1. INTRODUCTION

Eastern India has emerged as a new center of growth in the agricultural sector since 1980's. Over the period 1984/85-1994/95, the foodgrain production increased at a compound annual rate of 3.1% per annum in this region. Of India's incremental output of 45.6 million tonnes in foodgrains over this period, around 20% was contributed by the Eastern region. This impressive performance is a relatively recent phenomenon. Until the early 1980's, the growth of agricultural production in this region was low (around 1.6% per annum) and lagged behind the national average. This turn around, from a situation of low and less than the All India average rate of growth to high agricultural growth rates, occurred in the last two decades.

A notable feature of the accelerated growth performance in the eighties and early nineties is the striking performance of foodgrains, especially rice. For example, the growth rate of rice production increased to more than 6% per annum in West Bengal followed by Orissa (4.1% per annum) in the eighties. Studies by Saha and Swaminathan (1994), Rawal and Swaminathan (1998) reveal that the rapid growth in rice production in West Bengal was brought about primarily by an expansion in the boro (summer) crop (which is an irrigated crop based on HYV's of seeds). Over the period, the share of boro rice production increased in total rice production, primarily due to an expansion in area under cultivation, the yield growth was modest. Yield increases were significant for the aman (kharif) crop as well; however, the aus (rabi) crop saw a decline in the area under cultivation.

The significant upsurge in agricultural productivity in general is attributed to two major factors. One is the role of institutional changes. Studies by Mukherjee and Mukhopadhyay (1996); Raychaudhuri and Sen (1996); Sanyal, Biswas and Bardhan (1998); Rawal and Swaminathan (1998) highlight the role of Operation Barga in reversing the slow output growth in West Bengal. According to them, the acceleration in growth occurred during and after major changes in agrarian institutions and land relations. They argue that the establishment of the democratic Panchayati institutions in West Bengal and the conduct of `Operation Barga' were the main factors behind the transition in West Bengal's agricultural performance. Operation Barga, started in 1978, involved recording the names of the sharecroppers, thereby granting them heritable rights of cultivation and minimizing the risks of eviction. It also tried to ensure a just distribution of product between the landlords and sharecroppers. Quick recordings of Barga rights and provisions for institutional credit to the sharecroppers and the assignees of vested land raised the access of the small operators to technological inputs.

The second factor is the wider adoption of new technology, better utilization of fertilizers, credit and so on. So far, the literature on Eastern India has emphasized the role of institutional changes and relegated the role of productivity growth to be of secondary importance. This is not to suggest that institutional changes and productivity are mutually exclusive; rather institutional changes facilitate productivity: for example by enabling technological change. Yet, quantification of productivity growth and its sources has not been attempted systematically in the literature. It is this lacuna that the paper seeks to fill.

In particular, we focus on the role of input utilization in paddy cultivation in this accelerated growth in the eighties and early nineties. This exercise is carried out for West Bengal and Orissa by examining:

(a) the changes in aggregate, state-level factor productivity growth (Section II),
(b) the extent of technical inefficiency, and differences if any, across seasons, crop varieties, states and over time (Section III),
(c) whether there is a perceptible shift in the production technology over time in the case of West Bengal (Section IV).

A summary of the principal results and their implications are highlighted in Section V.

For the state-level study (Section II), the time period spans from seventies to early nineties; in particular, West Bengal - 1971/72-1991/92 and Orissa – 1971/72-1992/93. State-level aggregates on input use, prices and yields per hectare collected under the *Comprehensive Scheme for Studying Cost of Cultivation of Principal Crops* form the basis of this analysis[1]. The farm-level study (Section III and IV) is carried out for the years 1986/87 and 1990/91 for West Bengal and for the year 1990/91 for Orissa, separately by season and crop variety. The farm-level data on Cost of Cultivation collected from Directorate of Economics and Statistics, Ministry of Agriculture, is used for the analysis.

[1]These are published by the Directorate of Economics and Statistics, Ministry of Agriculture in *Cost of Cultivation of Principal Crops* (1991 and 1996) and supplemented by the *Reports of Commission for Agricultural Costs and Prices* (various volumes).

2. TOTAL FACTOR PRODUCTIVITY

Total factor productivity growth (TFPG) measures the increase in output that is not accounted for by the increase in total inputs. Changes in the TFP index can be used as one measure of the effects of the technological change. As is well recognized, partial productivity measures such as output per unit of individual inputs have limitations as indicators of real productivity change. A total factor productivity index that measures the growth in net output that is not accounted for by the growth of basic factor inputs such as land, labour and capital, is superior to the partial approach, as it is a composite measure of productivity, which relates output to all inputs simultaneously.

Studies analyzing total factor productivity for rice are limited. An exception is a recent study by Kumar and Rosegrant (1994) who examine the total factor productivity growth for rice in India during 1971-88. Their results indicate that nearly one-third of the output growth in Indian rice was contributed by total factor productivity, which grew at 1.03% per annum.

At the disaggregated level, wide variations in productivity growth were observed across the major rice producing regions of India. Productivity growth accounted for 62% of total output growth in the Southern region (comprising Andhra Pradesh, Tamil Nadu, Karnataka and Kerala), 16% in the Eastern region (comprising Assam, Bihar, Orissa and West Bengal) and 11% in the Northern region (comprising Haryana, Punjab and Uttar Pradesh). In the Eastern region, the input, output and TFP index during 1970/71-1988/89 increased by 1.8% per annum, 2.2% per annum and 0.36% per annum, respectively, all of which was much lower than the Northern and the Southern regions. In addition, the Eastern region follows the Northern and the Southern regions with a lag with respect to growth in input use (especially, fertilizer and HYV technology). The growth in fertilizer use was 1.7% per annum in the Eastern region as compared to 10.7% per annum in the Northern and 2.9% per annum in the Southern region. The evidence on the use of inputs suggests that the existing level of application of inputs is relatively low in the Eastern region. The further spread of inputs in this region would contribute to the rise in the productivity per unit of input as well as ensuring more equitable distribution of benefits. The results reflect great potential to increase the output growth in this region with more efficient utilization of the inputs.

Total factor productivity growth may be computed using Divisia-Tornqvist index. In this method, the total output, total input and TFP indices are calculated as follows (Caves, Christensen and Diewert, 1982):

Total output index (TOI):

$$TOI_t/TOI_{t-1} = \Pi_j (Q_{jt}/Q_{jt-1})^{(Rjt+R\ jt-1)/2}$$

Total input index (TII):

$$TII_t/TII_{t-1} = \Pi_i (X_{it}/X_{it-1})^{(Sit+S\ it-1)/2}$$

Total factor productivity index (TFPI):

$$TFP_t = (TOI_t/TII_t) * 100$$

where,

R_{jt} is the share of output j in total revenue,

Q_{jt} is output j,

S_{it} is the share of input i in total input cost,

X_{it} is input i, and

t is the time period.

By specifying TOI, TII equal to 100 in the initial year, the above equations provide the total output, total input and TFP indices for the specified period t.

This TFP index is computed using the state-level data on costs of cultivation with a base year of 1981/82=100. The time period spans from the 1970's to early 1990's; in particular, West Bengal-1971/72-1991/92 and Orissa-1971/72-1992/93. However, for some years, the data on cost of paddy cultivation is not available. For instance, the data for the years 1985/86-1988/89, 1990/91 for West Bengal; and 1987/88-1989/90 for Orissa are not available in the published reports. As a result, these missing years have not been considered in this analysis. The value of grain and straw of paddy are included in the output index. The inputs include land, seed, manure, fertilizer, pesticides, human labour, animal labour, machine labour, irrigation and working capital. For inputs such as machine labour, irrigation, pesticides and working capital, for which the cost of cultivation data set provides only the input cost, the quantities have been computed by dividing the input cost by the price indices of these inputs.[2]

The results on the rates of growth of output, input and TFP are presented in Table 1. Over the two decades beginning in 1971/72, the input and output indices in West Bengal

[2] I am grateful to Professor Praduman Kumar for providing these price indices.

increased at the rate of 2.42% per annum and 4.27% per annum., while total factor productivity increased at the rate of 1.75% per annum. Thus, both inputs and total factor productivity growth have played an equally important role in the output growth realized in this state. Among inputs, fertilizers have shown a substantial increase at the rate of 14% per annum over the period.

To examine whether output growth has been substantially different after Operation Barga, we compare the average annual growth in input, output and TFP before and after 1978/79. Results indicate a sharp increase in the growth rates. While the rate of growth of inputs increased steadily from 1.87% per annum to 2.8% per annum, the growth in output showed wide variations during 1971/72-1978/79 leading to a negative growth of (-)1.4%[3] (Table 2). This slow growth in output during seventies is consistent with the operation of several constraints cited in the RBI Committee Report (1984) and by James Boyce (1987), such as: limited development of irrigation and water control, inadequate supply of fertilizers, modern varieties of seeds and credit facilities. However, after 1978/79, the output and total factor productivity increased substantially to 6.22% per annum and 3.4% per annum, respectively.

A comparison of growth rates before and after structural change period as suggested by Saha and Swaminathan, and Gangal reveal qualitatively same results, that is, an increase in the rate of growth of input and output and TFP indices between the seventies and eighties (Table 2). Also, input growth has as much to do with output growth as TFP. In fact, in the eighties, the growth in inputs is greater than total factor productivity growth. This is in line with the trends in input usage, which indicate a substantial increase in the levels of inputs, especially fertilizers, in the eighties and early nineties.

In Orissa, the average annual growth in inputs, output and TFP indices show a steady increase at the rate of 1.11% per annum, 2.7% per annum and 1.5% per annum respectively, during 1971/72-1992/93, with modest variations in growth rate over the period (Table 1). The growth indices show that both inputs as well as TFP have been important contributors to output growth. Over the period, fertilizers increased considerably at the rate of 9% per annum. A break-up of the reference period based on the structural change observed in the aggregate output by Gangal (1983/84) indicates a substantial increase in the annual growth rate of input, output and TFP indices after 1983/84; with the rate of growth of inputs increasing steadily from 0.6% per annum to 1.86% per annum between 1971/72-1983/84 and

[3] Refer to Appendix 1.

1984/85-1992/93 (Table 2). Fluctuations due to weather variations (droughts, cyclones) affected the output growth adversely in the seventies. Particularly large drops in output occurred in the severe drought years of 1973/74, 1975/76, 1980/81 and 1981/82[4]. As a result, the output and TFP growth is negative at (-)1.01% per annum and (-)1.14% per annum. However, with increase in inputs and technological change, output and TFP growth have risen sharply to 6.3% per annum and 4.4% per annum in the eighties and early nineties.

Thus, there has been a considerable improvement in input productivity over time, especially in the eighties and early nineties. Disparities among the states are also reflected with West Bengal surpassing Orissa. As compared to the results obtained by Kumar and Rosegrant's study (1994), our results indicate a substantial increase in the total factor productivity growth over the entire period.

3. TECHNICAL EFFICIENCY

Total factor productivity growth is the net effect of changes in both efficiency and technology. An improvement in technical efficiency is implied by the farmer operating more closely to the existing frontier, while technological change is represented by an upward shift in the production frontier.

The concept of technical efficiency in a broad sense is used to characterize the utilization of resources. In other words, efficiency is a statement about the performance of a process in transforming a set of inputs into a set of outputs. This basic concept may be formalized through a frontier production function, defined as one that yields maximum output for given levels of inputs. The production frontier is estimated using stochastic frontier approach, where the disturbance term consists of two components, one representing technical inefficiency and the other the usual random noise (Aigner, Lovell and Schmidt (1977), Meeusen and Broeck (1977)). The one-sided component (say, $u_i \geq 0$) reflects technical inefficiency relative to the frontier output, in the sense that it measures the shortfall of output from its maximal possible value given by the stochastic frontier. In other words, the disturbance u_i reflects the fact that each farm's output must lie on or below its frontier. Thus, $u_i=0$ for any farm lying on the frontier, while $u_i>0$ for any farm lying below the frontier. The closer is $u_i = 0$, the more efficient the farmer is.

[4] Refer to Appendix 2.

There have been ample applications of frontier methodologies to agricultural data in other countries around the world. However, the application of stochastic frontier models to Indian agriculture is limited[5]. Kalirajan and Shand's (1989) study is notable in that it sought to identify the factors causing technical efficiency differences amongst farms. Their study estimated a translog frontier production function using panel data for Indian paddy farms (1981-83). The major results of the study were (1) the farm specific technical efficiencies ranged from 0.60 to 0.95. The largest concentration of farms (29%) occurred in the range of 0.71 to 0.75. The average technical efficiency was around 0.70 implying that on an average, sample farms were realizing around 70% of their technical efficiencies; (2) the production frontier was found to be time-invariant; (3) all the coefficients of the linear regression involving technical efficiency as the dependent variable and socio-economic factors such as farming experience, education, access to credit and extension as the explanatory variables, were found to be statistically significant.

Using the method proposed by Aigner et.al (1977), the level of technical efficiency is estimated using stochastic frontier model.

Consider a translog specification of production technology,

$$\ln y_i = \alpha_o + \Sigma_k\alpha_k (\ln x_{ik}) + 1/2\Sigma_k\Sigma_l\beta_{kl} (\ln x_{ik}) (\ln x_{il}) + \varepsilon_i \ , \quad (i=1,2\ldots\ldots n) \quad \ldots\ldots\ldots\ldots(1)$$

where,

y_i = crop output per hectare for observation i,

x_{ik} = quantity of the k^{th} input per hectare for observation i,

ε_i = error term for observation i.

The translog production function is a flexible functional form, which allows for variable elasticity of substitution. The stochastic frontier model postulates that the error term ε_i is made up of two independent components,

$$\varepsilon_i = v_i - u_i \qquad (i=1,2\ldots\ldots\ldots n)$$

The error component v_i represents the symmetric disturbance and permits random variation in output due to factors like weather and plant disease, which are outside the control of farmers. It is assumed to be identically and independently distributed as $N(0, \sigma_v^2)$. The error component $u_i \geq 0$ represents technical inefficiency and is generated from a one-sided

[5] Battese, Coelli and Colby (1989) and Battese and Coelli (1995) applied stochastic frontier Cobb-Douglas production function to measure the technical efficiencies of agricultural farm households in Aurepalle village in Andhra Pradesh. The results of the study showed that the technical efficiencies ranged from 0.662 to 0.914. About 88% of the farm households were situated in the ranges of 0.85 and 0.90. The mean efficiency was also high.

probability distribution. It is assumed to be distributed independently of v_i. u_i is distributed as the absolute value of a $N(0,\sigma_u^2)$, i.e, the distribution of u is half-normal.

M.A.Weinstein (1964) first derived the distribution function of the composite error. The density function of ε can be stated as:

$f(\varepsilon) = (2/\sigma) f^* (\varepsilon / \sigma)[1- F^* (\varepsilon\lambda\sigma^{-1})]$, $-\infty \leq \varepsilon \leq +\infty$ ……….(2)

where $\sigma^2 = \sigma_u^2 + \sigma_v^2$, $\lambda = \sigma_u / \sigma_v$, and f*(.) and F*(.) are the standard normal density and distribution functions, respectively.

This density is asymmetric around zero, with its mean and variance given by,

$E(\varepsilon) = E(u) = (\sqrt{2}/\sqrt{\pi})\,\sigma_u$ ..……….(3)

$V(\varepsilon) = V(u) + V(v)$

$= [(\pi - 2)/\pi]\,\sigma_u^2 + \sigma_v^2$

The mean technical inefficiency can be calculated from (3). The above model (2) is parameterized in terms of λ and σ^2. λ is interpreted to be an indicator of the relative variability of the two sources of random error that distinguish farms from one another. $\lambda^2 \rightarrow 0$ implies $\sigma_v^2 \rightarrow \infty$ and/ or $\sigma_u^2 \rightarrow 0$, i.e., that the symmetric error dominates in the determination of ε. Similarly, when $\sigma_v^2 \rightarrow 0$, the one-sided error becomes the dominant source of random variation in the model. In addition, the variance ratio σ_u^2/σ^2, represented by γ, can also be a useful indicator of the influence of the inefficiency component in the overall variance. However, the variance of the half-normal random variable u_i (V (u)), is $[(\pi -2)/\pi]\,\sigma_u^2$, not σ_u^2 . In the decomposition of the total variance into two components, the contribution of u_i is $[(\pi -2)/\pi]\,\sigma_u^2 / \{\sigma_v^2 + [(\pi -2)/\pi]\,\sigma_u^2\}$. γ is computationally more convenient as it ranges from zero to one in value whereas λ can be any positive real number. A value of γ close to one implies that the one-sided error u_i dominates the symmetric error v_i and the shortfall of realized output from the frontier is largely due to technical inefficiency.

The measurement of the individual farm technical inefficiency requires the estimation of the non-negative error, namely decomposing ε_i into the individual component u_i and v_i. Jondrow et.al (1982) have suggested a decomposition method from the conditional distribution of u_i given ε_i. This distribution contains whatever information ε_i yields about u_i. Either the mean or the mode of this distribution can be used as point estimate of u_i .

The measure of farm efficiency based on the conditional mean is given by:

$$E[\,u_i | \varepsilon_i\,]_{\text{half-normal}} = (\sigma_u^2\, \sigma_v^2 / \sigma^2)\ \{\ [\ f(\varepsilon_i\lambda/\sigma) / 1- F(\varepsilon_i\lambda/\sigma)]- (\varepsilon_i\lambda/\sigma)\ \} \quad \ldots\ldots\ldots(4)$$

where

f and F represent the standard normal density and distribution functions, respectively and ε_i are the maximum likelihood estimated residuals. The mean of the conditional distribution is used as a point estimate of u.

The stochastic frontier production function (1) is estimated using the farm-level data for ten sets of sample farms by the method of maximum likelihood. Of the ten sample sets, eight correspond to West Bengal for the years 1986/87 and 1990/91 and two correspond to Orissa (1990/91).[6] The sample consists of input quantities and prices of 600 farms in West Bengal for the years 1986/87 and 1990/91. It has been partitioned into eight sub-samples based on season and variety. These correspond to aus local variety, aman local and high yielding variety and boro high yielding variety of paddy for each of the two years. Aus (November to March), aman (kharif, from June to November) and boro (summer, from March to June) are the three major rice seasons of West Bengal. In addition, a sample of 450 farms in Orissa for the year 1990/91 is used. This sample has been divided into two sub-samples based on seed varieties. These correspond to kharif local variety and kharif high-yielding variety of paddy.[7]

Six inputs are distinguished in the stochastic frontier model: hired labour, family labour, non-human labour (comprising machine and bullock labour), fertilizers, seed and

[6] Ideally, changes in productivity should have been analysed between the 1980's and 1990's, when there was substantial productivity growth. However, due to the non-availability of farm-level data for earlier years, we restrict our analysis to West Bengal for the years 1986/87 and 1990/91 and Orissa for the year 1990/91.

[7] Some observations have been deleted due to missing data for certain inputs. As a result, the entire sample for the specified years has not been used. The number of sample farms for West Bengal and Orissa across seasons and varieties used in this study, are:

West Bengal- 1986/87:

- Aus local variety- 80
- Aman local variety-205
- Aman HYV- 77
- Boro HYV- 90

West Bengal- 1990/91:

- Aus local variety- 87
- Aman local variety-220
- Aman HYV- 127
- Boro HYV- 77

Orissa- 1990/91:

- Kharif local variety- 220
- Kharif HYV- 257.

manure.[8] The summary statistics table on inputs is given in Appendix 6. The maximum likelihood estimation is carried out using LIMDEP econometrics package. Under the assumption of the stochastic frontier model satisfying the standard regularity conditions, inference about its parameters can be based on maximum likelihood estimators.

The maximum likelihood estimates of the translog stochastic frontier production function (1) are presented in Appendix 3-5. In order to justify that the translog functional form is a more appropriate specification as compared to the Cobb-Douglas production technology, the model is tested for Cobb-Douglas specification[9] using likelihood ratio test. We find that for two sets of sample farms (i.e., West Bengal - 1986/87 (boro HYV) and 1990/91 (aman HYV)), Cobb-Douglas production technology is accepted; as a result of which Cobb-Douglas stochastic frontier is estimated for them[10].

In most cases, the estimated coefficients of inputs such as fertilizer, seed, manure and non-human labour are found to be statistically significant. The estimated coefficients of the remaining inputs, however, turn out to be insignificant in most cases. As with most production function estimates, multicollinearity appears to be the cause[11]. However, it would be inappropriate to drop the variables from the equations: doing so would relegate their effects to the disturbance term, biasing the subsequent calculations of technical efficiency. As is evident from (4), measures of technical inefficiency are calculated from the residuals, so that the difference between the actual and estimated values of output is important. Thus, the variables with insignificant coefficients remain in the equation[12].

Estimates of Technical Efficiency

Across seasons- West Bengal, 1986/87:

Estimates of the mean technical efficiencies indicate that the farms cultivating local variety of paddy are about 76% technically efficient in the aus and aman seasons (Table 3). This implies that the farmers are operating around 24% below their respective frontiers and

[8] Though irrigation is an important input in paddy cultivation, it has been excluded from the set of inputs for two reasons: one, irrigation charges recorded in the farm-level Cost of Cultivation data form an insignificant fraction of total operating costs; and two, the available data is inconsistent. The absence of irrigation as input due to data limitations may result in biased measures of technical efficiency.

[9] Test for Cobb-Douglas specification: $\beta_{lk}=0$.

[10] Krishna and Sahota (1991) suggest that the choice of functional form has little impact on the results of productivity and technical efficiency.

[11] See Pillai (1999).

[12] Dawson and Lingard's (1989) study, which reveals insignificant estimated coefficients due to ulticollinearity, does not drop the variables to provide unbiased measures of technical efficiency.

there exists potential for increasing the yields at the existing level of resources and technology. From the production function estimates, γ for these two samples are estimated at 0.99 and 0.89 respectively, so that the shortfall of realized output from the frontier is largely due to technical inefficiency.

The estimates of technical inefficiency ranges from 0.01-0.96 in the aus and 0.03-0.94 in the aman season, respectively. Nearly half of the farmers (58% in the aus and 49% in the aman season) are found to be more than 80% technically efficient (Table 6).

With regard to high-yielding variety of paddy, farmers are found to be 73% and 64% technically efficient in the aman and boro season respectively (Table 3). This again indicates considerable scope for increasing yields using the given level of inputs, since the farmers are operating 27-36% below their respective frontiers. The value of γ is estimated at 0.99 and 0.84 respectively, implying that most of the total variation in output from the frontier is due to technical inefficiency.

Technical inefficiency ranges from 0.02-0.97 in the aman and 0.07-0.87 in the boro season, respectively. While around 52% of the farmers in the aman season lie in the range of technical efficiency greater than 80%, only 24% of the farmers are more than 80% technically efficient in the boro season (Table 6).

Thus, seasonal variations in technical efficiencies are more apparent in high-yielding variety. In contrast to the aman season, the average technical efficiency and the percentage of farmers who are more than 80% technically efficient are much lower in the boro season. This suggests that the farmers cultivating HYV are more efficient in the aman season.

Across seasons- West Bengal, 1990/91:

For 1990/91 as well, the samples show a large range of inefficiency across seasons for local as well as high-yielding varieties of paddy. In particular, farmers are found to be 68% and 77% technically efficient under local variety of paddy in the aus and aman season, respectively, implying a great potential to raise the yields at the existing level of resources and technology (Table 4). The ratio of total variance explained by systematic variance (γ) are calculated as 0.99 and 0.59, respectively. This indicates that while most of the total variation in output from the frontier is attributed to technical inefficiency in aus season, only 59% of the total variation in output is due to technical inefficiency in aman season and the remaining 41% is due to random error (i.e., the symmetric error component v_i).

Technical inefficiency ranges from 0.01-0.97 in the aus and 0.07-0.64 in the aman season. Around 46-51% of the farmers have technical efficiency higher than 80% in these seasons (Table 7).

In the case of high-yielding variety of paddy, the estimates of mean technical efficiencies are computed as 78% and 80% in the aman and boro season respectively (Table 4). However, there still exists potential for further increasing yields using the given level of resources. The value of γ is estimated at 0.81 and 0.99 for aman and boro crop respectively, so that most of the total variation in output from the frontier is attributed to technical inefficiency. The one-sided error u_i dominates the symmetric error v_i and the shortfall of realized output from the frontier is largely due to technical inefficiency.

The range of technical efficiency is from 0.04-0.87 in the aman and 0.003-0.76 in the boro season, respectively. In the aman season, 62% of the farmers in the sample are found to be more than 80% technically efficient. Boro farmers are more efficient than their aman counterparts since more than 70% of the farmers have technical efficiency higher than 80% (Table 7).

Thus, it is evident that there is considerable seasonal variation in technical efficiency, for both local and high-yielding variety in 1990/91. For the local variety of paddy, farmers are operating more efficiently in the aman season and for the high-yielding variety, farmers are more efficient in the boro season.

Across local and high-yielding varieties of paddy - West Bengal:

The estimates of average technical efficiency across local and high-yielding varieties are not very different. In 1986/87, farms cultivating local and high-yielding varieties are about 76% and 73% technically efficient in the aman season. Similarly, in 1990/91, farmers are found to be 77% and 78% technically efficient in local and high-yielding variety of aman paddy, respectively. Although technical efficiency gap exists for both local as well as HYV aman paddy in both years, the efficiency difference across seed varieties is small. However, a higher percentage of farmers (52% in 1986/87 and 62% in 1990/91) are over 80% technically efficient under aman HYV than under aman local variety.

The rank correlations of technical efficiency are found to be high (0.8 in 1986/87 and 0.6 in 1990/91) for HYV across seasons in both 1986/87 and 1990/91. This is to be expected, as the adoption of these new varieties is accompanied by a set of crop practices, which contribute to increasing technical efficiency.

In contrast, for local variety, the rank correlations of technical efficiency across seasons are found to be low (-0.05 in 1986/87 and –0.04 in 1990/91). This is also not entirely unexpected: farmers cultivating local variety may be relatively more cash-constrained, a constraint that may be more binding in one season than in another. For the most part, these farmers are not the same as those cultivating HYV's across seasons. This impact of a credit constraint may be to adversely affect the timing of operations accounting for the implied seasonal differential in technical efficiency.

There is however a subset of farmers who cultivate both local and high-yielding variety in the aman season. For these farmers, and for both years, there is the expected high (0.7-0.8) degree of association between technical efficiency of farmers across local and high-yielding variety.

Across time- West Bengal:

The results on average technical efficiency also highlight considerable improvement over time. In particular, the farmers cultivating high-yielding variety of aman and boro paddy are respectively found to be 78% and 80% technically efficient in 1990/91, as compared to 73% and 64% technical efficiency in 1986/87. This indicates that the farmers in 1990/91 operate more closer to their respective frontier production function than do their 1986/87 counterparts with respect to their frontier production function. In addition, in 1990/91, a higher percentage of farmers cultivating HYV (62% in aman and 70% in boro season) are more than 80% technically efficient as compared to 1986/87 (52% in aman and 24% in boro season). Thus, over the five year period (1986/87 – 1990/91), the average technical efficiency and the percentage of farmers who are more than 80% technically efficient have increased substantially (especially under HYV). Note that a similar comparison across time is not possible for Orissa since the data is available only for one year, i.e. 1990/91.

Across local and high-yielding variety- Orissa, 1990/91:

The estimates of average technical efficiencies for local and high-yielding varieties of paddy in kharif season are found to be 76% and 78% respectively (Table 5). This reveals considerable inefficiency relative to their respective frontiers implying that there exists great potential to increase the output of paddy using the existing level of resources without any additional cost. The value of γ is estimated at 0.61 and 0.68, implying that 61% and 68% of the total variation in output from the frontier is attributed to technical inefficiency and only 39% and 32% is due to random error (i.e., weather conditions, plant disease, etc.).

Technical efficiency ranges from 0.07-0.79 under local variety and 0.05-0.78 under HYV. Around 44-53% of the farmers are found to be more than 80% technically efficient (Table 8). Although average technical efficiency difference across seed varieties is not so apparent, but a higher percentage of farmers (i.e., 53%) are more than 80% technically efficient under HYV. This is also evident from a high rank correlation (0.62), which suggests a high degree of association between technical efficiency of farmers across seed varieties.

Across States:

The results reveal that difference in average technical efficiency between West Bengal and Orissa is not so apparent. For local variety, farmers are found to be around 76% technically efficient in both West Bengal and Orissa. Farmers cultivating HYV are around 78% technically efficient in West Bengal and Orissa.

4. CHANGES IN PRODUCTION TECHNOLOGY

The output elasticities as obtained from the estimated coefficients of the production frontiers[13] have changed over time, suggesting a change in production technology over time across local and high-yielding varieties of paddy.

Table 9 suggests that in contrast to the aus local variety in 1986/87 and 1990/91, the output is more responsive to fertilizer in the aman season, since the elasticity of output with respect to fertilizer is higher. In the case of high-yielding variety of paddy, output is more responsive to fertilizer in the boro season, as compared to the aman season.

Across seed varieties, output is more responsive to fertilizer under high-yielding variety than its local variety counterpart. In 1986/87, aman HYV fertilizer elasticity of 0.31 is higher than that of aman local variety, which is only 0.05. A similar difference obtains in 1990/91.This is also observed for Orissa. Moreover, across states, output is found to be more responsive to fertilizer in West Bengal than in Orissa for both local and high-yielding varieties of paddy.

In West Bengal, the output elasticities with respect to inputs as obtained from the maximum likelihood estimates of the frontier production functions have changed significantly over time. The fertilizer elasticity shows a sharp decline over time, indicating that output has become less responsive to fertilizer use. Since elasticity estimates are indicative of changes in the marginal productivity of inputs, this may suggest a decline in fertilizer productivity over time, which can be attributed to poor irrigation management in this region as suggested by Kumar and Rosegrant (1994). However, it should be noted that a decrease in fertilizer elasticity might not necessarily imply a decline in fertilizer productivity. For example, if relatively inferior land has been brought under cultivation over time, fertilizer elasticity may decline but that is probably due to decrease in land productivity. With regard to other inputs, such as seed, human labour and non-human labour, elasticity estimates do not show significant change across season for local as well as HYV. However, over time, the responsiveness of output with respect to human labour has increased substantially. The increased labour productivity is mainly the result of increased mechanization.

Since studying the change in production technology for all the inputs is not manageable; we have examined the shifts in production frontiers by focussing on fertilizer, which is one of the major inputs in paddy cultivation. The fertilizer response curves, y= g (F), are examined for both years using estimated functions, holding all inputs other than fertilizer at their 1986/87 mean levels[14].

An upward shift in the fertilizer response curve is observed for the high-yielding variety of boro paddy. This is evident from Fig. 1, which portrays a higher fertilizer response curve for boro HYV rice in 1990/91 relative to 1986/87. In addition, the production function estimates of input coefficients show a uniform increase in 1990/91. This suggests that production technology for boro HYV has improved in 1990/91. The upward shift in the fertilizer response curve over time is not a contradiction to the declining fertilizer elasticity. This is so because fertilizer elasticity, which is calculated at the mean levels of all inputs including fertilizer, presents only a partial picture because it measures the changes in output

---

[13] The maximum likelihood estimates of the production frontier coefficients are presented in Appendix 3-5.

[14] y = g(F), holding other inputs at their mean levels

where, y = crop output per hectare

F = quantity of fertilizers per hectare

For Translog production technology,

$g(F)= \alpha_1 + \beta_1'(\ln F) + \beta_2(\ln F)^2$

where,

$\alpha_1 = \alpha_o + \Sigma_i\alpha_i(\ln x_i) + \Sigma_i\Sigma_j\alpha_{ij}(\ln x_i)(\ln x_j)$

$\beta_1' = \beta_1 + \Sigma_i\beta_i(\ln x_i)$

For Cobb-Douglas production technology,

$g(F) = \alpha_1 + \beta_1(\ln F)$

where,

$\alpha_1 = \alpha_o + \Sigma_i\alpha_i(\ln x_{Ii})$.

at the mean levels of fertilizer use. Moreover, fertilizer response curves corresponding to 1990/91 are flatter than that of 1986/87.

With regard to aman HYV, the fertilizer response curves are intersecting. The fertilizer response curve for 1990/91 lies above that of 1986/87 for levels below 60 kilogram nutrients per hectare. Beyond that level, the curve for 1986/87 tends to lie above that of 1990/91. Even at the average level of fertilizer use (i.e., 100 kilogram nutrients) fertilizer response curve for 1986/87 lies above that of 1990/91. This suggests that there may have been a deterioration in production technology in 1990/91 with respect to aman HYV, an aspect that may be the subject to future research.

An upward shift in the fertilizer response curve is also observed over time, for both aus and aman local variety paddy. This is evident from Fig.1, which displays the fertilizer response curve for 1990/91 lying above that of 1986/87. The upward shift in the fertilizer response curve along with the higher estimated values of the input coefficients of the production function indicate that the farmers cultivating local variety of paddy are operating relative to a higher level of technology in 1990/91. Assuming weather is not a major factor influencing output, local variety has thus seen a shift in production frontier over time. This suggests that even though local variety is associated with lower yields, it is not a stagnant technology.

Moreover, the fertilizer reponse curves suggest seasonal variations in the state of production technology. Across seasons, boro HYV and aman local variety perform better than their aman and aus counterpart in 1986/87 and 1990/91, respectively. The improved production technology for boro HYV paddy supports the growing significance of boro crop. Over time, the proportion of total rice produced in the boro season doubled during the 1980's. As boro has always been an irrigated crop based on HYV's of seed, yields have always been relatively high (Rawal and Swaminathan, 1998). The average level of input use and output per hectare in the boro season are relatively higher.

Thus, we can infer that boro HYV's performance has improved substantially over time. This can also be studied by doing a simple decomposition exercise showing changes in the output per hectare due to increase in input use (i.e, holding technology constant) and change in technology (i.e., the increase in output at the average level of input use). The increase in the output per hectare between 1986/87 and 1990/91 calculated at the 1990/91 average level of fertilizer use is 140 quintals per hectare. But the increase in the output per hectare between 1986/87 and 1990/91 when calculated at their respective years mean levels of fertilizer use is 80 quintals per hectare. This suggests that the change in technology dominates the increase in input use in the output growth. In other words, output growth under boro HYV has been mainly due to improved production technology rather than increased input use. Therefore, with respect to HYV, boro paddy shows substantial productivity improvements over time.

Although aman HYV's performance is not as dramatic as that of boro HYV, improvements in efficiency and technology are apparent in the local variety of aman. In contrast to the boro crop, aman crop is sensitive to both weather fluctuations and agroclimatic specificities. It is grown under more uncontrolled production environment. Aman paddy is largely rainfed and lack of assured irrigation is perhaps the most important factor contributing to the general production uncertainity in this season. As a result, HYV may fail to perform well as compared to the local variety. Thus, with regard to local variety, aman paddy continues to be the most important crop with substantial productivity improvements.

Moreover, Fig.1 displays a higher fertilizer response curve for West Bengal as compared to Orissa, for local as well as high-yielding varieties in 1990/91. This indicates that the state of production technology is more advanced in West Bengal. Thus in 1990/91, West Bengal farmers are operating with respect to a higher production frontier as compared to Orissa farmers.

Thus, West Bengal has seen a remarkable improvement in the state of production technology over the five year period (1986/87 – 1990/91). This clearly highlights the significant contribution of technological change in the productivity growth realized in this state. In addition, this technological change has been complemented by improved technical efficiency of farmers over time. Therefore, over the five-year period, the farmers have not only moved more closer to their frontier, but they are now operating with respect to a higher frontier or production technology. Across states, technical efficiency differences are not so apparent for both local and HYV. However, the state of production technology is more advanced in West Bengal than in Orissa in the year 1990/91. This indicates that the better performance of West Bengal in contrast to Orissa, is primarily because of the more advanced state of technology.

5. CONCLUSIONS

The overall picture that emerges from this analysis is that input productivity has indeed played an important role in the growth performance in the 1980's and early 1990's in this region. While growth in inputs and total factor productivity have contributed significantly to the output growth in both the states, performance of West Bengal has been better than Orissa. This improvement in input productivity in West Bengal has been brought about both by efficiency and technology in the presence of variations across seasons and seed varieties. Improvements in production technology are apparent between 1986/87 and 1990/91. Although use of inputs and technical efficiency increased over time, it has not been as dramatic as the improvement in the state of technology. Improvements in production technology between 1986 and 1990 are most evident in boro paddy. This clearly indicates the significant contribution of technological change to the productivity growth realized in West Bengal. Over time, the farmers in this state have not only moved more closer to their frontier (which has possibly been ensured by various socio-economic factors such as extension efforts, improved farmer education, etc.), but are operating with respect to a higher frontier or production technology (through invention of new ploughs, fertilizers, pesticides, new varieties of seeds, etc.). Across states comparisons for the year 1990/91 do not reflect much difference in technical efficiency. However, the state of production technology is more advanced in West Bengal than in Orissa in that year. This clearly indicates that the better performance in terms of input productivity achieved in West Bengal is primarily because of the more advanced state of production technology.

A notable feature of West Bengal's success story is that this productivity growth was preceded by a series of institutional reforms. Limited redistribution of surplus land to the poor and small farmers, strengthening of the rights of the tenants and successful implementation of the Panchayat system at the grass roots level, are some of the changes that marked a clear shift in the agrarian policy in West Bengal during the late seventies and early eighties. Panchayats were involved in various development activities such as planning of tubewell development at the local level, management of minor irrigation schemes, agricultural extension work, etc. New tenancy laws created new incentives for land improvement and technological change. These institutional changes may have facilitated the technological change in this state. However, no such distinct policy shift was visible in Orissa.

Thus, improvements in productivity, both through efficiency and technology, have been and will continue to be critical to agricultural growth in these states. Orissa, which is characterized by similar agroclimatic conditions, has the potential to replicate West Bengal's performance. The extent to which institutional constraints preclude the realization of this potential is a subject for further research.

Table 1:
Average Annual Rate of Growth in Total Input, Output and TFP in Paddy

(percent)

State	Total input index	Total output index	Total factor productivity index
West-Bengal (1971/72-1991/92)	2.42	4.27	1.75
Orissa (1971/72-1992/93)	1.11	2.70	1.50

Table 2:
Average Annual Rate of Growth in Total Input, Output and TFP in Paddy before and after Structural Change

(percent)

State	Total input index		Total output index		TFP index	
	Before	After	Before	After	Before	After
West Bengal (Structural change in 1978/79-Operation Barga)	1.87	2.80	-1.40	6.22	-3.17	3.40
West Bengal (structural change in 1983/84, reported by Saha and Swaminathan)	1.33	5.42	-2.01	7.96	-3.34	2.70
West Bengal (structural change in 1989/90, reported by Gangal)	1.40	9.08	1.15	14.20	-0.25	5.12
Orissa (structural change in 1983/84, reported by Gangal)	0.60	1.86	-1.01	6.30	-1.60	4.40

Table 3:
Estimates of Average Technical Inefficiency, West Bengal, 1986/87, Paddy

	Aus- Local variety	Aman - Local variety	Aman -High-yielding variety	Boro- High-yielding variety
σ_u^2	0.08850	0.08903	0.11777	0.20906
σ_v^2	0.00001	0.00588	0.00026	0.02203
Technical inefficiency Average Range	0.24 0.01-0.96	0.24 0.03-0.94	0.27 0.02-0.97	0.37 0.07-0.87
γ	0.99	0.89	0.99	0.84

γ : variance ratio : σ_u^2 / σ^2 : indicator of the influence of the inefficiency component in the overall variance.

Table 4:
Estimates of Average Technical Inefficiency, West Bengal, 1990/91, Paddy

	Aus- Local variety	Aman - Local variety	Aman -High-yielding variety	Boro- High-yielding variety
σ_u^2	0.16096	0.08032	0.07470	0.06141
σ_v^2	0.00028	0.03203	0.00987	0.1E-07
Technical inefficiency Average Range	0.32 0.01-0.97	0.23 0.07-0.64	0.22 0.04-0.87	0.19 0.003-0.76
γ	0.99	0.59	0.81	0.99

γ : variance ratio : σ_u^2 / σ^2 : indicator of the influence of the inefficiency component in the overall variance.

Table 5:
Estimates of Average Technical Inefficiency, Orissa, 1990/91, Paddy

	Kharif- Local variety	Kharif -High-yielding variety
σ_u^2	0.09295	0.07486
σ_v^2	0.03315	0.01986
Technical inefficiency Average Range	0.24 0.07-0.79	0.22 0.05-0.78
γ	0.61	0.68

γ : variance ratio : σ_u^2 / σ^2 : indicator of the influence of the inefficiency component in the overall variance.

Table 6:
Frequency Distributions of Farm-Specific Technical Efficiency in West Bengal, 1986/87

Percentage efficiency	Aus- Local variety		Aman- Local variety		Aman- High-yielding variety		Boro- High-yielding variety	
	Number of farmers	% age of farmers	Number of farmers	% age of farmers	Number of farmers	% age of farmers	Number of farmers	% age of farmers
0-10	1	1.25	1	0.50	1	1.30	0	0.00
11-20	1	1.25	0	0.00	1	1.30	1	1.10
21-30	2	2.50	2	0.90	3	3.90	0	0.00
31-40	2	2.50	4	1.90	0	0.00	3	3.30
41-50	1	1.25	11	5.40	8	10.40	9	9.90
51-60	8	10.00	15	7.40	6	7.80	13	14.30
61-70	6	7.50	30	14.60	11	14.30	19	20.90
71-80	13	16.25	41	20.00	7	9.10	24	26.30
81-90	16	20.00	54	26.40	15	19.50	19	20.90
91-100	30	37.50	47	22.90	25	32.40	3	3.30
Total	80	100.00	205	100.00	77	100.00	91	100.00

Table 7:
Frequency Distributions of Farm-Specific Technical Efficiency in West Bengal, 1990/91

Percentage efficiency	Aus- Local variety		Aman- Local variety		Aman- High-yielding variety		Boro- High-yielding variety	
	Number of farmers	% age of farmers	Number of farmers	% age of farmers	Number of farmers	% age of farmers	Number of farmers	% age of farmers
0-10	6	6.90	0	0.00	0	0.00	0	0.00
11-20	2	2.30	0	0.00	1	0.80	0	0.00
21-30	1	1.10	0	0.00	0	0.00	1	1.30
31-40	4	4.60	1	0.50	1	0.80	1	1.30
41-50	5	5.70	8	3.60	3	2.40	5	6.50
51-60	8	9.20	12	5.50	13	10.20	4	5.20
61-70	7	8.10	30	13.60	9	7.10	5	6.50
71-80	14	16.10	56	25.50	21	16.50	6	7.80
81-90	10	11.50	92	41.80	57	44.90	16	20.80
91-100	30	34.50	21	9.50	22	17.30	39	50.60
Total	87	100.00	220	100.00	127	100.00	77	100.00

Table 8:
Frequency Distributions of Farm-Specific Technical Efficiency in Orissa, 1990/91

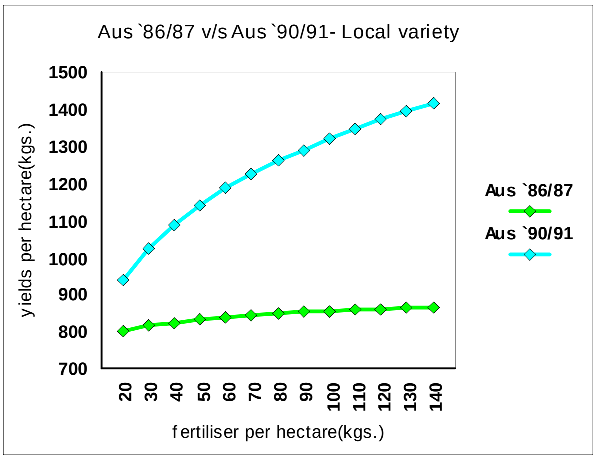
Percentage efficiency	Kharif- Local variety		Kharif- High-yielding variety	
	Number of farmers	% age of farmers	Number of farmers	% age of farmers
0-10	0	0.00	0	0.00
11-20	0	0.00	0	0.00
21-30	1	0.50	2	0.80
31-40	5	2.30	4	1.50
41-50	4	1.80	5	1.90
51-60	17	7.70	13	5.10
61-70	24	10.90	31	12.10
71-80	71	32.30	66	25.70
81-90	79	35.90	97	37.70
91-100	19	8.60	39	15.20
Total	220	100.00	257	100.00

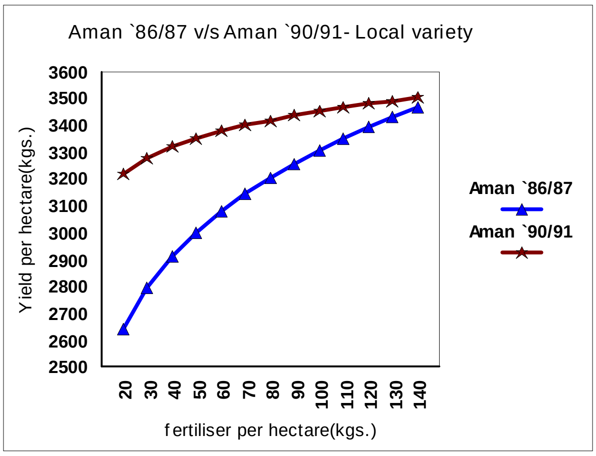
Table 9:
Elasticity of Output with respect to Inputs, Paddy

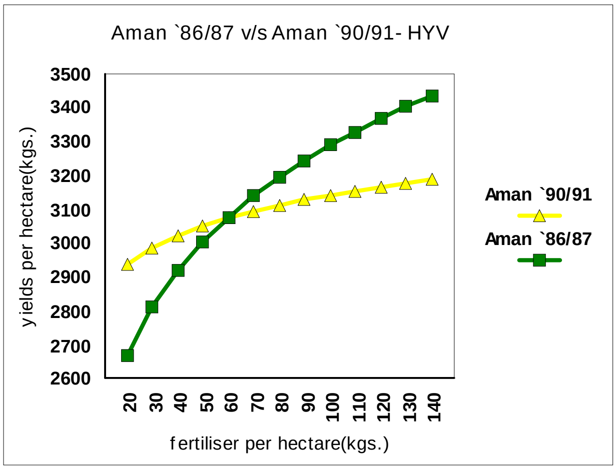
Elasticity of output with respect to	WB`86/87 Aus LV	WB`86/87 Aman LV	WB`86/87 Aman HYV	WB`86/87 Boro HYV	WB`90/91 Aus LV	WB`90/91 Aman LV	WB`90/91 Aman HYV	WB`90/91 Boro HYV	OR`90/91 Kharif LV	OR`9 Kha HY
Fertilizer	0.251	0.092	0.311	0.310	0.006	0.050	0.133	0.231	0.002	0.1
Hired labour	0.047	0.011	0.158	0.002	0.027	0.021	0.008	0.049	0.053	0.0
Family labour	0.098	0.001	0.049	0.029	0.126	0.027	0.025	0.015	0.248	0.0
Non-human labour	-0.003	0.027	0.006	-0.013	-0.056	0.083	0.007	-0.017	-0.241	-0.0
Seed	0.237	0.250	0.002	0.234	0.938	0.006	0.048	0.643	0.205	0.0
Manure	-0.066	0.048	0.153	0.049	0.103	0.039	0.045	-0.014	-0.269	-0.0

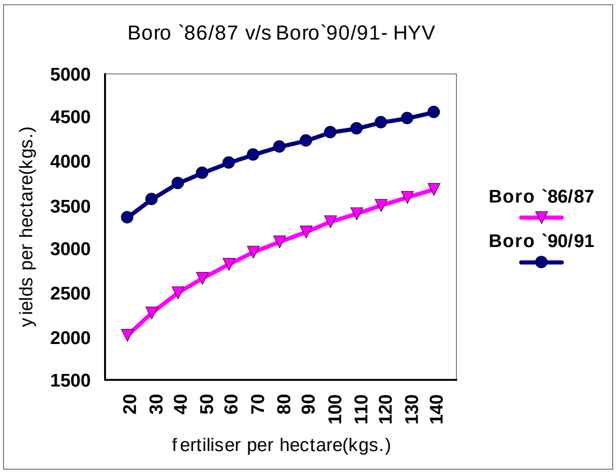
Source: Calculated from the *Farm-level data on Cost of Cultivation*, Directorate of Economics and Statistics, Ministry of Agriculture.
WB: West Bengal
OR: Orissa
LV: Local variety
HYV: High-yielding variety

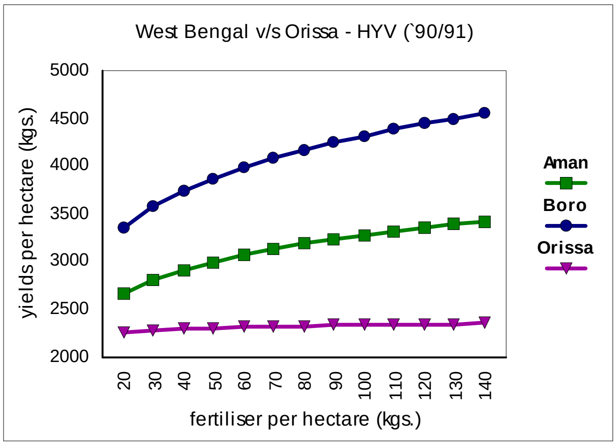
Fig. 1: Fertilizer Response Curves

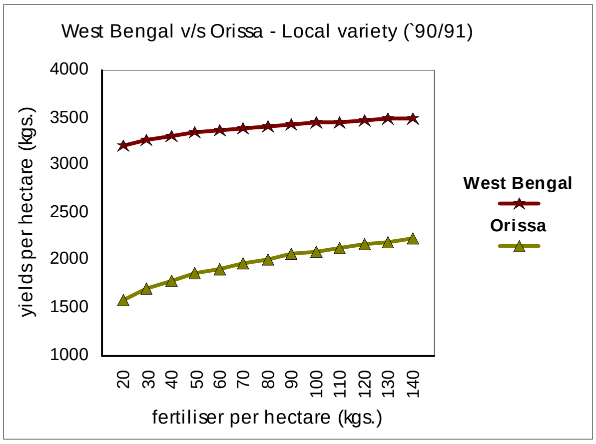












REFERENCES

Aigner, D.; Lovell, C.A.K.; Schmidt, P. (1977), "Formulation and Estimation of Stochastic Frontier Production Function Models", *Journal of Econometrics*, 6, 21-37.

Battese, G.E.; Coelli, T.J. and Colby, T.C. (1989), "Estimation of Frontier Production Functions and the Efficiencies of Indian Farms using Panel Data from ICRISAT's Village Level Studies", *Journal of Quantitative Economics*, 5, 327-348.

Battese,G.E. and Coelli,T.J. (1995), "A Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data", *Empirical Economics*.

Boyce, K.J. (1987), "*Agrarian Impasse in Bengal : Institutional Constraints to Technical Change*", Oxford University Press.

Caves, D.O. ; Christensen, L. and Diewert,W.E. (1982), "The Economic Theory of Index Numbers and the Measurement of Input, Output and Productivity", *Econometrica*, 50.

Dawson, P.J. and Lingard, J. (1989), "Measuring Farm Efficiency overtime on Philippine Rice Farms", *Journal of Agricultural Economics*, 40, 168-177.

Gangal, Namita (1998), "Analysis of Agricultural Growth Performance of Eastern Indian region in the Eighties", *MPhil Thesis, Delhi School of Economics, Delhi*.

Government of India, Ministry of Agriculture, Directorate of Economics and Statistics, *Area and Production of Principal Crops in India*, various volumes.

Government of India, Ministry of Agriculture, Directorate of Economics and Statistics, *Cost of Cultivation of Principal Crops in India*, 1991 and 1996.

Government of India, Ministry of Agriculture, Directorate of Economics and Statistics, *Report of Commission on Agricultural Costs and Prices*, various volumes.

Jondrow, J.; Lovell, C.A.K.; Materov, I.V.; Schmidt, P. (1982), "On Estimation of Technical Inefficiency using the Stochastic Frontier Production Function Model", *Journal of Econometrics*, 19, 233-238.

Kalirajan, K.P. and Shand, R.T. (1989), "A Generalized Measure of Technical Efficiency", *Applied Economics*, 21, 225-234.

Krishna, K.L. and Sahota, G.S. (1991), "Technical Efficiency in Bangladesh Manufacturing Industries", *Bangladesh Development Studies*, 19, 89-105.

Kumar, Praduman and Rosegrant, M.W. (1994), "Agricultural Productivity and Sources of Growth for Rice in India", *Economic and Political Weekly*, Dec.31, A183-A188.

Meeusen, V. and Broeck, J. (1977), "Efficiency Estimation from Cobb-Douglas Production Function with Composed Errors", *International Economic Review*, 18, 435-444.

Mukherjee, B. and Mukhopadhyay, S., "Impact of Institutional Change in Productivity in a Small-Farm Economy: The Case of Rural West Bengal", in A.Raychaudhuri and D.Sarkar (1996), eds., *Economy of West Bengal: Problems and Prospects*, Allied Publishers Ltd.

Pillai, Renuka (1999), "An Analysis of Productivity Growth and Technical Efficiency in Paddy Cultivation in Eastern India", *MPhil Thesis, Delhi School of Economics, Delhi*.

Rawal,V. and Swaminathan, M. (1998), "Changing Trajectories: Agricultural Growth in West Bengal,1950 to 1996", *Economic and Political Weekly*, Oct.3, 2595-2602.

Raychaudhuri, A. and Sarkar, D. (1996), *Economy of West Bengal: Problems and Prospects*, Allied Publishers Ltd.

Raychaudhuri, A. and Sen, A.K., "Agricultural Reform and Productivity: Some Important Lessons to be Learnt from West Bengal's Operation Barga", in A.Raychaudhuri and D.Sarkar (1996), eds., *Economy of West Bengal: Problems and Prospects*, Allied Publishers Ltd.

Reserve Bank of India (1984), *Report of the Committee on Agricultural Productivity in Eastern India*, Vol. 1and 2.

Saha, A. and Swaminathan, M. (1994), "Agricultural Growth in West Bengal in 1980's: Disaggregation by Districts and Crops", *Economic and Political Weekly*, Mar.26, A2-A11.

Sanyal, M.K.; Biswas, P.K. and Bardhan, S. (1998), "Institutional Change and Output Growth in West Bengal Agriculture: End of Impasse", *Economic and Political Weekly*, Nov.21, 2979-2986.

Weinstein, M.A. (1964), "The Sum of Values from a Normal and a Truncated Normal Distribution", *Technometrics*, 6, 104-105 (with some additional material, 469-470).

APPENDIX 1:

Year to Year Growth Rates of Total Output, Input and TFP Indices, West Bengal, 1971-1991, Paddy

Year	TII_t	TOI_t	TFP_t
1972/73	1.263	-0.784	-2.027
1973/74	-12.503	-5.826	-18.329
1974/75	3.345	-18.691	-22.036
1975/76	13.948	-3.064	-17.012
1976/77	3.186	24.239	20.403
1977/78	1.971	-8.535	-10.303
1978/79	2.961	8.716	5.589
1979/80	-9.378	-3.109	6.917
1980/81	0.111	6.3615	6.251
1981/82	15.579	4.370	-11.209
1982/83	-5.744	-7.974	-2.366
1983/84	5.861	41.645	35.784
1984/85	-2.355	-4.517	-2.215
1989/90	5.227	1.173	-3.853
1991/92	12.925	27.233	14.308

APPENDIX 2:

Year to Year Growth Rates of Total Output, Input and TFP Indices, Orissa, 1971-1992, Paddy

Year	TII_t	TOI_t	TFP_t
1972/73	-0.464	-1.075	-0.611
1973/74	-4.487	-20.931	-17.217
1974/75	3.706	7.729	3.879
1975/76	7.516	-13.349	-19.407
1976/77	1.947	30.259	28.312
1977/78	-0.674	-9.397	-8.781
1978/79	-10.544	-11.223	-0.758
1979/80	8.121	32.422	24.301
1980/81	3.167	-9.748	-12.518
1981/82	-2.198	-12.256	-10.284
1982/83	0.558	14.517	13.881
1983/84	5.183	26.817	20.567
1984/85	0.865	-16.690	-17.405
1986/87	3.528	-5.178	-80.409
1990/91	4.253	30.259	26.006
1991/92	-0.618	15.335	16.053
1992/93	-2.054	-12.792	-10.963

APPENDIX 3:
Maximum Likelihood Estimates for the Stochastic Frontier Production Function, West Bengal, 1986/87, Paddy

(Dependent variable: log crop output per hectare)

Variable	Aus- Local variety	Aman- Local variety	Aman- High-yielding variety	Boro- High-yielding variety[a]
α_O	-3.6949	3.3168**	-2.9672	5.2904**
α_{HL}	0.2694	0.4147	5.2115**	0.0021
α_{FL}	3.1787**	0.3265	1.7301	0.0289
α_{NL}	-3.0872**	-0.8092*	3.1821	-0.0131
α_F	-1.4359	-0.001	-0.7824	0.3102**
α_S	2.1722	-0.9479	-2.292	0.2340
α_M	2.5394*	0.7972**	-0.7002	0.0493
$\beta_{HLHL}/2$	-0.1146	-0.0105	-0.5061*	
$\beta_{FLFL}/2$	-0.0173	0.0266	-0.0171	
$\beta_{NLNL}/2$	0.0661	-0.0134	-0.1841	
$\beta_{FF}/2$	0.1394	0.1163**	0.1169	
$\beta_{SS}/2$	0.2289	0.4265**	0.0188	
$\beta_{MM}/2$	-0.1078	-0.0681	0.05	
β_{HLFL}	0.0144	0.0111	-0.21**	
β_{HLNL}	0.0584	0.0043	-0.4359	
β_{HLF}	0.2115*	-0.0174	0.1292	
β_{HLS}	-0.1315	-0.088	0.3123	
β_{HLM}	-0.0247	-0.0081	0.0026	
β_{NLFL}	-0.0796	-0.0241	-0.0834	
β_{NLF}	-0.0565	0.0291	0.0587	
β_{NLS}	0.6782**	0.2047**	0.1348	
β_{NLM}	0.0288	0.00945	0.1128	
β_{FFL}	0.1213	0.0105	0.0758	
β_{FS}	-0.2327	-0.0781	-0.1831	
β_{FM}	0.0419	-0.0225	-0.1178	
β_{SFL}	-0.6132**	-0.1045**	-0.0338	
β_{SM}	-0.3954	-0.0996	0.0964	
β_{MFL}	-0.1086	0.0002	0.0268	
Log Likelihood value	38.4736	63.9449	51.4666	-18.1626
No. of observations	80	205	77	91

** indicates significance at 5% level of significance
* indicates significance at 10% level of significance
[a] : model (Cobb Douglas): hired labour, family labour, non-human labour, fertilizers, seed and manure
HL: Hired labour, FL: Family labour, NL: Non-human labour, F: Fertilizer, S: Seed, M: Manure.

APPENDIX 4:
Maximum Likelihood Estimates for the Stochastic Frontier Production Function,
West Bengal, 1990/91, Paddy

(Dependent variable: log crop output per hectare)

Variable	Aus- Local variety	Aman- Local variety	Aman- High-yielding variety[a]	Boro- High-yielding variety
α_O	3.1805	3.7277**	6.9208**	-28.5803**
α_{HL}	-0.0765	0.5586	-0.0083	-0.2549
α_{FL}	0.306	-0.0183	0.0251	0.1096
α_{NL}	-1.638	-0.5008	0.0070	0.5447
α_F	-0.2989	0.1996	0.1335**	2.7269
α_S	-8.5989	-5.5479**	0.0480*	12.653*
α_M	0.6367	0.3123	0.0454**	2.0543
$\beta_{HLHL}/2$	-0.1756	-0.0033		0.0031
$\beta_{FLFL}/2$	-0.0496	-0.0018		-0.0581
$\beta_{NLNL}/2$	-0.0908	0.1007		-0.0148
$\beta_{FF}/2$	-0.169**	0.0013		0.1416
$\beta_{SS}/2$	1.8438	1.4347**		-0.8136
$\beta_{MM}/2$	0.1952	0.057**		-0.1071
β_{HLFL}	-0.0837	0.0261		-0.0263
β_{HLNL}	0.1919	-0.0274		-0.0108
β_{HLF}	-0.0939	0.0106		-0.0335
β_{HLS}	0.2199	-0.1184		0.1876
β_{HLM}	-0.0336	-0.0315		-0.0366
β_{NLFL}	0.0709	-0.0295		0.0937
β_{NLF}	0.1538	0.0286		0.0419
β_{NLS}	-0.0691	0.0448		-0.2336
β_{NLM}	0.1018	0.0265		-0.046
β_{FFL}	-0.1145	-0.0205		0.1139
β_{FS}	0.1029	-0.0206		-1.0546*
β_{FM}	0.2495**	-0.0547**		-0.086
β_{SFL}	0.2348	0.0212		-0.2342
β_{SM}	-0.3819	-0.0364		-0.2616
β_{MFL}	-0.1384	-0.0053		0.0757
Log Likelihood value	12.4246	14.3308	33.9754	51.4816
No. of observations	87	220	127	77

** indicates significance at 5% level of significance
* indicates significance at 10% level of significance
[a] : model (Cobb Douglas): hired labour, family labour, non-human labour, fertilizers, seed and manure
HL: Hired labour, FL: Family labour, NL: Non-human labour, F: Fertilizer, S: Seed, M: Manure.

APPENDIX 5:
Maximum Likelihood Estimates for the Stochastic Frontier Production Function,
Orissa, 1990/91, Paddy

(Dependent variable: log crop output per hectare)

Variable	Kharif- Local variety	Kharif- High-yielding variety
α_O	13.0176**	15.133**
α_{HL}	0.1179	0.3842
α_{FL}	0.7576	0.4117
α_{NL}	-0.1921	-1.4692
α_F	-0.9817	-0.9717
α_S	-4.356	-6.4738**
α_M	-0.4524	0.0944
$\beta_{HLHL}/2$	-0.1668	0.0503
$\beta_{FLFL}/2$	0.0024	-0.0119
$\beta_{NLNL}/2$	0.2071	0.1022
$\beta_{FF}/2$	0.1662**	0.1747**
$\beta_{SS}/2$	0.9137	0.9229
$\beta_{MM}/2$	-0.1711	-0.3106**
β_{HLFL}	0.0033	0.0711
β_{HLNL}	-0.0307	-0.0947
β_{HLF}	0.0169	-0.0172
β_{HLS}	-0.1767	-0.1011
β_{HLM}	0.2819**	-0.0094
β_{NLFL}	-0.0689	-0.0533
β_{NLF}	-0.0154	0.0107
β_{NLS}	0.2404	0.3684
β_{NLM}	-0.4554**	0.0296
β_{FFL}	-0.0231	0.0375
β_{FS}	0.2579	0.2179
β_{FM}	-0.1598*	-0.2189**
β_{SFL}	-0.2377	-0.1736
β_{SM}	0.1859	0.3297
β_{MFL}	0.2452**	0.0329
Log Likelihood value	-12.3089	50.9647
No. of observations	220	257

** indicates significance at 5% level of significance
* indicates significance at 10% level of significance
HL: Hired labour, FL: Family labour, NL: Non-human labour, F: Fertilizer, S: Seed, M: Manure.

APPENDIX 6:
Average Levels of Yields and Input Use, Paddy

Input quantity per hectare	WB`86/87 Aus LV	WB`86/87 Aman LV	WB`86/87 Aman HYV	WB`86/87 Boro HYV	WB`90/91 Aus LV	WB`90/91 Aman LV	WB`90/91 Aman HYV	WB`90/91 Boro HYV	OR`90/91 Kharif LV	OR`90/91 Kharif HYV
Hired labour (man hrs.)	605.95	549.16	844.6	839.99	375.82	600.40	888.73	522.43	559.03	659.31
Family labour (man hrs.)	440.01	338.39	295.45	640.27	270.91	385.83	625.78	833.55	322.85	352.79
Non-human labour (hrs.)	269.64	247.97	268.54	469.23	181.31	244.52	350.44	662.35	289.11	318.33
Fertilizer (kg. Nutrients)	42.95	31.14	105.73	159.62	36.83	43.37	100.01	150.00	32.86	61.13
Seed (kgs.)	80.74	77.25	82.59	95.11	83.70	71.67	65.00	92.32	34.54	86.22
Manure (kgs.)	28.67	34.26	33.81	61.97	24.37	22.13	13.99	54.51	22.99	25.85
Yield (qtls. per hectare)	24.19	27.09	38.69	47.72	18.30	33.03	37.18	50.71	20.44	27.02
Number of observations	80	205	77	91	87	220	127	77	220	257

Source: Calculated from the *Farm-level data on Cost of Cultivation*, Directorate of Economics and Statistics, Ministry of Agriculture.
WB: West Bengal
OR: Orissa
LV: Local variety
HYV: High-yielding variety.