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SOURCES OF VARIATION IN AGRICULTURAL PRODUCTIVITY:

A CROSS-SECTION-TIME-SERIES STUDY OF INDIA

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CHAPTER I

INTRODUCTION

The generation and sustenance of economic growth, especially in the early stages of most developing countries, are to a large extent determined by the performance of the agricultural sector /Ranis and Fei (1961), Jorgenson (1961), Adelman and Morris (1968), Hayami and Ruttan (1970)/. An agriculture unresponsive to stimuli or unstable in nature may substantially impede steady growth of the economy. An intensive examination of the characteristics of this sector, particularly as they relate to agricultural production is, therefore, an essential aspect of growth studies.

Apart from the problem of inducing a steady rise in the level of agricultural production, there are two major problems confronting economists concerned with agricultural development. First, there exists a wide disparity in agricultural production per unit of individual inputs or all inputs together among different regions of most countries as well as among different countries of the world. And second,

agricultural production fluctuates from year to year much more than industrial production and the extent of this fluctuation varies from one region to another. The problem of regional disparity is studied mostly on the basis of cross-sectional comparisons at given points in time and is explained by differences in the levels of inputs and technology used in the different regions, while the problem of temporal variation is usually considered in comparisons over time and is generally attributed to natural factors (e.g., rainfall). /A brief review of regional and temporal studies is presented in Appendix A./

While these studies provide useful information on the structure of agricultural production, they are often marred by methodological problems. Many of these studies are based on the level of aggregate agricultural production and consider total output across regions or years. In aggregating the different products that constitute total output, these studies often use a fixed set of weights given by the prices of the products in some base region or year and assume that the relative prices of the products are constant over regions or years. This assumption being unrealistic, biases often enter the output measures on which the regional or temporal studies are based. Secondly, very few of these studies use the concept of region as defined by some agro-climatic or product-composition criteria and are

based instead on administrative regions. Therefore, a good deal of information pertinent to agricultural production is often lost due to the lack of coincidence between the natural and administrative regional units. Moreover, the regional studies, based on cross-sectional comparisons of production in given years, are unable to consider the temporal peculiarities of the regions, and similarly the temporal studies ignore the differences among regions. Therefore, such studies cannot view agricultural production in a space-time context and adequately understand the macro-economic perspective of agriculture. In these somewhat partial analyses, the regional units lose their specific attributes that are invariant over time, and the temporal variations cannot distinguish the disparate regions.

In the present thesis it is argued that regional disparity and temporal variation in agricultural output are characteristics of the same production activity, and that they should be studied in a general framework that combines both cross-sectional and inter-temporal comparisons. It is hypothesized that sources of variation in output can be classified into three categories:

(i) Input-effect: output may vary due to differences in the level of known input used; a region or a year with a lower level of inputs is likely to produce a lower level of output, ceteris paribus.

(ii) Region effect: it is often observed that even though the same levels of the known inputs are used in two regions, there are still differences in output levels. This may be due to differences other than input use in the very nature of the regions that are stable over time. For example, one region may have a more fertile land than another, or the quality of other inputs used may differ between the two regions. It may also be that one region is using more of some input (e.g., management service) not explicitly included in the calculation, than another region. The regions may be on different technological levels or even the history and tradition of one region may be more conducive to greater efficiency in the use of identical inputs. (iii) Temporal-effect: output may vary from region to region and year to year as a result of factors that are stochastic in nature and change over space and time.

The objective of this thesis is to attempt an analysis of agricultural production within a general framework that can consider the various sources of differences in output among regions and over time. An analytical model will be developed combining cross-section and time-series observations that permit one to decompose the measured sources of growth and regional variations in agricultural output by providing

estimates of the contributions of inputs, time persistent regional peculiarities and temporal factors. The problem of aggregating different commodities into total agricultural output will be considered and a measure will be used that avoids the bias arising from the usual assumption of constant relative prices. Also the regions for the study will be chosen on the basis of agro-climatic and crop-pattern, rather than administrative, criteria. The empirical investigation will be conducted on India, a major developing economy where the disparity between regions is a growing concern and where temporal variability in agricultural output is such that the monsoon has been called the "traditional dispenser of India's destiny" (Britannica Book of the Year 1974, p. 361).

In general, the information obtained from such a study, it is believed, should help policy formulation in dealing with the problems of regional inequalities and instability in agricultural output -- part of the development objectives of India. In particular, by shedding some light on the sources of growth in agricultural output the study might aid regional allocation of resources for agriculture. Measured inputs may not account for a large fraction of the variations in output between regions. But regional effects will be approximated

and used to rank regions in terms of their production efficiency. The same quantity of inputs will produce a greater output in a region with a higher region effect. This information might be useful also for directing research into the causes of the differences in regional effects and to develop the productive potential of the poorer regions. The effects of weather and other temporal factors should provide measures of the dependence of Indian agriculture on the temporal vagaries of nature and should help identify areas with high annual variability from those with low variability.

The sequence of the thesis is as follows: In Chapter II a brief review is made of the problems that arise in econometric analyses pooling cross-section and time-series data and the properties of the method of estimation adopted here as against other alternative methods for the specification and estimation of production functions. Chapter III presents the forms of production function used here, the theoretical model and the statistical method of estimation. Chapter IV deals with the selection of the regions, the choice of data and the construction of variables, including a discussion of the index number problem encountered in the measurement of aggregate output over time. Chapter V discusses the parameters estimated for

the production functions, while Chapters VI and VII present the estimates of the region effects and temporal effects on production, respectively. Chapter VIII summarizes the main findings and indicates their implications for policy.

CHAPTER II

PRODUCTION FUNCTION USING CROSS-SECTION AND TIME-SERIES DATA: PROBLEMS OF ESTIMATION AND ASSUMPTIONS

In order to examine the differences in agricultural development between regions and over time, a production function model is proposed based on cross-section and time-series data. The purpose of this chapter is to review briefly approaches to pooling cross-section and time-series data for the estimation of production functions.

In recent years, the pooling of cross-section and time-series data for production, demand or cost functions has been increasingly popular. Two reasons lie behind this: first, the lack of adequate time-series of cross-sections poses the problem of adequate degrees of freedom in estimation by regions (or any other cross-sectional units) whereas by pooling the time-series of cross-sections an attempt can be made to make the most efficient use of data

across regions to estimate the behavioral relationship containing variables that differ widely from one region to another, so that the lesser information over time can be used to best advantage [Nerlove (1971), Balestra & Nerlove (1966)]. Second, the use of the analysis of covariance method on the combined cross-section time-series data helps avoid the problem of simultaneous equation biases existing in time series data when there are increases in productivity over time [Hoch (1962)]. But although there are some distinct advantages in the use of cross-section and time-series data, their pooling involves problems that vary in nature with the statistical estimation procedure used.

A number of studies [Klein (1953), Marshak (1943), Solow (1964)] combined cross-section and time-series data to estimate the parameters of their models by first using cross-section data to obtain estimates of some of the parameters of the model and then introducing these estimates into time-series regression to obtain estimates of the other parameters of the model. The problem is that the estimates obtained from the time-series data are conditional upon the estimates from cross-section data and the time-series regression yields only conditional estimates of the parameters

/Chetty (1968)/. It has been suggested that cross-section estimates may often be biased and thus can contaminate the combined estimates if they are introduced as point estimates /Tobin (1950), Kuh (1959)/. This leads to the need for simultaneous estimation of the parameters from cross-section and time-series data.

The simplest method of combining cross-section and time-series data to obtain estimates of parameters is by the use of direct ordinary least squares on the pooled data. But it has been shown /Nerlove (1965), Balestra and Nerlove (1966), and Nerlove (1971)/ that ordinary least squares on combined cross-section time-series observations yield estimates which are poor or even incompatible with theoretical expectations. One possible explanation is that when cross-section and time-series data are combined in the estimation of a regression equation there may be present some "other effects" in the data which should be explicitly taken into account. This can be accomplished by the assumption that the cross-sectional (and/or time-series) units have some additive effect specific to each of them. This specific effect can be assumed to be either a constant or variable.

The assumption of a constant individual effect enables the use of individual shift variables in the form of "dummy"

variables [Mundlak (1961), Hoch (1962)]. The problem in making the rather restrictive assumption of a constant region (or household or firm, as the case may be) effect, as shown by Balestra and Nerlove (1966) is that the dummy variables "appear to reflect too much and then to reduce the coefficient -- to too low a level." An alternative way to take into account the region (and/or time) effect is to relax the assumption of its constancy and use what has been known as "residual model."

A residual model is formulated on the simple relation given in

$$Y_{rt} = \alpha X_{rt} + U_{rt} \qquad \text{II-1}$$

where U_{rt} are random variables for region r and year t. These residuals are supposed to represent the net effects of variables whose explicit inclusion was not possible in the analysis. In a pure cross-section analysis, it is usually assumed that the large number of factors which affect the regions (or households or firms) in the sample and the value of the dependent variable for each of them, but which could not be explicitly included as independent variables, may be summarized as a random disturbance. Econometric analysis takes as its basis the assumption of the stochastic mechanism that generates the disturbances, e.g. U_{rt} in Eqn. II-1. Similarly, in pure

time-series analysis an assumption is made about stochastic disturbances. When cross-section and time-series observations are pooled, the disturbances become conceptually more complicated. It is, however, possible that some of the omitted variables reflect differences which affect a given region more or less in the same manner over time. Some other omitted variables reflect factors peculiar to years (or time units) but affect all cross-sectional units similarly. Other omitted variables which represent factors peculiar to both regional (cross-sectional) and time units may also exist and be captured in a third error component. That is, the disturbance can be broken up into three components,

$$U_{rt} = \mu_r + \lambda_t + \gamma_{rt} \qquad \text{II-2}$$

where μ_r represents the regional effects, λ_t represents the time effects and γ_{rt} represents the remainder effect that varies with both region and time. Model II-2 has been called the "error components model." The error components model in the form of II-2 has been developed by Wallace and Hussain (1969) with all three components, whereas Balestra and Nerlove (1966) have broken up the disturbance term into the regional and the random effects, assuming the time effects (λ_t's) to be absent. As Nerlove

(1971) suggests, the "assumed absence of period effects is largely a question of judgment in any particular application."

There are several alternative approaches to the estimation of the error components model. Wallace and Hussain (1969) compare analytically a method that basically assumes μ_r and λ_t as parameters with another method treating them as random variables and estimating their moments from the calculated residuals of ordinary least squares and using the estimated variance proportions to transform the data before running a second regression. Their conclusion is that under certain assumptions, as both the number of cross-sectional and time-series units tend to infinity, both methods lead to asymptotically equal variance-covariance matrices.

Amemiya (1967) estimates the regression coefficients of an error-components model in three different ways: (i) least squares, assuming that μ_r are fixed constants; (ii) generalized least squares based on a consistently estimated value of the ratio of the variance of the regional effect to the total variance, [this parameter, called by Nerlove "intra-class correlation coefficient" is defined as $\rho = \sigma^2_\mu / \sigma^2$ where $\sigma^2 = \sigma^2_\mu + \sigma^2_\gamma$]; and (iii) maximum likelihood.

Amemiya's conclusion is that, under assumptions similar to Wallace and Hussain's, all three estimates are consistent and asymptotically efficient as the number of regions and years are allowed to tend to infinity. The results of both Wallace and Hussain and Amemiya show that the methods of estimation mentioned above yield estimates that are asymptotically equivalent and so it is not possible to distinguish between these methods asymptotically. Nerlove (1967) shows that ordinary least squares either ignoring the region effects or assuming them as constants gives poor estimates of coefficients, which demonstrates the difficulty of assuming large sample asymptotic results in typical econometric problems.

In order to evaluate the relative merit of the different approaches to estimation in a cross-section time-series study, Nerlove (1971) conducts Monte Carlo experiments with five such methods:

(i) generalized least squares estimates employing the true value of ρ (used to generate the observations);

(ii) ordinary least squares estimates assuming $\rho = 0$;

(iii) least squares estimates assuming μ_r as parameters to be estimated;

(iv) two-round generalized least squares estimates assuming $\rho = \hat{\sigma}^2_\mu / \hat{\sigma}^2$, where $\hat{\sigma}^2 = \hat{\sigma}^2_\mu + \hat{\sigma}^2_\gamma$; and

(v) maximum likelihood estimates.

Nerlove's conclusion from the experiments is that method IV, i.e., the two-round generalized least squares procedure that uses a value of $\hat{\rho}$ estimated from first-round regressions including individual constant terms, yields estimates which seem to be better than the estimates provided by any other procedure in terms of both relative bias and mean square error. The present study is based on this two-round generalized least squares estimation approach to the pooling of cross-section and time-series data. The model and the estimation procedure are presented in Chapter IV.

Specific Application to Production Function

This study is of the relationship between output and inputs (e.g., land, irrigation, etc.) in a time-series of cross-sections. Such relationships are formulated in production functions and the following paragraphs deal with the production function postulated here and the implications of the assumptions and the expected results.

A critical assumption in production function analysis is that the same technical possibilities are available to all producers. This assumption is made in cross-section studies -- using both international and regional data. Jyoti Bhattacharjee's study on cross-country aggregate production function for the agricultural sector /Bhattacharjee (1955)/, Griliches' study on the aggregate agricultural production function using states in the United States as observations /Griliches (1964)/ and Anne Krueger's study on the contribution of factor endowment differentials to variations in per capita income in different countries /Krueger (1968)/ -- all make the assumption that the countries and regions are subject to a uniform production function. Consistent with this assumption, Hayami and Ruttan (1970) estimate a cross-country production function which they view as a "meta-production function." The individual producers in a given time have available to them only a part of the full range of technological possibilities described by a meta-production function. Hayami and Ruttan assume that "the invention and diffusion of a new "location specific" agricultural technology through the application of the concepts of physical, biological and chemical science and of engineering, craft and husbandry skills is capable of making the factor productivities

implicit in the cross-country production function available to producers in less developed countries." Thus the use of the assumption of different units operating on the same production function - of the neo-classical or meta-production function variety - is widely practiced in economic literature.

In a cross-section-time-series study of the present variety the assumption boils down to the parameters being invariant from individual to individual except for the constant term. The disturbing elements in the model affect only the level, and not the form of the functional relationship - this simplification "is the basis of nearly all econometric work" /Nerlove (1971)/. Of course, models of more general type have been constructed where the parameters to be estimated are functions of the levels of certain other variables or are themselves random variables /Hildreth and Houck (1968)/. But apart from being extremely complicated, such models "have not proved highly productive" /Nerlove (1971)/. The present study, while adhering to the assumption that the relationship to be estimated is homogeneous, even though disturbed, will construct production functions on the entire cross-section time-series data.

Another assumption in the use of the error-components model in production function analyses is that the explanatory variables (x's) are independent of the disturbance U_{rt} in Eqn. II-1. This implies that the input levels are independent of the regional efficiency component (μ_r), the time component (λ_t) and the random component (γ_{rt}) of the disturbance U_{rt}. This assumption can be justified following the argument of Hoch [Hoch (1962) and Mundlak (1961, 1963)] which is based on the fact that, by the very nature of the production process, inputs precede output in time, and therefore, at the date when inputs are being determined the actual output is not known with full certainty, the reason being the dependence of output on U_{rt}. The producer will, therefore, base his decision with regard to input use on expected output considering some parameters of the purely random function of γ_{rt} rather than γ_{rt} itself. There is no a priori reason to believe that the levels of inputs will depend on the levels of U_{rt}.

In most production function analysis, especially in agriculture, the range of the relevant explanatory variables is very wide. Many of these variables are hardly ever measurable and for many others data are not available and, therefore, these are omitted from the estimation. The

exclusion of relevant variables has some important effects on the estimates of the function. When the omitted variables are related to the included variables in a production function, the coefficients estimated by ordinary least squares will be biased upward or downward depending on the relationship between the dependent and the omitted variable on the one hand, and the omitted variable and its related included variable on the other. [See Kmenta (1971), Griliches (1957)]. If the omitted input varies less than proportionately with the included inputs the method of ordinary least squares will lead to an underestimate of the returns to scale (i.e., the sum of the coefficients in a Cobb-Douglas production function). For example, assuming that managerial input varies less than proportionately with the included inputs, the exclusion of managerial inputs will cause an underestimate of the returns to scale. Of course the same omitted input may not be related to all included inputs in the same manner, and the total effect will depend on the effects on the individual included inputs. For example, if managerial input is related positively with tractor, but negatively with labor, its exclusion will lead to an overestimate of the returns to tractor and underestimate of the returns to labor and the effect on the returns

to scale will depend on the sum of the two opposite effects. Similarly, if labor quality and quantity are inversely related, the returns to labor quantity will be underestimated as a result of the omission of the quality. On the other hand, if the quality and quantity of land are positively related and quality is omitted, there will be an upward bias in the coefficient of land area. When cross-section and time-series data are pooled the problems become compounded as a result of the introduction of some additional effects which can be either region-specific or time-specific. Estimates by the ordinary least squares method in this case are more likely to be biased. The covariance analysis used by Hoch (1962) and Mundlak (1961, 1963) is claimed to have removed this bias.

In the Balestra-Nerlove method used in the present study (see Chapter III) the original variables are transformed on the assumption that the residuals from the ordinary least squares estimation can be broken down into three components: (i) region-specific, (ii) time-specific, and (iii) random. In the present study this implies that the factors which have not been included in the inputs can be classified in the three types. What this means, for instance, is that a region with a better

quality land in one year has throughout the period its relative position in land quality unchanged (region-effect), a year which is good/bad relative to other years in crop production (e.g., in rainfall) is good/bad in all the regions (time-effect) and that there are some factors behaving purely in a random fashion, such as the vagaries in natural phenomena (e.g., pest or flood) from year to year.

A basic point to remember in comparing the estimates of an ordinary least squares (OLS) and those of an error-components model that explicitly recognizes region and time effects is that the estimates in the former method are subject to certain influences which are removed in the latter. The nature of change in the estimates, therefore, depends on the nature of the influences present. Past results of the studies in cross-section-time-series data indicate that some coefficients are reduced while others are increased as a result of considering the cross-section and time effects but in general their efficiency is increased. [Kuh (1954), Balestra and Nerlove (1966), Mundlak (1961), Hock (1962)].

The present production function study using an error components model based on a time-series of cross-section data and assumptions mentioned above, is designed to yield useful

estimates of production elasticities and residuals for purposes of dealing with differences in agricultural development over space and time. The elasticities derived from the production function together with differences in quantities of inputs can measure the contribution of the respective inputs [Hayami and Ruttan (197[illegible]]. Apart from explaining part of the variation in growth, this information, together with information on elasticities of supply of inputs, would indicate the extent to which such variations could be reduced, under the given technology. Supplies of certain inputs (e.g., irrigation) may be highly inelastic in some regions indicating the limits of the existing technology, reflected in the parameters of the production function, in bringing about growth in the particular region. This would call for a search for a different technology or a different product composition for the region (possibly switching to pasture or livestock farming) that use relatively less of the scarce inputs. The production elasticities would also be helpful in the construction of demand functions for inputs, and thus facilitate allocation of resources in the different regions.

The residuals in the variations in agricultural production represent the segment that are due to factors not accounted for in the observed inputs, and to this extent production variations cannot be controlled by relaxing the constraints on known inputs. The residuals for the regional units (districts) may be used to formulate a useful regional agricultural development policy and to examine regional boundaries built on other criteria, e.g., administrative, crop-pattern, agroclimatic, etc. This will facilitate examination of the hypothesis of varying rates of diffusion of new technologies in different clusters of regional units (e.g. states) where certain factors such as research expenditures may have perhaps differed. A second stage exploration into the causes of the residuals after these are estimated, both quantitative and otherwise, should help to improve our specification of agricultural production function for developing areas such as India.

Likewise, the residuals for the temporal effect represent effects due to factors peculiar to the given years that are not captured in the known inputs. Typically, these would be variations in rainfall and similar climatic factors. If development is accompanied with an increasing scientific

base for agriculture that can counter the vagaries of nature, and if new inputs are applied not piecemeal, but in entire packages, the temporal residuals should decline over time. This provides a test of the increasing stability of agricultural growth, and indicates the range in which agricultural production under the present technology might fluctuate from year to year, irrespective of variations in the known inputs. This knowledge could help in the formulation of an inventory policy to smooth out fluctuations in agricultural prices.

CHAPTER III

A MODEL OF REGIONAL AND TEMPORAL EFFECTS IN PRODUCTION

The purpose of this chapter is to specify the production functions constructed in this study, to develop the theoretical model for regional and temporal effects in production and to present the estimation procedure followed in the analysis.

PRODUCTION FUNCTIONS

Subject to the availability of data which are limited to the physical amounts of inputs and output and output prices (see Chapter IV for a discussion on data), two types of production function have been estimated in this analysis, first, Cobb-Douglas or linear in logarithm type, and second, quadratic type.

The Cobb-Douglas type of production function is given by Eqn. III-1 and III-2:

$$Y_{rt} = K \prod_{j=1} X_{jrt}^{\alpha j} \; e^{U_{rt}} \qquad \text{III-1}$$

$$\text{or} \quad \log Y_{rt} = \log K + \sum_{j=1} \alpha_j \log X_{jrt} + U_{rt} \qquad \text{III-2}$$

where

Y = output;

K = constant;

X_j = input j;

$j=1, 2, \ldots, J$ = number of inputs;

α_j = elasticity of output with respect to input j;

U = random disturbance;

r, t = region and year respectively.

The Cobb-Douglas form of production function has some well known properties that justify its wide application in economic literature. [Henderson and Quandt (1971)]. It is a homogeneous function that provides a scale factor enabling one to measure the returns to scale and to interpret the elasticity coefficients with relative ease. But at the same time, the Cobb-Douglas production function makes several restrictive assumptions. It is assumed that the elasticity coefficients are constant

implying constant shares for the inputs. The elasticity of substitution among factors is unity in the Cobb-Douglas form. Moreover, this being linear in logarithm, output is zero if any of the inputs is zero and the output expansion path is assumed to pass through the origin.

Some of these restrictions could be avoided by constructing a C.E.S. type /see Arrow, Chenery, Minhas and Solow (1971)/ production function with elasticity of substitution among inputs being constant but not unity, or a Transcendental Logarithmic type /See Christensen, Jorgenson, and Lau (1973)/ production function which permits factor shares to change. But such functions could not be fitted in the present case due to lack of data. However, the available data permits the construction of a quadratic production function of the general type given by Eqn. III-3:

$$Y_{rt} = M + \Sigma_{j=1} (b_j X_{jrt} + c_j X^2_{jrt}) + U_{rt} \qquad \text{III-3}$$

where

Y = output;

M = constant;

X_j = input j;

$j=1, \ldots j$ = number of inputs;

U = random disturbance;

r, t = region and year respectively, and b and c are the coefficients for the variables.

The expected signs of the coefficients for the input levels are positive while those of the squared terms are negative to denote diminishing marginal returns. As this function shows, several of the restrictions of the Cobb-Douglas form are relaxed here. Here output is not forced to be zero with any one input being zero. The output expansion path is a straight line but it need not pass through the origin as in the Cobb-Douglas case. Also unlike the Cobb-Douglas, output elasticity is not a constant but varies with input quantity; it declines with increasing level of input if the estimated signs of the coefficients are as expected. [See Heady and Dillon (1961)]. Another property of the quadratic production function is that the iso-quants here are not asymptotic to the input axes as in Cobb-Douglas, but can intersect them, implying that certain levels of output can be attained with one input at a positive level while the other is at zero. Another property of the Quadratic type of production function which perhaps explains why it is not very often used in the analysis of actual (as against experimental) data, is that here marginal

productivity of inputs can be negative. The production surface can have a peak that stands for a maximum output feasible for a given combination of factors. The maximum output that can be obtained from input X_j in Eqn. III-2 is given by $\frac{b_j}{2C_j}$. With quantities of X_j higher than this level, output will decrease, unless other inputs also are increased. The Quadratic production function does not make the usual assumption of free disposal of inputs and allows for a declining segment in the production surface /See Patinkin (1973)/.

In this study we have constructed production functions of Cobb-Douglas and Quadratic types on the total amount of output as a function of the total amounts of inputs as well as on the amount of output per unit of land as a function of other inputs per unit of land. This standardization by land might help indicate the effect of differences in the size of the districts as the units of observation.

The main objective of the analysis is to examine after accounting for the variations in known inputs, the residual variation in production due to the pecularities of

the (i) regional unit and (ii) year. The underlying idea is that agricultural production in a given region can be attributed to (a) the known inputs, (b) a purely regional effect and (c) a random effect that varies from region to region and year to year.

An analytical framework can be developed to obtain the above results by adapting a model pooling cross-section and time-series that enable breaking up of the residuals into desired region or time components. In the following sections such an adaptation is done for regional and temporal analysis on the basis of the model and the statistical estimation procedure developed by Balestra and Nerlove (1966) in their study of demand for natural gas, Schultz (1969), Nerlove and Schultz (1970), and Schultz (1973) in studying family decision making in Puerto Rico and Taiwan.

THE MODEL

Let the no. of regional units (r) = R

no. of Years (t) = T

a) Dependent Variable = y_{rt}

So

$$y = \begin{bmatrix} y_1 \\ y_2 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ y_R \end{bmatrix} = \begin{bmatrix} y_{11} \\ y_{12} \\ \cdot \\ \cdot \\ Y_{1T} \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ y_{RT} \end{bmatrix}$$

An RT X 1 Vector

b) Let the No. of Explanatory Variables (X) = N

$$X = \begin{bmatrix} X_{11}^{(1)} \cdots\cdots X_{11}^{(N)} \\ X_{1T}^{(1)} \cdots\cdots X_{1T}^{(N)} \\ X_{RT}^{(1)} \cdots\cdots X_{RT}^{(N)} \end{bmatrix}$$

An RT X N Matrix.

c) Residuals : U

$$U = \begin{bmatrix} U_1 \\ U_2 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ U_R \end{bmatrix} \qquad \begin{bmatrix} U_{11} \\ \cdot \\ \cdot \\ U_{1T} \\ \cdot \\ \cdot \\ U_{RT} \end{bmatrix}$$

An RT X 1 Vector.

d) Also let α be an NX1 Vector of constant coefficients of explanatory Variables.

Now from the combination of cross section and time-series data we estimate the relation:

$Y = X\alpha + U$ where U is an RT X 1 vector of residuals.

The residual U can be divided into two components representing (i) the purely regional (or time) factors that are assumed constant over time (or region), and (ii) purely random effects that vary from time to time and region to region.

Let us now consider only regional effects. Time effects can be derived in a parallel fashion.

Breaking the residual we have,

$$U_{rt} = \mu_r + \gamma_{rt}, \qquad \text{III-4}$$

where μ and v are statistically independent,

i.e.,

$$E\mu_r\gamma_{rt} = 0 \quad \text{For all r, t.}$$

Assume that there is no serial correlation among U_{rt}. Also these are independent of each other.

So,

$$\left.\begin{aligned} &E\gamma_{rt}\gamma_{r't'} = \sigma^2_{\gamma}, \quad \text{For } r=r',\ t=t' \\ &E_{rt\ r't'} = 0 \quad \text{in all other cases.} \end{aligned}\right\} \qquad \text{III-5}$$

Similarly,

$$\left.\begin{aligned} &E\ \mu_r\ \mu_{r'} = \sigma^2_{\mu}, \text{ for } r = r' \\ \text{and} \quad &E\ \mu_r\ \mu_r = 0, \text{ other wise.} \end{aligned}\right\} \qquad \text{III-6}$$

This assumption implies heteroskedasticity, i.e., disturbances for all observations are <u>not</u> constant, and cross-sectional independence.

Define $\sigma^2 = \sigma^2_{\mu} + \sigma^2_{\gamma}$ III-7

and $\rho = \sigma^2_{\mu} / (\sigma^2_{\mu} + \sigma^2_{\gamma}) = \sigma^2_{\mu} / \sigma^2$ III-8

Then from the relation $E_{\mu_r \gamma_{rt}} = 0$ we have the variance-covariance matrix of the residuals U as follows:

$$E_{uu} = \Omega = \sigma^2 \begin{bmatrix} M & 0 & \cdots & 0 \\ 0 & M & \cdots & 0 \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ 0 & 0 & \cdots & M \end{bmatrix}$$

Ω is an RT X RT Matrix

and

$$E_{u_r u_r} = \sigma^2 M = \sigma^2 \begin{bmatrix} 1 & \rho & \rho & \cdots & \rho \\ \rho & 1 & \rho & \cdots & \rho \\ \cdot & \cdot & \cdot & \cdots & \cdot \\ \rho & \cdot & \cdot & \cdots & 1 \end{bmatrix}$$

M is a T x T Matrix

In the case of a pure cross-section study we have for each region only one time period. Then each M will have only the upper left-hand corner entry, so we have

$\Omega = \sigma^2 I$, where I is an R x R identity matrix.

In the case of a pure time-series, we have only one region, so we cannot decompose the residual into 'regional' and 'random' effects. So we can assume $\mu_r = 0$ and $\sigma_\mu = 0$. Here also we have

$\Omega = \sigma^2 I$, where I is a T x T identity matrix.

METHOD OF ESTIMATION

We have $U_{rt} = \mu_r + \nu_{rt}$

Recall $\sigma^2 = \sigma^2_\mu + \sigma^2_\nu$

$\rho = \sigma^2_\mu / \sigma^2$

Balestra-Nerlove derived the following Maximum-likelihood estimates of σ^2 and ρ :

$$\hat{\sigma}^2 = \frac{\sum_{r=1}^{R} \sum_{t=1}^{T} U^2_{rt}}{RT} \qquad \text{III-9}$$

$$\hat{\rho} = \frac{\sum_{r=1}^{R} \left[\sum_{t=1}^{T} U_{rt}\right]^2 - \sum_{t=1}^{T} U^2_{rt}}{(T-1) \sum_{r=1}^{R} \sum_{t=1}^{T} U^2_{rt}} \qquad \text{III-10}$$

The maximum-likelihood estimates have the desireable properties of consistency, asympotic normality and asympotic efficiency. But the above estimate of ρ can

yield values which are negative, if the variance of regional effects (represented by the first term in the numerator) is smaller than the overall variance (represented by the second term). Since it is difficult to interpret a negative ratio of variances, an alternative estimate of ρ developed by Balestra-Nerlove may be used:

$$\hat{\rho} = \frac{\sum_{r=1}^{R} \sum_{t=1}^{T} \sum_{t=1}^{T} U_{rt} U_{rt'} - \frac{1}{R} \sum_{r=1}^{R} \sum_{t=1}^{T} U_{rt}^{2}}{RT^2 \hat{\sigma}^2} \qquad \text{III-11}$$

which will yield values of $\hat{\rho}$ that lie between 0 and 1. The U_{rt}'s can be calculated by OLS with individual constant terms from the equation $Y = X\alpha + U$. Now let

$$\xi = \sigma^2 [(1-\rho) + T\rho] \qquad \text{III-12}$$

and

$$\eta = \sigma^2 (1-\rho) \qquad \text{III-13}$$

where ξ and η are the two distinct characteristic roots of the matrix $E(uu') / \sigma^2$

Take the original variable Y, we have an RT x 1 Vector of Y. For a given region over time calculate

$$Y_r = \frac{\sum_{t=1}^{T} Y_{rt}}{T}$$

Now transform the original variable in the following way:

$$\underset{(T \times 1)}{Y^*_{rt}} = \underset{(T \times 1)}{\left[\frac{Y_{rt} - Y_r}{\sqrt{\eta}} + \frac{Y_r}{\sqrt{\xi}} \right]} \qquad \text{III-14}$$

where Y^*_{rt} is the transformed variable.

This method of transformation is to be repeated on all the variables -- dependent and independent -- and the transformed variables will yield the desired variance-covariance matrix.

CHAPTER IV

REGIONS, VARIABLES AND DATA

Regions

The Indian economy has been subjected to planning for economic development for over two decades and there should be interesting lessons to learn from a study of the experience. The land area of India is vast and is characterized by extreme variations not only in climatic but in economic, social and cultural factors. Such variations have their impact on the agricultural sector of the country, which produces about half of India's national output and employs about 80 percent of India's working force. During the history of Indian agriculture, variability in its production from year to year has been one of the important features to reckon with. There are indications that the nature of Indian agriculture is undergoing substantial change in the recent years due to various factors including the introduction of the new high yielding varieties of seeds for a number of crops. No less important, there is available a substantial body of data on Indian agriculture. All these

factors should justify the selection of India for the present study while it is believed that the results should be of interest not only for planning for the economic development of India, but for other developing economies too.

In order to restrict the scope of the empirical inquiry to feasible limits, it has been decided to use selected regions, rather than entire India. For this purpose, I have relied on the study by K. William Easter and Martin E. Abel (1972, 1973), referred to in Appendix A. Easter and Abel have classified the crop producing districts of India (except in Himachal Pradesh, Jammu and Kashmir, Assam and the Hill States, the Union Territories and six northern hill districts of U.P.) into crop regions for 21 individual crops and three groups of crops. The criteria used in the delineation of the crop regions are two-fold: (i) the percentage contribution of a district to the total national 1967-69 production of the crop; and (ii) the percentage of the district's gross cropped area under the crop. The second criterion avoids exclusion of low-productivity districts from respective crop regions. Each district selected in the wheat regions either produced at least 0.5 percent of the national wheat output and used at least 10 percent of its gross acreage for wheat, or produced less

than 0.5 percent of the national wheat output and used at least 20 percent of its gross acreage for wheat.

The Easter-Abel crop regions for wheat spread over six states and 79 districts that have been classified into nine regions Out of this, the present study is concerned with five states and 72 districts that comprise eight wheat regions. These eight wheat regions produced about 75 percent of the total wheat output in India in 1967-69. These wheat regions belong to the states: Punjab, Haryana, U.P., Rajasthan and M. P.

Easter also developed another set of regions for India using agro-climatic factors, namely, climate, soil types and cropping patterns. On this basis the country has been divided into three divisions, ten subdivisions and 52 regions.

This study covers parts of two agro-climatic divisions and five subdivisions. In the Indo-Gangetic Alluvial Plains Division this study includes the Upper Plains subdivision, the Central Plains subdivision and parts of Lower Plains subdivision. In the Plateau and Hills division the study covers only parts of the Central Black soils subdivision.

The purpose of restricting the analysis to the major wheat regions is to look at the part of India which has the potential of being influenced by the new wheat technology. Nonetheless, for purposes of analysis of agricultural production the study does consider the production of 30 crops that constitute the bulk of India's crop output. These crops are: wheat, rice, jowar (sorghum), maize, bajra (millet), ragi (millet), barley, grain (chick pea), tur (pigeon pea), other pulses, ground nut (peanuts), niger seed, linseed, sesamum, rapeseed and mustard, castor seed, sunhemp, mesta, jute, tobacco, sugarcane, potatoes, dry chillies, turmeric, safflower, cotton, black pepper, dry ginger, and small millets. Within the wheat regions the crop compositions of the districts vary widely as do their yields, extent of irrigation, fertilizer consumed, spread of the high yielding variety, etc. Therefore, although the present study deals with the 72 predominantly wheat districts during 1959-69, it is possible to extend it both over region and time. A map of the districts studied here is presented below, and a list is given in Appendix B.

FIGURE 1
MAP OF INDIA
Districts selected for study

Variables and Data

Subject to the availability of data, the basic production function constructed here has used only seven variables -- aggregate Agricultural Output as the dependent variable, and Land, Irrigation, Fertilizer, Tractor, Literate Labor and Illiterate Labor as independent variables. The source of data on output, land and irrigation is the Abel-Easter Project on Regional Agricultural Development Planning in India currently undertaken at the Economic Development Center, University of Minnesota while other sources have been used for the remaining data as mentioned below.

Total Agricultural Output

Total crop output, the independent variable in the analysis, has been measured for each district and each year on the basis of the quantity of each of the 30 crops mentioned above. Data on price of the crops received by farmers in each district and year are available and these have been used for aggregation of the output by two methods -- Divisia and Laspeyres. A note on the different measures of output and their relative merits is presented below.

Measurement of Output -- An Index Number Problem*

Any study, like the present one, that deals with the aggregate of a number of heterogeneous products is faced with the problem of how to add these products up. Essentially the problem is one of choosing the appropriate weights to combine the dissimilar products. The problem becomes complicated when, as in this study, comparisons over time and space are involved and prices, the natural choice of a weight, vary over observations. In this section this index number problem is discussed and a method is suggested for measuring agricultural output of the regions of India.

The most common measures of aggregate output rely on fixed price weights using either initial year prices (Laspeyres Index) or final year prices (Paasche's Index). Apart from neglecting relevant information on the time variation in prices, these fixed weight indices are based on the assumption that relative prices of different commodities are constant between regions and years. In reality this assumption is seldom valid. The same total physical output configuration, valued at

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* I am grateful to Professors Willis Peterson and Marcel K. Richter for illuminating discussions on this problem.

different relative prices, will show apparently different measures of output levels. This is shown in Figure 2. /Ruttan (19[illegible])/.

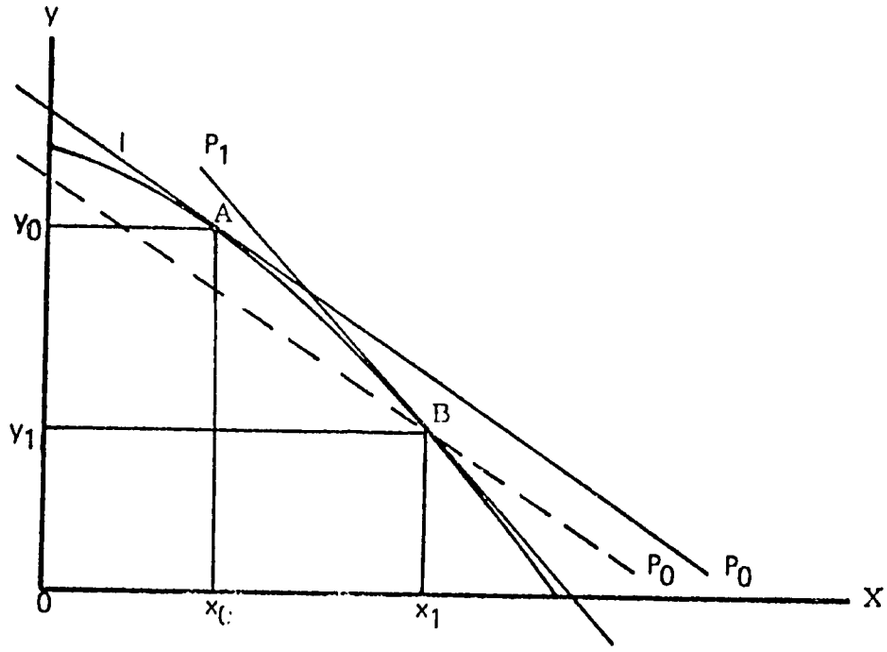

Figure 2

Suppose there are two products X and Y, and I is the production possibility curve for given inputs. If relative price is given by P_0, the output configuration is

X_oY_o at point A on the production possibility curve. Now if relative price is P_1, the output configuration will be X_1Y_1 at point B without any real change in total output. But if this configuration is valued at the old relative price P_o rather than P_1, the measure of total output will be smaller. Thus Laspeyres method will show an apparent decline in output without there being any real decline. Similarly, the Paasches index will show an increase in output.

To minimize this problem weights have been defined as the geometric mean of the initial and final year prices, where it is assumed that the downward and upward biases are offsetting. /Hayami and Ruttan (1970) use geometric mean of prices in three countries in order to avoid the biases in their international productivity comparison./ In addition to still being wasteful of price information, this measure reflects neither the initial, nor the final year weight, and in reality the biases may not be equal in extent and thus may fail to be offsetting. Moreover, the problem of inter-regional comparison still remains.

These problems can be dealt with in an output measure that uses weights changing freely between regions and years

and that are not based on the assumption of constant relative prices. Divisia index offers such a measure that has changing, rather than fixed weights, and that is suitable for studying a situation characterized by changing relative prices. It has been proved that Divisia index has the unique property of minimizing the error of approximation as the economy moves from one production configuration to another. /See Richter (1966)/. Following Dale W. Jorgenson and Zvi Griliches (1967, 1972) a Divisia measure of aggregate output is presented below.

The basic objective of the Divisia measure of output is to approximate a quantity measure as distinct from a value measure. This is done by separating the index of value products into price and quantity indexes. Let V, p, q represent value, price and quantity respectively, and $\dot{V}$, $\dot{p}$, $\dot{q}$ the corresponding time derivatives.

For n commodities,

$$V = V_1 + V_2 \ldots\ldots\ldots\ldots + V_n$$

$$= p_1 q_1 + p_2 q_2 + \ldots\ldots\ldots + p_n q_n$$

Differentiating with respect to time,

$$\dot{V} = \dot{p}_1 q_1 + p_1 \dot{q}_1 + \dot{p}_2 q_2 + p_2 \dot{q}_2 + \ldots\ldots + \dot{p}_n \dot{q}_n + p_n \dot{q}_n$$

$$\dot{V} = \left[\frac{\dot{p}_1}{p_1} (p_1 q_1) + \frac{\dot{p}_2}{p_2} (p_2 q_2) + \ldots\ldots + \frac{\dot{p}_n}{p_n} (p_n q_n) \right] +$$

$$\left[\frac{\dot{q}_1}{q_1} (p_1 q_1) + \frac{\dot{q}_2}{q_2} (p_2 q_2) + \ldots\ldots + \frac{\dot{q}_n}{q_n} (p_n q_n) \right]$$

$$\frac{\dot{V}}{v} = \left[\frac{v_1}{v} \cdot \frac{\dot{p}_1}{p_1} + \frac{v_2}{v} \cdot \frac{\dot{p}_2}{p_2} + \ldots + \frac{v_n}{v} \cdot \frac{\dot{p}_n}{p_n} \right] +$$

$$\left[\frac{v_1}{v} \cdot \frac{\dot{q}_1}{q_1} + \frac{v_2}{v} \cdot \frac{\dot{q}_2}{q_2} + \ldots + \frac{v_n}{v} \cdot \frac{\dot{q}_n}{q_n} \right]$$

$$\frac{\dot{V}}{v} = \sum_i w_i \frac{\dot{p}_i}{p_i} + \sum_i w_i \frac{\dot{q}_i}{q_i} \ldots\ldots \qquad \text{IV-1}$$

where

$$w_i = \frac{v_i}{v} = \frac{v_i}{\sum_i v_i} \quad \frac{p_i q_i}{\sum_i p_i q_i} .$$

The left hand side denotes the rate of growth of the value of output, the first term on the right hand side denotes the weighted rate of growth of prices, and the second term on the right hand side denotes the weighted rate of growth of

quantity, the weights being the share of each commodity in the total value of output. Thus the rates of growth of the Divisia price and quantity indexes add up to the rate of growth of the Divisia value index. This yields an index of quantity of output aggregated by using value shares as weights that can change continuously. For application to discrete points of time (years) this index can be modified as follows [Tornquist (1936) quoted by Jorgenson and Griliches (1972)]:

$$\log q_t - \log q_{t-1} = \Sigma \bar{w}_{it} \left[\log q_{it} - \log q_{i,\ t-1} \right] \qquad \text{IV-2}$$

where $\bar{w}_{it}$ is the arithmetic mean of the weights (relative shares of commodities in the total value) in the two years t and t-1, i.e.,

$$\bar{w}_{it} = \frac{w_{it} + w_{i,\ t-1}}{2} \qquad \text{IV-3}$$

This measure of output provides an efficient approximation of the quantity in the sense of (i) avoiding the problem of changing relative prices, (ii) satisfying the time-reversal test, and (iii) satisfying the factor reversal test [Theil (1967)].

But, as pointed out by Richter, the Divisia index assumes that the index at time t is not independent of the path by which the output level at time t was attained. This is illustrated in Figure 3. Consider Figure 3 for a region with two goods X and Y with a given endowment of inputs.

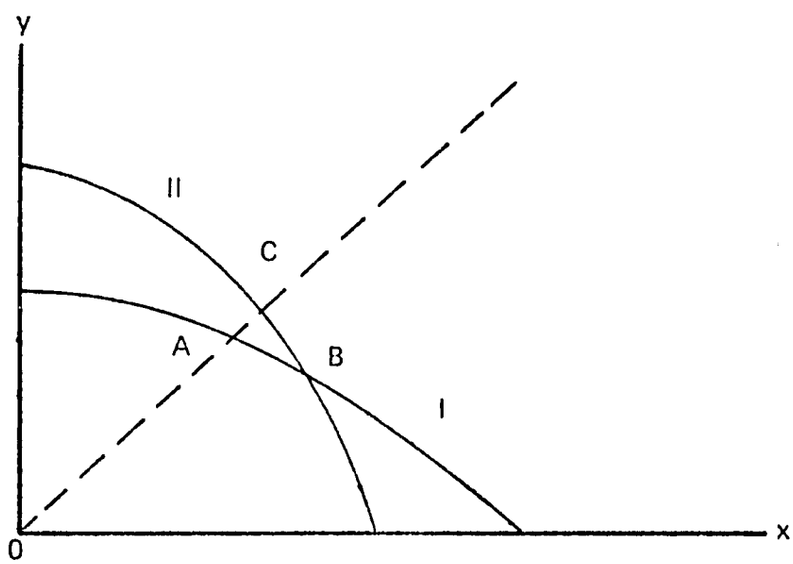

Figure 3

I describes the product transformation curve for the region, and in the initial period the output configuration is given by A. Now suppose the economy of the region slides down on the product transformation curve, so that the output configuration becomes B.

Since both A and B are on the same product transformation curve, the Divisia index of output will remain unchanged. Now suppose there is a change in the input composition in the region so that it is now technically possible to produce new configurations of the two products with the product combination B being still available. [Example of such a situation may be the simultaneous occurrence of a plant disease for one crop and an improved seed for the other.] In other words, there is a new product transformation curve (denoted by II in the Figure) with the point B being common to both the old and new transformation curves. During the shift to the new product transformation curve the output index remains unchanged because there has not yet been any change in the output configuration B. Now suppose there is again a rising demand for Y and a rise in its relative price so that there is a movement along the new transformation curve to C. The invariance axiom of Divisia index guarantees that the output index will remain the same at C as at B.

But now consider a movement direct from A to C without taking into account the actual path travelled by output. In this case, since C is to the north-east of A

there will be an increase in the output index. Thus Divisia index remains unchanged if we consider the path travelled by the output but increases if we ignore the path. Divisia index does assume that the index of the final configuration (C) is not independent of the path travelled (from A to C via B) by it, and the path determines the change (or lack of it) in the output index. The applicability of Divisia index, therefore, depends on the main purpose of the analysis involved. If the purpose implies assumption of independence of the time path taken by the output and only terminal points are considered, Divisia index will not be the answer. Otherwise, this will provide a measure free from the biases of the other indexes.

In the present study, involving cross-section and time-series, annual data for different regions are used. Measures for each year (not only the beginning and final years) are taken into consideration and thus there is no assumption of independence of the path travelled by the output. Moreover, the period under study is also not very long, and in such cases, as Richard Nelson suggests (1973) there is no real problem introduced as a result of using Divisia index which is more appropriate in view of the changes in output configurations that took place in the regions studied. The present study, in

order to indicate the differences due to relative price changes, has calculated output by both Divisia and Laspeyres methods, and some of the results are presented for illustration in the table below. It may be noticed that the two measures do differ for the districts and that the difference in general increased over time. This seems consistent with the fact that relative prices also did change over time. It appears that although the two indices differ by varying margins (due to the effect of relative price changes) they moved in the same direction.

Land

Data on total hectares of land used for each crop for each year and each district are available and have been used as the measure of the land variable. This is a gross measure of the acreage for each crop that includes multiple cropping.

Irrigation

The irrigation variable has been measured by using data on total hectares of land under irrigation for each crop, each district and year. The total irrigated area is also a gross measure rather than a net measure. The measure

TABLE 1

INDEX OF AGGREGATE CROP OUTPUT IN SOME DISTRICTS

Year	LUDHIANA PUNJAB		HISSAR HARYANA		GORAKHPUR U.P.		BHARATPUR RAJASTHAN		SAGAR M.P.	
	Laspeyres Index	Divisia Index	Laspeyres Index	Divisia Index	Laspeyres Index	Divisia Index	Laspeyres Index	Divisia Index	Laspeyres Index	Divisia Index
1959-60	100	100	100	100	100	100	100	100	100	100
1960-61	105	105	110	110	110	111	93	92	108	108
1961-62	148	150	123	124	126	127	126	127	95	94
1962-63	131	132	136	136	112	113	120	124	102	102
1963-64	178	182	198	186	119	132	91	92	84	84
1964-65	189	196	222	209	129	151	133	138	105	106
1965-66	169	179	208	189	134	156	115	121	84	85
1966-67	181	192	219	209	119	140	102	110	58	60
1967-68	198	209	308	294	126	148	145	165	119	124
1968-69	168	174	275	265	127	152	120	134	108	113

of land includes both unirrigated and irrigated land and thus the measure of irrigation here cannot exceed the corresponding measure of total land.

Fertilizer

Data on fertilizer is available in Effective Demand for Fertilizers in India, a joint study by the International Bank for Reconstruction and Development and the Government of India [Donde and Brown (1972)]. This study had data on fertilizer consumption in metric tons of nutrients by district for each year from 1959-60 to 1970-71, separately for N, P and K. We have used the sum of the three nutrients of N, P and K for each district and year as the measure of fertilizer consumed.

Tractor

The quinquinnial Livestock Census of India [Government of India (1961, 1966)] presents data on the number of tractors for each district. These data for 1961 and 1966 (the latest year for which the reports are available) were used to interpolate the figures for the other years assuming constant rates of change. This gives us our data on the number of tractors for each district in each year.

Literature and Illiterate Labor

There is no regular annual labor force data available for agriculture in India at the district level. The Indian Census reports publish for census years data on agricultural laborers and cultivators for each district, and we have used these as our source.

The difference between agricultural laborer and cultivator lies in whether the labor is hired from outside the farm or offered by the proprietors of the farm. For purposes of our analysis we have taken the number of agricultural laborers and cultivators separately for each district in 1961 and 1971 and estimated for the other years district-wise the number of agricultural laborers and cultivators. The sum of the two gives us our measure of the labor variable. The estimates have been made on the assumption that change in agricultural labor and cultivator in each district took place at an exponential rate calculated on the basis of the 1961 and 1971 figures. This assumption of a constant exponential rate of change for a period of ten years and for each district separately for agricultural labor and cultivator seems fairly realistic. Regarding the comparability of the

definitions of working population in the two censuses, it seems that they are the same regarding male labor, but there is a slight difference in the definition of female labor which perhaps tends to underestimate the female labor in the 1971 census in some cases. /Government of India, Census of India, 1971, p. 23./* Since our estimate includes both male and female labor, this limitation is present in our estimates. But considering the level of disaggregation in region and the percentage of female labor in the agricultural labor (much less than half in most districts), this is not likely to bias our findings.

The Census of India reports also present district-wise literacy rate for the rural population. Using these rates for 1961 and 1971 and assuming constant rates of change, the literacy rate for each district and year was calculated for the rural population. Then these district-wise literacy rates for each district and year were used on the labor force data

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* In 1961 Census, if an adult woman, "in addition to her household work she engages herself in work such as rice pounding for sale or wages . . . should be treated as a worker," whereas in 1971 "a man or woman who is primarily in household duties . . . even if such a person helps in the family economic activity but not as a full time worker should not be treated as a worker for the main activity."

to calculate literate labor (labor force times literacy rate) and illiterate labor (difference between total labor force and literate labor). These are the two labor force variables used in our analysis.

CHAPTER V

EMPIRICAL RESULTS: PRODUCTION FUNCTION

This chapter deals with the estimates of the aggregative agricultural production function for selected regions in India. A production function seeks to identify the relationship between output and inputs, and the inputs in the case of agriculture range from physical and measurable inputs through climatic to the difficult-to-measure social institutional factors. To list some of the major inputs in agricultural production: (i) Land area; (ii) Quality of land -- forest or hill areas, desert or river basins, humus content, organic composition, salinity, alkalinity, etc.; (iii) Irrigation and extent of control over water supply; (iv) Type of irrigation -- canal or tube-well or traditional persian wheel; (v) Fertilizer quantity and its nutrient content; (vi) Pesticides; (vii) Labor hours; (viii) Quality attributes of labor, e.g., age and sex-composition of the labor force, general education and skill, social and professional background, etc.;

(ix) Mechanical power -- number and type of tractors and other equipment used; (x) Livestock -- number and condition of livestock used; (xi) Seed type and quality -- traditional or high yielding; (xii) Rainfall; (xiii) Managerial and supervisory service; and (xiv) Socio-economic institutional factors, e.g., land tenure system, cooperation, credit availability, transportation, storage and marketing facilities, fragmentation and size of land holdings, etc. Variations in agricultural production may be due to any or all of these factors which might vary from place to place and time to time. From the number and nature of these inputs it is understandable why even the most exhaustive specification of inputs is likely to omit some. In the present study we have been able to include only six inputs: land area, irrigated area, total fertilizer consumed, number of tractors, literate labor which can be interpreted as an education variable and illiterate labor. (See Chapter IV for a discussion of these variables and their derivation.) The estimates of the production function, therefore, have to be considered in the light of the fact that a number of important variables listed above had to be omitted from the analysis. (The implications of such omissions have been discussed in Chapter II.)

The production function has been constructed for the aggregate annual crop output in 72 districts in India for the period 1959-60 to 1968-69, and the form of the function is Cobb-Douglas or linear in logarithm given by the equation:

$$Y = K A^{\alpha 1} I^{\alpha 2} F^{\alpha 3} T^{\alpha 4} L_1^{\alpha 5} L_2^{\alpha 6} \cdot e^{U_{rt}} \quad . . . \quad (V-1)$$

where

Y = Aggregate Crop Output Measure

K = Scaling constant

A = Hectares of Area Cultivated

I = Hectares of Irrigated Area Cultivated

F = Fertilizer (in nutrients)

T = Number of Tractors

L_1 = Number of Literate Labor

L_2 = Number of Illiterate Labor

U_{rt} = Residual

Two assumptio. underlie the specification of this function: (i) the districts lie on the same production function, and (ii) the production function can be approximated in the Cobb-Douglas form given above. These will be examined later.

The estimates of the Cobb-Douglas production function are presented in Table 2. Three sets of estimates have been

TABLE 2

AGRICULTURAL PRODUCTION FUNCTION FOR WHEAT REGIONS OF INDIA: COBB-DOUGLAS

(Dependent variable: Agricultural Production - Divisia Measure)

Variables	Original Variables		Deviations From District Means		Transformed Variables	
	Coefficient	T-Value	Coefficient	T-Value	Coefficient	T-Value
(col. 1)	(col. 2)	(col. 3)	(col. 4)	(col. 5)	(col. 6)	(col. 7)
Land	.48	8.12	.07	2.24	.07	2.27*
Irrigation	.27	13.87	-.01	.20	.04	1.94*
Fertilizer	.56	3.16	.09	7.39	.08	6.25*
Tractor	.14	6.16	00	.14	.02	.59
Literate Labor	.12	1.89	-.08	.48	.05	.34
Illiterate Labor	-.82	13.65	.36	2.26	.15	1.12
Constant	7.55	15.78			5.63	4.76
R^2 (adjusted)	.63		.19		.18	
F (6, 713)	204.81		29.27		28.30	
$\hat{\rho}$					.95	

*Significant at 5% level.

calculated, using (i) ordinary least squares (OLS) on the original levels of the variables, (ii) ordinary least squares on the deviations from the means of each district, i.e., using dummy variables for each district, and (iii) ordinary least squares on the transformed variables.

As mentioned earlier, the OLS estimates from the levels of variables are likely to be subject to the effects of the omission of relevant regional time-invariant factors as well as the special problems of pooling cross-section and time-series data. For example, the OLS coefficient of illiterate labor has a negative sign. Such theoretically unexpected results from the ordinary least squares were obtained also in the studies using these estimation procedures by both Balestra-Nerlove (1966) and Nerlove-Schultz (1970). Several alternative hypotheses may be proposed to account for this negative coefficient. It is plausible that significant differences in agricultural productivity are associated with quite different input mixes and technologies. The efficient traditional input mix probably uses much more illiterate labor per unit of output than the modern input mix. Consequently our omission of many modern inputs, and the

associated management expertise that facilitates the adoption of the modern agricultural technology embodied in these inputs will be associated both with less utilization of illiterate labor and more agricultural output per unit of input, contributing to the negative influence on the illiterate labor input parameter in the OLS estimated production function. To the extent that the differences in traditional and modern input mixes and agricultural productivity are region-specific and time-invariant in the time-series of cross-sections, the Balestra-Nerlove model will eliminate this influence. Another possible reason for the negative coefficient may be the very nature of data on labor. We have used total labor available rather than effective hours of work for which data could not be obtained. Districts with a smaller available labor force per unit of output may use that labor force more effectively. It is also likely that districts with higher rate of effective hours of work would have higher output. Thus the omission of information on the effective utilization of the illiterate labor force might have affected the OLS estimate of its parameter.

The ordinary least square estimates on the variable levels do not distinguish regional effects. One method of

introducing the regional effect is to use regional dummy variables which has been done in columns 3 and 4 in Table 2. The results show that not only were all the coefficients except that of illiterate labor drastically reduced, but two of them, for irrigation and literate labor, changed from positive to negative sign. A similar reduction in the magnitude of coefficients occurred in the Balestra-Nerlove (1966) study. A possible explanation suggested by Balestra-Nerlove is that the dummy variables perhaps reflect much more than only the regional effects and they are wasteful of degrees of freedom.

The coefficients obtained from the transformed variables are presented in columns 5 and 6. The transformation here has been performed by decomposing the residuals into two components -- regional and random, assuming that the time component is negligible. The value of $\hat{\rho} = .95$ reported in the table shows that 95 percent of the variance of the combined disturbances are attributed to the region-specific time-invariant component. (The time-specific factors will be discussed later.) A comparison of the results from the variables before and after transformation shows that five out of the six coefficients have been reduced while that of illiterate labor has increased and that all have now the expected positive

sign as a result of the transformation. Similar changes took place in all the other studies that sought to include regional and time effects through analysis of covariance or error-components model. /See for example, Hoch (1955), Mundlak (1963), Hoch (1962), Balestra-Nerlove (1966), Nerlove-Schultz (1970)/. One possible hypothesis for the reduction of the coefficients is that the variables that are excluded -- e.g., the quality variables, the management variables and efficiency variables are region-specific and time-invariant and are all positively associated with the included inputs whose coefficients have decreased. The transformation of data, by removing this effect, produces reduced but efficient estimates. The changes take place in the opposite direction only in the case of some inputs which, due to misspecification (e.g., use of total labor instead of manhours) or some other causes, are negatively related with the omitted quality and efficiency variables. When correction is made for that in the transformation of data, this coefficient is increased as illustrated by the coefficient for illiterate labor in the present study and the coefficient for capital in Hoch's study (1955). The differences in the coefficients yielded by the OLS on pooled data and the transformed variables may be interpreted as reflecting the effects of region-specific

factors such as quality, efficiency and management. If allowances are made for these factors, there should be larger application of those inputs with coefficients decreased by the transformation and smaller application of those whose coefficients increased [Mundlak (1961)]. Thus for Indian agriculture the results suggest that for increased production the inputs of land, irrigation, fertilizer, tractor and literate labor should perhaps be increased while that of illiterate labor be decreased.

The coefficients thus obtained by transforming the original variables considering regional and temporal effects in production are supposed to be efficient and consistent. However, the statistical significance levels of the coefficients as shown in the t-values is rather low. It appears that the coefficients of only land, irrigation and fertilizer remain significantly non-zero at 5 percent level of confidence in the regression on transformed variables. Therefore, in the cross-section time-series context of these data on Indian agriculture, it is difficult to derive any firm conclusion about the quantitative contribution of tractors, education or labor to aggregate output. Nonetheless, the signs of these coefficients are positive, and their apparent positive

contribution to output is consistent with several other studies on Indian agriculture /Schultz, T. W. (1964); Paglin (1965); Chaudhuri (1969); (Chaudhuri had a negative but insignificant coefficient for labor and a positive and significant coefficient for education), Wellisz, et al. (1970), and Bardhan (1973)/. Among the coefficients that are significant, the relative importance of fertilizer followed by land and irrigation seems consistent with the broad pattern in most of the studies referred to earlier and in accord with expectations. The consistency of the relative size of the coefficients appears to be borne out in their marginal physical products (in Divisia Measure) calculated at the mean level of respective inputs (Table 3), which shows that the marginal physical product of irrigated land is twice that of all land taken together and that the marginal physical product of literate labor also is more than double that of illiterate labor. The number of tractors being small, it shows a high marginal product although its elasticity coefficient is the smallest in the production function, and the marginal physical product of fertilizer is also high both because of the low level of fertilizer use, on the average, and because of its relatively high elasticity coefficient.

TABLE 3

MARGINAL PHYSICAL PRODUCT AT MEAN INPUT LEVELS*

Input	Marginal Physical Product	Standard Error of Estimate
Land	.0018	.0008
Irrigation	.0037	.0032
Fertilizer	.4336	.07
Tractor	.7096	.92
Literate Labor	.0123	.04
Illiterate Labor	.0064	.005

*The marginal physical product is calculated by multiplying the average product of an input at mean level by its production coefficient. The standard errors of estimates have been calculated by the Carter-Hartley method. /Carter and Hartley (1958) /.

Alternatively, it is also possible to check the consistency of the production coefficients on the basis of the average share of each unit of input in the total output. Out of the total land under cultivation, about 28 percent is irrigated and the rest is unirrigated and about 15 percent of the labor force is literate. The production function parameters show that this 28 percent of total land has the share of 4 percent in total output, while the share going to

the 72 percent of land that is unirrigated is only 3 percent of the product. Per hectare of land, therefore, the share of irrigated land is more than three times that of unirrigated land. Similarly, only 15 percent of labor has a share of 5 percent of output whereas 85 percent of labor (illiterate) claims 15 percent of output which means that per head, a literate labor's share is twice that of an illiterate labor. This implies that it is economically worthwhile to cultivate an irrigated rather than an unirrigated hectare of land. Similarly as long as the wage rate of literate labor does not exceed twice that of an illiterate labor, it is economical to use a literate rather than an illiterate labor.

In the construction of the production function it has been assumed that the 72 districts under study can be described in terms of one production function and that the production function can be approximated in a Cobb-Douglas form. Regarding the first assumption, the selected districts are contiguous [Easter-Abel (1973)], lending support to the hypothesis that the same production technology has been available to them. Of course, the econometric technique used here allows the districts to vary in the intercept or level of technology and input use. In order to provide a test

for the homogeneity assumption, the sample of 72 districts was divided into two groups -- one consisting of the relatively more progressive 20 districts of Punjab, Haryana and Western U.P., and the other consisting of the 52 districts from the rest of U.P., Rajasthan and M.P., and an F-test was conducted /Johnston (1972), p. 204/. First, a regression was run for all the 72 districts pooled together letting them vary only in intercepts and the sum of squares of residuals was estimated. Then similarly the sums of squares of residuals were estimated for the two groups separately, assuming that the districts within groups vary only in intercepts but between groups vary both in intercepts and slopes of their production function. The F-ratio calculated on this basis suggests that the null hypothesis that the districts in the two groups do not vary in the slopes of their production function cannot be rejected at 10 percent level of significance (See Appendix C).*

Arguments have been made (in Chapter II) for the Cobb-Douglas form of the production function both on a priori

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*In a recent farm production function study for India, Bardhan (1973) assumed with statistical support not only the absence of inter-farm differences in the slope of the function, but also no difference in intercepts.

theoretical grounds and in the light of the available data. This form of the production function has been widely applied in Indian agriculture. /Some of the important studies are: Krishna (1964); Wellisz, et al. (1970); Herdt (1971); Sidhu (1972); Bardhan (1973). For a summary of the numerous small area studies using Cobb-Douglas production function, see Chand (1967)/. Yotopoulos, Lau and Somel (1970) considered fitting a C. E. S. production function for Indian agriculture. Also, Sidhu (1972) and Bardhan (1973) used the Kmenta approximation of the C. E. S. production function to test for the deviation of the elasticity of substitution from unity assumed in the Cobb-Douglas form. None of them, however, could reject the hypothesis that the Cobb-Douglas form fits the Indian agricultural data adequately.

Both Cobb-Douglas and C. E. S. production functions are homothetic in nature and rule out variable returns to scale. Paglin (1965) constructed a production function for Indian agriculture which was non-homothetic in nature and allowed the elasticity of substitution to vary with the average productivity of land. Also Bardhan (1973) used a non-homothetic function to test whether the returns to scale coefficient varies and

again came to a negative conclusion. In the present study, in addition to the Cobb-Douglas function, a quadratic production function is tried that is non-homothetic and that allows for variations in the elasticity of output with respect to inputs. (See Chapter IV for a discussion of the quadratic production function.) The estimates (see Appendix D) of three out of eleven variables have significant T-values. It may be noted that the coefficient for irrigation-fertilizer interaction is both positive and significant. This is consistent with the recent changes in Indian agriculture, where new high yielding varieties have been grown where irrigation facilities are available because these require both assured water supply and fertilizer application [Abel (1971)]. However, contrary to expectations, the signs of both the coefficients relating to fertilizer are negative. Also, there is no improvement in the size of R^2 over the Cobb-Douglas form. Moreover, when the districts are classified into two regions (as in the Cobb-Douglas case) and quadratic production functions are constructed on them (Appendix E), the two regions appear to vary in both intercept and slope. This indicates that the districts cannot be described by the function of the quadratic form. It seems, therefore, that the quadratic form does

not represent the situation in Indian agriculture as well as the Cobb-Douglas form does.

Two other questions should be considered concerning the production function estimates presented in Table 1. The first relates to the decomposition of the residual and the second to the measurement of aggregate output.

It was shown earlier (Chapter II, Eq. II-2) that the residuals from a model using cross-section-time-series data may be decomposed into three parts: region effect, time effect and random effect. But the production function in Table 1 has been constructed on the basis of a two-component breakdown of the residual: (i) a region effect specific to each region, and (ii) a random effect for each region and year interpreted as the effects of factors that change from region to region and year to year, e.g., flood, drought, pests, etc. Thus it is assumed here that there are no important year-specific but region-invariant effects. We have sought to provide some tests as to whether this is a realistic assumption in the present case.

First, we have constructed a production equation by OLS, using dummies for both districts and years (see

Appendix F). It appears that the production coefficients for the independent variables do not change significantly from those using only district dummies. This indicates that even if both region-specific time-invariant and time-specific region-invariant effects were assumed to be present together, thereby decomposing the residuals into three components, the results would not have changed much.

We have also constructed an equation similar to the production function in Table 2, but assuming that the residuals are composed of only (i) time-specific region-invariant effects and (ii) random effects, that is, assuming that the region-effects are negligible. The results show that (see Appendix G) the value of $\hat{\rho}$, the intra-class correlation coefficient is quite small, .12, as against .95 in the regional effects model, signifying that the effects of specific years across the regions are low relative to the variations from district to district over time. As a result the production coefficients undergo little change in the three sets of regression, the OLS estimates from the variable levels remain virtually unchanged in spite of the transformation by time effects. It seems, therefore, that the production function in Table 1 using only two components of the residuals is not likely to

change much with the inclusion of year-specific effects.

Regarding the measurement of output, it may be noted that even though the analysis here is conducted in terms of the Divisia measure of output, we also constructed the same production function using the Laspeyre's measure of output. A comparison of the two sets of coefficients (see Appendix I) indicate that the coefficients based on the Divisia measure seems to reflect the recent changes in the use of new inputs in Indian agriculture better than the Laspeyre's measure.

An important consequence of considering regional and temporal effects in production has been the consistently low sum of output elasticities with respect to the included inputs in the Cobb-Douglas production function, signifying diminishing returns to scale in terms of the measured inputs. [See Hoch (1955, 1962), Mundlak (1961)] In Table 2 this sum appears to be .41, which implies that aggregate agricultural production in India is quite inelastic with respect to the several inputs we have been able to consider.* If the

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*We also estimated the same production function on the basis of per acre of land in the form:

$$Y/A = K.A^{\beta_1} \; I/A^{\beta_2} \; F/A^{\beta_3} \; T/A^{\beta_4} \; L_1/A^{\beta_5} \; L_2/A^{\beta_6} e^{\Pi rt} \qquad (V-2)$$

where $\beta_2, \beta_3, \ldots \beta_6$ are the same as $\alpha_2, \alpha_3, \ldots \alpha_6$ of Equation V-1, and the value of β_1 (-.66) which stands for the deviation of the sum of the other β's from unity, turned out to be significant indicating diminishing returns to scale.

production function were homogeneous of degree one, the elasticity of output with respect to "regional effects" would be .59. Similar elasticities of output with respect to the farm (regional) effects in Hoch's study of Minnesota farms was .40 and that in Mundlak's study of Israel was .21. The present elasticity of output with respect to regional effects in India appears to be much higher than that of Minnesota or Israel which does not seem very surprising in view of the relatively large variations in land quality, irrigation type, types of machinery, degree of skills and climatic and managerial factors in India that we have omitted from these estimates as compared to those omitted from the Minnesota or Israel studies. Our finding is also consistent with the Indian experience of agricultural production being fairly inelastic on the aggregate in spite of several districts and several crops showing high growth. This study implies that if the quality and other variations collectively called regional effects are kept unchanged, a doubling of the land area, irrigation, fertilizer, tractor and labor inputs are likely to increase aggregate production by 41 percent. The input data used in this study are highly aggregative and if these could be broken down by different types and qualities, it is quite likely that a much larger proportion of the output variation

could be explained. Recently, Star has shown that by disaggregating data on capital and labor the unexplained residual in the variation in output in U.S. manufacturing industry during 1950-1960 could be reduced from 47 to 13 percent /Star (1974)/.

It is relevant to note that in a recent study Evenson (1973) has found that only less than half of the increase in agricultural production in India could be explained by increases in known inputs, the rest being attributed to research and extension. Although the data and methodology are entirely different, Evenson's finding is consistent with that of the present study that increases in the known inputs can lead only to limited increases in agricultural output in India and explanations for growth or lack of it should be sought beyond known and traditional inputs.

In conclusion, it may be asked if we should be surprised that variation in the quantities of a limited number of observed inputs fail to explain most of the variation in output. Perhaps the answer is implied in the statement of T. W. Schultz more than a decade ago when he attributed such apparent "puzzle" to the fact that the measurements of inputs excluded "many of the improvements that have been

made in the quality of these resources" /see Schultz (1962), p. 2/. Reviewing the sources of growth of output over time, Kuznets observes that "the inescapable conclusion is that the direct contribution of man-hours and capital accumulation would hardly account for more than a tenth of the rate of growth in per capita product -- and probably less. The large remainder must be assigned to an increase in efficiency in productive resources . . ." /Kuznets (1972), p. 81/. Our study of Indian agricultural production perhaps shows that what is true over time for given economies in the above observations is also true over space and time in India. The role of variations in efficiency and quality of inputs and their use is a dominant one in explaining variations in output per unit of measured inputs.

CHAPTER VI

REGIONAL DISPARITY IN PRODUCTION EFFICIENCY

As has been said earlier, there are a large number of factors, including qualitative, climatic and institutional factors, which are specific to regions and invariant over time, and have been omitted from the production function measurement. Assuming that none of these factors change systematically over time in such a way as to alter the rankings of the districts with respect to the use of the input concerned, the combined effects of these omitted factors are reflected in what we call the "regional effects." These effects can be interpreted as estimates of the differences in static technical efficiency among districts that reflect their varying productivity per unit of inputs. Dichotomizing economic efficiency into technical efficiency and price efficiency, Yotopoulos and Lau (1971) define a farm as "more technically efficient than another if it consistently produces larger quantities of output from the same quantities of measurable inputs." Applying this

definition to a district, given the existing set of factors that determine region-effects, a district with a higher region-effect has an advantage in producing agricultural output over a district with a lower region-effect.

In this chapter the empirical estimates of the regional effects for the 72 districts are presented and their implications discussed. The estimates represent the regional component e^{μ_r} of the residual in the production function:

$$Y_{r_t} = K \prod_{j=1} X_{jrt}^{\alpha_j} e^{\mu_r + \gamma_{rt}}$$

which is the same as Equation III-1 in Chapter III. The econometric method employed to construct the production function in an error-components model enables the derivation of the regional effects from the residuals of the function.

Table 4 presents the estimates of the regional effects on the basis of the Cobb-Douglas production function constructed for the 72 wheat districts of India for 1959-60 to 1968-69.

The estimates ranging from .36 in Allahabad (Southern U.P.) to 5.47 in Ludhiana (Punjab) indicate a wide disparity between districts of India in agricultural development. The implication of the region effects is that if, for

TABLE 4

DISTRICTS ARRANGED IN DESCENDING ORDER OF REGION EFFECTS

Rank	District (State)*	Region Effect**
1	Ludhiana (P)	5.47
2	Karpurthala (P)	4.00
3	Amritsar (P)	3.60
	Sangrur (P)	3.60
	Hissar (H)	3.60
6	Patiala (P)	3.50
7	Ganganagar (R)	3.32
	Mathura (UP)	3.32
9	Jullundhur (P)	3.00
10	Bulandshar (UP)	2.40
11	Aligarh (UP)	2.35
12	Rohtak (H)	2.34
13	Gurdaspur (P)	2.10
14	Karnal (H)	2.00
	Muzaffarnagar (UP)	2.00
16	Meerut (UP)	1.91
17	Ferozepur (P)	1.90
	Indore (MP)	1.90
19	Saharanpur (UP)	1.73

*P stands for Punjab; H for Haryana; R for Rajasthan; UP for Uttar Pradesh; and MP for Madhya Pradesh.

**The value of μ_r from Equation III-4 in Chapter III.

Table 4 (continued)

Rank	District (State)*	Region Effects**
20	Agra (UP)	1.64
21	Ambala (H)	1.50
22	Hoshangabad (MP)	1.35
23	Gurgaon (H)	1.25
24	Bijnor (UP)	1.23
25	Etah (UP)	1.16
26	Sehore (MP)	1.12
27	Etawah (UP)	1.08
25	Kanpur (UP)	1.06
29	Rampur (UP)	1.00
30	Dehra Dun (UP)	.94
31	Bundi (R)	.92
32	Budaun (UP)	.90
33	Hoshiarpur (P)	.88
34	Moradabad (UP)	.87
35	Bhatinda (P)	.80
	Kotah (R)	.80
	Guna (MP)	.80
38	Unnao (UP)	.79
39	Kheri (UP)	.78

Table 4 (continued)

Rank	District (State)*	Region Effect**
40	Nainital (UP)	.77
41	Shivpuri (MP)	.75
42	Chhatarpur (MP)	.74
43	Farrukkabad (UP)	.72
44	Damoh (MP)	.67
45	Pilibhit (UP)	.66
46	Gwalior (MP)	.65
	Mainpuri (UP)	.65
	Sitapur (UP)	.65
	Bharatpur (R)	.65
50	Panna (MP)	.63
51	Datia (MP)	.62
	Jalaun (UP)	.62
53	Deoria (UP)	.60
54	Shahjahanpur (UP)	.59
55	Lucknow (UP)	.58
	Satna (MP)	.58
56	Vidisha (MP)	.55
	Raisen (MP)	.55
	Sagar (MP)	.55
	Baireily (UP)	.55
61	Faizabad (UP)	.51
62	Gorakhpur (UP)	.48
	Hardoi (UP)	.48

Table 4 (continued)

Rank	District (State)*	Region Effect**
64	Tikamgar (MP)	.47
65	Barabanki (UP)	.46
66	Jhansi (UP)	.45
	Jabalpur (UP)	.45
	Bahraich (UP)	.45
69	Bonda (UP)	.42
70	Basti (UP)	.40
71	Banda (UP)	.38
72	Allahabad (UP)	.36

example, Ludhiana uses the same quantity of land, irrigation, fertilizer, tractor and literate and illiterate labor as Allahabad, the output in Ludhiana is likely to be about 15 times that in Allahabad, provided, of course, that there is no disturbance due to the weather effect. Similarly, with the same dose of inputs, Faizabad will produce about 50 percent less output than Rampur. It should be noted, however, that in reality the quantities of inputs are almost in all cases different between districts either adding to or dampening the purely regional effects. The effect of the weather and other temporal factors are similar; one district with a high region-effect may suffer an unusual drought or flood in a given year thus wiping out its favored technical advantage.

The measures of region-effects provide only some quantitative indication of the relative efficiency of the districts as it exists today, and it says nothing about why the effects range so widely and why each district belongs where it does in the hierarchy of the effects shown in the table. Therefore, much more research needs to be done in order to explore the nature and magnitude of the region

effects. To do justice to such questions it is necessary to have more information not only about the district-wise differences in the type and quality of each input used and omitted, but also on the geo-climatic, physical, social, political and other factors that might influence differences in the efficiency of production. This being beyond the scope of the present study, only a brief general discussion is attempted below.

It may be asked whether the efficiency ranking of the districts is arbitrary or there is some broad regional pattern. If the districts are classified into three broad groups:* high productivity [regional effect above 1.5], medium productivity [regional effect between 0.5 and 1.5], and low productivity [regional effect below 0.5], it would appear from the attached map that, with a few exceptions, the three groups form adjacent clusters of districts that cut across state boundaries. The high productivity districts are to the north-west portion of the area under study. The

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* The purpose of this classification is only illustrative and the boundary lines can be moved up or down to change the groupings.

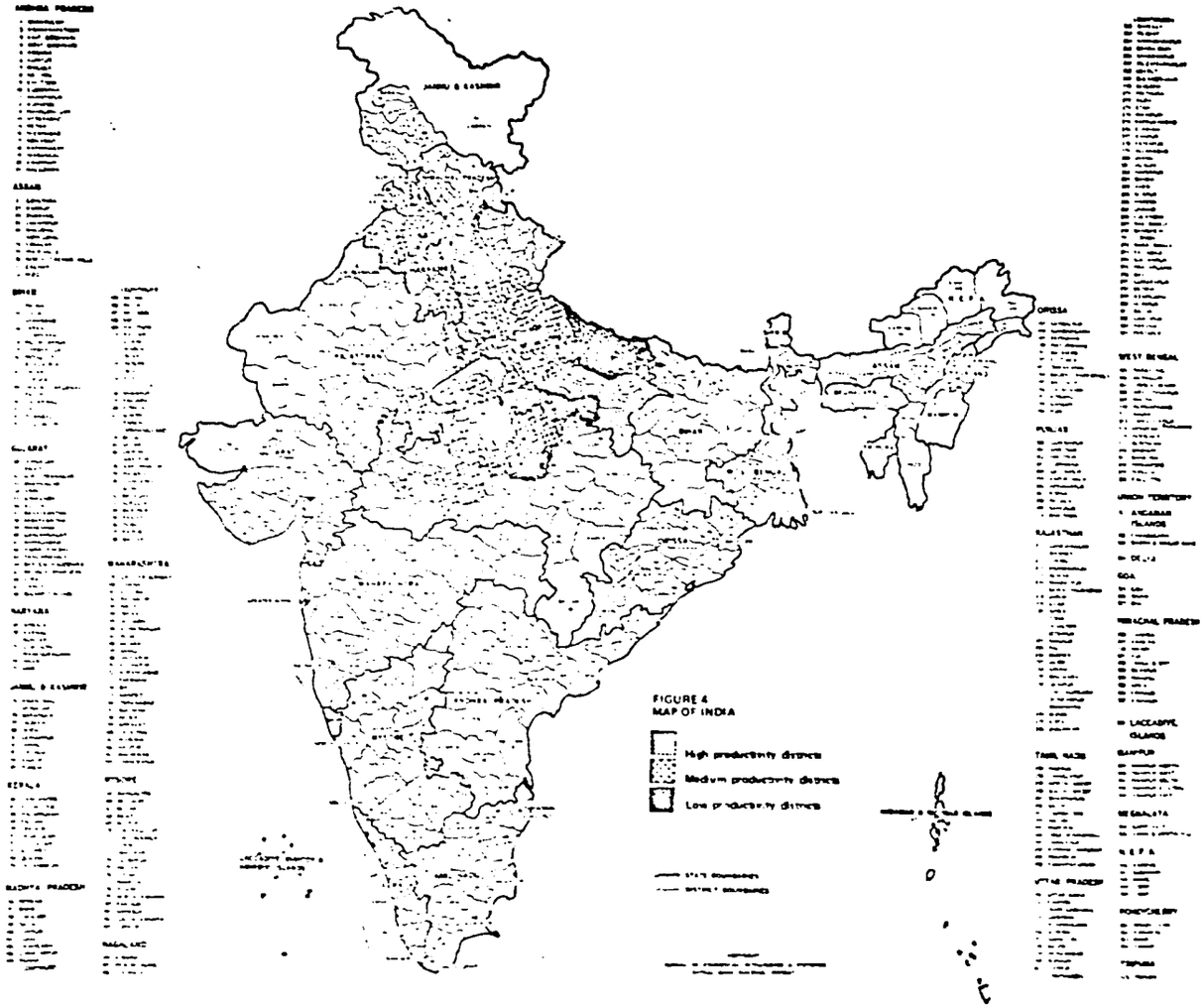

FIGURE 4
MAP OF INDIA

medium productivity districts appear in the middle of the area north-to-south and then these are bordered by the low productivity districts on the east. Broadly speaking, if two vertical lines are drawn on the map -- one through Delhi and another through Lucknow in the north and Panna in the south -- the high-productivity districts fall to the west of the first line, the low-productivity districts to the east of the second line, and the medium-productivity districts lie between the two.

In view of the multitude of factors that might cause variations in regional effects, there are, as we might anticipate, some exceptions to this overall pattern.

It may be noted that the regional pattern of the districts based on their production efficiency conform broadly to the crop and agro-climatic regions developed by Easter (1972). Out of the eight wheat regions distinguished by Easter, the Punjab, Haryana and Western U.P. regions correspond to our high productivity districts; the North-East U.P., and parts of Southern U.P. and central M.P. correspond to the low productivity districts and the remaining regions correspond to the medium productivity districts. As Easter has discussed, the above regions are

characterized by differences in both crop-pattern and agro-climatic characteristics. As one moves eastward from the north-west high productivity districts (the Upper-Plains Sub-Division of the Indo-Gangetic Alluvial Plains Division), one gradually encounters areas where wheat becomes relatively less and less important in the output mix. The Upper-Plains Sub-Division of Punjab-Haryana-Western U.P. has very large percentages of land under wheat and most of it under the high yielding variety wheat. (See Appendix J.) Moving to the east into the Central Plains Sub-Division that covers the western two-thirds of U.P., one notices that although wheat is still a dominant crop, its importance is shared with sugarcane in the Western U.P. wheat-sugarcane areas, with Bajra and Pulses in the Southwestern U.P. wheat-bajra region and in the Central U.P. Wheat-Pulses region. And in the North Central U.P. Wheat-Rice region rice and wheat become almost equally important. Further east in the Lower Plains Sub-Division, rice takes over the position of the dominant crop with wheat as a subsidiary crop. The East Central U.P. Rice-Pulses Region and the Eastern U.P. Rice Region are

on the eastern border of the regions selected in our study. In the south our study extends to the Northwestern M. P. Wheat-Jowar-Pulses Region of the Central Black Soils Sub-Division under the Plateau and Hills Division. Since seed technology has developed most in wheat during the late 1960's, which occupies varying importance in the aggregate crop output of the districts, it is not surprising that in general the areas with wheat as the most important crop are also the high productivity areas. Moreover, as Easter has suggested, the quality of soil also varies a great deal from the high-productivity Indo-Gangetic Alluvial soils area to the low-growth plateau and hills area. The extent and quality of irrigation vary a great deal between the regions. The high productivity areas are also generally areas with a stable irrigation system and use electric tube-wells whereas the proportion of tank and traditional persian-wheel irrigation is relatively high in the low productivity areas of eastern U. P. and northern M. P. An exception in M. P. is the district of Indore with a high regional effect. It may be noted that Indore, unlike any other M. P. district, is irrigated almost entirely by electric

pumps. (See Livestock Census Report.) Moreover, our low productivity areas are also the same as the ones identified by Easter as constrained by historical deficiency in resource base and infra-structure. The Eastern U.P. Rice Region is described as "a deficit area for centuries so that the basic infra-structure and ability to move market surpluses and inputs is not readily available" [Easter, (1972)]. Thus differences in crop pattern with uneven advances in crop-technology, differences in soil types and agro-climatic factors, differences in the quality of irrigation, resource base and infra-structure -- factors that should account for at least part of the regional variations in production -- are by and large consistent with the pattern and range of the regional efficiency factors estimated in this study. There must be, as mentioned earlier, many more factors to fully explain the disparity that is found to exist between the regions and another study is needed to explore them.

CHAPTER VII

TEMPORAL VARIATIONS IN OUTPUT

A peculiarity of crop production is that, being partly dependent on natural factors not entirely under the control of farmers, it is susceptible to fluctuations from year to year. This is illustrated well in the experience of Indian agriculture where years of bumper crops and extensive crop failures have often followed each other. Such fluctuations lead to instability in farm prices and incomes and create problems for the overall economy.

The nature of the factors behind such fluctuations is such that they vary from year to year in a seemingly random and unpredictable manner and can thus be described as temporal factors. These consist of anything that is relevant in crop production but is not considered in the set of measured inputs in the production function or the regional factors that are invariant over time. Some of the temporal factors are fairly widespread in their incidence while some

are highly localized. For example, a good rainfall or a severe drought in a given year may affect large regions more or less similarly, a flood may affect parts of a region, while a cyclone or a locust or pest attack may affect only individual districts or even parts thereof. The effects of temporal factors, therefore, vary from year to year and from district to district, and thus cannot be captured in a production model that assumes that these effects are invariant over districts and specific to years. (Such a production function is presented in Appendix G.) It is also inappropriate to use the amount of rainfall in the production function and call its effects temporal effects or weather effects [Krishna (1964)], because rainfall is only one of the many elements that constitute the temporal factors.

In this chapter we attempt to discuss the estimates of the temporal effects on agricultural production based on the error-components model applied to the 72 districts of India. The estimates are not direct measures of the weather factors, but they are derived from the Cobb-Douglas production function constructed for those districts. These are the random components of the residuals between the actual and predicted

output of each district and year (e^{Urt} in Equation III-1). The measures thus vary from district to district, from year to year. Since the effects of the known input levels and the district-specific and time-invariant factors (e.g., region effects) have been already isolated, the present estimates may be assumed to reflect the effects of factors which are random in nature and thus these are, by and large, effects of the weather variables on district agricultural output.

The model is based on the assumption that the effects of the temporal factors are irrespective of the efficiency level of a region and the amounts of the known inputs used are independent of the temporal effects. It can be argued that in the short run this assumption holds, because farmers choose the levels of inputs to maximize expected earnings and have little control over the temporal factors in their effect on crop output. Also droughts may strike districts at different levels of region effect in similar proportions. In the long run, however, temporal factors are not entirely uncontrollable. For example, adequate flood prevention measures might reduce the ravages of flood in given years and help increases in the region effect of the areas while reducing the temporal effect. Better water storage facilities might dampen the

effects of droughts and adequate provision of insecticides might help crop damages from pests. Moreover, in some cases input levels (e.g., labor hours for harvesting) may depend on the temporal effects. But in view of the use of total laborers as the labor variable and the short run nature of our analysis, it may be said that the assumption of the temporal effects being independent of the input levels and the region effects is not entirely unrealistic. The temporal effects in our analysis, which are assumed to reflect uniformly across our sample the effects of weather on agricultural production, present a separate and potentially important source of variability in agricultural production in India.

The estimates of temporal effects (see Appendix K) indicate how at the district level the impact of the temporal factors caused crop output to fluctuate from year to year. The extent of this impact varied widely among districts suggesting their varying degrees of susceptibility to the temporal factors. It also appears that even in given years not all the districts moved in the same direction in their temporal effects. For example, in 1966-67 which was one of the worst drought years in recent India, 58 out of the 72 districts suffered adverse temporal effects and produced less than their "normal"

year output, while the remaining districts produced above their normal year level. This perhaps shows that there is no "good" or "bad" year universally valid for all the districts.

In spite of the diversity in the temporal characteristics of the districts, it may be inquired whether there can be discerned any climatic cycles for the districts that conform to their varying temporal effects. For this purpose the districts may be classified into three broad groups on the basis of the coefficient of variation of their temporal effects: (1) Low Variability Districts with coefficient of variation below .20, (2) Medium Variability Districts with coefficient of variation from .20 to .50,and (3) High Variability Districts with the coefficient above .50. It is noticeable that, unlike in the case of region effects, the temporal effects do not display any clear geographical pattern of the variability levels. This implies varying degrees of sensitivity to temporal factors among neighboring districts. Moreover, the temporal effects are not due to weather factors only but to a variety of causes which are random in nature.

Nonetheless, the major explanation for the variation in temporal profiles of the districts may be sought in the climatic patterns of individual districts and the extent of their built-in resistance to weather fluctuations and pest problems. A district in a normally dry and desert-like area is likely

to be less affected by a drought than one in a rainy region. This seems to come out of the location of the districts with relatively good performance in the drought years. It may also be noted that some districts (e.g., Ganganagar, Hissar and Karpurthala) with relatively high coefficient of variation of their temporal effects behaved differently from others. Their temporal effects started from a lower than normal level at the beginning of the decade and rose steadily throughout the period. A possible hypothesis for these cases is that these districts systematically increased their built-in resistance to the adverse temporal factors. To the extent that these resistances are not reflected in their measured inputs or their regional effects, the temporal effects of these districts are picking up those residuals. Gradual changes in the nature of their irrigation systems, increasing use of insecticides, changes in the composition of crops to more sturdy types, etc. may be examples of such built-in resistances.

The average temporal effects for the three groups of districts and for all districts together (Table 5 and Figure 5) appear to follow certain regular patterns. First, they seem to conform closely to the climatic cycles experienced in India. As far as the level of crop production is concerned,

TABLE 5

TEMPORAL EFFECTS ON OUTPUTS AT DIFFERENT VARIABILITY LEVELS

District \ Year	1959-60	60-61	61-62	62-63	63-64	64-65	65-66	66-67	67-68	68-69
Low Variability Districts	.97	1.03	1.04	.99	.93	1.07	1.00	.91	.99	1.03
Medium Variability Districts	.98	1.06	1.06	1.05	.90	1.09	.96	.86	1.07	1.06
High Variability Districts	1.02	1.05	1.12	.98	.98	1.08	.90	.78	1.25	1.21
All Districts	.98	1.05	1.06	1.01	.93	1.08	.97	.87	1.07	1.08

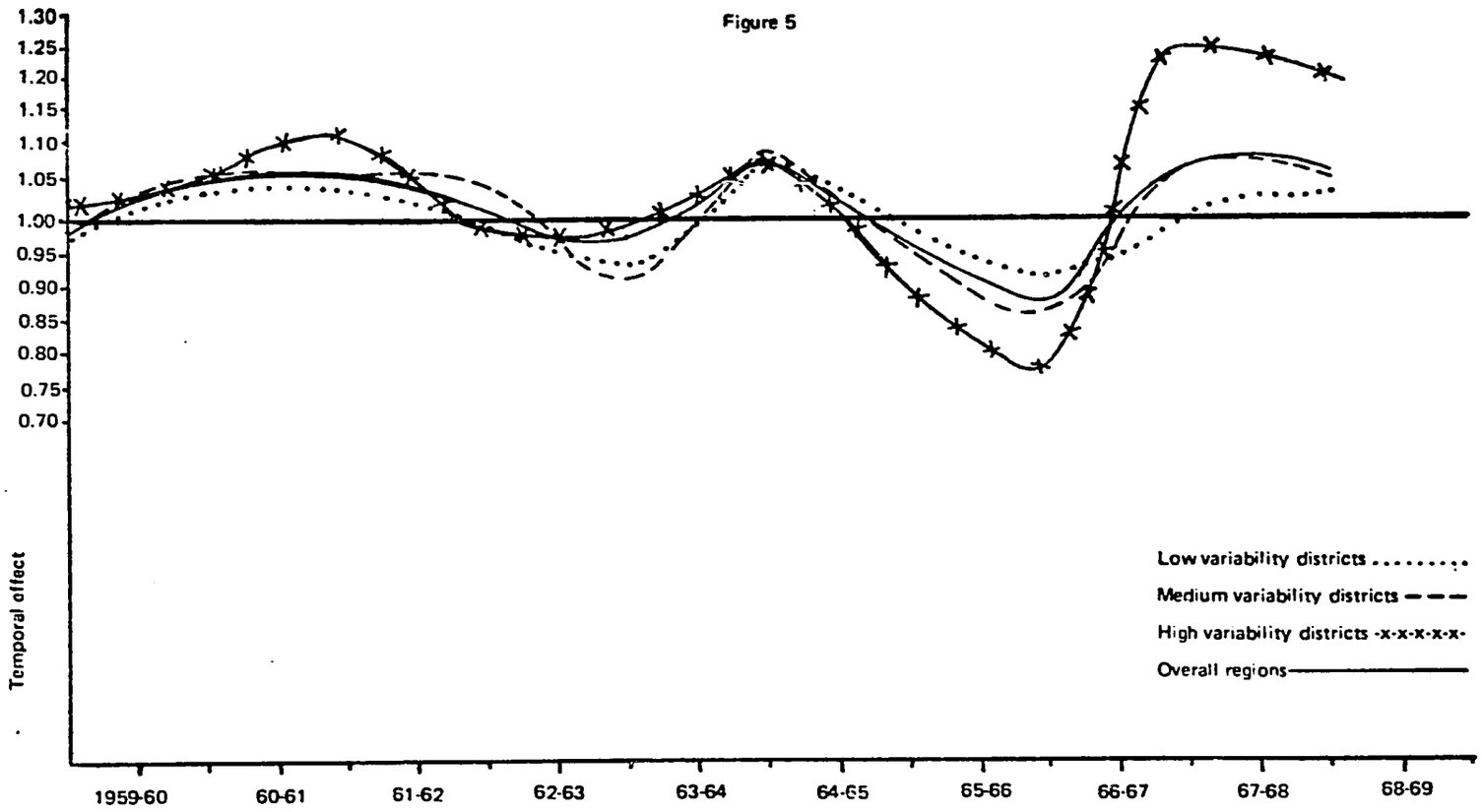
Figure 5
1.30
1.25
1.20
1.15
1.10
1.05
1.00
0.95
0.90
0.85
0.80
0.75
0.70
Temporal affect
1959-60
60-61
61-62
62-63
63-64
64-65
65-66
66-67
67-68
68-69
Low variability districts
Medium variability districts
High variability districts
Overall regions

during the decade under study there were four rather "bad" years, 1959-60, 1963-64, 1965-66 and 1966-67, both for the regions studied here and all India (See Table 6).* This pattern is borne out by the temporal effects of the overall region as well as the three sub-regions.

The second noticeable feature of the temporal effects is that, although individual districts may behave otherwise, the three regions have the same cyclical pattern in their temporal effects as the overall region. The amplitudes of the fluctuations, however, are different for the different regions, as expected. Moreover, it seems that both in frequency and magnitude the fluctuations seem to be more pronounced in the second half of the decade than in the first. The peaks and troughs of the cycles in the later half exceeded those in the earlier half. It may be mentioned that toward the latter part of this decade the Indian farmers began to introduce the high yielding varieties of crops. During this period there was also increased use of the new inputs like fertilizer, insecticides, etc., and farming was extended to new lands as

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*There is, however, some difference between the two. In the regions studied here the level of output in 1963-64 was slightly lower than that in 1962-63 whereas for all India, the index is higher in 1963-64 than in 1962-63.

TABLE 6

INDICES OF TOTAL CROP OUTPUT, 1959-60 TO 1968-69; 1959-60 = 100

Year	1959-60	60-61	61-62	62-63	63-64	64-65	65-66	66-67	67-68	68-69
Index of total crop output in the Districts studied*	100	102	106	109	108	128	119	118	140	143
All India Index of total crop output**	100	109	111	107	109	122	101	101	124	122

*Divisia Index of crop output.

**Calculated from the Index of Total Crop Production in India (1949-50 = 100)

Source: Economic Survey 1968-69; Statistical Abstract, 1958-65, Government of of India, New Delhi.

well as old land was used more intensively -- all these resulting in a higher rate of growth (See Table 6). It may be asked whether our finding thus seems consistent with a positive association between growth and variation in agricultural output observed in India [Sen (1971)]. The usual hypothesis for such a presumed association is that the initial phases of application of new inputs in agriculture, while leading to higher output, render production more sensitive to temporal factors. The major reason for this is the relative lack of experience on the part of farmers in the use of these inputs and the non-availability of the appropriate kinds and quantities of the inputs to individual farmers. However, the extent of sensitivity to temporal fluctuation is more in some crops (e.g., rice) than others (e.g., wheat) and more in the case of extensive farming than in intensive farming. The present results are based on a short period of time at the end of which there was an unusually severe drought followed by a relatively good year. So, without a more extensive examination it is not possible to say anything firmly about the hypothesized association between periods of growth and fluctuation.

CHAPTER VIII

SUMMARY OF FINDINGS AND IMPLICATIONS FOR POLICY

Three problems are quite commonly confronted in the macro-economic planning of agriculture in most developing economies: (i) the limited response of output to the additional use of known and measured inputs; (ii) the wide disparity in the level of output per unit of inputs in the different regions of the economy; and (iii) the variation in output from year to year. There have been studies in different countries dealing with one or another of these problems but none addressed all the three within a single analytical framework. The major reason is that studies of production function based on purely cross-sectional or time-series data and using OLS estimates fail to consider the basic regional and temporal characteristics of agricultural production. On the other hand, studies dealing with regional differences in productivity mostly use the comparative static method of decomposing output or productivity differences into the components due to differences

in input levels, without being able to generate the production parameters needed to explain output inelasticity with respect to increased inputs. Moreover, most of these studies are based on an inadequate specification of the spatial unit of observation without regard to the cropping pattern or agro-climatic features of the regions. An almost inevitable problem in these studies lies in their measurement of aggregate output based on the assumption of given relative prices that is often unrealistic.

It is the basic contention of this thesis that the macro-economic problems of output inelasticity, regional disparity and temporal variations in agricultural output are manifestations of the production mechanism in agriculture and so they should be dealt with in a production function analysis based on a careful specification of the regions and explicitly considering the index number problem of aggregation of output. A model has, therefore, been designed, an estimation procedure has been chosen, and the regions have been selected for an analysis of the agricultural production in India during 1959-60 to 1968-69.

Aggregate crop output has been measured by the Divisia method that does not assume constant relative prices and ignore differences in cropping patterns. The wheat regions,

developed by Easter and Abel on the basis of cropping patterns and agro-climatic characteristics at the district level, have been selected as the terrain of our analysis. The analytical model and the estimation procedure, designed by Balestra and Nerlove, pooling cross-section and time-series data and using a two-stage least squares method, generates good estimates of parameters and residuals decomposed into regional and temporal effects. Applied for the first time in a production analysis, this model is able to provide in one general framework information regarding some basic problems of agriculture. Therefore, based on well-specified regions and aggregate output measures that permit relative prices to vary, the present study yields estimates of the coefficients of different measured inputs indicative of the elasticity of output in respect to them, the effects of omitted inputs that are specific to regions (districts) and stable over time (i.e., region-effects) and the effects of factors that vary from time to time and from district to district (i.e., temporal-effect). The form of the production function constructed is Cobb-Douglas which seems justified in view of tests performed on the Indian economy in several studies and because of the nature of data available in the present case. A quadratic form of production function was also tried.

SUMMARY OF FINDINGS

The empirical findings of the study are somewhat different from conventional cross-sectional production function studies. The coefficients for the inputs of land, irrigation, fertilizer, tractors, education and labor are rather small in size and only the first three have statistically significant t-values. The sum of the coefficients indicates a low elasticity of aggregate crop output with respect to these inputs. If the quantities of these inputs are doubled, output is likely to increase by only about 41 percent. The major reasons for such small coefficients seem to be that there are a large number of relevant factors specific to the regions but omitted from the analysis, and that the inputs are considered in highly aggregative forms. A cross-section-time-series analysis employing the present method of estimation makes adjustments for these and generates efficient estimates of the parameters. Although seemingly surprising, this finding is perhaps consistent with the actual experience of agricultural production in India which has shown limited response to change on the aggregate level, notwithstanding striking cases of growth in specific areas or in specific crops. The relative size of the coefficients also are consistent with expectations that production in Indian agriculture is most

responsive to fertilizer and irrigation among the inputs considered.

Our results show that only a small proportion of the variation in output is explained by measured inputs. Decomposing the large residuals into two components -- regional effects and temporal (or random) effects -- 95 percent of the variance of the total disturbances are attributed to the region effects. Not only is output variation largely due to time-invariant, region-specific factors omitted from the measured inputs, but the contribution of these region effects is widely divergent from district to district. It appears that in a normal year, with the same quantity of measured inputs, the most productive districts in Punjab produce about five times the average output for the entire sample, while the least productive districts produce with the same level of measured inputs only about one-third of the sample average. This disparity might be due to the large differences in the quality of all the inputs as well as their climate, management efficiency, land-tenure system, cultural practices with bearings on agricultural production, cumulative effects of past technology and investments, and so on.

If the districts are ranked by their regional effects, a broad geographical pattern is discernible in the productivity regions in India. Out of the 72 districts in five north and central Indian states included in this analysis, the Punjab-Haryana-North-Western U.P. districts are in the high productivity region followed by the medium productivity region of Central U.P., Rajasthan and some M.P. districts and the low productivity districts are on the eastern edge of the wheat growing areas.

The analysis also provides measures of the effect of factors that change randomly from place to place and year to year on the output of each district in each year (temporal effect). These indicate the extent of dependence of the districts to natural factors (e.g., drought, flood, pest, etc.). The results show that at the district level such dependence varies widely, the worst being the district of Banda (U.P.) and Satna (M.P.) which could produce in the drought year of 1966-67 only 40 percent of their normal year output. The variability of the districts' output are independent of their productivity levels and the high, medium and low variability districts do not follow any regional pattern unlike in the case of the productivity levels. The temporal effects for all the districts

in the aggregate indicate that agricultural output varied subject only to these random factors by about 21 percent between the worst (87% of its normal output in 1966-67) and the best (108% of normal output in 1968-69) years. The cyclical pattern of the temporal effects both at the overall level and at different levels of variability follow the broad climatic pattern experienced in India during the decade.

In Indian agriculture, the secular inelasticity of the aggregate output levels with respect to measured traditional inputs, the disparity between regions in productivity, and the variations from year to year are facts of life. The present study has attempted to provide quantitative measures of these facts and offer some guidelines for policy. However, the analysis is subject to a number of limitations and the results, therefore, should be considered in the light of them.

Most of the limitations relate to the availability and nature of data used in the study. Independent, annual district level observations were available for the amounts of crops harvested and prices received by farmers for them, the hectares of land cultivated, the hectares of irrigated land and quantity of fertilizer consumed. Data on tractor, literate labor and illiterate labor were developed from district level

data in the quinquennial livestock censuses and the decennial censuses of population. Constant rates of change were assumed between censuses for the districts. Although this is a restrictive assumption and rules out some variation in these inputs, the error should not be too high in view of the fact that we have been able to maintain the cross-sectional variations with the district-level data. There were no data available on education by level and kind of education for laborers. So we used the literacy rates of rural population from census data on total labor (cultivators and agricultural laborers) to construct the series on literate labor. This is, of course, an inadequate measure of the education variable in agricultural production. Changes in census definitions and enumeration accuracy would introduce additional problems in the data used here.

Perhaps more serious, we used aggregate numbers of laborers rather than actual manhours. In the absence of any series on district level manhour data, we had to use the labor force data assuming somewhat unrealistically that the actual manhours were a constant percentage of the laborers. In the context of the model used here this is

equivalent to the assumption that actual manhours used as percent of number of laborers is an omitted variable. Hypothesizing certain relationship between the two, the estimates in the analysis, however, should remain unbiased and efficient. On tractors we used only the number of tractors rather than data by size and type. Similar limitation applies to the data used on gross land and irrigated land cultivated without any data on multiple cropping, quality and soil type of land and mode and source of irrigation. Moreover, the study had to omit many other factors pertinent to agriculture (e.g., nature of seed used, amount and monthly distribution of rainfall, humidity, insecticides, etc.), and it is believed that their inclusion might perhaps explain a larger proportion of the variation in output, and reduce the region and temporal effects estimated. With regard to the form of production function, although we have experimented with the Cobb-Douglas and Quadratic forms, we could not for lack of data test for several other possible forms (e.g., C.E.S., Trans-Log, etc.) and had to rely on other studies as to their inapplicability in Indian agriculture. In sum, it may be argued that the model employed seems to be appropriate in an analysis of the present problem and the results, as far as they go, provide the right indicators.

IMPLICATIONS FOR POLICY

The findings of this macro-economic study provide some important implications for the agricultural and economic development policy of India. However, these should be considered in the light of the limitations of the study and be used to enunciate broad guidelines rather than precise magnitudes of the policy variables.

The Government of India in their five year plans have laid down the objectives of sustained economic growth and reduction in regional disparity. Increases in agricultural output are usually forecast on the basis of schematic tables of coefficients that give expected increases in output as a result of increases in specific inputs /Etienne (1971), p. 302, Dantwala (1961)/. In reality projected output has repeatedly differed widely from actual output. This seems consistent with the findings of the present study which suggest that in the existing macro-economic structure of Indian agriculture, the application of additional current inputs can only bring about limited increase in the level of output. It is also suggested that there is substantial interaction between the inputs which should be taken into account in

forecasting future output. (The coefficient for the interaction between irrigation and fertilizer is positive and statistically significant. See Appendix D.) The present study indicates that at the level of individual current inputs, irrigation and fertilizer seem to be the most important in Indian agricultural production. Since the potential for irrigation facilities is unevenly distributed in the different regions, development efforts are likely to pay off more if directed at such areas where irrigation potential is relatively high. From this point of view, the Gangetic plain seems to deserve particular attention in the irrigation policy of India. /Abel (1970, 1971)/.

The argument of this thesis is that the disparity between regions in the levels of output is the result of varying levels of current inputs used as well as the levels of efficiency at which those inputs can be used in the different regions. Individual districts have been identified by their respective levels of efficiency and that indicates almost a staggering difference in such levels between districts. It appears that only a small part of the disparity in output levels is due to variations in the levels of known inputs and, therefore, it is difficult to remove the disparity only by the reallocation of such resources. The bulk of the disparity

is due to the region effects and seems to originate from sources not yet identified and measured -- the peculiarities of specific regions that are stable over time. Among such factors, some are amenable to human influences in the long run while others are harder still to control. For example, it is possible to change the nature of certain inputs or their method of application, e.g., switching from traditional or well-type irrigation to the use of electric pumps, increasing the skill and changing the attitudes and practices of laborers through extension and practical training, and so on. But it is extremely hard to influence factors like the basic type and humus content of the soil or the height or geographical location (e.g., nearness to the sea, river or desert) that influences the productivity of land in a region. (However, some of these factors also can perhaps be partially influenced over time through aforestation or even replacement of the top soil.)

The study indicates that the simultaneous attainment of the goals of maximizing output and reducing disparity is far from a simple task. Much depends on the nature of the regional effects, to what extent they are amenable to changes by present or past investments, as well as the nature of such investments. Assume that the region effects are not at all

amenable to change by known policy instruments. In such a situation, if two regions are using the same levels of measured inputs but have different region effects, the allocation of additional inputs to the region with higher region effect will help to maximize output, but it will also increase the disparity between the two regions. Here there is a trade-off between the two goals. The actual situation, however, is much more complicated and the trade-off is not necessarily present in all cases. The region effects, as indicated above, are likely to be somewhat amenable to change and the regions are at different levels of input use with different marginal productivities for the inputs. Decisions on the allocation of developmental resources in such cases will have to be based on relative differences in regional effects and marginal productivities of inputs in different regions. What is needed, therefore, for a realistic policy formulation is to examine intensively the nature of the region effects and the existing levels of input use for each regional unit.

Also, due to lack of proper research, information and opportunities, some regions may be engaged in producing crops for which they are not best suited. The cropping

pattern of such regions may be improved. For example, some regions with low region effect may be suitable for orchards, some for pastures, poultries, dairies, and animal farms and some may not be very suitable for any agricultural activity and so non-agricultural investments should perhaps be considered for their development.

For both the creation of factors related to high productivity and the evolution of the product suitable for the region or component of a region (district) intensive research is needed. Some studies suggest that regional growth is highly correlated with regional research expenditures /Evenson (1973)/. The findings of the present study are consistent with this and it is suggested that a sustained policy of research in specific districts into their geo-climatic-socio-economic characteristics is essential for understanding the causes of disparity and trying to alleviate them.

The continued flow of inputs to regions with high region effects is likely to aggravate the regional imbalances in the supply of agricultural products. Unless appropriate policies are taken simultaneously to deal with this problem the policy of growth will be faced with danger. There should

be provision for a smooth and quick flow of both food and industrial raw materials from the centers of production to the centers of processing and consumption and the two centers may not be very near each other. Failure of this may on the one hand lead to problems of over-production, fall in prices and incomes and loss of farmers' incentive for producing more in the production centers; and on the other hand to scarcities, inflation, fall in industrial production and unemployment in the remaining areas. To prevent this, there is needed a set of policies for pricing, transportation, storage, procurement and supply. Here the policy of agricultural development is a component of the overall economic policy of the country. The policy of industrial location should be to complement the short run imbalance in agricultural development so that areas with low region effect in agricultural production can still have the economic demand for the products from high productivity areas, and one is not choked off due to lack of contact with the other.

Apart from the problems of growth and regional disparity, the government of India has also been concerned with the question of this growth being "steady" or "sustained." The biggest threat to a steady growth of output in India has been the periodic fluctuations in her agricultural output

subject to the impact of natural calamities like variations in rainfall, flood damages, insect and locust problems, etc. The present study provides a measure of the extent to which agricultural output in districts varied from year to year due to these problems. In the sample area studied, output has fluctuated between the low of 87 percent of the normal level to a high of 108 percent. This information might be used for short run policy of building stocks to meet natural calamities. Moreover, further research may be undertaken to identify the nature of causes governing the temporal variability of output in individual districts. For instance, policies to reduce such fluctuations will depend on whether these are due to a drought recurring every few years or whether it is caused by pest damages.

Similar exercises in the analysis of time series and cross sectional variation in agricultural production are required of other regions of India to aid in the formulation of economic and regional development policy. Investigations over longer periods of time could also be valuable. Such undertakings will generate heavy demand for detailed sub-regional data on agricultural inputs and their quality, as well as agricultural outputs. Moreover, it seems useful to conduct similar

studies in other developing countries for a better understanding of the regional and structural characteristics of agricultural production in diverse settings.

To sum up, the broad message of the study seems to be one of restrained optimism: in the existing structure of production aggregate agricultural output in India seems to respond only to a limited extent to increases in current known inputs and there is a large unexplained residual in the variation in output. Regions vary widely with respect to their levels of productivity and it is through a long-term policy of sustained research at regional levels and provision of region-specific measures that the disparities could be reduced and aggregate productivity increased. Meanwhile, there should be a whole set of policies to sustain the growth in agricultural output in the more efficient areas. These should include provision of incentive prices for the products, transportation and storage facilities, procurement and delivery policies and location of non-agricultural activities to generate demand for the output produced.

APPENDICES

APPENDIX A

REGIONAL AND TEMPORAL ANALYSIS: A BRIEF SURVEY

The purpose of this appendix is to briefly review some major contributions in the field of regional and temporal analysis in general and in the case of Indian agriculture. Analytical studies of spatial and temporal factors in production are neither numerous nor very old. However, this area of economic research, particularly in regional analysis, is relatively rich in the application of several methodological contributions from general economic theory that deal mainly with location, income distribution and trade.

Regional Analysis

Prior to the 1950's, there was hardly any regional study separate from business cycles analysis. Regional economics then was concerned with the inter-regional propagation and diffusion of business cycles [Vining (1945, 1946, 1949)]. It is during the last two decades that regional analysis developed as a distinct area in economics and rendered possible the integration of the theories of general

economics and the empiricism of regional analysis studies [Meyer (1963)].

Based on the theoretical foundations of location theory, multiplier theory, input-output analysis and mathematical programming [Meyer (1963)] regional analysis has its major thrust to quantification, forecasting and the development of frameworks. This accomplishment, however, has been at a relative neglect of another important approach. In the words of J. R. Meyer, "regional analysis has reached a stage where it could benefit from some redirection of effort away from the design of broad conceptual frameworks and accumulation of regional income accounts toward the formulation and testing of behavioral hypotheses, with the initial emphasis being placed on hypotheses that could be quite readily developed from the application of general economic concepts already available" [Meyer (1963)]. Meyer notes that most of the work with regional analysis in underdeveloped countries display the more formalistic tendencies, made popular by the need for long-range problems of development and large-scale development investment.

However, as Meyer himself pointed out, there are interesting studies with an orientation to hypothesis testing

Williamson's study (1965) on regional inequality and process of development explicitly tests hypotheses relating to the cross-sectional and historical pattern of regional inequality vis-a-vis the stage of economic development. He compiles international data to support the hypothesis that a "statistic describing regional inequality will trace out an inverted 'U' over the national growth path." The statistic used by Williamson to measure regional inequality were regional income per capita and the share of agricultural laborers in the total labor force by regions, and one interesting finding of this study is that regional inequality is much more extensive within the agricultural than within industrial sector.

It might be expected that in view of the problems of generation and mobility of factors of production and the specificity of the location of economic activity, regional analyses should assume added significance in studies of economic development and agricultural progress. Paradoxically, until very recently, Williamson's study has been one of the few* in this area that confronts hypotheses with actual data.

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*Some other important studies of regional inequality and economic development are Baer (1964), Chenery (1960), and Eckaus (1961).

Recently the United Nations Research Institute for Social Development has commissioned a series of studies on a world-wide basis on Regional Development: Experiences and Prospects. These studies review the past experiences and future prospects of regional development, with an accent on regional planning, of both developed and developing economies. The objective of these studies is to fill the gap between two types of approaches, namely, broad generalizations regarding regional development that are not able to handle specific differences between countries, and purely case studies particular to individual regional units.

Striking a balance between the two extremes mentioned above in a regional analysis is not an easy task. Simply dividing the world into some continental zones serves little purpose because of the very wide variations in them that need to be dealt with individually. The U.N. studies do not develop a general methodological framework, and they (at least some of them) have to cover in one study areas as disparate as Afghanisthan and Thailand, and topics as diverse as city planning and customs unions. It is hard in such studies to derive conclusions other than of a general and diffused nature. For example, the volume on South and South-East Asia has

the only identifiable thesis that what is needed is massive improvements in the distribution of income in favor of the unemployed and the underemployed to promote economic development, not only to meet social justice. [See Desai (1973)].

In sum, regional analysis, in its two-decades-old lifetime as a distinct area of economics, has grown by assimilating sophisticated analytical tools from general economic theory and seeking to explain some empirical questions. The accent, however, has been on the development of analytical frameworks and the problems related mostly to interregional flows and behavior of income differences on the macro level. Regional peculiarities that are stable over time and that influence production over space and time, particularly in agriculture in developing economies have been less explored so far. The present study belongs to this area.

Regional Analysis of Indian Agriculture

India is a country with a vast geographical area with widely divergent characteristics from one region to another. During the last two decades India has passed through three five year plans for economic development, and is about to complete the fourth. In spite of the regional variations and the proximity of regional analysis to policy questions, scientific

regional studies had been conspicuous by their scarcity in Indian economic literature until recently [Bhagwati and Chavravarty (1969)]. Not that Indian planners were entirely unaware of the problem of regional balance. Both the first and second year plans had references to regional disparities and the need to reduce them. With a slightly more emphasis, the third five year plan reviewed the policies in this field. The fourth five year plan, recognizing the importance of multi-level (District, State, National) planning went one step further in recommending sizeable development assistance programs for the purpose of reducing regional disparities. But throughout these plans and through much of the thinking on regional disparity in India, the overwhelming emphasis has been given to the problem of urban and metropolitan development, almost to the exclusion of the much more inherent disparities in the rural and agricultural sector. Even the United Nations study seems to view the problem of agricultural development as largely one of rapid urbanization [See Lefeber and Datta Chaudhuri (1971)]. Indian planning thus for a long time tended to think in terms of dispersal of industries and special assistance programs (e.g., public works and relief) as means to maintain regional balance. The not

so unexpected result has been that development efforts have been faced with the scarcity of already scarce resources for industrialization/urbanization while a large source of regional imbalance ingrained in agricultural production has remained relatively untouched. It is only in the late sixties that attention has turned toward this problem in any significant manner. This recognition of regional imbalance in agriculture has coincided with, if not caused by, the introduction in 1966-67 of what has been termed the New Strategy for Agricultural Development in India, comprising the use of fertilizer-responsive high-yielding varieties, greater emphasis on irrigation than on drought protection, arrangements for the provision of fertilizer, insecticides and credit, etc. The New Strategy brought to the fore the urgent need for removing imbalances in agriculture, namely between rainfed and irrigated areas, between crops (cereals and others) and between farms (large, medium and small).

During the recent past several studies have been made both by the Government and by individual researchers dealing with the regional development of Indian agriculture. These studies can be divided into two groups, (a) studies dealing with the measurement and explanation of regional disparity

in agriculture on the basis of existing administrative units of region, e.g., district or state; and (b) studies designed to classify the country into homogeneous regions for purposes of a meaningful policy of regional agricultural development. Some studies from each group are briefly summarized below.

(a) Studies in Regional Variation in Agriculture

The studies in this group are quantitative and are, therefore, subject to the constraint of the availability of data. Broadly, two types of approaches have been made to measure and explain regional variation in Indian agriculture, first, growth component approach, and second, descriptive approach.

The growth component approach is based on the assumption that the growth in output in a region during a period of time can be decomposed into a number of components, for example, growth due to change in area cultivated and due to change in yield per unit of area. Using this approach Alan Heston (1968) shows that growth in acreage had been a major contributor (almost half) to the total growth of crop output in Indian agriculture during 1952-53 to 1961-62. While the rate of growth and the relative contributions of the two sources varied widely in different states, Heston's conclusion is that "future growth will be difficult because with no

additional land upon which to expand traditional methods of output expansion will not be available." Commenting on the regional variation in growth rates, Heston offers the explanation that such differences are mainly "due to natural conditions, foremost of which are whether the soil and monsoons permit a crop or plantation crop."

But the contribution of crop pattern which is one of the four components into which crop output growth in India during 1951-56 to 1958-61 has been decomposed by Minhas and Vaidyanathan* (1965) is not borne out to be a significant

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*Minhas and Vaidyanathan decomposed change in total crop output between the years into four components using the following additive scheme:

Definition: $0_1 = A_1 \sum_i p_i c_{ij} y_{i1}$

$0_2 = A_2 \sum_i p_i c_{i2} y_{i2}$

Scheme of Decomposition:

$$0_2 - 0_1 = (A_2 - A_1) \sum_i p_i c_{i1} y_{i1} + A_2 \sum_i p_i c_{i1} (y_{i2} - y_{i1})$$

$$+ A_2 \sum_i p_i y_{i1} (c_{i2} - c_{i1}) + A_2 \sum_i p_i (y_{i2} - y_{i1})(c_{i2} - c_{i1})$$

where

0	= crop output; A = gross crop area
c_i	= proportion of area occupied by crop i
p_i	= constant price weights
y	= yield (three-year average)
1, 2	= subscripts denoting the two years of comparison

The four components on the right hand side of the identity denote respectively the effects of change in area, change in yield, change in crop pattern and interaction. This is one of the many possible identities for decomposing growth in output and many growth component studies use some variant of this general scheme.

explanation of variation in agricultural growth. In this study also variations in the extent of area and yield changes turn out to be the most important factors in the inter-state and inter-district variations in output. While these studies identify yield change as a source of growth, no attempt is made to explain changes in yield.

Using a modified, but still basically a growth component mode, S. K. Rao (1971) breaks up growth in output into two segments -- due to change in irrigated area and due to extension of cultivation to virgin land. The study confirms the hypothesis that the proximate cause of interstate variations in crop-output is the differences in the growth of irrigated area, consistent with the conclusions of several other studies [Raj (1970) and Rao (1965)]. S. K. Rao looks into the financing of the irrigation projects and suggests that it was public investment that played a major role both in directly bringing about the growth in irrigation and indirectly attracting and facilitating private investment in well irrigation. And since public investment has been induced largely by the already rich farmers inter-regional variations in irrigation and, therefore, in agricultural growth, has increased, making rich regions relatively more rich.

Using a growth component model similar to that used by Minhas and Vaidyanathan, the Government of India prepared several studies on regional variations in crop output -- for several states (Punjab, Madras, Orissa and U.P.) and all-India. The broad conclusion of these studies is that variations in yield increases and area increases are the most important sources of variation in growth of crop output, changes in crop pattern being important only in some cases. These studies seek to offer some general information on several yield-increasing inputs like fertilizer, irrigation, pesticides, improved seeds, mechanical power, improved implements, etc., and such factors as quality of soils, rainfall, growth rate and other attributes of population and social, economic and institutional factors e.g., share cropping, co-operation, infra-structure like road and transportation, etc.

The role of socio-institutional factors, rather than physical factors, in explaining regional variation in agricultural growth has been highlighted in a paper by V. Nath (1970) who stressed the importance of land reforms, development of co-operatives and expansion of infra-structures like communication and rural electrification. Nath develops an

index of economic development and conducts his analysis in the light of a general comparison of the ranks of states in this index and their rank in agricultural productivity increases.

The constraint of data availability that plagued most disaggregated studies of Indian agriculture has been, at least partly, relaxing recently, thanks to the new program of agricultural development undertaken by the Government of India in collaboration with U.S. agricultural experts. Dorris Brown's study Agricultural Development in India's Districts deals with the above Intensive Agricultural Development Program and presents a wealth of statistics for most of India's 320 districts. Brown's conclusion that the districts selected in the program showed no significantly different performance than other districts is subject to the assumption that initially all the districts were similarly situated on the production possibility frontier. Instead of analytically separating the effects of the IADP measures from other effects on production, Brown based his conclusion on a simple comparison of the apparent end results.

An explanation of the above is offered by Robert Evenson (1973) in his recent analysis of varying rates of agricultural growth in the regions of India. Evenson traces

the sources of variation in "total factor productivity" (rather than "yield") to the contributions of "traditional inputs" and "modern inputs," and finds that the substantial and increasing disparity in agricultural productivity between regions is consistent with the variation in cumulative research investment. In this study, "regional disparity in production is also quite consistent with the hypothesis that the research program in India has been the major determinant of change." With regard to the IADP districts, Evenson suggests that the lack of any significant superiority in their performance may be due to the fact that (i) these districts, declared to be relatively "advanced," might have by the early 1960's exhausted the "easy" gains to be had from non-technological sources (e.g., market improvement, land reform, etc.); and (ii) the heavily subsidized inputs in these districts might have induced farms to use "too much" of these and thereby some productivity gains might have been "lost."

(b) Studies on the Classification of India into Homogeneous Regions

The preceding studies on the regional variation in agricultural growth have been conducted along existing administrative boundaries of states and districts. But administrative boundaries are often inconsistent with physical

and economic boundaries. So the urgency of the need for developing a more meaningful set of regions for purposes of economic planning in India has prompted a number of attempts at re-classifying the states and districts into regions on the basis of physical and economic characteristics. Some of these studies will be briefly mentioned below (for a useful summary view of these studies, see Kanungo and Sarma (1973)).

I. Crop Regions /Directorate of Economics and Statistics, Ministry of Food and Agriculture./

This exercise identified 107 crop regions for India on the basis of the existing cropping patterns of the districts assuming that these patterns reflected the resultant effects of all physical and economic factors. The study considered the patterns for 20 crops during 1957-59. For each crop, indices were constructed for relative spread (area under crop) and relative yield.

II. Crop Zones /Indian Council of Agr. Research and Directorate of Economics and Statistics (1968)/

Taking into account the crop regions and the spread and yield indices developed in "I", this study classified the country into four broad zones with respect to the place and potential of several important crops. These zones would be useful for rational planning of crop patterns for the country. The zones are:

Zone I - High Yield High Spread

Zone II - High Yield Low Spread

Zone III - Low Yield High Spread

Zone IV - Low Yield Low Spread

III. Resource Development Regions /Planning Commission (1964)/

With a view to aiding balanced development of different regions with varying physical conditions and resource development potentials, this study by the Planning Commission classified the country into 15 regions and 61 divisions. These were based on information relating to topography, soils, climate, geological formations, land utilization, irrigation, cropping pattern, and availability of mineral resources for each district of the country.

IV. Agricultural Regions /P. S. Sharma (1968)/

In this study 300 districts of India were classified into agricultural regions on the basis of two composite indices -- land resource indices and value productivity indices. The land resource indices were calculated by combining the weighted decile ratings for six individual indicators, namely (i) gross area irrigated as percent of gross area sown, (ii) extent of cultivated area, (iii) intensity of cropping,

(iv) gross area sown per capita, (v) average annual rainfall, and (vi) soil characteristics, e.g. topography, texture, etc. The value productivity indices were calculated for 20 crops for the triennium ending 1961-62, taking the average all-India per acre gross value productivity as base (=100). The two indices were then combined into different ranges to yield agricultural regions into indices: very low, low, medium, high and very high.

V. Agro-Climatic Regions /Abel and Easter (1972)/

In a paper entitled "Agricultural Development Planning with a Focus on Regional Restraints," Abel and Easter point out that the advantage of regional agricultural development planning is to identify the key factors that are holding back agricultural development in specific areas and to suggest the nature of remedial measures. The possible such restraining factors are 1) Water and Land Development, 2) Rural Intrastructure, 3) Farmer Incentives and Institutions, 4) Agricultural Research, 5) Education and Training, 6) Provision of Inputs, 7) Markets and International Trade, and 8) Employment. The constraints may be operative at two levels, micro or the regional level (e.g., problem of water resources) and macro or 'national level' (e.g., price policy or international trade). The paper has classified India into five divisions on the basis

of broad geologic and topographic factors, fourteen zones on the basis of climatic and soil factors, and 31 agro-climatic regions on the basis of cropping patterns and quality of agricultural and human resources.

VI. Regions for Agricultural Planning and Management /K. William Easter, 1972-73/

Easter in this study has developed two types of regions for Indian agriculture with a view to helping plan the specific crop production for the nation and a rational agricultural development taking into account the variations in agro-climatic factors.

a) The crop regions have been constructed on the basis of two factors: (i) the percentage contribution of a district to the total national production of a crop in 1967-69; and (ii) the percentage of the districts' gross cropped area under the crop. Each region has two types of districts, core districts and satellite districts. All districts with 0.5 percent or more of a crop's production were chosen, and to these were added districts with a given percentage of the gross cropped area under the crop so that the low productivity districts are not excluded. A minimum of three adjoining districts, at least one of which is to be a core district, is required to form

a crop region. /In an extension of this work Easter and Abel have developed crop regions for 23 crops and three groups of crops in India; (Econ. Dev. Center, University of Minnesota, 1973)/.

b) The agro-climatic regions designed to aid over-all agricultural planning were developed on the basis of resource-endowments like climate, soils, geology and cropping differences. Regions were demarcated by means of plastic overlays for each crop and by the percentage of cropped area under different combinations of crops. The combinations of crops selected were such that they included at least about 75 percent of the crop area. Further, a district should have at least 5% of the area under each crop in the combination. On this basis the country has been classified into three Divisions, ten Sub-Divisions and 52 Regions.

VII. Agro-Climatic Regions /National Commission on Agriculture/

The National Commission's undertaking, when completed, will perhaps present the most comprehensive and detailed regional classification of Indian agriculture. Designed to establish the relationship between cropping patterns and natural factors, this study is building agro-climatic regions for the

highly disaggregative regional units, e.g. taluk or tehsil, on the basis of a host of information, namely, physical features, land use, population, soils livestock, irrigation, rainfall, temperature, cropping patterns and yield. Work on this project is in progress.

To sum up, there have been several studies in the regional variation in agricultural growth in India, apart from the useful attempts at reclassifying the Indian agriculture into agro-climatic or crop or resource zones. Regional studies have mostly sought to explain variations in growth by using component method that sets up identities to break up the total variation. Such studies used two points in time for growth comparison, and set up different forms of identities and the conclusions depended heavily on the years, assumptions and regions preferred. It is not surprising, therefore, that there were various explanations for the growth variations. Moreover, very few studies sought to explain analytically yield variations and none used production functions. For this purpose the present study will be based on all the years during the period selected, and regional units will be chosen at a sufficiently disaggregative level, and by using production

function analysis an attempt will be made to measure the contributions of specific factors. For purposes of selecting regions this study will make use of the regional classification of Indian agriculture made by K. William Easter and Martin E. Abel.

Temporal Effects on Production

Climatic influences on economic production as part of the influence of environment* have two aspects -- the distribution of climates in space and the fluctuations of weather from year to year. While variations over space constitute the subject matter of regional analysis, the effects of year to year fluctuations in weather on production, though equally visible, have played a relatively less important role in economic theory and measurement.

However, economists have long been aware of the importance of weather fluctuations and have taken it into account in some theories of business cycles /H. S. Jevons (1909), Garcia-Mata and Shaffner (1934-35)/. There have

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*In the words of Paul B. Sears, "Environment is of course complex, but the limiting factors may be grouped into those which are climatic, edaphic (soil, topography, etc.) biotic (e.g., competition) and cultural," in D. Gale Johnson and Robert L. Gustafson (1973).

also been numerous case studies of the effects of weather fluctuations on specific crops, in specific regions and in specific periods.

One study in the measurement of the effect of the weather variable was made by James L. Stallings in studying the influence of weather on annual yields of major crops in the U.S.A. /Stallings (1960)7. Stallings built weather indexes for the U.S. for a long period of time on the basis of experiment station annual yield series for a number of crops. He removed from each series the effects of non-weather effects by fitting a linear least-squares trend line. The residual was the effect of weather.

The validity of Stallings' results (although his methodology could be subjected to criticism, see Johnson and Gustafson, p. 29-31) was supported in several subsequent studies. Dale E. Hathaway (1959) showed that Stallings' index was negatively correlated with the business cycles indicating that the indexes did not reflect the influences of changes in demand and prices on yield. Griliches (1960) used Stalling's index and showed that during 1911-1958 the weather index explained a significant part of the total variance in crop output in the U.S.A. Johnson and Gustafson presented scatter diagrams of relations between yield (of selected crops),

Stallings' indexes and "precipitation," and concluded that a large part of the long-run (decade-to-decade) variation in average yield of the major grains could be explained by weather.

Studies of the effects of weather on agricultural production in India

India has been long familiar with consequences of the vagaries of climate on her agricultural production. But there has not been much systematic study of the extent of the dependence of Indian agriculture on rainfall and other climatic variations from year to year, except for some specific case studies [e.g., Mann (1955), Krishna and Rao (1967)].

In an address delivered at the Indian Society of Agricultural Statistics, Sen (1971) observed that during the present century periods of high rates of growth of agricultural production have been characterized by higher year to year fluctuation in such production. He urged more research into the nature and causes of this observed phenomenon by separating the effects of man made decisions from those of variation in weather.

Using a method developed by Hendrix, Naive and Adams (1968), Cummings, and Ray (1969) estimated the contributions of weather and technology to the 1967-68 and 1968-69 foodgrain production in India. The basic methodology was to estimate the contributions to production from factors like area sown, irrigation, fertilizer and seeds applied in a "normal" base year. While this method involves some rather restrictive assumptions regardin the "normal" year and production coefficients from experimental data, this seems to be the only attempt at a quantitative measure of weather-effects on Indian agricultural production.

The present study, based on actual rather than experimental data, will seek to measure the effects of weather on each year's agricultural output and thus provide a time-series view of the changing pattern of Indian agriculture's dependence on nature.

APPENDIX B

THE EASTER-ABEL WHEAT REGIONS OF INDIA SELECTED FOR STUDY

I. Punjab Region

District	Percent of National Wheat Production		Percent of District in Wheat	
	1967-69	1959-61	1967-69	1959-61
1. Ferozepur	4.4	3.7	41	37
2. Ludhiana	3.4	1.4	46	41
3. Sangrur	3.2	2.6	36	28
4. Bhatinda	3.0	1.8	34	24
5. Amritsar	2.4	1.3	45	41
6. Patiala	2.3	1.9	42	36
7. Jullundur	1.9	1.4	49	47
8. Gurdaspur	1.2	0.7	43	42
9. Hoshiarpur	1.0	1.0	42	37
10. Karpurthala	0.7	0.4	48	48
Total	23.5	16.2		

II. Haryana and Western Uttar Pradesh Region

1. Karnal	3.0	2.0	35	25
2. Rohtak	1.8	1.6	28	21
3. Gurgaon	1.3	0.8	22	13
4. Ambala	1.1	0.8	30	26
5. Meerut (U.P.)	2.2	2.0	39	30
6. Bulandshahr (U.P.)	1.9	1.3	34	22
7. Muzaffarnagar (U.P.)	1.5	1.2	36	32
8. Saharanpur (U.P.)	1.0	0.8	34	28
9. Hissar	1.6	1.6	12	10
10. Ganganagar (R)	1.1	1.4	14	14
Total	16.5	13.5		

III. West Central Uttar Pradesh Region

District	Percent of National Wheat Production		Percent of District in Wheat	
	1967-69	1959-61	1967-69	1959-61
1. Moradabad	1.2	1.4	36	32
2. Rampur	0.5	0.5	30	22
3. Budaun	1.0	1.2	33	29
4. Bareilly	0.6	0.7	25	33
5. Shahjahanpur	0.7	0.7	28	24
6. Hardoi	0.8	1.0	22	22
7. Sitapur	0.6	0.8	24	20
8. Bijnor	0.9	0.9	31	26
9. Dehra Dun	0.1	0.2	29	28
10. Nainital	0.1	0.4	24	21
Total	6.5	7.8		

IV. Northeastern Uttar Pradesh Region

1. Basti	1.0	0.9	22	15
2. Gonda	0.9	0.9	22	19
3. Gorakhpur	0.7	0.6	21	14
4. Bahraich	0.7	0.6	21	19
5. Kheri	0.7	0.6	23	20
6. Bara Banki	0.6	0.7	21	17
7. Faizabad	0.6	0.6	21	17
8. Deoria	0.8	0.6	19	13
9. Pilibhit	0.4	0.3	27	23
Total	6.4	5.8		

V. Southwest Uttar Pradesh Region

1. Aligarh	1.7	1.0	30	20
2. Mathura	1.2	0.9	33	22
3. Etah	1.0	1.0	26	22
4. Mainpuri	1.0	0.7	27	19
5. Lucknow	0.4	0.4	30	22
6. Agra	0.8	0.8	26	18
7. Farrukhabad	0.9	0.9	28	22
8. Etawah	0.9	0.6	28	15
9. Unnao	0.6	0.5	28	15
10. Bharatpur (R)	1.0	0.7	19	11
Total	9.5	7.5		

VI. Southern Uttar Pradesh Region

District	Percent of National Wheat Production		Percent of District in Wheat	
	1967-69	1959-61	1967-69	1959-61
1. Jhansi	0.9	0.9	31	27
2. Jalaun	0.8	1.0	28	27
3. Kanpur	0.9	1.0	25	18
4. Banda	0.7	1.0	21	20
5. Allahabad	0.5	0.4	15	15
6. Tikamgarh (M. P.)	0.4	0.3	20	16
7. Chhatarpur (M.P.)	0.4	0.4	22	18
Total	4.6	5.0		

VIII. Central Madhya Pradesh Region

1. Vidisha	0.9	1.6	47	55
2. Sagar	0.9	1.6	50	58
3. Raisen	0.6	1.1	41	48
4. Sehore	0.6	1.4	37	55
5. Damoh	0.4	0.8	38	46
6. Hoshangabad	0.4	1.0	31	44
7. Indore	0.3	0.5	31	43
8. Satna	0.4	0.6	26	31
9. Jabalpur	0.4	0.9	25	29
10. Panna	0.2	0.4	21	26
Total	5.1	9.9		

IX. Madhya Pradesh Rajasthan Region

1. Guna	0.4	0.7	25	30
2. Kotah (R)	0.7	0.9	28	32
3. Gwalior	0.5	0.8	34	35
4. Bundi (R)	0.3	0.5	27	26
5. Datia	0.2	0.3	29	35
6. Shivapuri	0.3	0.6	21	25
Total	2.4	3.8		

Source: K. William Easter and Martin E. Abel, Cropping Regions in India, Bulletin Number 1, Economic Development Center, Department of Economics and Department of Agricultural and Applied Economics, University of Minnesota, Minneapolis and St. Paul, June 1973.

APPENDIX C

REGIONAL PRODUCTION FUNCTIONS (COBB-DOUGLAS) USING DUMMY VARIABLES FOR DISTRICTS

(Dependent Variable: Agricultural Production: Divisia Measure)

Variable	All 72 Districts		Region A*		Region B*	
	Coefficient	T-Value	Coefficient	T-Value	Coefficient	T-Value
Land	.07	2.25	.10	2.06	.05	1.28
Irrigation	-.01	.20	.23	2.52	-.03	.82
Fertilizer	.09	7.39	.11	4.11	.09	5.97
Tractor	00	.14	-.04	.52	-.03	.89
Literate Labor	-.07	.48	-.14	.36	-.60	.33
Illiterate Labor	.36	2.26	.40	1.21	.53	2.22
Sum of Squares of Residuals	22.34		4.37		17.42	
Degrees of Freedom	713		193		513	

*Region A consists of the 20 Districts from Punjab, Haryana and Western U.P., and Region B consists of the remaining 50 Districts.

APPENDIX D

AGRICULTURAL PRODUCTION FUNCTION FOR WHEAT REGIONS OF INDIA: QUADRATIC

(Dependent Variable: Agricultural Production (Divisia Measure) Per Acre of Land Cultivated)

Variables	Original Variables		Deviations From District Means		Transformed Variables	
	Coefficient	T-Values	Coefficient	T-Values	Coefficient	T-Values
Irrigation per acre	.03	1.99	.02	.96	.03	1.15
[Irrigation per acre]^2	.02	.72	-.08	2.08	-.04	1.20
Fertilizer per acre	-1.52	3.27	-.13	.46	-.50	1.79
[Fertilizer per acre]^2	10.21	.99	-12.85	2.38	-6.36	1.17
Tractor per acre	12.72	3.40	12.58	3.12	13.55	3.45
[Tractor per acre]^2	-3975.51	4.51	-3038.85	4.80	-3297.43	5.20
Literate Labor per acre	.42	3.69	.10	.61	.17	1.01
[Literate Labor per acre]^2	-.88	2.23	-.18	.35	-.33	.66
Illiterate Labor per acre	-.08	3.91	.03	1.18	.01	.50
[Illiterate Labor per acre]^2	.02	1.74	-.005	.36	-.005	.40

APPENDIX D (continued)

Variables	Original Variables		Deviations From District Means		Transformed Variables	
	Coefficient	T-Values	Coefficient	T-Values	Coefficient	T-Values
[Irrigation-Fertilizer	3.64	3.84	2.75	5.30	2.66	4.98
Interaction]	.02	2.34			-.0002	.02
Constant						
R^2 (Adj)	.45			.20		.20
F (11.708)	55.53			17.77		17.02
$\hat{\rho}$						.91

APPENDIX E

REGIONAL PRODUCTION FUNCTIONS (QUADRATIC) USING DUMMY VARIABLES FOR DISTRICTS

(Dependent Variable: Agricultural Output (Divisia Measure) Per Hectare of Land Cultivated)

Variable	All 72 Districts		Region A*		Region B*	
	Coefficient	T-Value	Coefficient	T-Value	Coefficient	T-Value
Irrigation per Unit of Land	.02	.96	.04	.47	-.41	2.85
[Irrigation/Land]^2	-.08	2.09	-.10	.99	.11	3.91
Fertilizer/Land	-.13	.46	.62	.69	.98	3.90
[Fertilizer/Land]^2	-12.85	2.38	-17.54	1.52	7.72	1.54
Tractor/Land	12.57	3.12	11.82	.86	2.05	.78
[Tractor/Land]^2	-3038.85	4.80	-3125.46	1.68	667.37	.70
Literate Labor/Land	.11	.61	.18	.22	.02	.28
[Literate Labor/Land]^2	-.12	.35	-1.12	.57	.39	1.70
Illiterate Labor/Land	.03	1.18	-.04	.26	.05	4.28
[Illiterate Labor/Land]^2	-.005	.36	.09	.64	-.18	3.40
[Fertilizer-Irrigation Interaction]	2.76	5.31	2.37	1.94	-3.34	4.29
Sum of Squares of Residuals	.10		.086		.008	
Degrees of Freedom	708		188		508	

*Region A consists of the 20 Districts from Punjab, Haryana and Western U.P., and Region B consists of the remaining 50 Districts.

APPENDIX F

ORDINARY LEAST SQUARES ESTIMATES OF PRODUCTION FUNCTION (COBB-DOUBLAS) USING DUMMY VARIABLES FOR DISTRICTS AND YEARS

(Dependent Variable: Total Agricultural Output - Divisia Measure)

Variable	Using Dummies For Districts	Using Dummies For Districts & Years	
		Coefficient	Standard Error
Land	.07	.05	.03
Irrigation	-.01	-.02	.03
Fertilizer	.09	.10	.01
Tractor	0	.01	.02
Literate Labor	-.08	-.40	.21
Illiterate Labor	.36	.55	.19

APPENDIX G

PRODUCTION FUNCTION USING TIME AND RANDOM EFFECTS: COBB-DOUGLAS
(Dependent Variable: Total Agricultural Output-Divisia Measure)

Variable	Original Variables		Deviations From District Means		Transformed Variables	
	Coefficient	T-Value	Coefficient	T-Value	Coefficient	T-Value
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Land	.48	8.12	.54	9.40	.53	9.20
Irrigation	.27	13.87	.22	10.97	.23	11.41
Fertilizer	.06	3.16	.14	6.41	.13	5.96
Tractor	.14	6.16	.11	5.26	.12	5.41
Literate Labor	.12	1.89	.11	1.75	.11	1.78
Illiterate Labor	-.82	13.64	-.88	15.16	-.87	14.93
Constant	7.55	15.78			7.73	16.60
R^2 (Adjusted)	.65		.65		.65	
F (6, 713)	204.81		228.22		224.726	
$\hat{\rho}$					.12	

APPENDIX H

MEASUREMENT OF THE DEPENDENT VARIABLE -- ITS EFFECTS ON THE PRODUCTION FUNCTION

The present analysis has been conducted in terms of physical quantities of output and inputs, and aggregate output has been measured by the Divisia method. It is worthwhile to examine how the results would change if output is measured by the fixed weight Laspeyres' method. The difference between the two methods, as discussed earlier, lies in the fact that the weights vary between districts and years in the Divisia measure while those remain fixed at the base year level in the Laspeyres' measure. The latter uses as weights prices of individual commodities in the base year for the different districts and assumes that the relative prices of commodities remain constant over the entire period -- and also between districts. If in reality relative prices did not remain so constant, Divisia measure of output would reflect the joint effect of changes in both the weights and magnitudes of the different commodities, whereas Laspeyres' measure would aggregate the commodities using the initial weights

and thereby underestimate the change in the output measure. When different regions are pooled, this leads to difficulties in comparing changes in aggregate output measured in the two ways. In Figure 6 let A and B represent the output compositions and p_1 and p_2 the relative prices in region 1 and 2 respectively in year 1. Now suppose over time relative prices have changed in both the regions with region 1 moving to produce more of X and region 2 to produce more of Y so that in year 2 both produce the output configuration C at the same relative price p_3. Now if Divisia measure is used, the configuration C will represent the same aggregate output for both regions whereas if Laspeyres' measure is used C will be evaluated at the two relative prices p_1 and p_2 and will yield two aggregate output measures for the two regions. Thus if different regions have systematically changing relative prices over time so that there is a tendency for them to converge, the transformation for region effects will lead to a smaller amount of variation in the dependent variable to be explained in the Divisia measure than in the Laspeyres' measure.

In India, in view of the recent increases in the transport and communications facilities it seems reasonable to

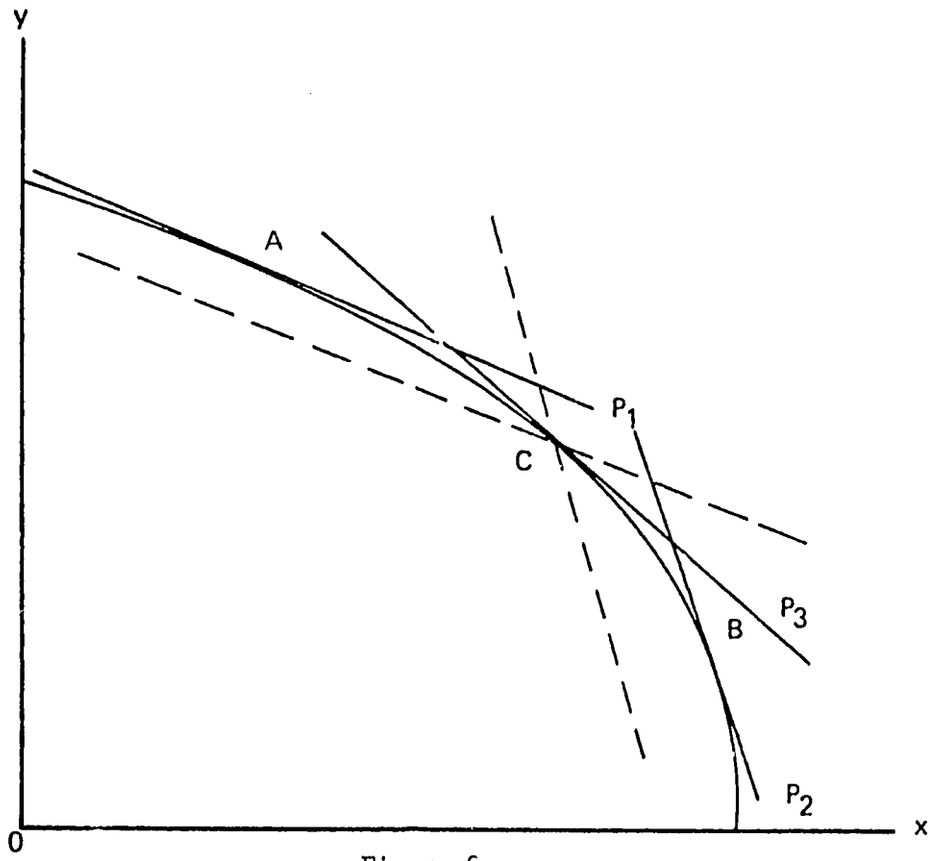

Figure 6

hypothesize that over time different regions have moved toward convergence of relative prices of commodities. So when the region effects are removed in the production function it may be expected that the independent variables will be able to explain a larger proportion of the variation in the Divisia measure of output than in the Laspeyres' measure. This is borne out by the value of R^2 which is .12 in the Laspeyres' measure (Appendix I) as against .20 in Divisia.

From a comparison of the two sets of coefficients it seems that the estimates for the relatively modern inputs in Indian agriculture are generally lower in the Laspeyres' than in the Divisia case. For example, the coefficient for fertilizer and literate labor are smaller in the Laspeyres' case. This may be due to the failure of the Laspeyres' measure of output to take into account the shifts in the composition of crops in favor of those using more of these newer inputs. On the other hand, the coefficients for the other inputs are higher in the Laspeyres' case than in Divisia. This may perhaps be understood with reference to the fact that the application of these inputs in Indian agriculture dates back earlier than fertilizer and education and that crop composition has not shifted particularly in favor of those earlier inputs. In other words,

fertilizer and education seem to be relatively more favorable to the new high yielding varieties of crops than the other inputs. These inputs, e.g., tractor and labor, are favorable when accompanied with inputs like fertilizer and skill. The shifts in crop composition toward the high yielding variety, underestimated in the Laspeyres' measure, might have caused the downward bias in the coefficients of the new inputs. The coefficients for the Divisia measure of output are supposed to be free from this bias.

APPENDIX I

AGRICULTURAL PRODUCTION FUNCTION FOR WHEAT REGIONS OF INDIA: COBB-DOUGLAS

(Dependent Variable: Agricultural Production - Laspeyres' Measure)

Variables	Original Variables		Deviations from District Means		Transformed Variables	
	Coefficient	T-Value	Coefficient	T-Value	Coefficient	T-Value
Land	.51	10.97	.06	2.13	.07	2.45
Irrigation	.22	14.41	.00	.02	.06	1.98
Fertilizer	.01	.91	.07	5.71	.06	4.72
Tractor	.30	17.03	.01	.36	.04	1.67
Literate Labor	.03	.67	-.28	1.96	-.30	2.23
Illiterate Labor	.06	1.27	.51	3.47	.60	4.67
Constant	9.46	25.36			14.77	13.33
R^2 (Adjusted)	.81				.11	
F (6, 713)	524.59				16.27	
$\hat{\rho}$					.95	

APPENDIX J

AREA UNDER HIGH YIELDING VARIETY OF WHEAT

State		1966-67	1967-68	1968-69	1969-70	1970-71	1971-72
PUNJAB	Area under HYV (000 HA)	59	639	1,012	1,413	1,499	1,620
	Area under HYV as % of area under wheat	3.7%	35.4%	48.5%	65.6%	65.2%	69.8%
HARYANA	Area under HYV (000 HA)	13	101	259	490	630	740
	Area under HYV as % of area under wheat	0.9%	11.9%	28.9%	43.3%	55.8%	63.1%
U.P.	Area under HYV (000 HA)	363	1,587	2,515	1,840	1,938	2,200
	Area under HYV as % of area under wheat	8.3%	31.9%	48.0%	30.5%	20.2%	38.4%

APPENDIX J (continued)

State		1966-67	1967-68	1968-69	1969-70	1970-71	1971-72
RAJASTHAN	Area under HYV (000 HA)	9	126	190	283	368	520
	Area under HYV as % of area under wheat	0.9%	10.0%	16.4%	23.0%	24.9%	34.1%
M.P.	Area under HYV (000 HA)	16	15	81	150	201	260
	Area under HYV as % of area under wheat	0.8%	1.7%	2.7%	4.7%	5.9%	8.0%

Source: Directorate of Economics and Statistics, Ministry of Agriculture, Government of India. (Correspondence of Dr. V. Vyas to Dr. Martin E. Abel.)

APPENDIX K

TEMPORAL EFFECTS FOR EACH DISTRICT AND YEAR

District	1959-60	60-61	61-62	62-63	63-64	64-65	65-66	66-67	67-68	68-69	Coefficient of variation of temporal effects
1. Meerut (UP)	1.05	1.05	.96	.93	.92	.97	1.03	1.05	.95	1.09	.03
2. Karnal (H)	1.04	1.05	.98	.90	1.04	1.06	.93	.98	1.11	.91	.04
3. Mainpuri (UP)	1.00	.95	.94	.97	.90	1.11	1.15	.95	1.03	1.02	.05
4. Rohtak (H)	1.05	1.02	.87	.90	1.00	1.00	1.00	.95	1.14	1.06	.05
5. Amritsar (P)	1.06	1.03	1.07	.96	.86	1.14	.94	.94	.94	1.05	.06
6. Patiala (P)	1.10	1.16	1.00	.95	1.00	1.04	.90	.96	.97	.88	.06
7. Bijnor (UP)	1.11	.98	1.13	.98	.90	1.11	1.02	.90	.88	1.00	.07
8. Moradabad (UP)	.98	1.10	1.04	.94	.83	1.16	1.02	.96	.95	1.04	.07
9. Rampur (UP)	.91	1.09	1.15	1.06	.88	1.10	1.02	.92	.95	.94	.08
10. Saharanpur (UP)	.81	.98	1.00	1.06	1.08	1.04	.91	1.00	.99	1.16	.08
11. Ferozepur (P)	.95	1.16	1.06	.88	1.09	.98	.93	1.02	1.06	.86	.08
12. Hardoi (UP)	.97	.98	.89	1.01	.78	1.07	1.04	1.03	1.09	1.12	.09
13. Gurdaspur (P)	1.07	1.16	.92	.94	.90	1.01	.88	1.08	.90	1.13	.09
14. Basti (UP)	.84	1.02	1.11	.97	.95	1.11	1.07	.82	1.08	1.05	.09
15. Raisen (MP)	.80	.92	1.00	1.00	1.00	.98	.99	.77	1.02	.95	.10
16. Ambala (H)	1.04	1.05	1.23	1.02	1.00	.93	.85	.92	1.11	.88	.11
17. Gorakhpur (UP)	.81	.89	1.05	.88	.99	1.10	1.20	1.06	1.03	1.02	.12
18. Muzaffarnagar (UP)	.74	1.06	1.00	.93	.96	.98	1.10	1.03	1.03	1.22	.14

'PENDIX K (continued)

strict	1959-60	60-61	61-62	62-63	63-64	64-65	65-66	66-67	67-68	68-69	Coefficient of variation of temporal effects
. Baireily (UP)	.93	1.12	1.20	1.02	.93	1.20	.90	.82	.94	.98	.14
. Etawah (UP)	.95	1.02	1.04	1.05	.89	1.28	1.03	.77	1.00	1.01	.15
. Dehra Dun (UP)	.96	1.07	1.07	1.03	1.02	.90	1.07	.68	1.13	1.11	.16
. Agra (UP)	.99	1.10	.99	1.02	.81	1.20	1.22	.94	.86	.90	.16
. Sehore (MP)	1.34	1.06	.81	.96	.95	.95	1.00	.95	1.04	.95	.16
. Gonda (UP)	.94	.97	1.18	.98	.87	1.08	1.02	.74	1.14	1.16	.17
. Pilibhit (UP)	.89	1.17	1.20	1.11	1.02	1.15	.87	.90	.86	.88	.17
. Bundi (R)	1.02	1.06	1.20	1.20	.95	1.06	.96	.77	1.00	.82	.17
. Guna (MP)	.91	.94	.82	.92	1.16	.90	.87	.82	1.10	1.82	.17
. Bahraich (UP)	1.05	.87	1.11	.95	.77	1.04	1.10	.82	1.09	.80	.18
. Etah (UP)	1.00	.87	.91	1.06	.80	1.26	1.20	.96	.96	1.03	.18
. Bharatpur (R)	.97	.97	1.16	1.09	.82	1.10	.87	.80	1.22	1.02	.18
. Lucknow (UP)	.87	1.11	1.01	.92	.71	1.15	1.18	.95	1.09	1.08	.19
. Unnao (UP)	.84	1.07	1.00	.88	.74	1.09	1.01	1.20	1.15	1.10	.19
. Chhatarpur (MP)	1.07	1.07	1.20	1.05	1.04	1.16	.82	.75	1.03	.86	.19
. Gwalior (MP)	.95	1.15	1.08	1.05	.90	1.19	1.04	.67	1.10	.98	.20
. Kanpur (UP)	.87	1.14	1.02	1.05	.83	1.22	1.13	.74	1.02	1.04	.20
. Kotah (R)	1.00	1.24	1.16	1.12	.98	1.03	.88	.72	1.05	.90	.20
. Bhatinda (P)	.78	.90	1.08	.90	.96	1.00	1.04	.95	1.08	1.35	.20
. Ludhiana (P)	.78	.81	1.05	.90	1.16	1.22	1.04	1.10	1.13	.90	.20
. Hoshiarpur (P)	1.19	1.08	1.16	1.15	1.14	.81	.80	.86	.95	.94	.21
. Sangrur (P)	1.03	1.03	1.20	1.08	1.04	1.03	.82	.92	.95	.78	.21

APPENDIX K (continued)

District	1959-60	60-61	61-62	62-63	63-64	64-65	65-66	66-67	67-68	68-69	Coefficient of variation of temporal effects
41. Shivpuri (MP)	.93	1.10	.91	1.07	1.23	1.11	.90	.74	1.18	.90	.21
42. Vidisha (MP)	1.20	1.18	.95	1.00	1.10	.88	.84	.74	1.16	1.04	.21
43. Indore (MP)	.92	1.16	.86	1.08	.90	1.12	.75	.95	1.05	1.28	.22
44. Farukkabad (UP)	.83	.96	.94	1.00	.80	1.26	.98	.92	1.17	1.23	.23
45. Budaun (UP)	1.07	.90	.94	1.04	.72	1.34	1.10	.90	1.03	1.06	.23
46. Deoria (UP)	.70	1.09	1.13	.98	1.00	1.12	1.18	.75	1.00	1.14	.24
47. Bulandshar (UP)	1.28	1.16	1.02	1.23	.76	.96	.98	.94	.81	.96	.25
48. Jhansi (UP)	1.07	1.25	1.23	1.00	.83	1.00	.81	.74	1.06	1.06	.26
49. Faizabad (UP)	.89	1.30	1.24	1.04	.87	1.11	.98	.72	.98	.98	.26
50. Shahjahanpur (UP)	.78	1.33	1.05	.90	.75	1.12	1.00	.95	1.08	1.14	.27
51. Aligarh (UP)	1.38	.80	.98	1.15	.87	1.00	1.10	1.08	.80	.94	.28
52. Jullundhur (P)	1.00	.99	.95	.94	.92	1.09	1.05	.98	.99	1.09	.31
53. Sitapur (UP)	.72	.80	1.19	.96	.81	1.24	1.10	.99	1.09	1.24	.32
54. Mathura (UP)	1.23	.89	.74	1.24	.81	.94	1.28	1.13	.87	1.00	.34
55. Bara Banki (UP)	.93	.92	1.10	.98	.65	1.27	.87	.81	1.20	1.18	.34
56. Allahabad (UP)	1.02	1.10	1.23	1.11	.89	1.15	.75	.63	1.22	1.04	.35
57. Sagar (MP)	1.11	1.28	1.05	1.10	.86	1.05	.82	.61	1.22	1.09	.36
58. Gurgaon (H)	.74	.88	1.06	1.01	.78	.97	.97	1.09	1.42	1.22	.36
59. Damoh (MP)	1.09	1.10	1.27	1.00	.90	1.14	.75	.61	1.27	1.09	.41
60. Ganganagar (R)	1.00	.96	1.03	.95	.77	1.00	.74	1.12	1.60	.98	.50

APPENDIX K (continued)

District	1959-60	60-61	61-62	62-63	63-64	64-65	65-66	66-67	67-68	68-69	Coefficient of variation of temporal effects
61. Panna (MP)	1.22	1.16	1.40	1.10	.86	1.16	.74	.73	1.12	.74	.51
62. Nainital (UP)	.80	1.04	1.03	.91	.82	.94	1.08	.74	1.49	1.35	.51
63. Datia (MP)	1.30	1.16	1.16	.90	1.05	1.15	.93	.44	1.22	.95	.54
64. Tikamgar (MP)	1.35	1.22	1.09	1.03	1.05	1.16	.60	.59	1.11	1.06	.55
65. Kheri (UP)	.57	.68	1.34	1.10	1.00	1.14	1.11	.90	1.07	1.35	.58
66. Jabalpur (MP)	1.28	1.22	1.38	1.22	1.00	1.10	.67	.58	1.09	1.07	.62
67. Hissar (H)	.67	.70	.78	.81	1.05	1.14	1.07	1.16	1.50	1.35	.70
68. Banda (UP)	1.23	1.50	1.33	1.10	.89	1.06	.75	.40	1.12	1.05	.87
69. Hoshangabad (MP)	.74	.90	.67	.60	1.65	1.30	1.25	1.00	1.08	1.18	.96
70. Satna (MP)	1.35	1.25	1.65	1.32	.88	1.03	.64	.42	1.42	.74	1.43
71. Karpurthala (P)	.78	.80	.74	.64	.77	.81	1.10	1.56	1.56	1.82	1.68
72. Jalaun (UP)	.95	1.09	.94	1.03	.90	1.09	1.00	.50	.92	2.18	1.88

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