ON ANALYSING AGRICULTURAL GROWTH*

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1. With your permission, Mr. Chairman, I take this opportunity to thank the Indian Society of Agricultural Statistics for honouring me with the invitation to deliver the Rajendra Prasad Memorial lecture this year. These lectures have provided an occasion for economists, scientists and administrators to reflect on various aspects of agricultural development from different viewpoints. Since the process of agricultural growth cannot be fully comprehended except in an inter-disciplinary perspective, such opportunities for increasing mutual awareness of diverse perceptions of the agricultural growth process and of approaches to analysing them, are very valuable. It is in this spirit that I place before you some thoughts on the problems of analysing agricultural growth.

2. The choice of this theme for the lecture, which incidentally is somewhat broader than I had indicated when accepting the invitation, was naturally dictated by my professional interest in this problem. But it is also important in its own right: The facile optimism of the early 1960's about the prospects of accelerating agricutural growth—an optimism which reached euphoric dimensions following the introduction of the High Yielding Varieties-has largely evaporated. The much heralded "Green Revolution" has not taken place; indeed the debate is not on whether the growth of output accelerated as a result of the "New Strategy" built around the High Yielding Varieties (HYV) but, ironically, on whether the rates realised in the fifties and the early sixties have been at least maintained following the introduction of HYVs. It seems appropriate in this context to discuss some of the problems, methodological and substantive, involved in analysing and interpreting the Indian agricultural growth experience since Independence.

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1. I have greatly benefitted from discussion with N. Krishnaji, Ashok Rudra and T. N. Srinivasan in classifying the methodological and substantive problems involved in analysis of agricultural growth.

3. Analyses of agricultural growth are usually concerned with three major questions (*a*) What have been the direction and magnitude of changes in production and productivity over time and how stable are they? (*b*) What is the contribution of different inputs, weather and other factors to these changes? And (*c*) what are the, in some sense more basic, factors determining the rate and pattern of absorption of inputs and technology and, hence, of agricultural growth. These questions have long been and continue to be the focus of research among economists and agricultural statisticians. There are not many definitive answers yet; in fact many issues remain controversial. My intention here is to highlight on some of these unresolved and controversial issues, and offer a few suggestions for carrying the analysis, and hopefully understanding, a step or two forward.

1. Measurement of Growth

4. The usual trend fitting exercises are based on the following conceptualisation:

$$y_t = f(t) \qquad \ldots(1)$$

where y_t is yield (or output) in year t

The relation can take any one of several functional forms, and the usual practice is to select a few, fit them to the time series in question, and choose that function which gives the best fit in terms of such criteria as R^2 and statistical significance of the regression coefficients. The procedure is defensible, and the criticism (Rudra 1978, Krishnaji 1979) that the selected functional forms constitute but a sub-set of various possible forms chosen without any apriori basis need not be crippling, so long as one is merely interested in a convenient way of summarising a long time series into 2 or 3 parameters. But trend lines are seldom treated merely for descriptive purposes. They are widely used as a basis for intepreting the nature and significance of the trend in agricultural production taken by itself (Vaidyanathan 1977) and also for explaining trends in the economy as a whole. (Patnaik 1972, Chakravarthy 1974, Raj 1976, Vaidyanathan 1977).

5. Consider for instance the effect of HYVs on foodgrain production trends: If indeed the HYVs had resulted in a "Green Revolution", one should find a sharp break in and significant divergence between, the trend growth rates of foodgrain output between the two periods. Standard statistical procedures have been used to establish that except in a few states and that too for a few

crops, the data do not corroborate this expectation. While there is general agreement on this proposition, controversy persists over whether output is growing at a steady rate or a decelerating rate[2]. (Srinivasan 1977, 1979, Rudra 1978, Vaidyanathan 1978). Those who hold the former view base themselves on (*a*) statistical tests to verify whether the rates of growth in the pre-and post-HYV period differ significantly from each other; and (*b*) comparing the goodness-of-fits of the constant growth rate function with that of quadratic form. These tests generally support the hypothesis of a constant growth rate in foodgrains output during the past 2-3 decades (Srinivasan 1979).

6. But Rudra (1966), and more recently Dey (1975) and Reddy (1978), have shown that a Gompertz curve fits the data at least as well as the semi-log function and that the parameters of the fitted curve imply a steadily declining growth rate throughout the period. There is an important difference between the two specifications : While the test of significance of the difference between the trend growth rates in two sub-period estimated from semi-log function assumes that within each sub period output has grown at a constant rate, the Gompertz curve makes on such prior assumption. Instead it allows a wider range of possible behaviour of output including constant growth rate. However the difficulty with the Gompertz curve is the lack of any standard estimation procedures and tests of significance of the coefficients.

7. In the event we have two summary statistical descriptions of data which are equally good in terms of "goodness of fit" but point to very divergent conclusions about the nature of the underlying trend. Which of the two is a more accurate description of the observed behaviour of output over the period cannot be settled on purely statistical considerations. One will have to appeal to other information and/or use other criteria to arrive at a judgement. (Rudra 1978, Krishnaji 1978)

8. Another example of the use of trend lines other than as convenient summary description of a time series is the speculation (Vaidyanathan 1977) regarding the factors responsible for the observed behaviour of foodgrains output based on a comparison of changes in the trend values of actual output between two points of time with the increase in "potential output" estimated from changes in the quantum of major input used and their expected productivity. Implicit in this approach is the assumption that the trend line is

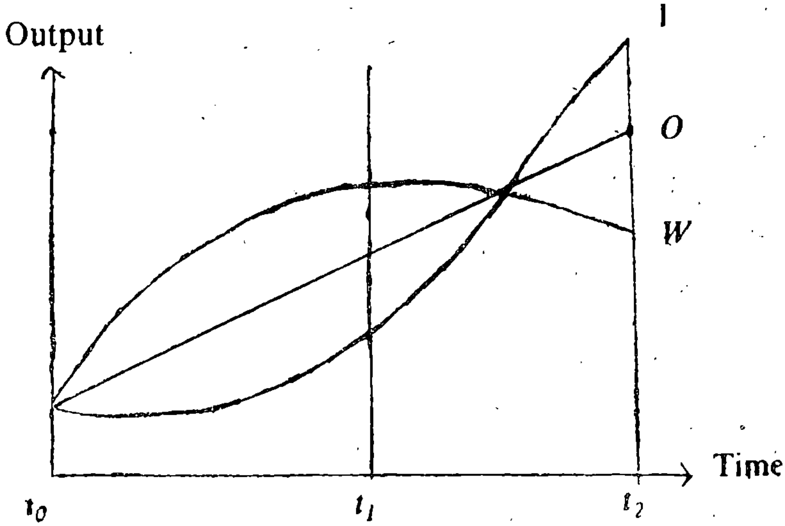
2. This debate started over a decade back in the columns of the *Statesman* (October-November 1966). References are to some recent contributions on the subject.

a reasonably good approximation of the composite effect of changes in input use on output levels. This would be true only if (*a*) the fitted trend is not significantly influenced by factors other than inputs and technology; and (*b*) the trend itself has been correctly specified. In other words the effect of variations in all non-input, non-technology factors on output-and this in (1) includes weather-are truly random in character. Should it happen that the weather variable shows a sustained change during the period to which the time series of output pertains-and this "sustained change" can be a falling or a rising trend or a cycle spanning all or alarge part of the period— the fitted trend with reference to time alone can no longer be interpreted as measuring the effects of sustained changes in inputs and technology. It will then be a compound of the effects of inputs *and* of the sustained change in weather.

9. That this point is of some importance for analysing the factors responsible for observed output trends can be illustrated by the following hypothetical example. In the figure below, 0 represents the best-fitting trend line for output. The shape of the curve implies declining growth rate over time. The curve I gives the potential output at various points of time corresponding to the inputs actually absorbed at each time point at thier expected levels of productivity. If weather variations during the period of analysis are random, and do not affect the productivity of inputs, 0 can be interpreted as reflecting the effect of changes in input use and their productivity. It would then be perfectly legitimate to compare it with the potential output curve I, the difference between the two being indicative of the direction and extent of divergence between the expected and realised productivity of inputs. In the particular example represented by the figure 1, the actual productivity of inputs is higher than the estimated potential between t_0 and t_1 while between t_1 and t_2, the position is reversed[3]. By analysing the reasons for this divergence between expected and realised productivity of inputs one hopes to come up with concrete suggestions for improving growth performance. Some of my work (Vaidyanathan 1978) is based on the above approach.

10. Suppose, however, that weather variations during the period of analysis follow a systematic pattern of which the type described by *W* is an example. If output is a positive function of weather, it is no longer possible to meaningfully compare *I* and *O*, or to draw valid inferences about the productivity of inputs from

3. The relative positions of the various curves is purely illustrative. Any number of combinations are possible. For instance if the position of I and W are reversed, the conclusions about behaviour of productivity of input will be the opposite of that discussed in the text.



such comparisons. For the output trend now reflects the composite effect of inputs, technology *and* weather. In-our example, the fact of actual output trend being larger (smaller) than technical potential in t_1 (t_2) can be partially explained by the sustained increase (decrease) in W in t_1 (t_2) even if the effects of inputs and weather are independent of each other.

11. The effect of weather has to be taken out of the estimated trend in output in order to get the contribution of inputs alone. Comparing O and I without making this adjustment is likely to lead to misleading conclusions : If the divergence between O and I is wholly or largely attributable to differences between potential and actual productivity of inputs, human intervention to correct the sources of divergence will help increase output faster. But if the divergence between O and I is largely due to weather, there is very little that human intervention can achieve.

12. Even if there is no sustained change in weather during the period of the analysis[4], since we know that output is affected by weather, it is desirable to net out weather effects in order to get a more precise measure of the contribution of other factors. This point has been recognised by several researchers. Bernard Oury (1965) in an attempt to test the effect of weather (specified in terms of preciptation and temperature) on yields, assumed that "crop yield is a function of time, allowing for technological advance, and weather

4. This could happen even when the long term behaviour of rainfall is marked by regular cyclical patterns,

only". He estimated the following relation (using different functional forms) for time series of corn yields in some parts of the USA covering the period 1890 to 1956 and found the coefficients for time and for a composite index of weather (defined as P/T) to be statistically significant and independent of each other.

$$Y = b + b_\theta \theta + b_p P + b_t T + E_t \qquad \ldots(2)$$

where Y stands for yield per acre ;

θ for time

P for preciptation

T for temperature

and E for residual variation.

The effect of technology and inputs are supposed to be captured by the coefficient for the time variable but, as Oury himself recognises, this assumes a constant rate of upward technical change and fails to capture occasional step-ups or set backs in technology. Also the problem of the apriori basis for the functional forms and of the criteria for differentiating between arbitrary functional forms remains.

13. Panse (1959) used analysis of variance to evaluate the extent to which observed changes in per acre yields of wheat and rice between 1945 and 1955 were really due to the introduction of planning and how far they reflected year-to-year and interdivisional variations. He found that the introduction of rainfall did not seem to make a significant difference to the conclusion on wheat but did in the case of rice.

14. Cummings and Ray (1969) attempted to disentangle the contributions of weather from those of inputs and technology to output changes observed in India. They used essentially the same framework as Oury except that weather was measured exclusively in terms of rainfall. Two alternative functions, one linear and another quadratic, were tried for the weather variable. The function using the quadratic form for weather was chosen because it gave a much higher R^2. The parameters estimated by fitting the function to the output series for the period 1951-52 to 1964-65 were used to compute the expected output for 1967-68 and 1968-69 on the basis of past "normal" technology and of actual rainfall in these years. Since HYVs had been introduced after the period covered by the regression, they made an independent estimate of the extra contributions of new technology (on the basis of the expected productivity of high yielding varieties) and added it to the values predicted from the

regression equation to get the expected total output in the two years with which they were concerned. On this basis they estimated the relative contributions of weather, normal trend and new technology in explaining actual output in these years.

15. More recently Ray (1977) carried this line of attack considerably further in studying the growth of area, production and yield of selected crops for the country as a whole over a much longer period. First he introduces weather along with time trend and specifies the following type of relations :

$$Y=a_0+a_1t+a_2 \log w_t \qquad \ldots(3)$$

where Y can stand for area (A_t), production (P_t) or yield (Y_t), as the case may be, in year t, and w_t represents rainfall in year t. The relations are also estimated for the period 1951-52 to 1974-75 with and without a Dummy variable to distinguish between the pre-and post-HYV periods. For comparison purposes, he also estimates the equation of $\log Y=a_0+a_1 t$ from which the unadjusted growth rate is computed. Rays 15 *a* estimates show that, taking the period as a whole, (*a*) rainfall has a statistically significant effect, in general of the quadratic form, on behaviour of area, production and yields ; (*b*) the weather-corrected trend growth rates differ significantly from the unadjusted rates in 7 out of 11 cases for area, 6 out of 11 cases for production and 5 out of 11 for yield ; and (*c*) the adjusted growth rates are in general higher than the unadjusted ones. Ray also reports the results of an extension of the above model incorporating prices as an additional explanatory variable, and finds the coefficient for prices to be generally positive and statistically significant in the case of area and production but apparently not for per hectare yields.

16. While this is a significant improvement the specification of the model is open to two major objections. The first relates to the use of total rainfall during the relevant crop season as the explanatory variable for *both* area and production : The area sown to a crop is likely to be affected, if at all, by the rainfall in the pre-sowing period and not by the preciptation during the growing season. Secondly, in analysing area responses one has to recognise that there are limits to the expansion of area sown to any particular crop set by agronomic factors and by the total availability of land and moisture. Moreover, the range and flexibility of choice is apt to differ significantly as between irrigated and unirrigated tracts. Robert Herdt's (1972) effort to estimate a model for the Punjab incorporating these considerations explicitely gives results which are promising

enough to deserve to be persued further. However, for the present, I shall restrict my observations to the relation between weather and per hectare of yields.

17. While the case for incorporating weather explicitly as an explanatory variable is strong, it is rather difficult to decide which dimensions of weather should be incorporated and in what form. Crop yields are affected by a variety of climatological factors including rainfall, temperature, humidity and sunshine. Also, the distribution of these elements of "weather" within the growing season of a crop often seem to be as important as their magnitudes over the season as a whole. On the other hand different elements of "weather" may affect crop yields differently and their effects may or may not be independent of each other. Scientific knowledge on crop-weather relations does not seem to have reached a point where the nature and form of these relations can be confidently specified in an estimatable form with a reasonable degree of precision.

18. One has only to review the massive amount of work, largely done by agro-meteriologists in the Indian Metereological Department[5], to appreciate the weak apriori basis for the specification of crop-weather functions. Part of the problem is that some of these exercises are based on data where factors other than weather are also variable. Even where controlled experiments are available (as in the crop-weather experiments organised by the Indian Metereological Department), the daily or weekly values of various weather variables may not be the appropriate ones to enter the relation : For instance in the case of rainfall what is relevant to plant growth is the amount of soil moisture available in the root zone of the crops so that a proper specification will have to find some way of transforming precipitation into soil moisture stock at various stages of crop growth. Because of such complexities, and also because the observations available for testing the relations often constrain the number of explanatory variables, there seems to be no choice but to work with a few weather variables (of which rainfall is admittedly among the most important) at a fairly high level of spatial and seasonal aggregation. Such crude specifications of weather may indeed be preferable to elaborate and refined formulations lacking in sound theoretical basis. It goes without

5. For a select bibliography of this work see Administrative Staff College of India, *Analysis of Rainfall Distribution Supporting Study to a Study on All India Grain Storage and Distribution* sponsored by the Ministry of Agriculture and Irrigation (mimeo, Hyderabad 1976). These studies have explored a variety of statistical estimation techniques both on experimental data and on data on behaviour of yields of particular crops in different parts of the country.

saying that results obtained from such crude models can only be taken as indicative and that continuing research to refine them are essential.

19. Ray's, as well as Oury's, formulations are also open to criticism for ignoring the influence of weather on the contribution of inputs which in the above formulation are supposed to be captured in the coefficient for "t". There are strong reasons to expect such interaction. For instance since the quantum of moisture is the sum of moisture from rainfall and irrigation, the amount of rainfall and its seasonal distribution will affect the moisture status of soils even on irrigated lands. The effect will be the greater when irrigation itself depends on small tanks and shallow wells fed by local rainfall. It is also well known that the amount of moisture and its time distribution affects the responsiveness of crops to fertilisers, and, therefore, the level at which fertilisers are likely to be used. In order to capture the effect of such interactions, the formulation in (3) above may be modified thus.

$$Y_t = f(W_t, t, W_t t) \qquad \ldots(4)$$

20. For reasons mentioned earlier, we will use rainfall (R_t) in the growing period of the crop concerned as the proxy for the weather variables. And given the necessity to reduce the relation to a linear form for purposes of estimation, our choice of functions is restricted to the linear, log-linear and semi-log forms. There is always the possibility that these functional forms may not quite capture the relations they are meant to comprehend.

21. In order to see whether the introduction of the interaction term makes any perceptible difference to the results, we attempted an illustrative analysis with data on rainfall, the yield of rice and of coarse grains in three regions of Andra Pradesh.[6] Since the three regions differ significantly in the amount of rain-fall, its seasonal distribution and reliability, such an exercise may be expected to better capture the relative importance of weather under varying rainfall regimes than is possible with all India or even state level data. The parameters of the best-fitting functions for these crops and regions with time alone, and with time and rainfall as explanatory variables are given in Table 1.

6. This part of the work, especially the estimation, is the product of collaborative work with Chandan Mukherjee. Some further results are presented in CDS working paper No. 104.

TABLE 1
Estimated Relations between cereal yields, rainfall and time, Andhra Pradesh 1955-56 to 1975-76

Function	*Regression coefficients for*					→ R^2
	$R.$	$R.^2$	T	T^2	RT	
Coastal AP						
Rice						
log $Y=F(T, T^2)$	—	—	.00981 (4.081)	.00108 (2.496)		.56
log $Y=F(R_t,T,T^2,R_tT)$	—.000089 (1.028)	—	.036840 (2.082)	:001064 (2.487)	—.00026 (1.573)	.63
Other foodgrains						
log $Y=F(T, T^2)$	—	—	—005397 (0.419)	.003352 (1.443)	—	.12
log $Y=F(R_s,R_s^2,T,T^2,R_sT)$	.022224 (2.912)	—.000017 (2.735)	.10513 (1.157)	.00203 (1.110)	—.000148 (1.056)	.57
Rayalaseema						
Rice						
log $Y=F(T)$	—	—	.016336 (5.317)	—	—	.61
log $Y=F(R_s,R_t^2,T)$	.0017 (1.956)	—.000001 (1.837)	.017211 (5.532)	—	—	.69
Other foodgrains						
log $Y=F(T,T^2)$	—	—	—.001667 (.367)	.001915 (2.343)	—	.25
log $Y=F(R_t,R_t^2,T,T^2,R_tT)$	.003751 (1.917)	—.000003 (1.849)	—.038657 (1.055)	.001959 (2.075)	.000057 (1.067)	.42
Telengana						
Rice						
log $Y=F(T,T^2)$	—	—	.031213 (7.132)	—.001287 (1.632)	—	.76
log $Y=F(R_t,R_t{}^2T,T^2)$	.003386 (3.128)	—.000002 (2.941)	.032343 (7.225)	—.000926 (1.361)	—	.86
Other foodgrains						
log $Y=F(T)$	—	—	.014505 (2.712)	—	—	.29
log $Y=F(R_t,R_t^2,T)$	.002346 (1.533)	—.000001 (1.368)	.018024 (2.815)	—	—	.43

Note: R : R_t R_t or R_s as the case may be
R_t : Total rainfall
R_s : South West monsoon rainfall
Figures in brackets refer to the absolute T-value.
$R.^2$ is not to be confused with R^2, the multiple correlation coefficient.

22. While an increase in the proportion of variance explained is to be expected as the number of explanatory variables increases, the results point to the following interesting conclusions :

(*a*) Even in the case of a predominantly irrigated crop like rice, rainfall has a significant effect on yield in Telengana, and in Rayalaseema. The signs of the coefficients also point to yields rising at a declining rate as rainfall rises. In the case of coastal AP, the coefficient for rainfall is weakly negative.

(*b*) The introduction of rainfall increases the proportion of variance explained only marginally in rice ; but makes a big difference in the case of other grains. The influence of rainfall on yield of foodgrains other than cereals is evidently much greater than on rice yields. Again the yield-rainfall relation is of the quadratic type and the coefficients have the expected signs though-not statistically significant (by the usual T value tests) in all cases.

(*c*) The interaction between rainfall and time trend shows no consistent pattern and seems to be in general quite weak. In the case of Telengana they do not figure in the equations which give the best fit to the data.

(*d*) Not only does the inclusion of rainfall improve the R^2, but it makes a substantial difference to the value of the "trend" coefficients and also, in general, reduces their standard error. Again, as a rule the growth rates corrected for rainfall variations are higher than the growth rates derived from simple trend fitting exercises. But the results for other foodgrains in Rayalaseema point to the possibility that Weather variations may also serve to mark the secular decline in yields.

23. The results provide strong corroboration for the argument implicit in the work of Oury Cummings, Ray and others that the effect of rainfall (and if possible other relevant weather variables) should be netted out in order to get a proper assessment of the trends in yield improvement attributable to development programmes alone. The "weather free" trend reflects the combined effects of increases in the quantum and composition of inputs as well as of changes in their quality and productivity. Unscrambling the individual contributions of these elements is however not possible within the framework of (4). This requires various input elements and their relation to output (yields) to be explicitly taken into account.

$$y_t = f(i_{1t}, i_{2t} \ldots i_{nt}, R_t) \qquad \ldots(5)$$

where i_{jt} is the quantum of the j^{th} input per hectare used in year t.

2. Sources of Growth

24. This leads us to analyses of sources of growth. It is quite simple to separate out the contribution of changes in area and in per hectare yields to the changes in output. There are also more elaborate decomposition schemes to estimate the relative contributions of area, crop pattern and per hectare yield. (Minhas and Vaidyanathan 1965). This has been refined further to separate out the effects of shifts in the spatial distribution of area under different crops (Dharam Narain 1976). There are also a few attempts to estimate the increase in production and yields which could be expected from the observed (targetted) changes in the absorption of major inputs namely, cropped area, irrigated area, fertilisers and improved seeds and compare it with actual realisation (National Commission on Agriculture 1974, Cummings 1971). All those exercises abstract from the effects of weather either by assuming the latter to be "random" in nature or by estimating expected yields under "normal" weather. The "yardstick approach" faces the further problem of inadequate data on response coefficients, doubts about how "representative" the coefficient are, and whether the assumption of independence and additivity of responses to individual inputs are valid.

25. Attempts at estimating the production function implied in (5) by multiple regression techniques have not been conspicuously successful either[7]. Not only is the explanatory power of such multiple regression low, but often one finds the signs of coefficients contrary to expectation. Part of the reason might be defective specification of the relations : For instance very few of such exercises incorporate the weather variable. There is also the ubiquitous problem of multi-collinearity between input variables arising from the fact that almost all of them tend to grow over time. The functional forms cannot accommodate varying degrees of complementarity and substitution relation between inputs. Also the mixing-up of intermediate inputs with primary factor inputs in some formulations causes confusion.

26. It seems possible to get around these difficulties to some extent by re-writing (5) as follows :

$$y_t = f(R_t, I_{ct}, R_t I_{ct}, t) \qquad \ldots(6)$$

7. There are however several attempts to use this technique for analysis of changes in output (yields) over time. For a discussion of the statistical problems involved see Minhas B. S. Rapporteur's Report. On measurement of Agricultural Growth, IJAE Oct-Dec. 1964. For a good example see Parikh, Ashok. Crop-wise, Districtwise Production Functions, IJAE, January-March 1970.

where

y_t=yield per hectare

R_t=rainfall in the relevant season in year t

I_{ct}=is a composite input index.

27. The concept of an input index[8] was first suggested by Abraham and Raheja (1967) as one way of getting around the problem of multi-collinearity between input variables. They defined the index thus

$$I_{ct}=\frac{Y_uA_{ut}+Y_iA_{it}+Y_fF_t}{Y_uA_{uo}+Y_iA_{io}+Y_fF_o}$$

where

A_{ut}=unirrigated area in year t

A_{it}=irrigated area ,, ,,

F_t=Total fertiliser use

Y_u=Average yield per hectare of unirrigated land

Y_i=average yield per hectare of irrigated land

Y_f=incremental yield response per kg of plant nutrient.

In their scheme, Y_u, Y_i, and Y_f, were to be taken from official yardsticks estimated from the best available survey or experimental data. It is easy to see that the input index can be expressed either in aggregate or in per hectare terms. In principle other inputs can be included; a finer break down of the land, water and fertilizer inputs can be used; and different weighting schemes can be tried without affecting the basic rationale of the scheme. The availability of data would, however, restrict the range of choice.

28. This index has several advantages: it overcomes the ever present problem of multi-collinearity between irrigated area, and fertiliser use both over time and in spatial cross-sections. Provided the inputs and their weights are chosen appropriately it can also be interpreted as corresponding to an index of production which could be expected from a given increase in selected inputs at a particular level of technology. Once this is done, the coefficients for R_t I_{ct} admits of a meaningful interpretation as measuring the interaction between responses to weather and to inputs. The coefficient for "t" can be interpreted as capturing the contribution of technical change (new techniques and more efficient use of existing techniques). Of course if the input variables do not discriminate between different

8. This concept is quite similar to the one used by Denison in estimating the contribution of technical change as distinct from increases in the quantum of factor inputs to the growth of aggregate real output in the US economy.

irrigation qualities, seed varieties, or synergetic responses to inputs, these effects will also be captured in the above formulation by the coefficient for "t". As long as we know the elements contributing to different coefficients, they admit of a meaningful interpretation. And in the process we can get much more insight into the factors contributing to yield changes than is possible with (3) or (4). The choice of an appropriate functional form remains as intractable as, but no more so than, in other 'models' designed to explore agricultural growth. Again dictates of convenience limit the range of choice in functional forms with the attendent risk of not being able to capture properly the true relations.

29. Model (5) was tested on the time series of per hectare yields of cereals in two States, namely, Punjab and Tamil Nadu. The estimated parameters of the best fitting function in each case are given in Table 2.

TABLE 2

Relation between Cereal yields, rainfall, inputs and time, Punjab (1951-52 to 1974-75 and Tamil Nadu (1950-51 to 1974-75)

State	*Function*	*Regression Co-efficients for variables included in function (in same order)*			R^2
Tamil Nadu	Log $Y=F(\text{Log } I_{ct} \text{ Log } R_t, t)$	−2.152877 (1.614)	.18036 (1.942)	.016436 (5.493)	.74
Punjab	Log $Y=F(\text{Log } I_{ct}, \text{Log } R_t, \text{Log } t)$	3.503795 (8.58)	.277163 (3.432)	.055913 (1.337)	.93

In the case of Punjab, over 90 per cent of the observed variations in per hectare cereal yields is "explained" by the model: the expansion of inputs is by far the most important factor; rainfall taken by itself exerts a significant positive influence on yields; but there seems to be no significant interaction between the effect of inputs and rainfall; and interestingly the coefficient "t" is only weakly positive.

30. The explanatory power of the model in the case of Tamil Nadu is much lower than in the Punjab. A major part of the explained variation is attributed to "time". Inputs and rainfall account for a relatively small fraction of both variation in yield and the regression coefficients for bothvariables are not statistically significant. The interaction between inputs and rainfall seem to be negligible. In

other words, the rate of improvement in the productivity of inputs has been high and that this is the principal element contributing to yield growth. This is consistent with the observed fact that the constancy of cropped and irrigated areas conceals major changes in the quality of irrigation as well as in the quantum of water supply arising from the phenomenal growth of pumpsets. The resulting improvements in yields and crop patterns are likely to be reflected in the coefficient for 't'. It is also possible that our method of constructing the input index does not give sufficient weight to the growth of fertilizer use; perhaps too the particular index of rainfall used in the exercise is defective. I do not, however, want to venture into further speculation without closer study of the results of the analysis.

31. The above scheme, as pointed out earlier, is essentially an extension of the model implicit in (4) to permit measurement, however approximately, of the contribution increased input use and of sustained changes in output per unit of input arising from technical progress as well as other factors to the estimated "weatherfree" trend in yields: The results of the exercise for punjab and Tamil Nadu are illustrative of the possibilities of this model. There is of course considerable room for improvement in the scope of the input index, the specification of the rainfall variable, and in the construction of both the input and the rainfall indices.

3. Critical Factors in Agricultural Growth

32. A proper understanding of the agricultural growth process however calls for much more than refinements in the analysis of sources of output growth. We need to explain why the levels and composition of inputs, their productivity and other determinants of output behave the way they do. Since their behaviour is influenced by a variety of factors—economic, technical and institutional—attempts at comprehending it must take explicit cognizance of this diversity of influences and the inter-relations among them. Analyses which fail to do this and instead seek to explain growth, or the lack of it in terms of one set of factors taken in isolation can be misleading.

33. Take for example the tendency of some economists to attribute the slow growth of production to low prices of farm products relative to input prices and the prices which the farmer has to pay for non-agricultural products generally. According to this school, agricultural growth can be significantly accelerated by shifting the terms of trade in favour of farmers. Quite apart from analytical flaws in such formulations, the empirical basis for this diagnosis is

very shaky indeed! That farmers are highly sensitive to changes in relative prices in deciding inter-crop allocation area does not necessarily mean aggregate supply responds to changes in terms of trade. As far as I know, such studies as are available on the latter show that yields and aggregate production are hardly responsive to prices. This pronounced assymetry in the response of farmers to price changes at the level of area sown to particular crops and at the level of aggregate production should not be surprising once we recognise that there are technical and institutional constraints on the extent to which aggregate input absorption and its productivity can be raised at any point of time.

34. Such problems are mitigated, but not overcome, by the linear programming type of exercises which explicitly incorporate technical and economic factors, including constraints on total resource availability, and seek to estimate the maximum level of output, and its pattern, attainable with given resources and technology. Such exercises invariably show that available resources are being used sub-optimally at a given level of technology. But to say that there is scope for significant increases in output from given resources and technology is not a particularly useful insight unless the reasons, mostly institutional in character, for the divergence between potential and actual output are identified. Very few exercises of this genre even attempt such an analysis. The few that do, offer explanations in such general terms (as for example 'defective extension services', 'wrong fertiliser recommondations,' and 'inefficient organisations for production and supply of inputs') that they do not advance our understanding much. Optimisation models have enough problems in capturing technical relations and constraints in a form which can be handled with linear estimation techniques. It is therefore unrealistic to expect them to capture the far more complex dimensions of institutional structure which have a bearing on how inputs and technology are in fact used. Nevertheless some way must be found to bring institutions into the analysis for any meaningful conclusions to be possible.

35. The effects of institutions on agricultural growth are as varied as they are complex. The most widely discussed aspect concerns the role which modes of production—a term which subsumes the distribution of land and other productive resources, the organisation of production, as well as the relations among the various classes participating in production—play in the process of growth. Apart from such considerations as that 'modes of production' understood in the above sense does not capture many other important

facets of the institutional framework and that the debate on this can all too easily mix-up questions of growth with those of distribution, analysis of agricultural growth in terms of 'modes of production' runs the risk of seriously underplaying the role of technical and physical factors in the growth process and, indeed, in shaping the institutional structure itself. Also one is unclear about how the analytical scheme accommodates the historically unprecedented fact that the State has taken over the primary role both in accumulation and innovation—the twin functions of the capitalist farmers who provided the dynamic element in the systems under the classical scheme.

36. Be that as it may, there can be no question that there are limits to the level of technology and yield improvements which can be attained under a given set of institutional conditions understood in the more general sense to include not only modes of production but also organisations affecting supply and use of inputs. Improvements beyond this limit will not be possible unless major changes are affected in the institutional framework. This is very well brought out by Ishikawa (1967) in his analysis of the Japanese experience over time and of the comparative levels of productivity in different countries of Asia. His discussion brings out that despite the apparent complexity of the problem, it is possible to identify certain elements of the institutional framework as being particularly important for agricultural growth, and to get useful insights into their role in specific historical and geographical settings.

37. One important 'clue' from Ishikawa's work is that we should not treat 'institutions' as if they were a homogenous category, but should differentiate between different componenets of the institutional structure in terms of the functions they perform, their importance as determinants of productivity, the extent to which they are affected by the prevailing agrarian structure, and the degree to which they can be manipulated independently of it. Also attention should be focussed on particular inputs and techniques under different agro-climatic and geographical contexts.

38. In the Indian context, the rate at which productivity of land can he raised is limited basically by the extent and quality of irrigation, the intensity of fertiliser use, and the efficiency with which the cultivation practices necessary for optimum results are applied on the farms. These three areas are therefore natural candidates for research designed to further understanding of the inter-relations between technical, economic and institutional factors in the process of agricultural growth.

39. Considerable research has been done, and continues to be done, on all these aspects under the auspicious of the ICAR, the NSS, as well as numerous universities and research organisations. But judging by results, these efforts tend to be not only fragmented in scope and perspective, but in general lack the continuity necessary for any study of change. Thus in the case of irrigation, despite a great number of surveys to assess the reason for delays in completing projects and under utilisation of water, the relative performance of different types of projects, and the impact of irrigation on the economy of the region and of farmers benefitting from it, several important questions remain unanswered.

40. It is often said, for instance, that Indian irrigation systems do not get the maximum output per unit of water because they tend to spread water too thinly over too wide an area: Available data on total irrigated area and total volume of irrigation water suggest that in many cases there is excess use of water on the average (Minhas and Vaidyanathan 1969). But in the absence of reliable data on actual area under different crops and seasons in the command area, and the seasonal distribution of water supplies from the projects, it is difficult to be categorical. Such data are simply not collected and published. On the other hand there are well documented examples (Dandekar, Deshmukh and Deuska, 1979) where systems designed for protective irrigation of staple cereal crops are found to have developed highly water intensive crop patterns on a fraction of the original command. How this came about despite the regulations governing crop patterns and the obvious conflicts of interest between different segments of the command have not been investigated carefully.

41. Again, it has become commonplace to say that efficient use of water is contingent on the construction and proper maintenance of field channels; on making necessary physical improvements in land by way of consolidation, levelling and relaying of plots; and on proper regulation of water use. (Irrigation Commission 1972, Planning Commission 1972). These operations, in the context of peasant farming, face considerable resistance arising in part from ignorance, but more often due to legitimate fears and genuine conflicts of interest. The mechanisms to resolve these conflicts on the basis of generally acceptable, and enforceable, rules and procedures is an enormously complex institutional problem. It involves relations between beneficiary farmers and the irrigation authority, between farmers in different parts of the system, and even within any one part of the system, and not the least important, between the bureaucracy, beneficiaries and the centres of political authority.

42. One would have thought that solution to these problems would have been based on a proper study of the experience of earlier projects. The fact of the matter however, is that we have very few detailed and well documented descriptions[9], not to speak of analysis, of the experience of either old or new projects in maintaining the distribution system, the working of the mechanisms for regulating crop patterns and water use at different levels, of the procedures for resolving conflicts, of the discrepancies between how the mechanisms are supposed to work and how in fact they do, and of whether there have been any significant changes in these respects over time and if so what caused them. We need detailed case studies addressed to such questions for projects of different types in different regions.

43. As regards fertilisers, agronomists tell us that irrigation and fertilisers are complementary ; that irrigated lands and high yielding varieties respond better to fertilisers, and that the economical dose of fertilisers on such lands is higher than on rainfed lands. However, the actual use of fertilisers even with the current level of irrigated area is much below the potential computed from official recommendations based on demonstration results. Almost all computations of "optimum" fertiliser dose are much higher than actual use levels at comparable relative prices. (Panse and Daroga Singh 1966, Bal and Bal 1973). The growth of fertiliser use has also been consistently falling short of targetted levels.

44. Since the response data from fertiliser demonstrations points to an attractively high rate of return on the average, the low level of actual use and its tardy growth must be due to one or more of the following: (a) The fertiliser recommendations evolved on research farms may not have made a sufficient allowance for the variations in soil quality and other variables affecting fertiliser response. (b) The farmer, being unfamiliar with a new techniques or inputs, does not observe all the practices (timing, quantity, sequence etc.) necessary for optimum results. (c) The necessary complementary inputs (especially water), in terms of quantum, timing and quality, may not be met for reasons beyond the farmer's control, (d) The response to the input are variable and therefore the farmer applies a discount for the risks involved in its use. On the other

9. See For example Reidinger, Richard B Institutional Rationing of Canal Water in North India... "*Economic Development and Cultural Change*" 1974 and Robert Chambers Men and Water; The Organisation and Operation of Irrigation, in Farmer BH (ed) *Green Revolution*, (Macmillan, London, 1977) ; Robert Wade, The Social Response to Irrigation : An Indian Case Study *Journal of Development Studying* Oct. 1979,

hand, all these factors are counteracted by the constant flow of technical improvements (via new seed strains, fertiliser materials and cultivation practices) combined with the increasing efficiency of use of old techniques due to learning from experience.

45. There is little empirical basis for judging which of these suppositions is valid, how widespread they are, and what their relative importance is. A few scattered studies (Herdt 1964, IRRI 1978) show responses under farm conditions are considerably less than under demonstration conditions. There is some evidence of a high degree of veriability in the response and therefore a high risk to fertiliser use. (Daroga Singh et. al. 1970, Abraham and Leelavati 1968). Whether or not the variability of response is greater in HYV compared to traditional varieties is not conclusively settled though results of some unpublished analysis suggest that the variability is less in the case of HYV[10]. Similarly while there is reason to believe that response under conditions of mass application may be below those obtained in field demonstration, the discussion (Parikh 1978, Vaidyanathan 1978) remains rather speculative and lacks any direct supporting evidence. On the other hand one of the most detailed and careful analysis of fertiliser trial data (Parikh, Srinivasan et. al., 1974) casts doubts on whether the degree of synergy between yield responses to genetic characteristics of seed, water and fertilisers is as high and as universal as the experimental data suggest. A systematic comparison, on a continuing basis, of the fertiliser response for different crops and seed varieties under varying conditions, obtained in experimental farms, model agronomic experiments and farmers fields is the only way to understand the relative importance of various factors affecting fertiliser use.

46. Changes in the extent and intensity of fertilisation, trends in yield response to fertiliser, as well as the factors which contribute to these changes *at the farm level* can only be studied through sample surveys designed to get the relevant facts on a continuing and comparable basis. Such a conception was evidently behind the design of the Surveys of Fertiliser Practices and in the more recent Surveys of the Impact of the High yielding Varieties conducted by the Institute of Agricultural Research Statistics. The former set of surveys seem to have been discontinued, but the HYV Surveys, started in 1969-70, are continuing and will hopefully continue.

47. The need for such continuing studies is underscored by the results of the HYV surveys which believe several popular impressions

10. This analysis was done by Minhas and Srinivasan.

on the process of technological diffusion: They suggest, for instance, that (a) among the crops and the districts covered (all of which incidentally are well-endowed with irrigation and other infrastructure compared to the average) the rate of spread varies a great deal: (b) while practically all farmers are now using mitrogenous fertilisers, a sizeable fraction of them still do not use phosphates and potash; (c) nor is the proportion of users rising to any significant extent or in a sustained fashion; (d) the average rate of application among fertiliser users is below recommended dosages in most cases and this is specially true, again, of phosphates and potash; and (e) there is no marked difference in the trends in the proportion of users, the intensity of use or the per hectare yields as between traditional and HYV plots (Raheja 1975). It is also noteworthy that data from crop cutting surveys do not show any significant differences in the growth rate of irrigated and unirrigated yields of rice and wheat in the principal growing tracts. One would have expected that in irrigated tracts, where conditions for use of HYV at high input levels is supposed to be favourable, yield would have increased faster than on rainfed land. These facts go against conventional wisdom among scientists and laymen alike, and they raise important questions about the dynamics of the diffusion of fertilisers, as well as about the extent to which experience with a new technique improves its efficiency over time thereby stimulating further increase in its use.

48. That findings of such importance are not evaluated critically, nor followed up by further factual and analytical investi gations to cross-check their veracity and seek out explanations is a rather unflattering commentary on the current state of research in this field. One can think of several plausible excuses : The extent of communication among researchers, especially across disciplines, is lamentably poor. The survey programmes perhaps do not have a sufficiently sharp focus. Nor do they have (or are not permitted to have) a sustained effort at compiling comparable data periodically and over sufficiently long periods to permit meaningful study of dynamics of various determinants of agricultural growth. There is also reason to believe that allocation of staff and resources between collection of data and their analysis is hopelessly lopsided to the latter's disadvantage. Perhaps too those who can make analytical use of the survey data (and among these economists are a major category) have been tardy in making use of the survey data. On this particular aspect, a more liberal and outgoing attitude on the part of data collecting agencies to involve analysts in the design of their surveys, to make the availability of information more widely known and, above all, to giving freer and easier access to the data for

non-official researchers could improve matters very considerably. But this is not the occassion for making prescriptions. My intention was only to point out some issues which deserve to be considered seriously by all concerned. Hopefully, action will follow reflection.

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