ECONOMIC GROWTH CENTER

YALE UNIVERSITY

Box 1987, Yale Station
New Haven, Connecticut 06520

CENTER DISCUSSION PAPER NO. 590

TECHNOLOGICAL CHANGE AND LABOR USE IN RICE AGRICULTURE:

ANALYSIS OF VILLAGE LEVEL DATA IN WEST BENGAL, INDIA

Sudhin K. Mukhopadhyay

Yale University
and
University of Kalyani, West Bengal, India

November 1989

Notes: This paper is based upon data collected in the research project on Differential Impact Study in Rice Technology sponsored by the Rockefeller Foundation and conducted at the Indian Statistical Institute, Calcutta and the University of Kalyani. I gratefully acknowledge the grant from the Rockefeller Foundation and thank the members of the Project Team.

Center Discussion Papers are preliminary materials circulated to stimulate discussion and critical comments.

I am grateful to Professors Robert E. Evenson and T. Paul Schultz for their valuable comments and suggestions. I thank Paul McGuire for helping me through the computations. Responsibility for any deficiencies and errors is mine alone.

Dr. Mukhopadhyay is a postdoctoral fellow at the Economic Growth Center.

TECHNOLOGICAL CHANGE AND LABOR USE IN RICE AGRICULTURE: ANALYSIS OF VILLAGE LEVEL DATA IN WEST BENGAL, INDIA

ABSTRACT

This paper attempts to examine the factors behind the relatively slow rate of technological progress in the rice-based agriculture of West Bengal, India. The basic argument is that technical progress is determined by environmental and market factors specific to given locations. Results of the analysis show that physical-environmental factors and relative profitability are strong determinants of technology adoption. Modern technology induces increases in cropping intensity which in turn helps higher labor use in agriculture. Labor use also depends positively upon the ratio of crop price to wages and negatively upon the level of unionization of laborers. Policy implications highlight environment-specific physical factors, e.g., irrigation, water control and other infrastructural facilities, economic factors, e.g., input and output prices, and technological factors, e.g., generation and diffusion of modern varieties suited to location-specific conditions that can ensure higher relative yield and profitability. These are critical elements for the sustained progress of agricultural technology in West Bengal.

TECHNOLOGICAL CHANGE AND LABOR USE IN RICE AGRICULTURE: ANALYSIS OF VILLAGE LEVEL DATA IN WEST BENGAL, INDIA*

I. Introduction

For more than two decades now, technological change has contributed much to the growth in agricultural production in many countries. However, the spread of modern technology has been uneven within countries. Current concern among agricultural scientists and policy makers in many developing countries relates to identifying the determinants and consequences of such regional disparity in technological progress. In India, for instance, major focus of the seventh and eighth Five Year Plans has been on improvements in rice production in the eastern region, which has been lagging behind other regions in agricultural development. The eastern Indian state of West Bengal presents such a case of slow growth and regional disparity in agricultural technology. Rice is the most important foodgrain in India, and the state of West Bengal is its largest producer. Nevertheless, estimates of West Bengal's rice production potential are much higher than the levels achieved and wide regional disparities persist in technological development within the state's agriculture [Mukhopadhyay (1982)]. In this paper an attempt is made to examine the major determinants of the spread of the high yielding varieties that represent the critical component of modern technology in rice production (henceforth called HYV) in West Bengal and its effects upon labor use in agriculture. The objective is to help formulation of policies for faster and regionally balanced agricultural and rural development.

Analysis is based upon data collected from 60 villages spread over 12 blocks in six districts, each in turn classified into *favorable* and *unfavorable* rice production environments. Section II presents the method of selection of sample villages and the basic criteria used, the variables constructed, their summary, and the method

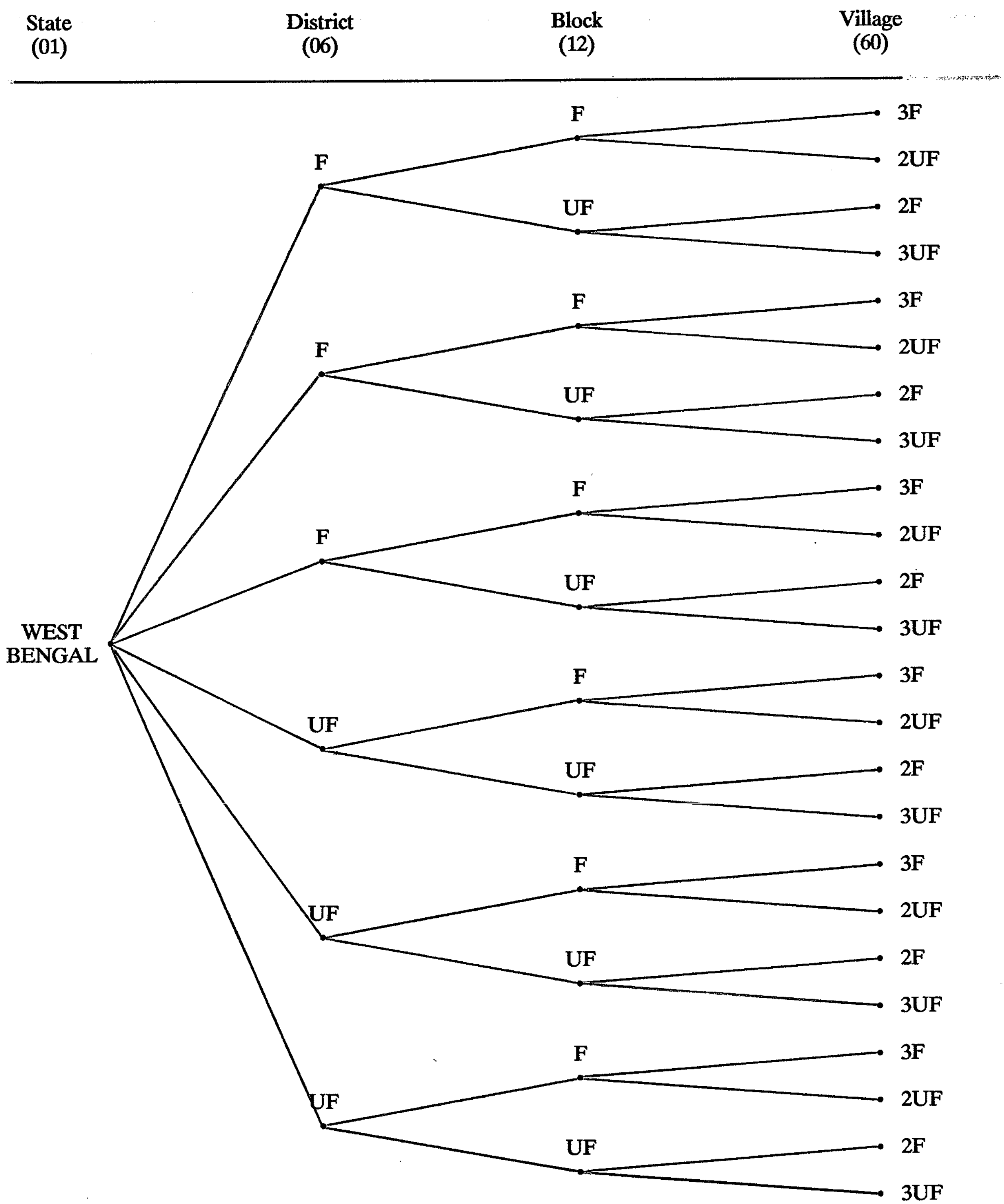
*The study is based upon data collected in a project entitled Differential Impact Study sponsored by the Rockefeller Foundation and conducted at Indian Statistical Institute and the University of Kalyani, West Bengal, India.

of analysis. Sections III and IV present the results of single-equation and two-stage models using OLS and Tobit estimates of HYV Adoption, Cropping Intensity and Labor Use functions. Section V constructs a logistic model for adoption of HYV in favorable and unfavorable villages, and Section VI presents summary of conclusions and implications for policy.

II. Data, Variables and Methodology

Analysis of agricultural technology involves both community and environmental variables on the one hand, and farm-household and individual level variables on the other. In this study it is hypothesized that the adoption of modern technology by a farmer would depend upon location-specific agro-climatic characteristics of the farm as well as socio-economic-demographic attributes of the farm-household. It is also hypothesized that technological change gives rise to changes in cropping intensity and factor demands. In the absence of adequate farm-household data to represent regional disparity in technological progress in rice cultivation, the present study uses primary survey data at the village level representing the entire state of West Bengal. Such data have been collected through a survey of 60 villages in West Bengal conducted in 1989 using a multi-stage purposive sampling procedure. In the first stage, six districts out of 16 were selected, three of which were to represent Favorable (F) rice-production environment, and the other three to represent Unfavorable (UF) rice-environment. The principal criteria used to select districts were agro-climatic and soil characteristics conducive or otherwise to the adoption of modern rice varieties. The distribution of the six sample districts may be seen with reference to the agro-climatic zones in Chart A-I in Appendix A. One district (Koch Bihar) was selected from the Terai Zone (UF) one (Hugli) from the Old Alluvium Zone (F), two (Nadia and Murshidabad) from the New Alluvium Zone (F), and one each from the Lateritic (UF) Zone (Bankura), and Coastal Saline (UF) Zone (Medinipur). At the second stage, two blocks--one representing F and the other UF rice-environments--were selected from each of the six districts. At this stage also, the principal criteria of classification were soil types, land level and water-logging. At the third stage, for each F block, both within F-districts and UF-districts, it was decided to select three F villages and two UF villages. On the other hand, for each UF-block, both within F and UF districts, two F-villages and three UF-villages were chosen. There is thus a sample of sixty villages selected in equal numbers from 12 blocks and 6 districts. The selection criteria for villages were primarily facilities for water

CHART I
Selection of Sample Villages for the Study



Sample sizes in parentheses.

Variables Used

Name	Definition
HYV Adoption	Percent of rice land under modern varieties
Cropping Intensity	Ratio between gross and net area cultivated
Labor Use in Agriculture	Hours of labor used in agricultural activities per hectare
Irrigation	Percent of farm land irrigated in the respective season in a normal year
Ownership	Percent of households in village cultivating own farm land
Size	Farm size in hectare (average of all plots in village)
Tenancy	Percent of households in village cultivating leased-in land
Literacy	Percent of village population literate
Relative Yield	Ratio of average yield of HYV to average yield of traditional variety rice in village (average of last 7 years collected from village)
Price-Wage Ratio	Ratio of rice price (average) to agricultural wage (average) in village)
Unionization	Percent of agricultural laborers in village belonging to some trade unions
Dummy for District	Dummy variables: $0 \neq$ Unfavorable; $1 =$ Favorable

control/irrigation/drainage and infrastructure, including nearness to markets, schools, transport, etc.[1] Convenience of operation of the survey and the study has been kept in view in the final selection of villages. Selection at all levels has been done on the basis of (a) official records at state, district, block and village levels; (b) discussions with concerned officials and village leaders; and (c) visits to the district and block headquarters and to villages. A schematic presentation of the sample selection is given in Chart I [DIS Project Team (1989)].

The analysis has been confined to kharif season for several reasons. First, kharif is the most important rice growing season in West Bengal, producing more than 70 percent of total rice in a year. Second, despite its importance in acreage and production, the spread of HYV has been the least in kharif season because of inadequate water control facilities. Third, the disparity between favorable and unfavorable areas is the sharpest in this season because most kharif rice is rainfed. Fourth, in rabi season the entire rice area is irrigated and under HYV, while pre-kharif rice is basically a supplementary crop grown mostly by those farmers who have grown a short duration rabi crop in the preceding season and are able to utilize the residual soil moisture and irrigation facilities. Moreover, many farmers view pre-kharif and kharif together for their largely overlapping months. Thus input and output data for pre-kharif rice, separated from kharif are hard to collect and not very reliable. The problem of technological improvement in rice cultivation in West Bengal (as well as in India) is critical for the kharif season [More about this aspect is available in Mukhopadhyay (1984)].

Summary of the variables used in the study (Table 1) shows that for most of the indicators of development the mean value is higher in favorable villages than in unfavorable ones, though the margin is not very high. As already mentioned, the primary classification was made on the basis of overall judgment of agro-climatic, soil type and socio-economic-demographic characteristics of villages, blocks and districts. Not all of these criteria could be presented in the statistical summary.

The study tests econometrically the effects of selected community as well as household-specific variables upon adoption, cropping intensity and labor use (or derived demand for labor) in agriculture. Single-equation and two-stage models have been estimated by OLS and Tobit. Each equation has been formulated both without and with dummy variables to represent favorable village effects. The dummy variable would reflect fixed effects of favorable villages representing such factors as are invariant over time and which are not captured in the

[1]The reason for this three-stage sample procedure is that the range from an F-F-F-sample village [i.e. Favorable-District-Block-Village] through a UF-UF-UF-sample village is presumed to largely portray the entire variation in rice production environment in the state. This assumption is statistically supported in another paper [DIS (1989)].

TABLE 1: Summary Statistics for Favorable and Unfavorable Villages

		Mean	Standard Deviation
Percent of rice area under HYV (kharif)	Favorable Unfavorable	38.03 17.16	25.71 21.08
Crop-intensity	Favorable Unfavorable	1.61 1.55	0.54 0.51
Average labor used days/ha./kharif season	Favorable Unfavorable	5.65 5.62	4.37 4.13
Area irrigated (percent)	Favorable Unfavorable	63.49 48.95	35.00 40.07
Percent land cultivated by owner farmers	Favorable Unfavorable	28.00 25.00	17.98 15.85
Farm size (ha.)	Favorable Unfavorable	1.79 1.64	2.11 1.21
Percent of land under tenant cultivation	Favorable Unfavorable	1.03 1.53	1.59 3.23
Percent of population literate	Favorable Unfavorable	46.40 41.40	17.17 15.54
HYV rice yield (kg./ha.)	Favorable Unfavorable	4080.00 3739.00	837.00 768.00
TV rice yield (kg./ha.)	Favorable Unfavorable	2821.00 2620.00	467.00 611.00
Average rice yield (kg./ha.)	Favorable Unfavorable	3712.24 3086.81	818.43 817.40
Average rice price (rs./kg.)	Favorable Unfavorable	214.00 204.00	20.00 26.00
Average wage rate (Rs. per day)	Favorable Unfavorable	16.45 17.53	3.87 5.96
Percent of average laborers unionized	Favorable Unfavorable	32.26 30.76	33.46 33.65

variables used in the quantitative analysis. However, as the results would show, although the coefficients for the dummy are significant in some cases, the estimates of the equation parameters do not vary much because of the dummy. Also for villages whose adoption is above zero, a logistic model has been constructed for the diffusion of HYV technology and differences in the importance of critical determinants have been examined by village types. Results show that irrigation facilities and profitability are the primary determinants of diffusion.

III. Technology Adoption, Cropping Intensity and Labor Use in Agriculture

It is argued here that three broad sets of factors are relevant in explaining adoption of a new crop technology and its relationships with cropping intensity and derived demand for labor in agricultural production. These are: (a) physical-environments, (b) social-institutions, and (c) economic factors. Assuming, these factors as exogenous, reduced form equations have been estimated here for technological change (i.e., adoption of HYV) in rice cultivation, changes in cropping intensity and labor use in agriculture in West Bengal. Since some of the variables, both dependent and independent, are limited in their range (e.g., percent area under HYV, cropping intensity, percent area irrigated, percent of labor unionized), maximum likelihood Tobit estimates have been made in addition to OLS [Rosett and Nelson (1975)].

The signs of OLS coefficients for most of the variables in the reduced form equations conform to expectations (Table 2A). Irrigation stands out as an important factor in adoption as well as cropping intensity. The dummy for favorable village, representing omitted physical and environmental factor, is important in adoption but not in cropping intensity or labor use. The only other significant variable affecting adoption is relative yield--a measure of relative profitability. Ownership, farm size, tenancy, literacy and price-wage ratio have no significant impact upon adoption [Ruttan (1977); Barker and Herdt (1985)]. However, farm size is negatively related to cropping intensity and labor use per hectare. Increases in farm size in general is associated with higher total requirements of complementary inputs, e.g. labor, fertilizer, chemicals, etc. Because of imperfections in input markets this leads to higher transactions and management costs per hectare per farm on larger farms. Smaller farms tend to be more intensively cultivated because of relatively large availability of family labor and smaller management cost per farm. The adoption of scale-neutral HYV rice technology would bring in larger income (output) flows to larger farms and may induce substitution effect resulting in relatively lower

TABLE 2A. OLS: Reduced Form Equations

Independent Variables	Dependent Variable					
	Percent area under HYV		Cropping Intensity		Labor Used	
	1A	1B	2A	2B	3A	3B
Irrigation	0.002 (2.76)	0.002 (2.52)	0.005 (3.36)	0.048 (3.46)	0.017 (1.29)	0.617 (1.31)
Ownership	0.00026 (0.15)	0.0004 (0.24)	-0.001 (-0.29)	-0.0011 (-0.32)	-0.14 (-4.21)	-0.140 (-4.18)
Size	0.015 (0.84)	0.018 (1.01)	-0.149 (-4.36)	-0.150 (-4.40)	-1.001 (-3.17)	-1.106 (-3.15)
Tenancy	-0.0022 (-0.22)	-0.0002 (-0.003)	-0.024 (-1.26)	-0.056 (-1.34)	-0.221 (-1.25)	-0.225 (-1.26)
Literacy	0.00001 (0.002)	-0.0008 (-0.46)	0.003 (0.66)	-0.0031 (0.82)	-0.004 (-0.12)	-0.002 (-0.064)
Relative yields	0.412 (5.41)	0.384 (5.25)	0.552 (3.91)	0.574 (3.81)	2.684 (1.95)	2.745 (1.95)
Price-wage ratio	0.008 (1.21)	0.005 (0.77)	0.0022 (0.12)	0.0007 (0.06)	0.191 (1.59)	0.197 (1.61)
Unionization	-0.0002 (-0.286)	-0.0004 (-0.606)	-0.002 (-1.32)	-0.002 (-1.19)	-0.010 (-1.21)	-0.016 (-1.56)
Dummy for favorable village	—	0.112 (2.61)	—	-0.093 (-0.97)	—	-0.259 (-0.29)
Constant	-0.486 (-3.25)	-0.424 (-2.31)	0.91 (3.13)	0.862 (2.91)	5.157 (1.91)	5.02 (1.81)
R^2	0.58	0.63	0.62	0.62	0.50	0.50

Note: Figures in parentheses are t-values. Equations A and B are without and with Favorable Village Dummies respectively.

TABLE 2B. Tobit Maximum Likelihood: Reduced Form Equations

Independent Variables	Dependent Variable					
	Percent area under HYV		Cropping Intensity		Labor Used	
	4A	4B	5A	5B	6A	6B
Irrigation	0.002 (3.09)	0.002 (3.84)	0.004 (3.65)	0.005 (3.79)	-0.016 (-0.40)	0.017 (1.43)
Ownership	-0.00059 (-0.30)	0.004 (0.21)	-0.001 (-0.31)	-0.001 (-0.35)	-0.139 (-4.57)	-0.138 (-4.802)
Size	0.013 (0.70)	0.016 (0.92)	-0.148 (-4.73)	-0.150 (-4.82)	-1.06 (-3.43)	-1.006 (-3.45)
Tenancy	0.0001 (0.01)	0.003 (0.32)	-0.024 (-1.37)	-0.025 (-1.47)	-0.221 (-1.36)	-0.225 (-1.38)
Literacy	0.0004 (0.180)	-0.0008 (-0.44)	0.002 (0.722)	0.003 (0.918)	-0.004 (-0.13)	-0.002 (-0.07)
Relative yields	0.449 (5.59)	0.417 (5.53)	0.552 (4.02)	0.573 (4.18)	2.684 (2.12)	2.745 (2.14)
Price-wage ratio	0.006 (0.92)	0.0002 (0.37)	-0.002 (-0.14)	0.008 (0.06)	0.171 (1.73)	0.197 (1.78)
Unionization	-0.0003 (-0.37)	-0.0006 (-0.80)	-0.002 (-1.43)	-0.002 (-1.31)	-0.17 (-1.31)	-0.016 (-1.27)
Dummy for favorable village	—	0.149 (3.01)	—	-0.093 (-1.06)	—	-0.259 (-0.032)
Constant	0.541 (3.435)	-0.458 (-3.08)	0.912 (3.39)	0.862 (3.14)	5.16 (2.07)	5.02 (1.99)

Note: Figures in parentheses are t-values. Equations A and B are without and with Favorable Village Dummies.

intensity of cropping for them. Large farmers have also non-farm and non-farm sources of income more often than small farms. This finding is consistent with the inverse size-productivity relationship observed in many cases in Indian agriculture. Labor use is strongly influenced by cropping intensity, as expected. Ownership, and to a lesser extent size, have negative effect upon labor use. Land owners, particularly large farmers, seem to prefer technology to save labor. The positive price-wage ratio coefficient, although not statistically significant, is consistent with this observation.

The maximum likelihood Tobit estimates of the adoption, cropping intensity and labor use functions produce almost identical results (Table 2B). The only differences appear to be in the stronger statistical significance of the positive effects of irrigation and relative yield upon adoption and cropping intensity, negative size effects upon cropping intensity and labor use, positive effects of cropping intensity and price-wage ratio, and negative ownership effect upon labor use.

The reduced form equations estimated by OLS and maximum likelihood Tobit thus consistently demonstrate that: (a) adoption of HYV is strongly and favorably affected by irrigation and relative yield; (b) cropping intensity is positively effected by irrigation, relative yield and labor use, and negatively by farm size; and (c) labor use is positively affected by cropping intensity and price-wage ratio, and negatively by ownership and farm size.

However, as the results have shown, adoption of HYV rice technology and cropping intensity are jointly determined. Adoption of HYV is facilitated by irrigation, and adoption in its turn introduces short duration varieties and makes it possible to increase cropping intensity. Cropping intensity thus becomes an endogenous variable and should not be used in single equation estimates of labor use functions. In view of this, two-stage regression has been used here to estimate adoption, cropping intensity and labor use functions. As in the case of single equations, for each function two regressions--one without and another with favorable village dummies --have been estimated. For each in its turn one set has been estimated by OLS and another by Tobit. In the first stage for each function already discussed above, exogenous variables representing environmental, technological, social and economic factors were used to estimate reduced form equations for adoption and cropping intensity by OLS and Tobit methods. In the second stage, a recursive system is used in which there is unidirectional dependency among endogenous variables. The three equations are ordered such that the first endogenous variable, e.g., adoption, is determined only by exogenous variables; the second, e.g., cropping intensity, is determined by the predicted value of the first endogenous variable and exogenous variables; and the

TABLE 3A. OLS: Two-Stage Estimates

Independent Variables	Dependent Variable: Percent area under HYV (E)		Cropping Intensity (E)		Labor Used (E)	
	7A	7B	8A	8B	9A	9B
P-HYV (E) $	—	—	1.318* (3.75)	0.378* (3.81)	4.542 (0.43)	3.578 (0.37)
P-Crop-int. (E) $			—	—	1.751 (0.29)	2.373 (0.48)
Irrigation (X)	0.002* (2.99)	0.002* (2.82)	0.003 (1.61)	0.003* (1.95)		
Ownership (X)	0.0007 (0.43)	0.001 (0.53)	0.001 (0.41)	0.002 (0.66)	-0.142* (-5.31)	-0.141* (-5.15)
Size (X)	0.014 (0.78)	0.016 (0.96)	-0.158* (-5.62)	-0.156* (-5.49)	-0.840 (-0.87)	-0.738 (-0.91)
Tenancy (X)	-0.003 (-0.33)	-0.001 (-0.13)				
Literacy (X)	-0.0003 (-0.17)	-0.001 (-0.65)				
Relative yields (X)	0.408* (5.38)	0.377* (5.21)				
Price-wage ratio (X)					0.195 (1.64)	0.190 (1.55)
Unionization (X)					-0.020 (-1.44)	-0.020 (-1.41)
Village dummy (X)	—	0.126* (2.76)	—	-0.240* (-2.22)	—	-0.384 (-0.22)
Constant	-0.318* (-3.41)	-0.366* (-3.47)	1.296 (10.19)	1.347 (10.34)	4.800 (0.56)	4.141 (0.54)
R^2	0.56	0.62	0.58	0.58	0.47	0.47

Note: E = Endogenous variables; X = Exogenous variables; $ = Predicted values of endogenous variables. Figures in parentheses are t-values. A and B denote equations without and with Favorable Village Dummies. * refers to significance level at 10 percent or better.

TABLE 3B. Tobit Maximum Likelihood: Two-Stage Estimates

Independent Variables	Dependent Variable					
	Percent area under HYV (E)		Cropping Intensity (E)		Labor Used (E)	
	7A	7B	8A	8B	9A	9B
P-HYV (E) $	—	—	-1.317* (-3.21)	1.378* (3.87)	4.542 (0.46)	3.578 (0.40)
P-Crop-int. (E) $			—	—	1.751 (0.31)	2.374 (0.51)
Irrigation (X)	0.002* (3.32)	0.002* (3.17)	0.003 (1.68)	0.003* (2.05)		
Ownership (X)	-0.0002 (-0.09)	0.0001 (0.00)	0.001 (0.43)	0.002 (0.70)	-0.142* (-5.65)	-0.141* (-5.53)
Size (X)	0.011 (0.63)	0.014 (0.85)	-0.158* (-5.87)	-0.156* (-5.79)	-0.840 (-0.93)	-0.738 (-0.98)
Tenancy (X)	-0.0009 (-0.09)	0.002 (0.17)				
Literacy (X)	0.0001 (0.05)	-0.001 (-0.54)				
Relative yields (X)	0.445* (5.49)	0.411* (5.41)				
Price-wage ratio (X)					0.195* (1.74)	0.190* (1.66)
Unionization (X)					-0.020 (-1.53)	-0.020 (-1.52)
Village dummy (X)	—	0.148* (3.06)	—	-0.240* (-2.34)	—	-0.384 (-0.24)
Constant	-0.466* (-3.82)	-0.445 (-3.94)	1.296 (10.65)	1.347 (10.90)	4.800 (0.60)	4.141 (0.58)

Note: First stage Tobit and second stage (Labor Use) Tobit. E = Endogenous variables; X = Exogenous variables; $ = Predicted values of endogenous variables. Figures in parentheses are t-values. A and B denote equations without and with Favorable Village Dummies. * refers to significance levels at 10 percent or better.

third, e.g., labor use, by the predicted values of the first two endogenous variables and exogenous variables. As expected, results of the regression [Tables 3A and 3B] show remarkable similarity between OLS and maximum likelihood Tobit estimates. Adoption is shown to be consistently determined by physical technological and economic factors (e.g., irrigation, village dummy and relative yield), while social and institutional factors (e.g., ownership, size, tenancy, literacy) turn out to be insignificant. Cropping intensity is positively affected by adoption of HYV and irrigation and negatively by farm size. Labor use is negatively influenced by ownership of land reflecting landowners' higher perceived cost of labor. The coefficients of price-wage ratio and unionization of labor, although statistically not significant, have expected signs that suggest inducement for labor saving technology.

As in the case of the reduced form single equations, the two-stage model consistently support the positive effects of irrigation and profitability upon adoption and cropping intensity and negative effects of land ownership and labor costs upon derived demand for labor in agriculture.

IV. Differences in Adoption: Logistic Functions for Favorable and Unfavorable Villages

The two-stage maximum likelihood Tobit estimates of the adoption function for HYV rice technology addressed the issues of limited dependent variable and simultaneity. The results found to be econometrically superior to the single equation OLS estimates, suggest the consistently positive roles of irrigation (as a production infrastructure variable) and relative profitability (measured by relative yield of HYV to TV technologies). Irrigation is assumed to be a function of public and private investments to facilitate technological progress, and relative yield depends upon superior modern varieties produced through investments in crop- and region-specific agricultural research and extension [Judd, Boyce and Evenson (1987)]. Policies for such investments in irrigation and research and extension are thus highlighted. However, it is useful to explore if there are differences in the respective importance of these variables in influencing adoption in areas with differential production environments. An attempt is made in this section to do this. Diffusion of new technology is commonly conceived as passing through three phases of an S-shaped logistic curve moving asymptotically from zero to 100 denoting percentage of area under new technology. In his seminal article on hybrid corn Griliches (1957) used such a logistic transformation of the area under hybrid corn as measure of technological change and fitted the curve over time. [For reviews of literature on diffusion of new technology, and the use of logistic function, see Feder, Just and Zilberman (1985); Feder and O'Mara (1982); Jarvis (1981); Roger (1983); and Thirtle and Ruttan (1986).] The parameter for time, slope of the equation, represents the rate of adjustment and is a function of the current stage of adoption and its distance from the ceiling or optimal rate of adoption possible in the area. This slope parameter, if calculated separately, has the advantage of showing differential rates of response to the determining factors then the regions vary distinctly among themselves.

Following Griliches, a logistic transformation of adoption of HYV rice in the villages is fitted here. However, since we do not have time series data, the curve is fitted to cross-section of villages with irrigation and relative yield as independent variables. The following specification is estimated:

$$\log_e\left(\frac{P}{K-P}\right) = a + b_1x_1 + b_2x_2$$

where P = % area under HYV, K = maximum % area under HYV attainable, x_1 = % area irrigated, x_2 = relative yield,[2] and a, b_1, b_2, are parameters to be estimated. In order to help estimation, villages with zero areas under HYV were excluded, leading to the loss of data for 9 villages from the analysis. The implications of the results should, therefore, be applicable to those villages who have already adopted the technology [Griliches (1957)]. The function is fitted to three combinations of villages, (i) all villages pooled, (ii) favorable villages, and (iii) unfavorable villages. The value of K, the ceiling attainable for HYV in a respective area is first assumed to be 1.00 for all villages together, and for favorable and unfavorable villages separately (Table 4A). Then in order to examine how the rates of adjustment would vary depending upon variation in the ceiling, estimates are made assuming alternative values of K, from $K = 0.9$ through $K = 0.5$ for unfavorable villages (Table 4B).

Several points of interest emerge from the logistic functions estimated. First, all the equations provide statistically good fit and all the coefficients are significant and have expected signs, signifying that logistic is a reasonable representation of the process of technological diffusion. Second, the parameters remain stable despite variations in the assumed ceilings of adoption. This implies that farmers would adopt the same processes of adjustment within the physically feasible limits of adoption of the new technology. Thirdly, the adjustment parameter (b) is higher for relative yield than for irrigation in all the equations calling for more concentrated

[2]In the absence of substantial differences in prices of products, yield ratios may be used as approximation to profit variations. [See Griliches (1957) for explanation.]

TABLE 4A. Estimates of Logistic Functions for HYV Rice Technology in West Bengal Favorable and Unfavorable Villages

Independent Variable	K = 1.00 For All villages	K = 1.00 For favorable villages	K = 1.00 For unfavorable villages
Constant	-4.965 (-9.73)	-3.683 (5.03)	-5.392 (-6.73)
Irrigation	0.013 (3.46)	0.012 (2.24)	0.014 (2.12)
Yield ratio	1.986 (5.075)	1.79 (3.681)	2.335 (3.20)
Dummy for favorable village	0.934 (3.50)	—	—
R^2	0.59	0.41	0.56
F	25.48	10.45	16.15
N	51	28	23

Figures in parentheses denote t-values.

TABLE 4B. Estimates of Logistic Functions
for HYV Rice Technology in West Bengal
Unfavorable Villages for Alternative Ceilings of Adoption (K)

Independent Variable	K = 0.9	K = 0.8	K = 0.7	K = 0.6	K = 0.5
Constant	-5.553 (-6.58)	-4.944 (-4.83)	-4.981 (-4.46)	-5.532 (-5.25)	-5.735 (-2.72)
Irrigation	0.012 (-1.98)	0.014 (2.01)	0.0149 (1.99)	0.009 (1.33)	0.011 (1.324)
Yield Ratio	2.605 (3.39)	2.145 (2.26)	2.331 (2.26)	3.135 (3.21)	3.39 (1.63)
R^2 (Adjusted)	0.59	0.47	0.46	0.53	0.42
F	16.62	10.44	9.94	12.12	7.53
N	23	22	22	21	19

Figures in parentheses denote t-values.

attention to the generation of new technology that assures higher yield. Fourthly, the adjustment parameters are higher in the unfavorable villages than in favorable villages. This may be due to the fact that unfavorable villages have lower levels of irrigation and relative yield than favorable villages as shown below. Slopes of the logistic function move from an initial low through high in the intermediate stage and then taper off to low again at the final stages. The unfavorable villages are at the intermediate stage with high relative rates of adjustment compared to favorable villages which are already on higher levels of irrigation and yield and lower rates of adjustment. Policy then should focus more on unfavorable villages with higher possible payoff in adoption.

Lastly, the exercise with alternative levels of ceilings of adoption assumed for unfavorable villages show that the best fit is obtained in the function for all villages pooled and the ceiling assumed at $K = 1.00$. This suggests the overall good fit of the logistic function as a description of the process of diffusion in West Bengal villages. The potential does not vary much between favorable and unfavorable villages. This observation is consistent with the argument that HYV technology represents a process of continual change, and the equilibrium levels also have a continuous flow that spread over areas which have the minimum physical requirements satisfied [Feder *et al.* (1985)].

	Mean Levels of		
	Percent Area under HYV	Percent Area Irrigated	Relative Yield
Favorable Villages	38	63	1.78
Unfavorable Villages	17	49	1.25
All Villages	28	56	0.53

The logistic representation of adoption of new technology thus supports the earlier results of the analysis that irrigation and relative profitability are important determinants of technological improvement in rice agriculture. It is, moreover, suggested that increases in these two factors should bring about faster rates of adoption in the unfavorable villages than in the favorable ones. Between irrigation and relative yield, the latter would call for greater response from farmers in the adoption of the HYV rice.

V. Conclusion

Agricultural growth in the state of West Bengal during the recent decades has been slow relative to several wheat and rice growing states in the western and southern regions of India. This paper has attempted to examine the factors behind such slow growth by focusing upon the adoption of High Yielding Variety rice, changes in cropping intensity and labor use in agriculture. Data have been used for 60 villages selected from a purposively selected sample of 12 blocks in six districts that represent the range of agro-climatic and socio-economic variations in production-environments of rice, the principal crop of the state. The study examines the hypothesis that technological progress in rice cultivation (reflected in the adoption of HYV) is determined by environmental and market factors specific to given locations. Adoption would presume availability of a technology suited to the environment as a necessary condition, and profitability of the new technology relative to traditional technology would determine the likelihood of its being adopted. Results of the study support this contention and show that physical-environmental factors are important determinants of adoption. Yield from modern relative to traditional technology as a measure of relative rates of return from land is also a strong positive factor inducing technological change. Cropping intensity is induced by adoption of HYV and irrigation, but adversely affected by farm size. Finally, labor use depends positively upon cropping intensity and ratio of rice price received by the farmer relative to wages paid to labor, but negatively upon ownership, size and the extent to which agricultural laborers are unionized.

The study suggests that policy should have to focus upon both environment-specific physical factors including irrigation, water control, and other infrastructural facilities, and on such economic factors as remunerative prices of products relative to labor and other costs--both actual and perceived, often caused by labor market imperfections and supply uncertainties. Relative prices affect profitability of new technology upon which depends increases in cropping intensity and labor use. The latter is critical for the sustained progress of agriculture consistent with the resource-endowment of the state.

The principal thrust of the conclusions of the study is on the potential relative merits of policy measures, mainly through greater accent on irrigation and generation of more profitable varieties. However, this should not be interpreted to underestimate the complexities and uncertainties that are inherent in these policy measures being successful [Schultz (1975)]. Irrigation here implies provision of water at the farm level at the needed time, to the required quantity and at economically viable rates. This calls for integrated water control involving irrigation and drainage. Realization of benefits of such measures at farm-household level is hardly a simple process. Similarly, relative profitability would involve a complete technology-land-location-management package. Returns from investment in research, education and extension needed to generate and provide such packages at farm-household levels are also fraught with uncertainties and complexities [Mukhopadhyay (1988)]. While these are important problems for comprehensive inquiries beyond the scope of the present paper, the results provide at least an indicator for policies for a more regionally balanced technological development of agriculture in West Bengal.

It should also be remembered that the study is based upon village-level survey data subject to limitations of extent of coverage and accuracy. Results of the analysis, therefore, should be considered as broad indicators of direction rather than exact measures of magnitudes. For that purpose and also for attempting a more comprehensive review of the implications of technological change for farm and landless rural households, it should be necessary to use micro data at household and individual levels. Nonetheless, the present study does provide insights into a vital problem in the state's economy not much examined so far.

APPENDIX A

Agricultural Production Environments in West Bengal

West Bengal, a North-Eastern state in India has a total area of about 88,000 square kilometers and a population of 54.5 million with a density of 814 persons per sq. km. In terms of area and population density the state ranks twelfth and second respectively, among the states of India. The state has about eight percent of the country's population on less than three percent of its land. About 70 percent of the total area, or about 8.34 million hectares of land is supposed to be cultivable and about 5.6 million hectare of land is under crops at present.

Average annual rainfall in the state is about 1800 mm. varying widely over the year and the different parts of the state. About 80 percent of the rainfall is concentrated in the monsoon season covering the five months, June to October, followed by a relatively dry span of four months (November to February) and a period of scattered rainfall during the remaining three months (March to May). Regionally, there is wide variation in average rainfall, declining from 2500-5000 mm. in the Himalaya region to about 1100-2000 mm. in the plains. Fluctuation in rainfall from year to year is high in the state and also in its different regions. The state's temperature varies from about 4° C in winter to 46° C in summer, the warm months being from March to September with a mean temperature of about 30° C. The rainfall-temperature combination of West Bengal helps most tropical crops in the warm and monsoon months and temperate crops in the winter. Paddy, the principal crop of the state grows practically round the year, though subject to the vagaries of regional and temporal variations in rainfall. Based upon climate, soil types and other physiographic characteristics West Bengal may be broadly classified into six agro-climatic zones. These zones, their locations and major agricultural products are given in Chart A-I.

As the Chart shows, West Bengal's agricultural production includes a variety of grains, vegetables, fibers, plantation and horticultural crops. The most important crop, however, is rice, occupying more than 70 percent of the total cropped area and accounting for about 80 percent of the state's grain production. West Bengal contributes about 17 percent of the total rice production of India. Responding to the emergence of the High Yielding Variety and favorable water-climatic conditions in limited areas, West Bengal adopted the new wheat crop remarkably well and it is now an important product in the state. Potato constitutes an important item in

CHART A-I

Agro-climatic zone and approximate area (in '000' hectares) (1)	Sub-divisions and districts covered (2)	Soil-climate characteristics (3)	Major agricultural products (4)
I. Hill Zone: 194.33	Darjiling (except Siliguri subdivision)	Rainfall annual average about 3000 mm. Sandy, acidic light soil	Potatoes, vegetable, ginger, cardamon, orange, rice and mai in monsoon water, and tea
II. Terai Zone: 647.78	Siliguri, Islampur, and Districts of Jalpaiguri, Koch Bihar	Rainfall average 3000 mm. annually. Soils highly leached, acicid and sandy, poor in bases and plant nutrients	Aus, aman, jute in Kharif season and wheat, mustard and pulses in Rabi. Boro and potatoes also increasing. Oilseeds have a promising future, pineapples
III. Old Alluvium Zone:	Maldah, Hugli and parts of Barddhaman, Birbhum, and West Dinajpur	Rainfall about 2000 mm. Soils acidic, fertile	Rice, jute in Kharif and rice, wheat pulses, oilseeds, potatoes and sugar cane in Rabi season
IV. New Alluvium 1597.11	Nadia, Murshidabad, Hoara and parts of Hugli and 24-Parganas	Annual rainfall about 15000 mm. Soil most fertile	Aman, rice, jute in Kharif andwheat, boro, pulses, oilseeds and potatoes in Rabi. Sugar cane, barley and flower also grow here
V. Lateritic Zone: 2454.79	Puruliya, Bankura, parts of Medinipur, Barddhaman and Birbhum	Annual rainfall about 1200 mm. Soil is red and latetitic with ferrogenous concretions. Little scope for irrigation, drought prone	Kharif crops and rice, maize, millet pulses
VI. Coastal Saline Zone: 1141.79	24-Parganas, Medinipur, and parts of Haora	Rainfall about 1900 mm. Soil PH varies from 6.5 to 7.5 accumulation of sodium chloride; soil fertile due to salt deposit	Kharif, rice, new crops and varieties can be grown. Research needed.

the state's vegetable production. West Bengal produces about 60 percent of the country's total output of jute and about 25 percent of tea, two of the most important agricultural exports of India.

There are three broad cropping seasons in West Bengal: pre-kharif (March-June), kharif (June-October), and rabi (November-March). Choice of crops is determined by the extent of rainfall, availability of irrigation, soil condition and land level. For example, during the kharif season, it is the level of land which is the most important factor because of the problem of waterlogging and drainage, while during the rabi and pre-kharif seasons it is the soil types and irrigation which would be most important.

Out of about 7.6 million hectare of the gross cropped area with a cropping intensity of about 140 per-cent, West Bengal has irrigation over 2.4 million hectare or more than one third of the cropped area. The major sources of irrigation are tanks and canals. However, an increasing proportion of irrigation is coming from tubewells and river lift systems. Increase in area irrigated has been accompanied with expansion of area under high yielding varieties rice and wheat and consumption of fertilizer. More than 40 percent of the total area under rice is now under HYV, mainly boro. The entire acreage under HYV boro, cultivated during the rabi season is irrigated. The same is true for wheat. However, for aus and aman the major components of rice, HYV is still less than 35 and 33 percent, respectively, the major constraints there being the lack of appropriate pest, disease and drought resistant varieties and varieties for rain-fed areas, lack of drainage facilities from water stagnated land (constituting about 60 percent rice area in the kharif season), deep water and flooding, and soil salinity in coastal areas. The consumption of fertilizer in the state approximates at about 74 kg. per hectare of gross cropped area and about 100 kg. per hectare net sown area.

As indicated above there is wide regional variation in the state in regard to technological progress in agriculture including rice cultivation. For instance, rice yield per hectare (average for 1985-88) varies from 1 tonne in the district of Jalpaiguri to 2.1 tonnes in Barddhaman. Similarly, fertilizer consumption per hectare of net sown area in the state ranges from about 50 kgs. in Jalpaiguri to about 278 kgs. in the district of Hugli. In terms of rainfall, soil types and land levels, groundwater potential, drainage and irrigation facilities as well as in socio-economic and infrastructural attributes, the districts of West Bengal vary over a wide range. Consequences of such variations are reflected in relative rates of technological progress and product and factor market behaviors. [See Mukhopadhyay (1982) for a discussion of agricultural growth and potential in West Bengal.]

References

Barker, R. and R. W. Herdt (1985), *The Rice Economy of Asia*, Resources for the Future, Washington, D.C.

DIS Project Team (1989), "Rice-based agro-environmental study of villages in West Bengal, India," Indian Statistical Institute, Calcutta, mimeo.

Feder, G., R. E. Just and D. Zilberman (1985), "Adoption of agricultural innovations in developing countries: A survey," *Economic Development and Cultural Change*, 33(2): 255-298.

Feder, G. and G. T. O'Mara (1982), "On information and innovation diffusion: A Bayesian approach," *American Journal of Agricultural Economics*, 64: 145-147.

Griliches, Zvi (1957), "Hybrid corn: An exploration in the economics of technological change," *Econometrica*, 25, 501-522.

Jarvis, L. S. (1981), "Predicting the diffusion of improved pastures in Urugay," *American Journal of Agricultural Economics*, 64: 495-502.

Judd, M. Ann, James K. Boyce, and Robert E. Evenson (1986), "Investing in agricultural supply: The determinants of agricultural research and extension investment," *Economic Development and Cultural Change*, 35(1).

Mukhopadhyay, Sudhin K. (1982), "Agricultural growth and potential in West Bengal," Planning Commission, New Delhi, and University of Kalyani, India.

________ (1984), "Constraints to technological progress in rice cultivation," sponsored by Ford Foundation, New Delhi.

________ (1988), "Factors influencing agricultural research and technology: A case study of India," in I. Ahmed and V. W. Ruttan (eds.), *Generation and Diffusion of Agricultural Innovations. The Role of Institutional Factors*, Gower (ILO).

Rogers, E. (1983). *Diffusion of Innovations* (Third Edition, The Free Press, New York

Rosett, R. N. and F. O. Nelson (1975), "Estimation of the two-limit probit regression model," *Econometrica*, 43, 141-146.

Ruttan, V. W. (1977), "The Green Revolution: Seven Generalizations," *International Development Review*, 19, 16-23.

Schultz, T. W. (1975), "The value of the ability to deal with disequilibrium," *Journal of Economic Literature*, 13, 827-846.

Thirtle, G. Colin and Vernon W. Ruttan (1986), "The role of demand and supply in generation and diffusion of technological change," Bulletin 110.86-5, Economic Development Center, University of Minnesota, September.