AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY

1. SUBJECT CLASSIFICATION

A. PRIMARY: Agriculture

B. SECONDARY: Agricultural economics

2. TITLE AND SUBTITLE

Regional differences in agricultural productivity in selected areas of India

3. AUTHOR(S)

Easter, K.W.; Abel, M.E.; Norton, George

4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1976	39 p.	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS

Department of Agricultural and Applied Economics, University of Minnesota, St. Paul, Minnesota 55108

8. SUPPLEMENTARY NOTES *(Sponsoring Organization, Publishers, Availability)*

(In Staff paper P76-12)

9. ABSTRACT

This analysis measures, using production functions, the contribution to total output of not only the quantity of traditional inputs (land, labor, fertilizer, etc.), but also the quality of certain inputs, particularly irrigation; technology; environmental factors (soil types, rainfall, etc.); and infrastructure (transportation, markets, etc.). Identification and measurement of the contribution to output of different types of inputs together with assessments of their supply provide valuable insights into the direction that agricultural development should take in different regions of a country. Two regions in India are studied, the so-called Wheat Region and the Eastern Rice Region. Data cover a ten-year period, 1959-60 through 1968-69, for all the districts for value of crop output, crop area, irrigation, and fertilizer. Data for tractors and labor are obtained for the ten-year period by interpolating and extrapolating trends based on two census years. A three-stage procedure to improve the specification of the estimated production functions is used. The first stage estimates production functions from the time series of cross-section data using an error components model. The second explains variations in regional effects by several factors not included in the original production function. Finally, the original production functions are respecified to include these additional factors and then reestimated for time periods when data on more of the relevant variables are available.

10. CONTROL NUMBER

PN-AAB-690

11. PRICE OF DOCUMENT

12. DESCRIPTORS

India
Productivity
Regional variations

13. PROJECT NUMBER

14. CONTRACT NUMBER

CSD-2815 211(d)

15. TYPE OF DOCUMENT

AID 590-1 (4-74)

CSD-2815 211(V)

Staff Paper P76-12 March 1976

REGIONAL DIFFERENCES IN AGRICULTURAL PRODUCTIVITY IN SELECTED AREAS OF INDIA

by

K. William Easter, Martin E. Abel
and George Norton

Staff papers are published without formal review within the Department of Agricultural and Applied Economics.

REGIONAL DIFFERENCES IN AGRICULTURAL PRODUCTIVITY IN SELECTED AREAS OF INDIA*

K. William Easter, Martin E. Abel, and George Norton**

Introduction

Earlier work by the authors strongly suggests that the restraints to changing the level and distribution of agricultural output vary among regions of a country [Abel and Easter, 1971; Easter, 1972; and Easter and Singh, 1974]. Recent work by Herdt, De Datta and Neely [1975] strongly supports this view. Agricultural development efforts can be improved if the relevant constraints within agricultural regions of a country are properly identified and development programs are focused on removing these constraints. Qualitative and quantitative differences in resource endowments among regions will dictate different types of technological development as well as different development strategies.

The focus of this analysis is to measure, by use of production functions, the contribution to total output of not only the quantity of traditional inputs (land, labor, fertilizer, etc.), but also the quality of certain inputs, particularly irrigation; technology; environmental factors (soil types, rainfall, etc.); and infrastructure (transportation, markets, etc.). Identification and measurement of the contribution to output of different types of inputs together with assessments of their supply would provide valuable insights into the direction that agricultural development efforts should take in different regions of a country. Certain factors affecting

output, such as soils or climatic conditions, may be fixed and production technology will have to adjust to them. Other factors such as the quantity and quality of irrigation or infrastructural investments may have varying elasticities of supply. The possibility and cost of expanding the supply of such inputs may vary considerably among regions. Strategies for increasing agricultural output and productivity should incorporate the different factor supply responses among regions.

The analysis covers two regions in India. One, defined as the Wheat Region, comprises 73 districts in the States of Punjab, Haryana, Uttar Pradesh, Madhya Pradesh and Rajasthan. These districts account for the bulk of total wheat production in India. The other region is the Eastern Rice Region, consisting of 69 districts in Eastern Uttar Pradesh, Bihar, West Bengal, Orissa, and Eastern Andhra Pradesh [Easter and Abel, 1973].[1/] The unit of observation is the district. (See appendix for a listing of districts.)

Data are available to us for a ten-year period, 1959/60 through 1968/69, for all of the districts for value of crop output, crop area, irrigation, and fertilizer. In addition, data for tractors and labor are obtained for the ten-year period by interpolating and extrapolating trends based on two census years.[2/] One would like to make use of the entire time series of cross section data. However, trying to explain productivity differences among districts using only the above variables would undoubtedly lead to seriously biased estimates because (1) some of the above variables, such as land and irrigation, do not reflect variations in the quality of these inputs and (2) there are other factors specific to each district which are not reflected in the above data and for which time series data do not exist.

We employ a three-stage procedure to improve the specification of the estimated production functions. The first stage involves estimation of production functions from the time series of cross-section data using an error components model. This model enables us to calculate regional effects for the districts which represent systematic variation in productivity levels among districts not explained by variations in the inputs used in the error components model. The calculated regional effects are summary measures of the effect on output of factors not included in the error components model. In the second stage we try to explain variations in regional effects by a variety of factors not included in our original production function. Finally, the original production functions are re-specified to include these additional factors and then re-estimated for time periods when data on more of the relevant variables are available.

Definition of Variables

Value of total crop output: Annual total value of crop output in each district in terms of 1959/60-1961/62 average prices, in thousand rupees.

Crop area: Annual gross cultivated area (hectares) in each district.

Irrigation: Annual gross irrigated area (hectares) in each district.

Fertilizer: Total metric tons of N, P, and K used annually in each district. This measure is an unweighted sum of the three nutrients.

Tractors: Number of tractors in each district. Data are available for 1961 and 1966 and were derived by interpolation and extrapolation for other years.

Labor: Number of male and female agricultural workers in each district, including both cultivators and laborers. Data are available for the census years 1961 and 1971 and were derived by interpolation and extrapolation for other years. This is a measure of the stock of agricultural labor available in each district, but not of the labor actually employed in crop production.

Work animals: Number of work cattle and bullocks in each district. Data are available for 1961 and 1966 and are derived by interpolation and extrapolation for other years.

Tubewells: Ratio of net crop area irrigated by tubewells to net crop area. Data are available for 1961 and 1968. This variable as well as the irrigation index is used to measure differences in quality of irrigation.

Irrigation index: Calculated measure of gross irrigated area in each district in which area irrigated by tubewells receives a weight of 1.5 and all other irrigated area receives a weight of 1.0.

Surfaced roads: Kilometers of hard surfaced roads per square kilometer of land in each district. Data available for 1968 for all states except West Bengal where 1960 data had to be used.

Soils (wheat region): Three soil types were used--black, alluvial and red. In general, a district was classified as belonging to a particular soil type if 50 percent or more of the land was accounted for by that soil type. Dummy variables are used for black and alluvial soils.

Soils (rice region): Three soil types were used--recent alluvial, red with coastal or deltic alluvium, and red. Districts were classified as described for soils in the wheat region. Dummy variables are used for recent alluvial and red with coastal or deltic alluvium.

Total rainfall: Average annual rainfall, 1901-1950, in millimeters, for each district.

Monthly rainfall: Average rainfall for specified months, 1901-1950, in millimeters, for each district.

Pumpsets: Number of pumps including electric and oil engines used for irrigation. Data are available for only 1961 and 1966.

Regional Effects

In analyzing a time series of cross-section data, one can employ an error components model to isolate effects which are specific to a region and relatively time-invariant. These effects would normally be captured in either the error term or the coefficients of the nonregional specific variables in ordinary regressions applied to the total set of data. The error components model is discussed and applied by Balestra and Nerlove [1966], Nerlove [1971a, 1971b], Schultz [1969, 1973], and Mukhopadhyay [1974].

In simplest terms we can think of the disturbances in the model as e_{it} where i refers to region and t refers to time. The error term can be decomposed into two independent components: a region-specific time-invariant effect, μ_i, and a region and time independent effect, ν_i. The stochastic structure for the disturbance term e_{it} can be expressed as

$$E(e_{it}\, e_{i't'}) = \begin{cases} \sigma^2 = \sigma_\mu^2 + \sigma_\nu^2, & i = i',\ t = t' \\ \sigma_\mu^2 \quad , & i = i',\ t \neq t' \\ 0 \quad , & \text{otherwise} \end{cases}$$

$$E(e_{it}) = 0, \text{ for all } i \text{ and } t.$$

We can define $\rho = \sigma_\mu^2/\sigma^2$ as the proportion of the variance of the disturbance term accounted for by the region-specific component. Nerlove [1971a] has shown that generalized least squares for a model with the above form of a variance-covariance matrix amounts to using transformed values of the variables which are a weighted combination of the original observations and the deviations from regional means. These weights can be expressed as a simple function of ρ. Computational details are presented in Mukhopadhyay [1974].

Production functions are estimated for both the wheat and rice regions using ordinary least squares (OLS) and the error components model (referred to as the transformed regressions). All variables are in logarithms and the full time series of cross-section data for the ten-year period 1959/60-1968/69 are used. The results are presented in table 1.

The values of the R^2 are much lower for the transformed regressions. This is to be expected since much of the variance explained by the OLS regressions is included in the calculated regional effects. The logarithmic value of the regional effects would enter the transformed regressions as multiplicative constants in estimating the logarithm value of district outputs. The regional effects represent the region-specific, time-invariant components of the model. The calculated actual values of the regional effects are given in the appendix. For both the wheat and rice regions the ranking of districts by the value of the calculated regional effects corresponds very closely to the ranking of districts by either output per hectare or by the importance of a district measured in terms of its contribution to total national production of either wheat or rice as calculated by Easter [1972] and Easter and Abel [1973].

Table 1. Regressions of Total Value of Crop Output on Selected Independent Variables, 1959/60-1968/69

Independent Variable	Wheat Region		Rice Region	
	OLS	Transformed	OLS	Transformed
Crop area	.189*	.076**	.835*	1.158*
	(6.016)	(2.542)	(20.325)	(16.058)
Irrigated area	.095*	.025	.0001	-.027
	(9.716)	(.945)	(.112)	(1.537)
Fertilizer	.040*	.026*	.102*	.015
	(6.214)	(3.040)	(9.804)	(1.507)
Tractors	.205*	.104*	.011	-.027**
	(19.028)	(4.117)	(.925)	(2.429)
Labor	.410*	.633*	-.099**	.233**
	(14.526)	(8.118)	(2.250)	(2.238)
Constant	1.915	1.960	1.903	-5.662
R^2	.834	235	.728	.313

t-values in parentheses

* Significant at the 1 percent level (two tailed test)
** Significant at the 5 percent level (two tailed test)
*** Significant at the 10 percent level (two tailed test)

In the wheat region the coefficients in the transformed regression are lower, except for labor, than the OLS coefficients. While irrigated area is significant in the OLS equation, it is not when the transformed regression is used.

In the rice region both the magnitude and significance of the coefficients differ between the OLS and the transformed regressions. Use of the transformed variables increases the coefficient of land, reduces and results in a negative but nonsignificant coefficient for irrigated area, reduces the size and significance of the fertilizer coefficient, results in a negative and significant coefficient for tractors, and increases and makes positive the coefficient of labor.

Much of the effect of omitted variables on output should be captured in the calculated regional effects. However, a measurement problem may remain with the labor variable. The variable represents the stock of labor available in each district, not the amount of labor actually used. It may not be too unreasonable to assume that in some cases the difference between labor available and labor actually used is negatively related to output per hectare; i.e., high productivity districts make fuller use of available labor than low productivity districts. To the extent that the labor variable is measured with systematic error, the estimated coefficients of the regressions would be biased.

The reason for the negative but significant coefficient for tractors in the rice region when the transformed variables are used is not obvious. It is also hard to explain the negative but insignificant coefficient for irrigated area except that possibly the area irrigated is negatively related to the quality of irrigation.

The next task is to describe what factors account for the regional effects. The regional effects were regressed on a number of variables thought to be important determinants of productivity (see table 2). The regressions are linear in the actual values of the variables. In the wheat region, about 50 percent of the variation in the calculated regional effects is accounted for by tubewells, a measure of the quality of irrigation.[3/] Differences in soil type also appear to be significant as is total rainfall. The negative coefficient of the latter variable is due to the fact that irrigation is more highly developed in the drier parts of the wheat region. The positive soils coefficients indicate that black and alluvial soils are more productive than red soils in the wheat region.

Several other variables were examined for the wheat region but were found to be statistically nonsignificant or so highly correlated with other independent variables as to result in statistically insignificant estimates of some of the coefficients. Work animals did not have a significant coefficient. Surfaced roads were not an important variable. This is probably because most of the wheat region had a reasonably well developed system of roads during the period of analysis. December and January rainfall were also examined, this being the important rainfall period for nonirrigated wheat. Again, the results were not too promising. A measure of research expenditures by district, developed by Robert Evenson, was tried. This variable, too, was not significant. Finally, area planted to high yielding varieties of wheat was tried as an independent variable but was insignificant because it is highly correlated with fertilizer and particularly tubewells.

In the rice region a somewhat different set of variables are important in explaining variation in regional effects, accounting for about 80 percent

Table 2. Regressions of Calculated Regional Effects on Selected Variables

Independent Variable	Wheat Region (1)	Wheat Region (2)	Rice Region (3)	Rice Region (4)
Tube wells	1.592* (8.104)	1.204* (5.359)		
Pumpsets			.00008* (3.620)	.00006* (2.717)
Black soil		.158 (1.654)		
Alluvial soils		.169* (2.117)	-.209* (-3.311)	-.195* (-3.102)
Red-coastal alluvial soils			.114 (1.397)	-.030 (-.273)
Total rainfall		-.003* (-3.185)	.0002* (4.468)	
June rainfall				.0005*** (1.893)
October rainfall				.0021*** (1.991)
Work animals			-.0000008* (-5.137)	-.0000008* (-5.041)
Surfaced roads			.037* (9.431)	.0348* (8.872)
Constant	.867	1.010	.675	.747
R^2	.473	.538	.798	.803

t-values in parentheses

* Significant at the 1 percent level
** Significant at the 5 percent level
*** Significant at the 10 percent level

of such variation. In contrast to the wheat region, surfaced roads are a highly significant variable. Two reasons explain this difference. First, traditional rice growing areas are heavy rainfall areas and it is difficult to transport inputs or products during the rainy season without adequate roads. Second, many parts of the eastern rice region have poorer roads compared to the wheat region.

Most of the irrigation in the eastern rice region is surface irrigation. Easter [1974] has shown that the quality of surface irrigation systems is important in determining agricultural productivity. Unfortunately, data are not available to measure either variations in the quality of surface irrigation or in the number of tubewells. Instead, we used the number of pumpsets as a measure of the quality of irrigation. This variable was statistically significant in explaining variation in regional effects.

The alluvial soils dummy is statistically significant but negative while the red-coastal alluvial one is negative and nonsignificant. This indicates that the alluvial soils are less productive than the red soils in the rice region.

Total rainfall is significant as are June and October rainfall, with results for only June and October rainfall reported in table 2. This is to be expected since rice production is heavily dependent on rainfall conditions. Even in the irrigated areas, most irrigation systems back significant reservoir capacity and are heavily dependent on rainfall, diverting stream flows to farmers' fields. The number of work animals is also a significant factor but is negatively related to the regional effects.[4/]

Reformulated Production Functions

The insights gained from the analysis of regional effects are used to reformulate the original production functions. Estimates of these new functions for the wheat and rice regions are presented in tables 3 and 6, respectively. It is not possible to utilize the ten-year time series of cross-section data because observations for the full period are not available for all the variables. Further, estimation of data for some of these variables by interpolation and extrapolation from census data is undesirable because (1) there is no reason to expect some variables to behave in a trend-like way, and (2) development of too many variables in this fashion results in serious problems of intercorrelation among independent variables. Consequently, the data used are three-year averages for the period 1959/60-1961/62 and two-year averages for 1967/68-1968/69. A two-year average is used for the latter period since 1966/67 was an unusually dry year and data were not available for 1969/70. Weather conditions for the years employed are considered to be reasonably normal.

The regression results presented in tables 3 and 6 stand by themselves. The coefficients are not comparable to the results presented in table 1. It is important to note that most of the variables which are important in explaining production and regional differences in productivity in tables 1 and 2 are also important in the reformulated functions.

Wheat Region

Equations (1)-(4) in table 3 are for the 1959/60-1961/62 period. Equation (1) contains the five independent variables originally used in table 1. All of the coefficients are significant. The addition of work

Table 3. Regressions of the Total Value of Crop Output on Selected Independent Variables, Wheat Region

Independent Variable	1959/60-1961/62 Average				1967/68-1968/69 Average			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Crop area	.512* (5.278)	.607* (8.025)	.893* (6.552)	.852* (5.857)	.431* (4.280)	.463* (4.508)	.544* (4.660)	.427* (3.414)
Irrigated area	.059* (2.922)	.097* (5.933)	.067* (2.716)		.100* (3.294)	.111* (3.552)	.054 (1.276)	
Fertilizer	.093* (4.290)	.092* (5.547)	.074* (3.011)	.098* (3.890)	.071* (3.051)	.074* (3.194)	.037 (1.022)	.079** (2.050)
Tractors	.132* (4.264)	.125* (5.279)	.093* (3.026)	.093* (2.819)	.167* (6.258)	.168* (6.340)	.131* (5.195)	.139* (5.018)
Labor	.152*** (1.929)	-.310* (-3.449)	-.130 (-1.193)	-.118 (-1.009)	.263* (3.120)	.101 (.700)	.181*** (1.979)	.246** (2.472)
Total rainfall			.296* (2.891)	.300* (2.748)			-.050 (-.761)	-.101 (-1.425)
Black soils			-.207** (-2.407)	-.196** (-2.118)			.096 (1.021)	.159 (1.537)
Alluvial soils			-.002 (-.018)	-.005 (-.050)			.108 (1.074)	.227** (2.143)
Tubewells			.044* (3.408)				.069* (4.088)	
Irrigation index				.082* (3.060)				.068 (1.415)

(continued)

Table 3. Regressions of the Total Value of Crop Output . . . , Wheat Region (Contd.)

Independent Variable	1959/60-1961/62 Average				1967/68-1968/69 Average			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Work animals		.489* (6.937)				.155 (1.375)		
Constant	1.560	-.216	-.947	-.813	.546	.108	1.481	1.522
R^2	.902	.942	.923	.912	.909	.910	.934	.919

t-values in parentheses for the two tailed test

* Significant at the 1 percent level
** Significant at the 5 percent level
*** Significant at the 10 percent level

animals in equation (2) results in a significant but negative coefficient for labor. This is due to the high intercorrelation between work animals and labor. Inclusion of work animals also increases the irrigated area and crop area coefficients. The addition of the soil dummy variables (of which black soils are significant), total rainfall, and tubewells has the effect of increasing the coefficient of crop area, reducing the size of the coefficients of irrigated area and fertilizer, and making the coefficient of labor negative but insignificant. The tubewell variable is correlated with both irrigated area and fertilizer, which may explain the decline in the size of the coefficients of these latter two variables in equation (3). To get around this problem we use the irrigation index, a combined measure of irrigated area and quality of irrigation, in equation (4). This measure is statistically significant and results in a significant and larger coefficient for fertilizer than when tubewells and irrigated area are included as separate variables.

Similar analyses for the period 1967/68-1968/69 are contained in equations (5)-(8). The behavior of the coefficients in this set of equations with respect to alternative specifications is similar to that in equations (1)-(4). In this latter period the interaction between the fertilizer variable and the measures of irrigated area and irrigation quality are even more evident with the coefficients of the latter two variables being smaller and statistically insignificant in equation (7) compared with the other equations.

A comparison of the results for 1959/60-1961/62 with those for 1967/68-1968/69 helps highlight some of the changes which have occurred. During this period there was a fairly rapid adoption of high-yielding varieties of wheat. By 1968/69, 48.5 percent of the total wheat area in the Punjab

was planted to high-yielding varieties; 48.0 percent in Uttar Pradesh; 28.9 percent in Haryana; 16.4 percent in Rajasthan; and 2.7 percent in Madhya Pradesh. The districts comprising the wheat region fall within these five states (table 4). These adoption rates reflect a rather rapid rate of technological change.[5/]

Comparing equations (3) and (7) and (4) and (8) in table 3, we see that there were some rather sizeable changes in the production coefficients associated with the introduction of the new varieties of wheat. The new technology had the effect of decreasing the coefficient of land, increasing the coefficients of tractors and tubewells, decreasing the coefficients of fertilizer and irrigated area with both becoming insignificant in the latter period, and increasing the coefficient and significance of labor. When the irrigation index is used in place of tubewells, the coefficient of fertilizer remains significant although the coefficient of the irrigation index itself is nonsignificant.

A Chow test is used to test if regressions (3) and (4) were significantly different from regressions (7) and (8), respectively. The calculated values of the F-statistic are 3.05 for the comparison of regressions (3) and (7) and 3.23 for the comparison of regressions (4) and (8). The hypothesis that the regressions are not different is rejected at the 1 percent level of significance for each comparison.

The calculated marginal products of the relevant independent variables corresponding to the equations in table 3 are given in table 5. Comparing the 1967/68-1968/69 period with 1959/60-1961/62, we observe the following: The marginal productivities of land, irrigated area, tubewells, and fertilizer decline, while those for tractors increase slightly and those for labor

Table 4. Percentage of Wheat Area Planted to High-Yielding Varieties, by States, 1966/67 to 1969/70

State	1966/67	1967/68	1968/69
	. . . . .	(percent)	. . . . .
Haryana	1.8	12.0	28.9
Madhya Pradesh	0.8	1.7	2.7
Punjab	3.6	35.4	48.5
Rajasthan	1.0	9.9	16.4
Uttar Pradesh	8.3	31.9	48.0

Source: Abel [1971].

Table 5. Marginal Products,[1/] Wheat Region

Independent Variable	1959/60-1961/62 Average				1967/68-1968/69 Average			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Crop area	.185	.219	.323	.308	.172	.184	.217	.170
Irrigated area	.154	.253	.175	-	.194	.216	.105	-
Fertilizer	58.27	57.64	46.37	61.40	4.81	5.01	2.50	5.35
Tractors	137.22	129.94	96.67	96.67	128.51	129.28	100.81	106.96
Labor	.076	-.155	-.065	-.059	.151	.058	.104	.141
Total rainfall	-	-	477.83	484.29	-	-	-95.06	-192.02
Tubewells	-	-	15,480.8	-	-	-	4,460.2	-
Irrigation index	-	-	-	.207	-	-	-	.197
Work animals	-	.337	-	-	-	.121	-	-

[1/] Change in the value of crop output in thousand rupees of a one unit change in the independent variable. For example, according to equation (3), a one hectare increase in crop area would increase the value of output by 323 rupees (in terms of 1959/60-1961/62 average prices).

increase substantially. The calculated changes in the marginal products are the result of both a change in technology and a change in the mean values of the independent variables, the two types of change reinforcing each other in some cases and offsetting each other in other cases. The two types of changes resulted in an increase in average crop output per district from Rs. 137,216 thousand for the 1959/60-1961/62 period to Rs. 161,600 thousand in the 1967/68-1968/69 period.

It is plausible to expect the new technology to lower the marginal product of land because it is land augmenting in nature. The geometric mean value of crop area per district also increased from 379,487 hectares to 405,889 hectares, which would ceteris paribus decrease the marginal product of land.

The new technology is dependent upon quality irrigation and fertilizer. It would not be unreasonable to expect the marginal products of both to increase. However, we observe a decline. The positive effect of technology on the marginal production may have been more than offset by increased average use of these inputs. The geometric mean value per district of irrigated area increased from 52,561 hectares to 83,180 hectares, the irrigation index went from 54 to 92, and the tubewell measure increased from .0039 to .025. The use of fertilizer increased dramatically from 219 metric tons per district to 2,387 metric tons. This increase reflected not only a higher productivity of fertilizer but a substantial decline in its price relative to the price of wheat. Over the study period the ratio of the wholesale price of wheat to the wholesale price of urea increased from .62 to 1.12, or by 80 percent.

While the new technology seemed to increase the marginal productivity of tractors slightly, its effect on increasing the marginal productivity

of labor appears to be substantial.

Rice Region

The regression results for the rice region presented in table 6 are organized in a similar way to those for wheat in table 3.

One of the striking results in all equations is the insignificance of irrigation. Most irrigation systems in the rice region have little reservoir capacity and are dependent upon rainfall and stream flow. This may be the main reason why irrigated area yields nonsignificant results. The effect of irrigation is being picked up by the total rainfall variable, which is significant. We also tried June and October rainfall in place of total rainfall, and these variables also had significant coefficients.

As mentioned earlier, data are not available on tubewells so we could not use this form of irrigation in developing a measure of quality of irrigation. Data were available on pumpsets and this measure had positive and significant coefficients for 1959/60-1961/62. Coefficients for pumpsets are negative but insignificant in the 1967/68-1968/69 period. Separate analyses by Easter [1974] for parts of the eastern rice region show that improvement of the quality of irrigation increases production substantially. Better measures of the quality of irrigation need to be developed.

The alluvial soils dummy is negative but statistically insignificant in both the 1959/60-1961/62 and 1967/68-1968/69 periods in all but equations (6) and (7). The red-coastal alluvial was positive and significant in the 1959/60-1961/62 period, but positive and insignificant in the 1967/68-1968/69 period.

Surfaced roads appear to be important in explaining productivity differences among districts, and their importance increases in the latter

Table 6. Regressions of the Total Value of Crop Output on Selected Independent Variables, Rice Region

Independent Variable	1959/60-1961/62 Average				1967/68-1968/69 Average			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Crop area	.751*	.769*	.798*	.716*	.821*	.834*	.803*	.768*
	(8.175)	(9.181)	(9.621)	(7.069)	(7.249)	(8.637)	(7.662)	(7.053)
Irrigated area	-.009	-.004	-.004	-.004	.014	.007	.010	.012
	(-.591)	(-.295)	(-.289)	(-.298)	(.685)	(.429)	(.619)	(.726)
Fertilizer	.129*	.069*	.051**	.067**	.117*	.135*	.148*	.156*
	(5.998)	(2.823)	(2.008)	(2.418)	(3.296)	(3.680)	(3.685)	(3.848)
Tractors	-.017	-.005	-.016	-.003	.041	-.009	-.004	.002
	(-.622)	(-.187)	(-.623)	(-.096)	(1.267)	(-.328)	(-.132)	(.081)
Labor	-.026	.083	.047	-.038	-.136	-.017	.013	-.071
	(-.279)	(.928)	(.524)	(-.353)	(-1.022)	(-.160)	(.118)	(-.523)
Total rainfall		.219**	.229**	.205**		.380*	.390*	.410*
		(2.173)	(2.323)	(2.068)		(2.688)	(2.739)	(2.868)
Red-coastal alluvial soil		.172**	.151**	.153**		.126	.112	.120
		(2.295)	(2.045)	(2.088)		(1.458)	(1.265)	(1.351)
Alluvial soils		-.108	-.101	-.082		-.133***	-.144***	-.121
		(-1.611)	(-1.538)	(-1.244)		(-1.816)	(-1.928)	(-1.565)
Work animals				.156				.128
				(1.389)				(1.164)
Surfaced roads		.147**	.150**	.133**		.210*	.212*	.208*
		(2.478)	(2.591)	(2.261)		(3.708)	(3.723)	(3.663)

(continued)

Table 6. Regressions of the Total Value of Crop Output . . . , Rice Region (Contd.)

Independent Variable	1959/60-1961/62 Average				1967/68-1968/69 Average			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Pumps			.041** (2.008)	.045** (2.202)			-.018 (-.783)	-.011 (-.475)
Constant	2.169	-1.119	-1.151	-.918	2.140	-2.626	-2.748	-3.106
R^2	.842	.888	.894	.895	.800	.882	.881	.882

t-values in parentheses

* Significant at the 1 percent level
** Significant at the 5 percent level
*** Significant at the 10 percent level

period. The absence of roads has the effect of raising input prices paid by farmers and lowering output prices received by them due to higher transportation costs. As Easter and Singh [1974] point out, these price relationships are unfavorable to the use of modern inputs such as fertilizer, and they retard tubewell development, especially where electricity is not available and diesel fuel has to be used.

Fertilizer use makes a significant contribution to production. The availability and price of fertilizer and their relationship to infrastructural development (roads and marketing facilities) appear to be important considerations in increasing production in this region.

During the study periods there was little technological change, as measured by the adoption of high-yielding varieties, in the rice region, in contrast to what occurred in the wheat region. Data on the adoption of new varieties of rice are given in table 7. Of the states under study, Andhra Pradesh had the highest adoption rate in 1968/69 with 16.6 percent of the paddy area planted to high-yielding varieties. Accordingly, we do not observe as large temporal changes in the coefficients of the production functions for rice as in those for wheat. Also, the change in the mean value of crop output per district was relatively small over the study period, from Rs. 200,845 thousand to Rs. 212,463 thousand.

Using a Chow test to test if regressions (3) and (7) and (4) and (8), respectively, were different, yielded calculated values of the F-statistic of 1.88 for the comparison of regressions (3) and (7) and 1.57 for the comparison of regressions (4) and (8). The hypothesis that the regressions are not different cannot be rejected at the 5 percent level of significance for each comparison.

Table 7. Percentage of Paddy Area Planted to High-Yielding Varieties, by States, 1966/67 to 1969/70

State	1966/67	1967/68	1968/69
	. . . . .	(percent)	. . . . .
Andhra Pradesh	8.3	10.3	16.6
Bihar	1.5	4.9	5.0
Orissa	1.1	2.8	3.4
Uttar Pradesh	1.6	3.4	7.3
West Bengal	0.6	3.4	4.0

Source: Abel [1971].

The calculated marginal products corresponding to the regressions in table 6 are presented in table 8. The marginal products for crop area, irrigated area, and tractors seemed to increase slightly; those for surfaced roads increased substantially; the marginal products for fertilizer declined substantially; and those for labor decreased somewhat between 1959/60-1961/62 and 1967/68-1968/69. Over this same period the mean values of the variables per district went from 435,164 to 458,670 hectares for cropped area; from 42,951 to 60,951 hectares for irrigated area; from 374 to 2,014 metric tons for fertilizer; from 26 to 75 for tractors; from 540,365 to 534,988 for laborers; and from 124 to 194 for pumps.

The results basically show a consistently slow rate of technical change and a decline in the price of fertilizer relative to rice. The ratio of the wholesale price of rice to the wholesale price of urea went from .75 to 1.24, or an increase of 65 percent during the period being studied.

Conclusions

We have shown that factors other than traditional inputs unadjusted for quality differences are important in explaining agricultural productivity differences within and among regions of a country. Identification of these additional factors is important for sharpening the focus of planning and development efforts and increasing the productivity of development resources by directing them at easing the binding constraints to increased output.

Some factors influencing productivity are fixed in nature and little can be done to alter their supply or quality. This would be basically true

Table 8. Marginal Products,[1/] Rice Region

Independent Variable	1959/60-1961/62 Average				1967/68-1968/69 Average			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Crop area	.342	.351	.363	.326	.380	.386	.372	.356
Irrigated area	-.041	-.018	-.018	-.018	.049	.024	.035	.042
Fertilizer	63.66	34.05	25.17	33.06	12.34	14.24	15.62	16.46
Tractors	-110.1[illegible]	-32.39	-103.66	-19.44	116.15	-25.50	11.33	5.67
Labor	-.009	.031	.017	-.014	-.054	-.007	.005	-.028
Total rainfall		32.39	33.87	30.32		59.45	61.02	64.15
Pumps			66.41	72.89			-19.67	-[illegible]2.02
Work animals				.090				.078
Surfaced roads		3,355.02	3,423.49	3,035.50		5,070.14	5,118.43	5,021.85

[1/] See footnote 1 in table 5.

for such things as rainfall, soil types, and the absence of any irrigation potential. Planners will have to direct development efforts toward investments and the development of new technology consistent with these factor endowments. In other cases, the opportunity to improve the quality of some factors (irrigation, education, etc.) as well as expand the supply of these and other factors (irrigation, roads, new varieties, etc.) may be great and development efforts should move in this direction.

In the case of the wheat region in India, the introduction of new varieties, the expansion of irrigated area and improvement in the quality of irrigation through the use of tubewells, and increased supplies of fertilizer led to substantial increases in production. In some parts of the wheat region, namely the Gangetic Plain portions of central and eastern Uttar Pradesh, there is further opportunity to expand the area irrigated by tubewells (and canals). Further development of water resources in these areas will promote the adoption of the new wheat technology. In other areas, such as parts of Madhya Pradesh and Rajasthan, the opportunities for further irrigation are severely limited. The limitation of water will likely be an important constraint to adoption of crop technologies requiring intensive use of water. Productivity increases in these areas will have to come from development and adoption of new technologies and production practices consistent with rainfed conditions.

In the eastern rice region somewhat different constraints appear to be binding during the period covered by our study. The development and adoption of improved varieties of rice were not widespread. Development efforts should be (and are being) directed toward the development of high-yielding varieties of rice adapted to local ecological conditions. Attention should

also be paid to improving roads and related market structures in the eastern rice region. Development efforts along these lines would increase the profitability of new crop technology and the use of supporting inputs and speed their adoption and increases in productivity. In separate analyses [Easter, 1974], it has also been shown that there are very high social and private returns from improving the quality of canal irrigation systems. However, the Government of India does not appear to give high priority to improving the quality of existing irrigation systems.

The usefulness of the foregoing analysis is illustrated by the work of Spriggs [1976]. Using data from table 6 together with other relevant information, he estimates benefit-cost ratios in the neighborhood of 8:1 for expanding the kilometers of surfaced roads in the Eastern Rice Region; a handsome social rate of return, indeed. Furthermore, the assumptions used by Spriggs are purposely designed to yield conservative estimates of the calculated benefit-cost ratios. Similar analyses could be carried out with respect to other investment possibilities in each of the regions to determine the socially most productive investments.

In our approach we have tried to disaggregate our analysis of agricultural productivity growth using the district as the basic unit of observation. As we have done in earlier work, we can combine these districts into relatively homogeneous sub-regions with respect to the constraints to increasing output, although there still may exist much variation among the important constraints and the quality of factors within each sub-region. Further disaggregation may be highly desirable to account for the remaining variability in productivity within regions and to better identify the binding constraints. The work by Herdt, De Datta, and Neely [1975] represents efforts in this direction and should provide valuable information for better directing development

resources toward removing the overriding barriers to increasing agricultural productivity and improving the distribution of these productivity gains.

FOOTNOTES

*University of Minnesota Agricultural Experiment Station, Scientific Journal Series Paper No. . We wish to thank Vernon Eidman, Jean-Claude Koeune, Willis Peterson, Terry Roe, Peter Warr, and Ian Wills for their helpful comments. The authors are responsible for any remaining errors. Support for research on this paper was provided from an AID 211(d) Grant to the University of Minnesota.

**The authors are professor, professor, and research assistant, respectively, in the Department of Agricultural and Applied Economics, University of Minnesota.

1/ Assam is not included in the analysis because of the nonavailability of data.

2/ Data on other variables, such as work animals, can be derived from census data in a similar manner. However, use of these additional variables leads to serious problems of intercorrelation among several of the independent variables.

3/ Farmers with tubewells have greater control over the timing of irrigation and the amount of water applied than do those using canal irrigation. We would expect tubewell irrigation to be more productive than canal irrigation.

4/ Work animals are measured as the stock of animals and not those actually used in production. The estimated coefficient of work animals would be biased downward if the measurement errors are negatively related to productivity; i.e., high productivity districts more fully utilized their stock of work animals than low productivity districts. Bias would also result if there exists a positive relationship between quality of work animals and productivity so that more work animals are needed to do the same amount of work as the quality of the animals declines. However, neither of these possible sources of bias would explain the negative relationship between the number of work animals and output.

5/ Area planted to high-yielding varieties of wheat was included as an independent variable. However, because high-yielding varieties are highly correlated with fertilizer and irrigation, either the coefficient of varieties or the coefficients of fertilizer and irrigation were insignificant, depending upon the specification of the equations.

REFERENCES

Abel, Martin E. and K. W. Easter, "Agricultural Development Planning and Program Evaluation with a Focus on Regional Restraints," Economic and Political Weekly, Vol. VI, Nos. 30-32, Special Issue, July 1971. Also in Viewpoints on Rice Policy in Asia, The International Rice Research Institute, August 1971.

Abel, Martin E., "The Distribution of Agricultural Development Gains in India: A Case Study for South and Southeast Asia," Staff Paper P71-25, Department of Agricultural and Applied Economics, University of Minnesota, November 1971.

Balestra, Pietro and Marc Nerlove, "Pooling Cross Section and Time Series Data in the Estimation of a Dynamic Model: The Demand for Natural Gas," Econometrica, Vol. 34, No. 3, July 1966.

Easter, K. William and Shrinath Singh, "The Importance of Regional Differences in Agricultural Development," Indian Society of Agricultural Statistics, New Delhi, India, 1974, pp. 35-42.

Easter, K. William, Regions for Indian Agricultural Planning and Management, The Ford Foundation, New Delhi, India, June 1972.

Easter, K. William and Martin E. Abel, Cropping Regions in India, Bulletin No. 1, Economic Development Center, University of Minnesota, June 1973.

Easter, K. William, "Returns from Investments in Improving Village Irrigation Systems: An Example from India," Staff Paper P74-13, Department of Agricultural and Applied Economics, University of Minnesota, July 1974.

Herdt, Robert W., S. K. De Datta and Douglas Neely, Farm Yield Constraints in Nueva Ecija and Laguna, Philippines, 1974, IRAEN WP-3, International Rice Research Institute, Los Banos, Philippines, March 1975.

Mukhopadhyay, Sudin K., Sources of Variation in Agricultural Productivity: A Cross-Section-Time-Series Study of India, Ph.D. thesis, University of Minnesota, June 1974.

Nerlove, Marc, "Further Evidence on the Estimation of Dynamic Relations from a Time Series of Cross Sections," Econometrica, Vol. 39, No. 2, March 1971 (a).

_____, "A Note on Error Components Models," Econometrica, Vol. 39, No. 2, March 1971 (b).

Schultz, T. Paul, "An Economic Model of Family Planning and Fertility," Journal of Political Economy, Vol. 77, No. 2, March/April 1969.

_____, "Explanation of Birth Rate Changes over Space and Time: A Study of Taiwan," Journal of Political Economy, Vol. 81, No. 2, Part II, March/April 1973.

Singh, Shrinath, "Modernization of Agriculture in a Traditionally Backward Agricultural Area; A Case Study in Eastern Uttar Pradesh," unpublished Ph.D. thesis, Department of Economics, Sardar Patel University, Vallabh Vidyanagar, 1974.

Spriggs, John, "Benefit-Cost Analysis of Surfaced Roads in the Eastern Rice Region of India," Staff Paper P76-13, Department of Agricultural and Applied Economics, University of Minnesota, March 1976.

APPENDIX

Calculated values of the regional effects, by district, for the wheat and rice regions.

Wheat Region

State	District	Regional Effect
Haryana	Karnal	1.63
	Hissar	1.37
	Ambala	1.26
	Rohtak	1.24
	Gurgaon	.90
Madhya Pradesh	Gwalior (Gird)	1.15
	Vidisha (Bhilsa)	1.13
	Raisen	.94
	Sehore	.94
	Guna	.89
	Hoshangabad	.86
	Damoh	.83
	Sagar	.82
	Shivpuri	.73
	Indore	.71
	Datia	.70
	Jabalpur	.70
	Chhatarpur	.69
	Panna	.66
	Tikamgarh	.56
	Satna	.54
Punjab	Ludhiana	1.82
	Ferozepur	1.61
	Jullundur	1.50
	Sangrur	1.50
	Bhatinda	1.45
	Amritsar	1.44
	Patiala	1.44
	Gurdaspur	1.34
	Kapurthala	1.33
	Hoshiarpur	1.06
Rajasthan	Kotah	.93
	Ganganagar	.86
	Bharatpur	.80
	Bundi	.79
Uttar Pradesh	Meerut	1.69
	Muzaffarnagar	1.61
	Bijnor	1.55
	Saharanpur	1.54
	Bulandshahr	1.35
	Kheri	1.35
	Aligarh	1.33
	Mathura	1.23

State	District	Regional Effect
Uttar Pradesh (Con't.)	Nainital	1.15
	Farrukhabad	1.14
	Pilibhit	1.11
	Sitapur	1.10
	Mainpuri	1.09
	Bareilly	1.07
	Etah	1.07
	Etawah	1.07
	Moradabad	1.05
	Hamirpur	1.04
	Kanpur	1.04
	Hardoi	1.01
	Badaun	1.00
	Rampur	.96
	Shahjahanpur	.92
	Agra	.90
	Banda	.89
	Bara-Banki	.84
	Jhansi	.84
	Jalaun	.83
	Unnao	.83
	Deoria	.82
	Bahraich	.77
	Faizabad	.76
	Basti	.75
	Gonda	.75
	Allahabad	.71
	Gorakhpur	.68
	Dehradun	.62
	Lucknow	.60

Rice Region

State	District	Regional Effect
Uttar Pradesh	Varanasi	1.03
	Deoria	.99
	Jaunpur	.97
	Ballia	.96
	Azamgarh	.91
	Ghazipur	.91
	Sultanpur	.85
	Pratapgarh	.82
	Rae-Bareli	.80
	Mirzapur	.75
West Bengal	Hooghly	2.43
	Darjeeling	2.32
	Howrah	2.27
	Jalpaiguri	1.94
	Birbhum	1.89
	Burdwan	1.86
	Bankura	1.66
	Cooch-Behar	1.60
	Purulia	1.36
	WestDinajpur	1.24
	Murshidabad	1.15
	Nadia	1.15
	Malda	1.09
	Midnapore	1.05
	Parganas	1.04
Bihar	Dhanbad	1.56
	Bhagalpur	.94
	Patna	.93
	Singhbhum	.91
	Champaran	.82
	Santhal Parganas	.82
	Hazaribagh	.75
	Saran	.74
	Saharsa	.72
	Darbhanga	.70
	Purnea	.70
	Shahabad	.70
	Monghyr	.68
	Gaya	.66

State	District	Regional Effect
Bihar (cont.)	Muzaffarpur	.60
	Palamau	.59
	Randhi	.50
Madhya Pradesh	Balaghat	.86
	Raigarh	.68
	Bastar	.61
	Raipur	.54
	Bilaspur	.53
	Surguja	.51
	Durg	.40
Maharashtra	Bhandara	.81
Orissa	Keonjhar	1.47
	Phulbani	1.46
	Dhenkanal	1.27
	Puri	1.21
	Cuttack	1.16
	Mayurbhanj	1.14
	Sundergarh	1.12
	Ganjam	1.10
	Kalahandi	1.03
	Sambalpur	1.02
	Balasore	1.00
	Bolangir	.99
	Koraput	.70
Andhra Pradesh	West Godavari	2.14
	East Godavari	1.87
	Krishna	1.54
	Guntur	1.17
	Visakhapatnam	1.06
	Srikakulam	1.03