td>
<td>(0.404)</td>
<td>(1.700)</td>
<td>(5.459)</td>
<td>(3.823)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>110</td>
<td>0.0034</td>
<td>0.2716</td>
<td>0.0024</td>
<td>-0.0029</td>
<td>3.68</td>
<td>0.603</td>
<td>2.121</td>
</tr>
<tr>
<td></td>
<td>(0.126)</td>
<td>(1.575)</td>
<td>(4.591)</td>
<td>(3.079)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>112</td>
<td>0.0018</td>
<td>0.2731</td>
<td>0.0022</td>
<td>-0.0028</td>
<td>3.66</td>
<td>0.560</td>
<td>2.242</td>
</tr>
<tr>
<td></td>
<td>(0.061)</td>
<td>(1.504)</td>
<td>(4.194)</td>
<td>(4.194)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>114</td>
<td>0.00088</td>
<td>0.2732</td>
<td>0.0022</td>
<td>-0.0027</td>
<td>3.66</td>
<td>0.534</td>
<td>2.298</td>
</tr>
<tr>
<td></td>
<td>(0.030)</td>
<td>(1.462)</td>
<td>(3.978)</td>
<td>(2.452)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>115</td>
<td>0.00052</td>
<td>0.2730</td>
<td>0.0021</td>
<td>-0.0027</td>
<td>3.66</td>
<td>0.523</td>
<td>2.319</td>
</tr>
<tr>
<td></td>
<td>(0.017)</td>
<td>(1.443)</td>
<td>(3.885)</td>
<td>(2.350)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Each growth profile for successive iterations of X (for each X we obtain a profile of g at different values of R_t on either side of X) attains its maximum at the specific value of R_t = X. For values of X = (101, 104), 1/β is greater than its corresponding value for X = 100.0 with its maximum value at X = 102. It shows that for any given investment-income ratio, for a rainfall range (101, 104), we find higher capital-output ratio reflecting either an unutilized capacity of capital stock or, as a strategy of capital intensive production techniques for the same composition of output or, even a different product-mix feasible only with a higher ratio.

It will be interesting to evaluate the ability of the function in providing meaningful estimates of growth rates for the subsequent period, i.e., from 1971-72 to 1979-80. Using the equation (11), growth rate estimates were projected with the help of the actual investment-income ratio (moving averages of the current and the past two values) and assuming R_t to be consistently equal to 100.0 (Normal) for this period 1971-72 to 1979-80. Values of \( \hat{g}_{GDP} \) thus obtained came closer to the actual \( g_{GDP} \) in 1973-74 and 1977-78. The years 1971-72 and 1974-75 turned out to be those of wide gaps between the two. If movements in some measure of aggregate rainfall can explain (\( g_{GDP} - \hat{g} \)), we find ourselves content with the functional form chosen and the equation estimated.

Troughs shown by the agricultural production index in 1972-73, 1974-75 and 1976-77 with extreme conditions of rainfall along with lower growth rates show the transmission process.
**TABLE IV—GROWTH RATES, AGRICULTURAL PRODUCTION INDEX, RAINFALL CONDITIONS, 1971-1980**

<table>
<thead>
<tr>
<th>Year</th>
<th>( \theta_{GDP} )</th>
<th>( \wedge \theta_{GDP} )</th>
<th>( \theta_{t} )</th>
<th>( \sum Y_{GDP} )</th>
<th>( \sum I_{GDCP}^{(c)} )</th>
<th>Normal</th>
<th>Excess</th>
<th>Deficient</th>
<th>Normal</th>
<th>Excess</th>
<th>Deficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971-72</td>
<td>-4.60</td>
<td>6.82</td>
<td>-11.42</td>
<td>111.2</td>
<td>18.4</td>
<td>17</td>
<td>10</td>
<td>7</td>
<td>9</td>
<td>11</td>
<td>14</td>
</tr>
<tr>
<td>1972-73</td>
<td>1.13</td>
<td>6.76</td>
<td>-5.63</td>
<td>102.3</td>
<td>16.9</td>
<td>15</td>
<td>3</td>
<td>1</td>
<td>19</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>1973-74</td>
<td>5.50</td>
<td>6.71</td>
<td>-1.21</td>
<td>112.4</td>
<td>20.0</td>
<td>28</td>
<td>6</td>
<td>1</td>
<td>10</td>
<td>16</td>
<td>9</td>
</tr>
<tr>
<td>1974-75</td>
<td>0.80</td>
<td>6.94</td>
<td>-6.14</td>
<td>108.8</td>
<td>18.9</td>
<td>15</td>
<td>3</td>
<td>17</td>
<td>11</td>
<td>9</td>
<td>15</td>
</tr>
<tr>
<td>1975-76</td>
<td>3.90</td>
<td>7.35</td>
<td>-3.45</td>
<td>125.3</td>
<td>20.5</td>
<td>17</td>
<td>17</td>
<td>1</td>
<td>11</td>
<td>15</td>
<td>9</td>
</tr>
<tr>
<td>1976-77</td>
<td>2.50</td>
<td>7.62</td>
<td>-5.12</td>
<td>116.5</td>
<td>21.3</td>
<td>26</td>
<td>6</td>
<td>3</td>
<td>5</td>
<td>7</td>
<td>28</td>
</tr>
<tr>
<td>1977-78</td>
<td>8.20</td>
<td>7.63</td>
<td>0.63</td>
<td>133.4</td>
<td>22.3</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>1978-79</td>
<td>4.10</td>
<td>—</td>
<td>—</td>
<td>137.3</td>
<td>24.1</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>1979-80</td>
<td>-5.00</td>
<td>—</td>
<td>—</td>
<td>21.8</td>
<td>4</td>
<td>7</td>
<td>24</td>
<td>4</td>
<td>14</td>
<td>17</td>
<td>—</td>
</tr>
</tbody>
</table>

(a) Values in parentheses are percentage deviations.

(b) Production index relates to all commodities with end year 1969-70 triennium as the base year equal to 100.0.

(c) Values correspond to actual levels during the year while those in parentheses are moving averages of current and past two values.

(d) These observations are numbers of rainfall subdivisions categorized as ‘Normal’, ‘Excess’ and ‘Deficient’ zones during monsoon and post-monsoon periods. The source for this data is Weekly Rainfall Reports, Indian Meteorological Department, Government of India.

No divergent trend was found in growth processes of various Plans that might have occurred possibly at the micro level because of differences in sources of capital formation or strategies or priorities. The aggregate performance of the economy was transacted to be almost the same throughout except the First Plan.

IV

**ALL THE REST ABOUT WEATHER — MEASUREMENT, IMPACT, CONDITIONING, ETC.**

The role played by weather variables in our country stresses (1) the need for systematic efforts towards improving our predicting ability of their movements, and (2) estimate losses to the economy in terms of output and employment, etc.
It is interesting to note that most of the knowledge acquired about the nature and causes of severity in weather around the world did not prove to be significantly helpful in controlling adverse weather as is discernible from an increased frequency of occurrence and magnitude of adverse impact on life, movement, goods, services, etc., of the eruption of weather elements like tornadoes, hurricanes and so on. Owing to the transnational impact of and effects on natural and civic rights of the citizens, legal implications of the weather-conditioning efforts have also drawn the attention of conscientious experts.13

Alteration (and creation) of weather are not only not warranted but positively uneconomical from the point of view of economic activity undertaken on a national or regional level.14 This may prove to be so even from the point of view of ecological balance and efficiency of bio-systems. The economic activity has been over years conditioned by the physical resources and secular weather trends.15 ‘Weather Conditioning’ only has to take the shape of creating infrastructure against cyclical fluctuations and levelling up the seasonally inactive periods. Capital formation of this nature coupled with advance weather predicting methods serves the purpose of realisation of the goals of economic planning with reduced uncertainties.

REFERENCES

9. V.S. Ramachandra, "Long Term Demand for Money in India 1900-1971 and Income Velocity Behaviour", Institute of Economic Growth, Delhi, 1974 (a part of the author’s dissertation) (mimeo.).


14. The subject of Economics of Weather has become a course of formal study at Universities and Colleges long ago and reflects the importance attached to it by those economies. Maunder (7) and Taylor (13) are pioneering works and in Indian case Ramdas (10) is an early outstanding work.

15. Events like temple festivals, PushkaraS of rivers, etc., have periodicity of recurrence related to the natural cycles of weather. It not only speaks of the amazing rhythm of nature but the amazing discoveries of the traditional man. Similarly, marriages, etc., in rural areas usually scheduled to be held in years of expected surplus produce.


