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AN EMPIRICAL INVESTIGATION OF THE NATURE AND CAUSES FOR GROWTH AND INSTABILITY IN INDIAN AGRICULTURE: 1950-80

S. K. Ray*

I

INTRODUCTION

One of the popular topics for research in Indian agriculture is growth and instability in crop production. The focus in most of the studies on the subject so far, however, has been confined to the measurement aspects. Except for providing some conjectures and tentative hypotheses, very few have attempted to examine empirically why the growth has accelerated or decelerated; or, why the instability in production has increased or decreased. Measurements too are made on purely statistical criteria without any theoretical justification regarding the selection of time period or choice of the model. The implications of these models for growth and instability analysis, as pointed out by Reddy, "are quite opposite in nature .... (and going by statistical criteria alone) the researcher can get away with whatever he wanted to show."[1]

Indeed, so great has become the confusion on the subject that the Indian Society of Agricultural Economics had to organize a seminar in 1980 in order "to focus attention on some of these questions and .... to provoke further discussion which is necessary, if the scepticism which seems to be creeping into this area is to be prevented."[2] Needless to report, the discussion that followed in the seminar was "by no means unanimous on many issues and indeed on certain critical questions it was sharply divided."

In a sense, the present paper will be one more addition to existing literature on the subject. We will, however, attempt to probe in a little deeper, and analyse the nature and causes for growth and instability in Indian agriculture during the period 1950 through 1980.[3] We will examine whether the pattern of growth and instability in crop production has recorded any significant change and test some of the suggested hypotheses by analysing the factors which are commonly held responsible for production fluctuations. Basic data for our investigation will be the official index numbers for area, production, yield and cropping pattern.

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* This paper is adopted from a larger version, Growth and Instability in Indian Agriculture, Institute of Economic Growth, Delhi, June 1983.

1. V. N. Reddy, "Growth Rates", *Economic and Political Weekly*, Vol. XIII, No. 19, May 13, 1978.
2. See V. M. Dandekar, "Introduction to Seminar on Data Base and Methodology for the Study of Growth Rates in Agriculture", *Indian Journal of Agricultural Economics*, Vol. XXXV, No. 2, April-June 1980. One wonders whether for provoking further discussion, Dandekar has deliberately allowed some mathematical mistakes in his excellent introduction !
3. Throughout the text, the agricultural year is identified as a single year corresponding to the calendar year in which the *rabi* harvest cocurred. Thus, 1950 is the 1949-50 agricultural crop year.

The paper is organized as follows. Section II examines the sources of change in the pattern of growth and instability in production arising due to area, yield and cropping pattern changes. Methodological issues for analysing the nature and causes for change in the pattern of growth and instability in production are then outlined in section III. This is followed in section IV by testing empirically a number of hypotheses relating to the causes for change in the pattern of growth and instability in production. Finally, some observations relevant for policy purposes which follow from this study are discussed in the last section.

II

SOURCES OF CHANGE IN THE PATTERN OF GROWTH AND INSTABILITY IN PRODUCTION

The methodology adopted by the Ministry of Agriculture, Government of India in the construction of index numbers (base triennium ending in 1970 = 100) allows a multiplicative decomposition of the production index 0_t for the year t for any individual crop or crop aggregate into its three constituent components—index of area A_t, index of yield Y_t, and index of cropping pattern C_t.[4] Thus, for any individual crop or crop aggregate, the following identical relation holds for any year t:

$$0_t = A_t \times Y_t \times C_t \times (100)^{-2} \qquad \ldots. \quad (1)$$

Taking first difference of the logarithm to the base 'e' of (1) and noting that for positive Z_t, $\log_e (Z_{t+1}/Z_t)$ is approximately equal to annual growth rate G_{zt} of Z at time t, we thus get

$$G_{ot} = G_{at} + G_{yt} + G_{ct} \qquad \ldots. \quad (2)$$

Clearly, over a time period of specified length T, the year-to-year changes in production and in its three constituent components will not remain constant, unless their respective paths precisely follow an exponential function of time over the period. Also, as the total log-change between the two end points of a period is the sum of the intervening one-year log-changes, simple averaging of the annual growth rates of a component may not provide a reliable summary measure of its growth rate over the entire period unless the annual rates are averaged with appropriate weights.[5] However, decomposi-

4. Following the official definition for all crops cropping pattern index, similar cropping pattern indices are defined and constructed for different crop aggregates. Evidently, for an individual crop the cropping pattern index will be always 100 while for a crop aggregate it will differ from 100 whenever the cropping pattern within the aggregate deviates from its base year pattern.

5. This is true since $\frac{1}{T} \log_e (Y_{t+T}/Y_t) = \frac{1}{T} \sum_{s=1}^{T} \log_e (Y_{t+s}/Y_{t+s-1})$.

tion of the variability in annual output growth rates may help to identify the sources of change in the pattern of instability in production over different periods. Using (2), the variability in annual output growth rates over a specified period can be decomposed as follows:

$$V(G_o) = V(G_a) + V(G_y) + V(G_c)$$
$$+ 2Cov(G_a, G_y) + 2Cov(G_a, G_c) + 2\,Cov(G_y, G_c) \quad \ldots\ldots (3)$$

Year-to-year changes in the production index result due to changes in area, yield and cropping pattern indices. Since the relative emphasis in production strategy may change from period to period, the three components of output growth rate may trace similar or dissimilar patterns over different periods. The nature of the association between the patterns traced out by these components, however, are important as they influence the variability in annual output growth rates over a period. Variability in the annual output growth rate is reinforced if year-to-year changes in some or all of the three components are positively correlated; it is dampened if some or all of them are negatively correlated. In other words, instability in production increases if there is synchronised movements in the three components; it decreases if the patterns in movements become dissimilar.

The sign of the covariance terms in (3) may provide some insight regarding the production strategy that might have been followed during the period. Thus, under rainfed conditions, if intensive cultivation is practised with yield-augmenting and land-augmenting techniques like multiple cropping, area, yield and cropping pattern indices may become more sensitive to weather changes, and production may increase with increasing amplitude of fluctuations in it. On the other hand, if intensification of production is carried out under more controlled conditions with strengthening of land infrastructure facilities like irrigation, drainage, flood control, etc., variability in the annual growth rates may decline and production may increase at a fairly stable rate.

A decadewise decomposition analysis of the variabilities in the year-to-year changes in production provides some insight regarding the sources of change in the pattern of instability in the production index of various crops and crop aggregates.[6] Among the three decades covered, instability in production turned out to be relatively low during the 1950s. However, for each of the successive decades that followed, instability generally showed a tendency to increase. Instability in production, as measured by the standard deviation in the year-to-year changes in production index, was low during the 1950s for all the crops and crop aggregates except tobacco. The standard deviation increased in the 1960s, and rose further for most of the crops during the 1970s. Except for wheat, production indices of all the crops and crop aggregates under foodgrains became progressively unstable. Instability

6. For details, see Ray: *op. cit.*

in wheat production also increased markedly during the 1960s, but its production grew at a fairly stable rate during the 1970s. Among the foodgrain crops, pulses production appeared to suffer from more severe intensity of production fluctuations in the 1970s, followed by rice, coarse cereals and wheat in that order.

The average intensity of fluctuations in cotton and oilseed production did not record any noticeable change over the last two decades. Instability in tobacco production declined considerably in the 1960s but increased again in the 1970s. Sugarcane production was more unstable in the 1960s, but like wheat, fluctuations in its production declined considerably in the 1970s. Among the non-foodgrain crops, jute suffered more from production instability, though here too, the instability appeared to be declining in recent years.

With the exception of three crops, *viz.*, sugarcane, jute and tobacco, variability in the year-to-year changes in area did not appear to be the major cause for production instability. Variability in the annual area growth rates was relatively high in the 1950s. It declined in the 1960s but increased again in the 1970s, particularly, for wheat, coarse cereals, pulses, cotton and oilseeds. Changes in the cropping pattern played a minor role in making the production indices of crop aggregates unstable. Variabilities in year-to-year changes in the cropping pattern indices were relatively high in the 1950s. However, by the 1970s, the variabilities declined to insignificant levels for all the crop aggregates except for the non-foodgrain group.

The major sources for production instability turned out to be yield fluctuations, and synchronised movements in year-to-year changes in the components determining the level of production. Variability in annual yield growth rates and its corresponding impact on production instability, however, appeared to be declining over the decades. On the other hand, correlated changes in area, yield and cropping pattern showed increasing tendencies to reinforce the variability in output growth rates. Synchronised movements in the year-to-year changes in area and yield indices strengthened progressively over the decades. Changes in cropping pattern generally recorded negative association with the corresponding year-to-year changes in area and yield indices; however, this negative association which helped to dampen the intensity of production fluctuations in the 1950s, weakened considerably in the next two decades and contributed little in reducing the instability in production.

The results of the decomposition analysis generally support the findings of similar investigation recently made by others.[7] However, the methodologies commonly used in this type of investigation are open for criticism. Instability in production is typically measured around an arbitrarily assumed trend line, depicting a mathematically specified hypothetical path for the

7. See Shakuntla Mehra: Instability in Indian Agriculture in the Context of the New Technology, Research Report 25, International Food Policy Research Institute, Washington, D.C., 1981 and Peter B. R. Hazell: Instability in Indian Foodgrain Production, Research Report 30, International Food Policy Research Institute, Washington, D.C., 1982. For a critical review of these reports, see Ray: *op. cit.*

progression of production over time intervals of fixed duration. Clearly, any inference regarding changes in the pattern of growth and instability in production will be greatly influenced by the choice of the mathematical function, the selection of which cannot be left alone to the statistical criteria of best fit. The decomposition analysis presented in this paper also suffers from similar shortcomings. It compares the instability in production over different periods under the assumption of stationary mean and variance in the year-to-year changes in the components of production index.

Evidently, the specification of a model for analysing the changes in the pattern of growth and instability in production should be based on a theory or postulates, underlying the year-to-year changes in the level of production over the period under investigation. Also, to make the analysis meaningful and useful for policy purposes, more important tasks should be to explain why the production traced a particular pattern over a specified period, and why the pattern changed from one period to another. We propose to do this by first developing in the next section an analytical framework for investigating changes in the pattern of growth and instability in production.

III

AN ANALYTICAL FRAMEWORK FOR MEASURING CHANGES IN THE PATTERN OF GROWTH AND INSTABILITY IN CROP PRODUCTION

A generalised production function approach is adopted for developing a model. Four sets of observable and non-observable variables are considered, which directly or indirectly determine the level of output Y_t of a crop from a given geographical region in year t.

1. The set of observable and measurable variables $X_t = (X_{1t}, X_{2t}, \ldots\ldots X_{gt})$, representing so-called farm practices or techniques employed by the farmers. The essential characteristic of these variables is that they are not random. They are endogenous to the decision opportunities of the farmers and change systematically in response to *a priori* knowledge and information on a large number of variables, some of which may be fixed and some may be stochastic during the crop's biological growth period.

2. The set of quantitative and qualitative characteristic variables $T_t = (T_{1t}, T_{2t} \ldots\ldots T_{ht})$, representing the physical, institutional, cultural, socio-economic and technical-organizational environment for production of the crop in the region in year t. Together, this set of variables define the frame of reference for crop production in the region, which may be considered fixed during a particular year but undergoes monotonic changes over a specified period. The set T_t crucially influences the farmers' decision-making and induces year-to-year changes in the levels of X_{it}s. Each X_{it} is, therefore, assumed to be a function of a sub-set of T_t, and since the latter is a monotonic function of t, X_{it} also incorporates in it a component which is a monotonic

function of t. Since the set T_t basically determines the technology of agriculture adopted by the people in a region, changes in T_t reflect changes in the technology of agriculture.

3. The set of controllable man-made factors $P_t = (P_{1t}, P_{2t}, \ldots\ldots P_{kt})$ which are outside the domain of farmers' control. The essential characteristic of this set of factors is that changes in them may or may not trace out a monotonic path over a period of years. Each P_{it} may have a systematic and a stochastic component, and depending upon the relative weightage of the two components, short run paths of P_{it}s may become more steady or unsteady. The set P_t does not enter directly in the production process. It affects the level of production indirectly by influencing the farmers' decision-making on the set X_t.

4. The set of variables $W_t = (W_{1t}, W_{2t}, \ldots W_{lt})$ which are not fixed in quantity by nature but whose magnitudes vary in some stochastic manner. Available information on W_t may influence the levels of P_t and X_t. Besides, the actual occurrences of W_t come as inevitable events. The set W_t, therefore, enters directly in the production process and may affect the level of production also through its interaction effects with the sets X_t, T_t, and P_t.

The level of production Y_t of a crop in year t can thus be represented by

$$Y_t = F(X_{1t}, X_{2t} \ldots\ldots X_{gt}, W_{1t}, W_{2t}, \ldots\ldots W_{lt}) \qquad \ldots.(4)$$

where

$$X_{it} = F(T_{1t} \ldots\ldots T_{ht}, P_{1t} \ldots\ldots P_{kt}, W_{1t}, \ldots\ldots W_{lt}) \qquad \ldots.(5)$$

The level of production experiences growth and instability over a period of time because the sets X_t, T_t, P_t, and W_t are not static; they undergo changes monotonically and/or stochastically. We assume that over a large region such changes are likely to have additive effects so that

$$\dot{Y}_t = (A_1 \dot{X}_{1t} + \ldots. + A_g \dot{X}_{gt}) + (B_1 \dot{W}_{1t} + \ldots. + B_l \dot{W}_{lt}) \qquad \ldots.(6)$$

and

$$\dot{X}_{it} = (a_{i1} \dot{T}_{1t} + \ldots. + a_{ih} \dot{T}_{ht}) + (b_{i1} \dot{P}_{1t} + \ldots. b_{ik} \dot{P}_{kt}) + (c_{i1} \dot{W}_{1t} + \ldots. + c_{il} \dot{W}_{lt}) \qquad \ldots.(7)$$

where $\dot{Y}_t = \frac{1}{Y_t}, \frac{dY_t}{dt}$, etc.

Cross-product terms in the above relations can be easily introduced for investigation of issues relating to interaction effects. Integrating, we thus get

$$\log Y_t = \text{Const.} + (A_1 \log X_{1t} + \ldots. + A_g \log X_{gt}) + (B_1 \log W_{1t} + \ldots. B_l \log W_{lt}) \qquad \ldots. \quad (8)$$

$$\log X_{it} = \text{Const.} + (a_{i1} \log T_{1t} + \ldots. + a_{ih} \log T_{ht}) + (b_{i1} \log P_{1t} + \ldots. b_{ik} \log P_{kt}) + (c_{i1} \log W_{1t} + \ldots. + c_{il} \log W_{lt}) \quad \ldots. \quad (9)$$

Since T_{jt} is a monotonic function of t, log T_{jt} and hence $(a_{i1} \log T_{1t} + \ldots. + a_{ih} \log T_{ht})$ is also a monotonic function of t, say f_i (t). Using Taylor expansion, $f_i(t)$ can then be represented by a polynomial in t. We thus get expressions of the form

$$\log X_{it} = a'_{i0} + (a'_{i1}\, t + a'_{i2}\, t^2 + \ldots) + (b_{i1} \log P_{1t} + \ldots + b_{i\bar{k}} \log P_{\bar{k}t}) + (c_{i1} \log W_{1t} + \ldots + c_{i\bar{l}} \log W_{\bar{l}t}) + \epsilon_{it} \quad \ldots \quad (10)$$

which on substitution gives

$$\log Y_t = \alpha_0 + (\alpha_1 t + \alpha_2 t^2 + \ldots) + (\beta_1 \log P_{1t} + \ldots + \beta_{k^*} \log P_{k^*t}) + (\gamma_1 \log W_{1t} + \ldots + \gamma_{l^*} \log W_{l^*t}) + \epsilon_t \quad \ldots \quad (11)$$

where $\bar{k}, k^* < k$ and $\bar{l}, l^* < l$.

Note that we have now added the error terms ϵ_{it} and ϵ_t as it is impossible to identify, specify and measure all the relevant variables for inclusion in the above equations. Even the polynomial expression in t cannot be specified *a priori*; it can only be approximated by appropriate statistical methods. This can be carried out by testing whether addition of successively higher degree terms in the polynomial expression results in statistically significant reduction in residual sum of squares. Moreover, to overcome the severe problem of multicollinearity, orthogonal polynomials should be used for estimating and testing statistical significance of the polynomial parameters.[8]

Inclusion of P_t and W_t sets of variables in the model specification helps to measure the impact of the forces causing growth and instability in crop production. Besides, their inclusion may provide valuable policy leads for devising appropriate measures for maintaining growth and stability in production at desired levels.

First, over relatively shorter periods, P_t and W_t may themselves record trend-like movements which may trace polynomials of different degrees. Or, they may record systematic cyclical fluctuations, either of constant period which may allow Fourier representation, or hidden periodicities of no constant period which may be approximated by harmonic functions. Under such situations, growth rates of X_t and Y_t estimated from polynomial trend functions may be masked by the systematic effects of P_t and W_t, and may provide erroneous conclusions regarding the adopted technology. Inclusion of P_t and W_t in the model specification helps to isolate their effects from the growth rates estimated from trend functions and provide scope to measure the pure effect of technology in promoting growth.

Secondly, if the technology of agriculture adopted by the people differ from one period to another, sensitivities of X_t and Y_t with respect to changes in P_t and W_t may not remain constant. The magnitudes of the estimated elasticities of X_t and Y_t with respect to P_t and W_t, and the corresponding

8. Although the severity of the multicollinearity problem was mentioned by T. N. Srinivasan in his paper, "Trends in Agriculture in India: 1949-50 to 1977-78", published in *Economic and Political Weekly*, Vol. XIV, Nos. 30-32, August 1979, he allowed it to "raise its ugly head" in interpreting the estimated results. We are of the opinion that if the hypothesis of acceleration or deceleration in growth rate is to be tested through fitting of polynomial regression function, one can ill-afford to allow multicollinearity to raise its ugly head. For, it adversely affects the statistical test of significance of the very parameters based on which conclusion regarding acceleration or deceleration in growth rate is made. For a more elaborate discussion and the use of orthogonal polynomials, see Ray: *op. cit.*

changes in them over the periods may provide valuable insight regarding the nature of technology adopted in different periods.

Thirdly, both the systematic and stochastic movements in P_t are generated by the actions of policy makers. And, even though W_t may occur as inevitable events, the impact of its systematic movements, if deciphered, can be influenced through human ingenuity. Therefore, so long as X_t and Y_t respond significantly to changes in P_t and W_t, the systematic movements of the latter sets of variables can be steered to induce growth in the former sets in predictable economically rational ways.

Finally, through proper control of inventory and other policy measures, the stochastic movements in P_t can be manipulated, and the unpredictable random effects of W_t can be reduced. Such measures can reduce the fluctuations in production and make it more stable around its envisaged growth path.

Clearly, compared to the conventional trend functions, a model for investigation of growth and instability which also incorporates the P_t and W_t sets of variables in the specification is more illuminating and useful for policy purposes. Also, its estimation in the form of equation (10) and (11) is more convenient and appropriate than the one which specifies the variables in the form of residuals, measured from their arbitrarily assumed trend paths.[9]

IV

CHANGES IN THE PATTERN OF GROWTH AND INSTABILITY IN CROP PRODUCTION: AN EXPLANATORY INVESTIGATION

While it is much easier to provide theoretical justification for inclusion of P_t and W_t sets of variables in the model specification, the more complex and difficult problem is the identification and measurement of them in forms amenable for statistical investigation. Each X_{it} depends upon different sub-sets of P_t and W_t variables, not all of which are quantifiable and measurable. To take account of all these details poses serious problems in statistical estimation unless the various factors are reduced to a manageable few. Consequently, aggregation of P_t and W_t sets of variables into some suitable indices become necessary. Evidently, however, these indices should be so constructed that they become relevant and meaningful for providing answers to the specific issues under investigation.

We have shown in an earlier study,[10] that in India, rainfall appears to be the most important nature-determined stochastic variable responsible for sharp fluctuations in production. Cropwise rainfall indices, constructed as proxy variables for measuring the effect of weather on area and output of different crops at the all-India level, have convincingly shown that a significant part of the fluctuations in area and output around their respective trend lines could be explained by the computed rainfall indices. The indices were

9. See R. Frisch and F. V. Waugh, "Partial Time Regression as compared with Individual Trends", *Econometrica*, Vol. I, 1933.

10. See S. K. Ray, "Weather, Prices and Fluctuations in Agricultural Production", *Indian Economic Review*, Vol. XVI, No. 4, October-December 1981.

computed by measuring the relative departure of weighted actual rainfall during the biological growth period of each crop in the different States of India from its corresponding weighted historic normal levels.

We have also argued in the same study that given the ecological constraints, high man-land ratio, and the built-in inertia generated from years of specialisation in the production of particular crops, rational behaviour of the farmers in response to policy stimuli like prices is likely to surface more in the variable inputs use, for it is only with a flexible variable input use plan they can immediately respond to price changes. Further, rational behaviour of the producers can be substantiated if it can be shown that they operate with the objective of maximizing income, and in the Indian context this can be reasonably examined by testing with a series reflecting producers' income relative to expenses incurred by them. Again, the constructed all-India cropwise index of price received relative to the prices paid, computed under certain assumptions from monthwise and cropwise index number of wholesale prices and used in a two-tier adjustment model developed for the purpose, provided statistically significant results in support of the above hypothesis. We will use these computed rainfall and price indices for investigation of some of the issues relating to changes in the pattern of growth and instability in production.[11]

A decadewise analysis of the cropwise rainfall indices and price ratios provides some useful insight regarding their systematic and stochastic movements over the three-decade period. Decadewise, mean rainfall indices showed a distinct pattern, and there appeared to be alternating decades of favourable and unfavourable weather with correspondingly increasing and decreasing amplitude of fluctuations in them. Mean absolute deviation from the normal showed a tendency to increase in the 1970s except for wheat, oilseeds and tobacco, probably due to spread in the cultivation of these crops to rain-assured non-traditional areas. Thus, to the extent variations in rainfall affect production, changes in the pattern of growth and instability in production observed over the last three decades appeared to have been influenced by the distributional pattern of the rainfall indices. This raises the question: Is the pattern which we have observed in the rainfall indices, due to a chance relationship or is there any deeper significance in the relationship ?

There is little scientific evidence to suggest that the forces which cause rainfall in India follow a systematic pattern.[12] The wind currents bringing the monsoons of India are very erratic and cause great variations in timing and amount of rainfall received. A historical analysis of cereals and rice rainfall indices computed from 136 meteorological stations rainfall data dating back from 1875, failed to provide any conclusive evidence regarding the presence of systematic movements in rainfall indices.[13] Non-parametric

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11. For the years upto 1975, the indices are given in S. K. Ray: Variations in Crop Output, Institute of Economic Growth, Delhi, 1976. They are extended upto the year 1980 based on the same methodology.

12. See P. K. Das: The Monsoons, National Book Trust, New Delhi, 1968.

13. For details see S. K. Ray, "Weather and Reserve Stocks for Foodgrains", *Economic and Political Weekly*, Vol. VI, No. 39, September 25, 1971.

tests conducted on the computed indices indicated that they were randomly distributed. However, the year-to-year fluctuations in cereals rainfall index turned out to be less severe during 1925 to 1951 than during the period 1901 to 1924. This was consistent with Sen's findings[14] and suggested that the relatively stable and unstable periods in past foodgrains production were, in greater part, due to rainfall. Also, the first 25 serial correlations computed from cereals and rice rainfall index series provided relatively higher values for correlations of the order of 4, 6, 8, 9, 14, 15, 18, 19, 22 and 24.

Using the above historical findings and following the graphic curvilinear correlation approach of Bean,[15] it appears that means of the cropwise rainfall indices might as well again record below normal values in 1980s. Cereals rainfall index is likely to be normal or above normal in 1981, 1982, 1984, 1989 and 1990; it is likely to record normal or below normal values in 1983, 1985, 1986, 1987 and 1988. In particular, cereals production in India may be adversely affected by a drought of severe intensity in 1988.

Changes in the per cent ratios of cropwise index of price received relative to prices paid also showed a pattern. For most of the foodgrain crops, the ratios were generally above 100 till around 1976; afterwards, the ratios declined except for pulses, and remained below 100. In the case of oilseeds, the ratio was mostly below 100 till around 1965; it then changed direction and remained above 100 for the remaining period. Sugarcane, cotton and tobacco recorded favourable price ratios upto the year 1962; subsequently, the ratios registered more frequent below 100 values. Over the entire period, the price ratio for jute remained very unfavourable; only in 5 out of the 30 years, the ratio crossed 100. For most of the crops, a distinct unfavourable trend in the price ratios surfaced from the beginning of 1977.

Changes in the means and variabilities of the cropwise price ratios were distinctly observed when the entire 30-year period was divided into two sub-periods: 1951 to 1965 and 1966 to 1980. A deliberate shift in production strategy was made during the latter sub-period in which prices were given explicit recognition as means for aggressively promoting the use of modern inputs for raising the level of production, particularly, for foodgrains. Mean of the price ratios for foodgrains and oilseed crops increased in the latter sub-period; simultaneously, variabilities in them increased markedly. However, in the case of sugarcane, cotton, jute and tobacco, means of the price ratios declined in the second sub-period but their variabilities increased considerably. It appears from the distributional pattern of cropwise price ratios that, during the second sub-period, prices were manipulated in less systematic manner and might have inadvertently made crop production more unstable.

A broad conclusion emerges from the above discussion: changes in the cropwise pattern of growth and instability in production observed over the

14. S. R. Sen, "Growth and Instability in Indian Agriculture", *Agricultural Situation in India*, Vol. XXI, No. 10, January 1967.

15. See the first and second report of Louis H. Bean submitted to Ministry of Agriculture on Weather and Crop Relationships in India and the Feasibility of Forecasting, 1969 and 1970 respectively.

last three decades appeared to have been influenced by the corresponding changes in the distributional pattern of rainfall indices and price ratios. To arrive at more definitive conclusions, cropwise output elasticities with respect to rainfall and prices are estimated, and examined for their stability over the period.

There are reasons to believe that new technology has made crop production in India more sensitive to variations in rainfall and prices. The responses of high-yielding varieties of seeds to modern inputs like fertilizer, etc. are considerably enhanced when the fields are properly drained, waterlogging problems are eliminated, and water from the irrigation sources are provided in controllable manner at right times. In the initial years when selective area approach was used for the introduction of new technology, careful attention was given to ensure that the new seed varieties were cultivated under ideal agronomic conditions. However, as the availability of new seed varieties eased and their cultivation spread rapidly, these ideal agronomic conditions were increasingly violated. Cultivation of high-yielding varieties is now widely carried out under more hazardous weather conditions in areas where fluctuating rainfall along with uncertain and uncontrollable supply of water from irrigation sources, causes serious drainage and waterlogging problems, and creates acute water stress situations. It seems therefore probable that new technology might have made crop production more sensitive to variations in rainfall than what it was under the traditional methods of cultivation.

Again the elasticity of response of the new seed varieties with respect to modern inputs is much higher than those obtained from the traditional varieties. Most of these modern inputs, however, are produced in the non-farm sector and require cash purchases which, in turn, are influenced by prices and farm business income. With widespread cultivation of high-yielding varieties of seeds, the level of application of these inputs and consequently their impact on the level of production, therefore, might have become more sensitive to price (and also rainfall) variations than those experienced during the traditional method of cultivation.

To test empirically the above propositions, equation(11) was estimated separately for each crop and for each of the two sub-periods, 1952-65 and 1966-75. The set P_t of decision variables outside the domain of farmer's control was assumed to contain only P_{1t}, representing the per cent price ratio of the index of price received for the crop to the index of prices paid. Similarly, the set W_t of nature-determined variables not fixed in quantity was assumed to contain only W_{1t}, representing the rainfall index of the crop. All the equations were estimated using logarithm to the base 10. Equation(11) was estimated step-wise: first, only with time trend, then with time trend and rainfall, and finally, with time trend, rainfall and price variables. This procedure was followed in order to examine separately the impact of the systematic changes (if any) in rainfall and prices on the estimated trend growth rates. Since the focus was on short-term variations in production, no adjustment mechanism was considered in the model specification; only one-year log price ratio was directly introduced in estimating the equations.

Consideration of the two specific periods was dictated by the fact that, while the first one broadly corresponded with the extensive production strategy followed in the first three Five-Year Plans of India, the latter period recorded a phenomenal increase in the use of modern inputs and experienced a shift in production strategy in which incentive price was given explicit recognition for raising the level of production. The last five years of 1980s were deliberately excluded from estimating the equations for the second period, as the increased instability in foodgrains production recorded from 1976 has recently raised the controversy of a suspected shift in production trend line. Instead, the computed rainfall and price variables were used for analysing the actual production of those years. The actual production of foodgrains for the years 1976 to 1980 was compared against their estimated values and, the impact of rainfall and price variations on production instability was estimated.

Table I provides the growth rates and the elasticity coefficients obtained from the estimated equations. The growth rates were derived by subtracting 1 from the antilog of the estimated coefficients for the time trend variable. The differences between the unadjusted growth rates and those adjusted for changes in rainfall provide some idea regarding the systematic effect of variations in rainfall on the estimated trend growth rates. Similarly, the differences between the growth rates adjusted for changes in rainfall and those adjusted for changes in both rainfall and prices provide some knowledge regarding the systematic effect of variations in prices on the estimated trend growth rates.

No significant trend in pulses production was obtained even after successively introducing the rainfall and price variables in the estimating equations. A similar result was also obtained from the coarse cereals production data for the second period. Rainfall effect on the estimated trend growth rate appeared to be more marked for foodgrain than for non-foodgrain crops. An opposite pattern was observed for prices; its effect on the estimated trend growth rate appeared to be more pronounced for non-foodgrain than for foodgrain crops.

In general, the estimated trend growth rates were depressed after eliminating the systematic effect of variations in rainfall; they were inflated when both the systematic effects of variations in rainfall and prices were eliminated. The estimated elasticity coefficients provided an explanation for this pattern. For all the foodgrain crops, the elasticity of response with respect to rainfall turned out significant and generally recorded a marked increase in the second period. The rainfall response coefficient for wheat also increased but it became insignificant, while for pulses the coefficient declined and became weakly significant. In the case of non-foodgrain crops, however, the rainfall response coefficients turned out insignificant except for oilseeds and tobacco, and they recorded marginal changes over the periods.

TABLE 1—ESTIMATED OUTPUT GROWTH RATES AND ELASTICITY COEFFICIENTS

Crop/Crop aggregate	Growth rate (per cent per annum) Unadjusted		Adjusted for changes in rainfall		Adjusted for changes in rainfall and prices		Elasticity of output with respect to rainfall		Elasticity of output with respect to price	
	1952-65	1966-75	1952-65	1966-75	1952-65	1966-75	1952-65	1966-75	1952-65	1966-75
1. Rice	3·61*	3·38*	3·56*	2·47*	3·78*	2·75*	0·3864*	0·4397*	0·4378*	0·5356*
2. Wheat	3·90*	9·85*	4·14*	8·74*	4·40*	11·56*	0·1176*	0·2103	0·1540	0·7641*
3. Coarse cereals	1·93*	1·18	1·81*	0·34	1·84*	—0·09	0·1492	0·7155*	0·4411*	0·3070*
4. Cereals	3·23*	4·16*	3·20*	3·13*	3·32*	3·23*	0·1769*	0·5912*	0·3119	—0·1203
5. Pulses	1·11	0·36	0·74	—0·23	0·74	—0·27	0·5235*	0·4046*	0·0783	0·0532
6. Foodgrains	2·90*	3·73*	2·87*	2·73*	3·18*	3·06*	0·2460*	0·5411*	0·5294*	0·5596*
7. Oilseeds	3·49*	2·99*	3·16*	2·73*	2·87*	1·46	0·3428*	0·3650*	0·2619*	0·5774*
8. Sugarcane	5·03*	3·11*	5·22*	3·40*	5·46*	5·68*	—0·1943	—0·3271	0·5137†	0·4788*
9. Cotton	3·85*	3·25*	3·99*	3·30*	5·56*	2·75†	—0·1307	—0·0686	1·2372*	0·2461
10. Jute and mesta	3·92*	1·06	3·87*	—0·09	4·95*	4·52*	0·2106	0·0307	0·5905*	0·5654†
11. Tobacco	3·56*	2·68*	3·16*	1·76	3·32*	1·20	0·2811*	0·3737	0·1263	—0·2503

Significance at 5 and 10 per cent levels are denoted respectively by * and †.

The elasticity of response with respect to price generally turned out significant for all the crops except for pulses, tobacco and cereals crop aggregate. However, the direction of change in its magnitude over the periods varied. For rice, wheat and oilseeds, the estimated elasticity increased markedly in the second period, while for coarse cereals, sugarcane, cotton and jute and mesta, the coefficient recorded a decline. The increase in the price response coefficient for wheat in the second period was as marked as its decline to insignificant level for cotton. Pulses production turned out to be completely insensitive to price changes.

The usual statistical tests for comparison of regression lines and for testing stability of the parameters estimated separately from the two periods were not possible due to the problem of heteroscedasticity. Use of dummy variables for testing simultaneously the stability of all the parameters was also not possible as, besides heteroscedasticity, it created severe multicollinearity problem. Even then, changes in the magnitudes of the coefficients were examined by testing each of them separately with a dummy variable. The results indicated that rice, coarse cereals, cereals and foodgrains production have become more sensitive to variations in rainfall in the second period. Similarly, the price sensitivity of rice, wheat and oilseeds production appeared to have increased in the second period.

Table II provides values of the estimated foodgrains production index for the years 1976-80, computed from the estimated regression equation for

TABLE II—ESTIMATED FOODGRAINS PRODUCTION: 1976 TO 1980 (FROM THE EQUATION ESTIMATED FROM 1966-75 PRODUCTION DATA: $\log Y_t = -0 \cdot 3005 + 0 \cdot 0131\ t + 0 \cdot 5411 \log W_t + 0 \cdot 5596 \log P_t$)

	1976	1977	1978	1979	1980
1. Basic data					
(*i*) Rainfall index	107·2	90·5	112·9	112·0	83·7
(*ii*) Per cent price ratio	128·2	123·6	98·7	104·9	105·6
(*iii*) Actual production index ..	127·2	115·7	133·6	139·3	113·9
2. Per cent increase (+) or decrease (—) from previous year in					
(*i*) Rainfall index	+33·50	—15·58	+24·75	—0·80	—25·27
(*ii*) Per cent price ratio	+9·20	—3·59	—20·14	+6.28	+0·67
(*iii*) Actual production index ..	+21·96	—9·04	+15·47	+4·27	—18·23
3. Estimated production index ..	132·3	121·9	124·9	132·6	117·2
4. Percentage error in estimated production index	+4·01	+5·36	—6·32	—4·81	—2·90
5. Estimated per cent increase (+) or decrease (—) in production from previous year due to					
(*i*) Time trend	1·31	1·31	1·31	1·31	1·31
(*ii*) Rainfall	+18·13	—8·43	+13·39	—0·43	—13·67
(*iii*) Per cent price ratio	+5·15	—2·01	—11·27	+3·51	+0·37
(*iv*) Total	+24·59	—9·13	+3·43	+4·39	—11·99
6. Estimated per cent increase (+) or decrease (—) in production due to deviation from					
(*i*) Normal rainfall index (100)	+3·90	—5·14	+6·98	+6·49	—8·82
(*ii*) 1966-75 mean price (119·3)	+5·00	+2·42	—11·51	—8·04	—7·64

the period 1966-75, and compares them with the recorded actuals of those years. For each of the above years, the per cent increase or decrease in production from the previous years' level were also estimated for isolating and measuring the fluctuations in production due to variations in rainfall index and per cent price ratio. These were estimated from the relation obtained by differentiating the regression equation and measuring approximately $\dot{Y}_t$, $\dot{W}_t$ and $\dot{P}_t$ by their respective annual rate of change.

The computed rainfall index recorded above normal values in 1976, 1978 and 1979. It was considerably below normal in 1977 and recorded a very low value in the severe drought year 1980. A distinct downward shift in the computed per cent price ratio was observed. It declined significantly in 1978 from the 1976-77 level, and then ruled slightly above 100 for the remaining two years. Mean price ratio declined by about 6 per cent from the level of 119.3 in 1966-75 to 112.2 in 1976-80.

The estimated production for each of the five years compared well with the corresponding actuals, suggesting no significant changes of the estimated coefficients during 1976-80. The estimates over-estimated the actual production thrice and under-estimated it twice. Further, the error in the estimate was small, ranging from 3 to 6 per cent. The estimated per cent increase or decrease in production from the previous year's level also compared well with the recorded actuals except for 1978. The downward shift in the price ratio appeared to have an adverse lag effect on production; for both the years 1979 and 1980, the estimated change under-estimated the actual change in production. A comparison of the estimated change in production due to departure of rainfall index from its normal level and the per cent price ratio from its 1966-75 mean level indicated that production was adversely affected by downward price adjustment. Growth in production declined by more than 0.5 per cent due to a shift in the mean price level.

To sum up, the findings of our investigation suggest that the major causes for change in the pattern of growth and instability in production were due to (*i*) an increase in the variabilities of rainfall and prices, and (*ii*) an increase in the sensitivity of production to variations in rainfall and prices. Also, an analysis of the 1976-80 foodgrains production indicates that rainfall alone was not responsible for sharp production fluctuations in those years. Significant changes in the price level also accentuated the fluctuations and depressed the estimated 1966-75 trend growth path.

V

CONCLUDING OBSERVATIONS

The findings of our investigation are relevant, particularly, in the context of the recent controversy among the economists regarding the causes for poor performance of Indian agriculture during the first three years of 1980s.

Extensive field visits carried out during the summer of 1983 gave an impression that new technology is now widely adopted and practised in an environment for crop production which is outside the range of its scientifically laid down tolerance limits. One can summarily describe this environment by rephrasing Ladejinsky's penetrating observation of the Indian rural scene when the new technology was just introduced.[16] When all is said and done, it is not the fault of the new technology if it no longer provides dramatic production results; that serious drainage and irrigation problems make adoption of new technology hazardous; that timely supply of adequate power and water is a luxury of hoping against hopes; that the seeds are not properly tested and the extension service is not living up to expectations; that ceilings on land are merely notional; that costs of production under new technology are exorbitant; that prices are deliberately kept low or subsidies are hardly sufficient to encourage optimum application of modern inputs.

The conceptual and methodological framework used in this paper allow no scope to entertain the thesis that "production instability is an inevitable consequence of rapid agricultural growth and there is little that can effectively be done about it."[17] Certainly, with rapid growth, stability can be achieved if the environment for crop production is brought under human control. Even with a slower growth rate, production can be made more unstable by changing prices and other controllable factors in crazy manner. To the extent instability is caused by uncontrollable natural factors, its intensity can be progressively reduced by controlling the factors that cause instability. And, to the extent prices are destabilised by such uncontrollable factors, those can be moderated by buffer stocks.

We have presented elsewhere, how a well-formulated buffer stock programme could be used to stabilise prices and farm incomes, and promote growth in agriculture.[18] To be effective and economically meaningful, buffer stock must not be used to even out fluctuations induced by controllable factors. Even then, one should recognize that buffer stock is a costly unproductive investment which, of course, is necessary to meet the future contingencies that may arise due to vagaries of nature. Probably, a more sensible strategy would be to gradually divert the funds for stabilisation from buffer stocks to land infrastructure development programmes like drainage and irrigation, water harvesting, etc. These programmes may not stabilise production in a year or so, but over a number of years they can considerably reduce the intensity of production fluctuations. Besides, they allow vertical expansion of land for crop cultivation, augment productivity, and improve the employment prospects in agriculture.

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16. Wolf Ladejinsky, "Green Revolution in Bihar, The Kosi Area: A Field Trip", *Economic and Political Weekly*, Vol. IV, No. 39, September 27, 1969.
17. See Hazell: *op. cit.*
18. S. K. Ray: An Analysis of Food Production and Grain Stock Potential in India, International Development Series, Iowa State University, Ames, Iowa, U. S. A., 1979.