Extent of technological change in rice cultivation over four decades in West Bengal, India

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Abstract: Rice is a principal food crop which occupies nearly a one-fourth of the gross irrigated area in India. However, the present study attempts to judge the essence of the Green Revolution in rice cultivation and its actual reflection regarding the factor contribution over four decades in West Bengal, India. The study measures the extent of technological change in rice cultivation using the Divisia-Tornqvist Theil index model for computing the total factor productivity (TFP) of rice for the state of West Bengal. Subsequently, the spatial change in the TFP as well as a comparative study on productivity, input use, break-up of cost components and economic return in the paddy cultivation over different size classes across all agro-climatic zones of West Bengal has been made in order to identify the most promising zone regarding technological advancement in rice cultivation. The study reveals that technological change in rice cultivation has occurred in the state of West Bengal for the entire four decades while its extent has not been equally disseminated in decades. The effect of the productivity change was robust in the 2nd decade (1981–1982 to 1991–1992) with a 4.19% TFP growth rate indicating that the good effect of the Green Revolution has began to start regarding the technological change in rice cultivation over West Bengal. On the other hand, the TFP_{rice} results in the state have given a dismal picture in the later phases under study where it starts declining with the change of time. At the end decade (2001–2002 to 2009–2010), the TFP growth has been found to be negative (–0.69) reflecting ill effects of a higher use of inorganic fertilizers, insecticides and pesticides to corrupt the soil fertility status of the state. It is the quality HYV seed that dominates among all factor contributors for the overall TFP_{rice} change along with the human labour use. Farm mechanization enters after the 90s indicating a major reform in the context of the technology adoption by the rice growers in the state. The region-wise scenario of rice cultivation in the state has proved that the Gangetic Alluvial tract has been the better technology adopter with higher TFP indices as compared to the problematic regions like the Red Lateratic zone and the Coastal Saline belt, the reason of which might be the improved fertility status of soil with a large number of progressive paddy growers operating in terms of a better knowledge gaining, a better education and extension.

Key words: factor contributor, green revolution, HYV seed, spatial change, technological change, Total Factor Productivity (TFP)

Rice is a principal food crop, which occupies nearly one-fourth of the gross irrigated area in India. Majority of agricultural and food policy initiatives over the period were largely centred on rice and also wheat. However, the public sector Research and Development (R&D) wing has given a top priority to the rice improvement in terms of resource allocation of both capital and human resources (Adlas and Achoth 2006). The crop breeders have released nearly 650 varieties of rice over the past 35 years in India. The varieties released till mid 70s were largely of higher yields while the subsequent generations of those varieties were mainly either with the improved resistance to pests and diseases or with the grain quality (Janaiah and Hossain 2004). These improvements in the successive generations of the HYV seeds are expected to reflect in the productivity growth in three ways viz., lowering the cost of production, a higher market price per unit output, and lowering yield instability. However, a serious concern has been raised on the long run sustainability of the productivity effects of the Green Revolution technologies under the irrigated ecosystem due to the degradation of the natural resource-base. Many studies (Flinn and De Datta 1984; Nambiar 1988; Cassman and Pingali 1995; Greenlands 1997; Pingali et al. 1997; Dawe et al. 2000; Yadav et al. 2000; Kumar and Yadav 2001) reported that rice yields were either declining or stagnant after the 1980s under the intensive irrigated rice systems due to the various resource-degradation problems. Most of these studies were, however, largely based on experimental data designed with a specific objective under the controlled environments (fixed nutrient doses, variety, other management practices, etc.) in the research farms and adaptive research trials. These studies provide an impression that the productivity impact of technological progress has been vanishing in the irrigated systems. But, the yield trends of those HYVs from the 'controlled environment' may not be matched with those of the farmers' fields (real farm environment) because the farmers access and adopt new variety seeds, and adjust their farm practices over the period to cope up with the changing production and micro-policy environments. It is also essential to recognize the fact that the yield growth is not a true measure of the technology impact, as it does not divide the effect of the input growth from the output growth. Thus, the total factor productivity (TFP) growth is a correct measure of the productivity impact of the technical change (Evenson and Pray 1991). The ultimate goal of this research article is to provide empirical evidence to the effect of the Green Revolution on rice production in the state of West Bengal, India over last four decades. To evaluate these evidences, a temporal analysis of the total factor productivity measure has been incorporated in the entire study in order to judge the technological vision of the farming community regarding sustainable rice cultivation in the state of West Bengal, India.

To add further, the state West Bengal has a wide variation in the topography, the agro-climatic condition, the rhythm of precipitation along with irrigation on availability are the major sources of variation in rice production. At the same time, the socio-geographic characteristics, particularly the access to modern agricultural inputs including the availability of credit, information technology, communication, market roads etc. are equally important determinants of variation in agricultural production. Kannan (2011) while measuring the TFP growth and its determinants in Karnatakian agriculture, India has came to the conclusion that the government expenditure on research, education and extension, canal irrigation, rainfall and balanced use of fertilizers are the important drivers of crop productivity in Karnataka. It is necessary that both public and private investment should be enhanced in the agricultural research and technology, and the rural infrastructure for sustaining the productivity growth in the long run. How far these natural endowments along with other social determinants influence the total agricultural output, it needs to be assessed and verified at the micro-level temporal and spatial data (Chatterjee 2005).

Regional studies in the farm sector require an examining stability of production along with the stability in the yield of paddy. The stability of those variables results in food security among the farmers as well as in the state. On the other hand, the growth of a stable agricultural production at the cost of the area extension is not always desirable where the land is a scarce resource.

Spatial analysis of the Total Factor Productivity of rice across different agro-climatic regions in West Bengal has been performed in this study in order to observe the behavioural pattern of the input use, the change in productivity as well as the variation in the technological adoption of the paddy growers across different zones of Bengal. Taking into account the small land holding size of the farmers of West Bengal, the variation in the technology adoption across all size classes has been done critically.

With this above viewpoint, the present study has fulfilled the following objectives:

(1) To evaluate the extent of the technological change in rice cultivation over four decades (1971–1972 to 2009–2010) in West Bengal.

(2) To identify major contributing factors responsible for the overall technological change in rice cultivation over four decades (1971–1972 to 2009–2010) in West Bengal.

(3) To compare the productivity, the input use pattern, cost components and economic return as well as the spatial change in the total factor productivity of paddy cultivation for different size classes across all agro-climatic zones of West Bengal during 2011–2012.

MATERIAL AND METHODS

The present study focuses on the extent of the technological change in rice cultivation over four decades in West Bengal (1971–1972 to 2009–20 10). The study also focuses on the comparative study on the productivity, input use, cost and economic return in the *kharif* paddy cultivation for different size classes of the farming community across all agro-climatic zones of the state and the spatial TFP analysis to compare the zonal variation in extent of the technology adoption by the paddy growers.

The relevant secondary data on the area, production and productivity of *aus aman* and *boro* rice as well as their farm harvest prices in West Bengal have been collected from different volumes of the Statistical Abstract, published by the Bureau of Applied Economics and Statistics, the Ministry of Agriculture, the Government of West Bengal, and also the Estimates of Area, Production and Productivity of Major Crops, published by the Socio-Economic Evaluation Wing, the Ministry of Agriculture, the Government of West Bengal. The relevant data on different input use as well as the cost for paddy cultivation in West Bengal for the entire period (1971–1972 to 2009–2010) have been collected from various reports of the Cost of Cultivation of Principal Crops in India and also the official website of the DES (eands.dacnet.nic.in) (Anonymous 1991, 1996, 2000, 2007 and 2009a).

Temporal analysis of the Total Factor Productivity of rice in West Bengal

Temporal analysis of the Total Factor Productivity (TFP) for rice in West Bengal has been performed for the last four decades (1971–1972 to 2009–2010) as well as the individual decades change in the TFP was done where the Total Output Indices (TOI), the Total Input Indices (TII) and the Total Factor Productivity Indices (TFPI) were computed and their growth has been estimated with the following functional form:

$$Y = ae^{bt}$$

where the dependent Y-value is a function of the independent time period (t)

Computation of the Total Factor Productivity (TFP)

The increased use of inputs, to a certain extent, allows the agricultural sector to move up along the production surface by increasing the production yield per unit of area. Their use may also induce an upward shift in the production functions to the extent that a technological change is embodied in them. It has long been recognized that the partial productivity measures, such as the output per unit of the individual inputs, are of a limited use as the indicators of the real productivity change as defined by a shift in production. The total factor productivity concept that implies an index of output per unit of the total factor input, measures properly these shifts or increases in output, holding all inputs constant. However, the recent studies on the TFP relating to Eastern India show a dismal picture of the whole region. Jha and Kumar (1998), while measuring the changes in the TFP for rice across the states of India, came to the conclusion that the Eastern states tend to drag the national average of the TFP growth rates down. Kumar and Mittal (2006), while estimating the TFP growth rate for paddy and wheat across different states of India, have registered that the TFP of paddy has started showing a deceleration in Haryana and Punjab, but the TFP of wheat is still growing in these two Green Revolution states. About 60 per cent of the area under coarse cereals is facing a stagnant TFP. Similarly, the productivity gains which occurred for pulses and sugarcane during the early years of the Green Revolution, have now exhausted their potential. Same feature in the TFP was also reported by Chand et al (2011) estimating the crop-level TFP for the period 1986–2005 in the Indian agriculture perspective using the Divisia-Tornqvist Theil index model. Further, they have formulated the TFP growth categories as the negative growth (less than zero), the stagnant growth (0–0.5%), the low growth (0.5–1%), the moderate (1–2%) and the high (greater than 2%), and they have concluded that the states of Punjab, Gujarat and Andhra Pradesh have the highest TFP growth with 90% or more of the cropped area having the TFP growth more than 1%, while the states of Madhya Pradesh, West Bengal, Bihar, Orissa, Karnataka, Kerala and Himachal Pradesh have a larger percentage of the cropped area reporting a negative or stagnant TFP growth in the agricultural crop sector.

The use of the TFP indices gained prominence since Diewert (1976) proved that the Theil-Tornqvist discrete approximation to the Divisia index is consistent in the aggregation and superior to the linear homogeneous trans-logarithmic production function. The same methodology for computing the TFP in agriculture and livestock sector was also used by Mukherjee and Kuroda (2001), Murgai (1999), Rao (2005), Nadeem et al (2012) and Munir et al (2012).

Thus, the Divisia-Tornqvist index is used in the present study for computing the total output, the total input and the TFP for the crop sector by districts and the state as a whole. The total output, total input and the TFP indices are computed as:

Total Output Index (TOI)

$$TOI_{t-1} = \prod_j \left(\frac{Q_{jt}}{Q_{jt-1}}\right)^{\frac{(S_{jt}+S_{jt-1})}{2}}$$

Total Input Index (TII)

$$TII_{t-1} = \prod_i \left(\frac{X_{it}}{X_{it-1}}\right)^{\frac{(S'_{it}+S'_{it-1})}{2}}$$

The Tornqvist Aggregate Output Index is given by: Tornqvist

$$\ln\left(\frac{Q_{jt}}{Q_{jt-1}}\right) = \frac{1}{2}\sum_{j=1}^{n}\left(\frac{P_{jt}Q_{jt}}{\sum P_{jt}\, Q_{jt}} + \frac{P_{jt-1}Q_{jt-1}}{\sum P_{jt-1}\, Q_{jt-1}}\right)\ln\left(\frac{Q_{jt}}{Q_{jt-1}}\right)$$

Similarly, the Tornqvist Aggregate Input Index is given by:

Tornqvist

$$\ln\left(\frac{X_{it}}{X_{it-1}}\right) = \frac{1}{2}\sum_{i=1}^{n}\left(\frac{C_{it}X_{it}}{\sum C_{it}\,X_{it}} + \frac{C_{it-1}X_{it-1}}{\sum C_{it-1}\,X_{it-1}}\right)\ln\left(\frac{X_{it}}{X_{it-1}}\right)$$

Where:

t = year

Q_{jt} = output of j^{th} crop at t^{th} year

Q_{jt-1} = output of j^{th} crop at $(t-1)^{th}$ year

S_{jt} = proportional value share of j^{th} crop to the total value of output at t^{th} year

S_{jt-1} = proportional value share of j^{th} crop to the total value of output at $(t-1)^{th}$ year

X_{it} = quantity of i^{th} input at t^{th} year

X_{it-1} = quantity of i^{th} input at $(t-1)^{th}$ year

S'_{it} = share of i^{th} input to the total cost of inputs at t^{th} year

S'_{it-1} = proportional of cost share of i^{th} input to the total cost of inputs at $(t-1)^{th}$ year

P_{jt} = harvest price of j^{th} crop at t^{th} year

P_{jt-1} = harvest price of j^{th} crop at $(t-1)^{th}$ year

C_{it-1} = cost of i^{th} input at $(t-1)^{th}$ year

C_{it} = cost of i^{th} input at t^{th} year

Total Factor Productivity Index (TFPI)

In general, the Total Factor Productivity at t^{th} year is measured by:

$$TFP_t = \frac{TOI_t}{TII_t} = \frac{\text{Aggregate Output}}{\text{Aggregate Input}}$$

Here,

$$TFPI = \frac{\text{Tornqvist Aggregate Output Index}}{\text{Tornqvist Aggregate Input Index}}$$

For the productivity measurement over a long period of time, the Output, Input & TFP indices are computed on the basis of the "Chain Base Index" expressed as percentages. With chain-linking, an index is calculated for two successive periods t and $(t-1)$ over the whole period t_0 to T, (sample from $t = 0$ to $t = T$) and the separate indexes are then multiplied together:

TOI × (t) = TOI (1). TOI (2) … TOI $(t-1)$

Similarly, TII × (t) = TII (1). TII (2) … TII $(t-1)$

The Total Factor Productivity Index (TFPI)

$$TFP_t = \frac{TOI *_t}{TII *_t}$$

Types of data used

The data on the following variables have been compiled for the period 1971–1972 to 2009–2010 for the whole West Bengal for the purpose of the TFP analysis.

– Quantity and rates of operational inputs like seed, fertilizer, organic manure, irrigation, machine labour, plant protection chemicals, bullock labour, human labour and interest on working capital required for paddy cultivation and paddy outputs for the entire study period

– Yearly data on area, production and productivity of *aus, aman, boro* as well as total paddy for West Bengal for the entire period under study

– Yearly Farm Harvest Prices of *aus*, *aman* and *boro* rice in West Bengal

– For the primary part, the input and output data have been collected through the personal interview and a detailed questionnaire

Stepwise regression analysis followed the model function

$$\ln\left(\frac{Y_t}{Y_{t-1}}\right) = \beta_0 + \beta_1\ln\left(\frac{X_{1t}}{X_{1t-1}}\right) + \beta_2\ln\left(\frac{X_{2t}}{X_{2t-1}}\right) + \beta_3\ln\left(\frac{X_{3t}}{X_{3t-1}}\right) + \beta_4\ln\left(\frac{X_{4t}}{X_{4t-1}}\right) + \beta_5\ln\left(\frac{X_{5t}}{X_{5t-1}}\right) + \beta_6\ln\left(\frac{X_{6t}}{X_{6t-1}}\right) + \beta_7\ln\left(\frac{X_{7t}}{X_{7t-1}}\right) + \beta_8\ln\left(\frac{X_{8t}}{X_{8t-1}}\right) + \beta_9\ln\left(\frac{X_{9t}}{X_{9t-1}}\right)$$

Where:

Y = total output

X_1 = quantity of seeds used

X_2 = quantity of fertilizer used

X_3 = quantity of organic manure used

X_4 = quantity of irrigation charges

X_5 = total machine hour required

X_6 = plant protection cost required

X_7 = bullock labour used (pair hours)

X_8 = total human labour used (man hours)

X_9 = interest on working capital

β_0 = constant

$\beta_{1,\ldots,}\beta_9$ = regression coefficients of respective variables for t^{th} over $(t-1)^{th}$ year

The step-wise regression analysis has been done here to identify the most relevant factors responsible for the TFP change over the decade and to exclude the irrelevant factors from the regression model. The entire analysis has been performed using the statistical package SAS 9.3 version.

Table 1. TOI, TII and TFPI growth rates of Rice in West Bengal (1971–1972 to 2009–2010)

Year	Exponential trend of the Total Output Indices (TOI)	Growth rate (%)	Exponential trend of the Total Input Indices (TII)	Growth rate (%)	Exponential trend of the Total Factor Productivity Indices (TFPI)	Growth rate (%)
1971–72 to 2009–10	$Y = 96.653e^{0.0304x}$ $R^2 = 0.884$	3.08*	$Y = 95.966e^{0.022x}$ $R^2 = 0.8735$	2.23*	$Y = 100.72e^{0.0083x}$ $R^2 = 0.3847$	0.84*
1971–72 to 1981–82	$Y = 106.16e^{0.0091x}$ $R^2 = 0.0691$	0.91	$Y = 87.873e^{0.0318x}$ $R^2 = 0.4887$	3.23*	$Y = 120.81e^{-0.0227x}$ $R^2 = 0.1987$	–2.24
1981–82 to 1991–92	$Y = 118.28e^{0.0748x}$ $R^2 = 0.8122$	7.77*	$Y = 98.405e^{0.0338x}$ $R^2 = 0.782$	3.43*	$Y = 120.19e^{0.0411x}$ $R^2 = 0.5752$	4.19*
1991–92 to 2001–02	$Y = 98.553e^{0.0234x}$ $R^2 = 0.699$	2.37*	$Y = 95.697e^{0.0121x}$ $R^2 = 0.1623$	1.22	$Y = 102.98e^{0.0113x}$ $R^2 = 0.2225$	1.13
2001–02 to 2009–10	$Y = 101.46e^{0.0009x}$ $R^2 = 0.0172$	0.09	$Y = 95.834e^{0.0078x}$ $R^2 = 0.2228$	0.79	$Y = 105.87e^{-0.007x}$ $R^2 = 0.152$	–0.69

* means significant at 5% level

Spatial analysis of the Total Factor Productivity Indices across all agro-climatic regions of West Bengal

For computation of the primary data on productivity as well as the different input use, their costs and economic return of *kharif* paddy across different agro-climatic zones of West Bengal, one representative predominant paddy belt block has been identified from each zone and subsequently ten exclusively paddy growers of different size classes (four marginal-small, four medium and two large farmers) have been chosen purposively from three villages of each block. In total, sixty paddy growers have been identified from six zones having different size classes and they have been surveyed through a detailed questionnaire. Further, it is to be noted here that for the author's convenience in choosing the farmers of different size classes, the conventional rule defined with regard to the size of holding for the marginal-small, medium and large farmers has not been followed here. The author has taken marginal-small farmers (< 0.67 ha), medium one (0.67–1.0 hectare) and large farmers (> 1.0 ha) for the convenience of his research work.

RESULTS AND DISCUSSION

Decade analysis of the Total Factor Productivity (TFP) of rice in West Bengal

The decade growth rates in the Total Output Indices (TOI), Total Input Indices (TII) and the Total Factor Productivity Indices (TFPI) of rice in West Bengal have been performed in order to evaluate the extent of the technological changes in paddy cultivation over the entire period under discussion (1971–1972 to 2009–2010). It is evident from the table (Table 1) that the overall technological change in rice cultivation has significantly occurred over four decades in West Bengal with an exponential growth rate of 0.84%. That means a change in the output surpasses over the change in the input uses for the entire period under study. At the onset of the Green Revolution in India, its effect throughout the entire agricultural production system has not been observed in the first decade (1971–1972 to 1981–1982), where a 3.23% growth of change in input uses was observed surpassing a stagnant change in the output rate of 0.91%, resulting a negative TFP rate of –2.24% over the decade. The agricultural production system was enhanced in the next phase where a mammoth increase in the output rate of 7.77% was observed surpassing the change in input uses of 3.43%, resulting a 4.19% TFP growth rates. It indicates that the good effect of the Green Revolution has been disseminated with a sound technological change that has been incorporated in the entire agricultural production system. The essence of the Green Revolution regarding enhancement in the productivity of agricultural crop sector was also observed in the next phase (1991–1992 to 2001–2002), where a 1.13% change in the TFP of rice was found. The TFP became still and stagnant in the last and final phase (2001–2002 to 2009–2010) under study, where a –0.69% change was observed indicating the ill effect of various input uses over the production system. The fertility status of the soil has been destroyed due to the overuse of chemical fertilizers and insecticides which would be reclaimed through the organic farming package and practices. The trend equations of TOI, TII and TFPI of rice for all decades are visualized in Figure 1–6.

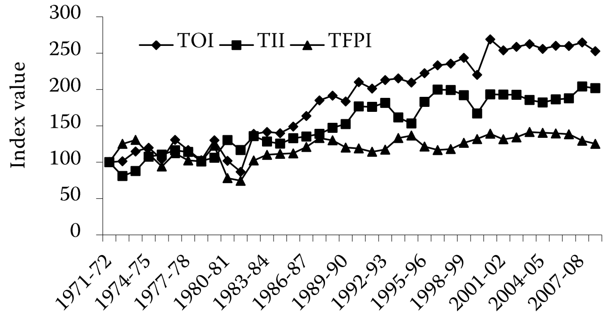

Figure 1. TOI, TII and TFPI of rice in West Bengal (1971–72 to 2009–10

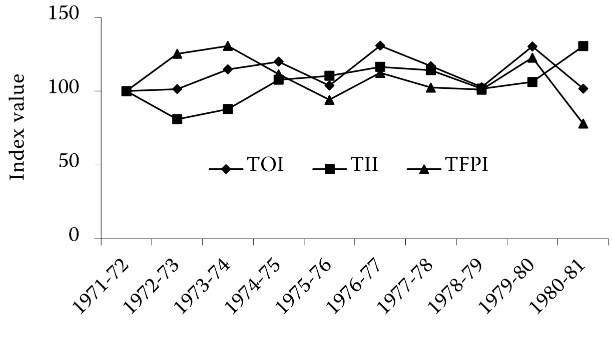

Figure 2. TOI, TII and TFPI of rice in West Bengal (1971–72 to 1981–82)

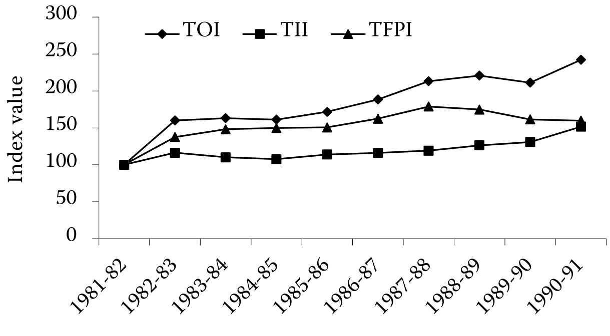

Figure 3. TOI, TII and TFPI of rice in West Bengal (1981–82 to 1991–92)

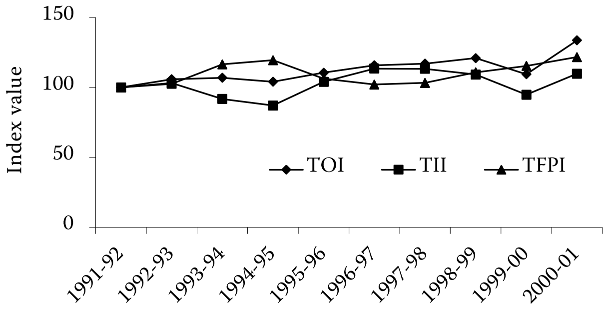

Figure 4. TOI, TII and TFPI of rice in West Bengal (1991–92 to 2001–02)

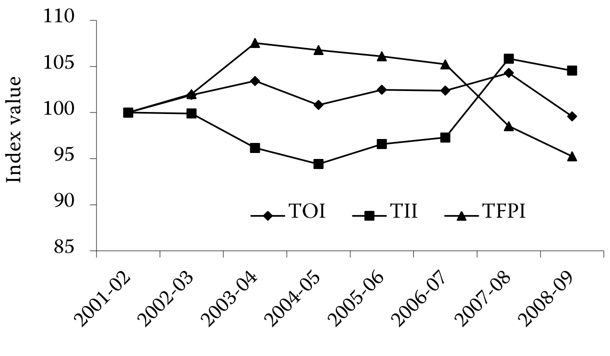

Figure 5. TOI, TII and TFPI of rice in West Bengal (2001–02 to 2009–10)

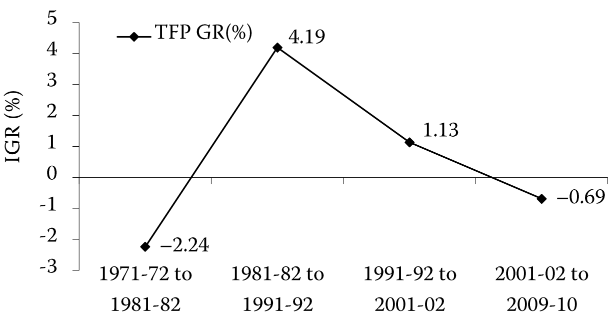

Figure 6. TFP Change in rice cultivation over decades in West Bengal (1971–72 to 2009–10)

Regression analysis for the identification of the factor contribution of rice in West Bengal

A multiple linear regression analysis between the changes in output over various input use during the decades as well as the entire period under study has been made in this research work to identify the most contributing factors responsible for the overall technological change in rice cultivation of the state and subsequently the degree of relationship between the changes in output with various input uses over the period under study. Out of nine operational factors taken under consideration, seed became the prime contributor for the overall technological change in rice cultivation in the state, followed by the interest on working capital which has been operated throughout the duration of the crop. The result shows a positive interpretation towards the introduction to quality seeds (HYV instead of the local) for the overall productivity enhancement in paddy cultivation for the state of West Bengal, which have been the ultimate goals and targets of the Green Revolution in India. Barring the last and final phase (2001–2002 to 2009–2010), the change in seed use has a strong positive relationship with the change in output across all the periods under study, what indicates a significant contribution over the

Table 2. Multiple step-wise linear regressions between the change in output over the change in various inputs use under the jute cultivation in West Bengal during different phases

Time period	Regression equation	Parameters	Remarks
1971–72 to 1981–82	$Y = 0.0017 - 2.51\ X_3$	X_3: organic manure use	organic manure use became the prime contributor at the initial phase
1981–82 to 1991–92	$Y = 0.044 + 2.60\ X_8$	X_8: human labour	human labour use became the prime contributor at 2nd phase
1991–92 to 2001–02	$Y = 0.00834 + 6.006\ X_5 + 1.26\ X_8$	X_5: machine labour use X_8: human labour use	farm mechanization and human labour use were the prime contributor at 3rd phase
2001–02 to 2009–10	$Y = 0.070 +(-)\ 0.889\ X_2 + 1.222\ X_3\ (-)\ 5.889\ X_4 + 10.556\ X_5 +(-)\ 27.556\ X_6 + 4.111\ X_7 + 0.0005\ X_8$	X_2: inorganic fertilizer use X_3: organic manure use X_4: irrigation charges X_5: machine labour use X_6: plant protection chemical use X_7: bullock labour X_8: human labour use	inorganic fertilizer use, organic manure use, irrigation charges, machine labour use, PPCs, bullock labour and human labour all included in the production system
1971–72 to 2009–10 (overall)	$Y_1 = 0.012 + 11.406\ X_1$	X_1 : seed use	seed use and interest on working capital has been inserted in the production system

productivity change as a whole. However, the present study has indicated the fact that the effect of the Green Revolution has not been disseminated among the paddy growers during the first decade (1971–1972 to 1981–1982) under study as the organic manure became the sole factor contributor for the change in output over time resulting in the technological degradation (TFP growth –2.24%) in rice cultivation of Bengal. The effect of the Green Revolution has been gaining impetus in the next phase (1981–1982 to 1991–1992), as there was a mammoth rate of change (4.19%) in the $TFP_{rice,}$ where the human labour use became the sole factor contributor for the overall change in the TFP featuring a strong positive relationship with the output change over all the decades (except the last phase). During the third phase, the farm mechanization has been incorporated in the production system as the machine labour use along with human capital has contributed to the overall change in the TFP_{rice} (1.13%) in the state. The correlation matrix between output and various input uses (Table 3) has registered a strong positive relationship between the machine labour use and the output at the third (0.319) and final phases (0.562), respectively, indicating that the effect of farm mechanization among paddy growers in the state has been gaining impetus after 1990s. However, a number of factors (inorganic fertilizer, organic manure, irrigation charges, machine labour, PPCs, bullock labour and human labour) have contributed to the production system in the last and final phase under study (2001–2002 to 2009–2010) where a marked technological stagnancy (TFP_{rice} –0.69) in paddy cultivation in the state has been observed. It may be due to the overuse of chemical and inorganic fertilizers, pesticides, fungicides that may hamper the overall fertility status of the soil (Tables 2 and 3).

Table 3. Correlation coefficients for the change in the relative input use over the change in output (1971–1972 to 2009–2010)

Year	Output	Seed use	Fertilizer use	Organic manure use	Irrigation charges	Machine labour use	PPC use	Bullock labour use	Human labour use	INTWC
1971–72 to 2009–10	1.000	0.481**	0.318*	–0.179	0.091	–0.006	0.360*	0.252	0.387**	0.416**
1971–72 to 1981–82	1.000	0.397	0.102	–0.502	0.253	–0.451	–0.039	0.054	0.124	0.290
1981–82 to 1991–92	1.000	0.650*	0.402	0.370	–0.242	–0.035	0.491	0.791	0.713	0.427
1991–92 to 2001–02	1.000	0.657*	0.466	0.369	0.237	0.319	0.715*	0.323	0.807**	0.776**
2001–02 to 2009–10	1.000	0.000	0.443	0.254	0.333	0.562	–0.090	–0.148	0.072	0.000

*means significant at 5% level, **means significant at 1% level

Comparative study on the economics of paddy cultivation for different size classes across agro-climatic zones of West Bengal

Regarding zone characteristics features in West Bengal, the state is constituted in the heart of a fertile geographical delta and thus it comprises a high geographical diversity with six agro-climatic zones. The net sown area is 61% of the total geographical area against the national average of 46%. The gross cropped area of the state presently is 97.5 lakh hectares with the cropping intensity of 184%. Small and marginal farmers represent over 95% of the total farm population and they own nearly 80% of the cultivated land. Irrigation covers 69% of the net cropped area though there is a high reliance on monsoon (Anon. 2009a). The problematic zones in West Bengal have been identified as the Hill, the Red Laterite and the Coastal Saline zones in terms of the cropping intensity. Then, the progressive zones (Old Alluvial and New Alluvial zones) comprise of the indo-gangetic delta basin of Bengal with a subsequently good soil fertility status and higher level of productivity and technology adoption by the farmers.

A comparative study on the productivity, input use, and break-up of cost components as well as the economic return in the paddy cultivation over different size classes across all agro-climatic zones of West Bengal has been made in order to identify the most promising zone regarding the technological advancement in rice cultivation. Taking the problematic zone like hill as a base, the study has been performed to judge the zonal variation in productivity as well as the input use, the cost structure and the overall economic return. However, a gradual movement from a regressive zone to a progressive one, the entire output scenario envisages the fact that Hill has recorded the lowest level of the average productivity (2772.12 kg/ha for the marginal-small farmer, 2787.15 kg/ha for the medium one and 2799.90 kg/ha for the large farmers), followed by the coastal saline, terai, red lateratic, old alluvial and new alluvial zones of the state. The new alluvial zone being rich in terms of soil fertility, socio-economic conditions of the farming community, their livelihood status as well as the technology adoption in paddy cultivation have emerged as the maximum productive zone for paddy and other crops. The zone comprises an average of 4719.00 kg/ha, 4575.00 kg/ha and 4987.50 kg/ha of paddy productivity across the different size classes of the farming community. Regarding zonal variation in the input use, the marginal-small and medium farmers of the terai zone have the tendency to use more seed as compared to other zones (around 68.0 kg per ha), where the large farming community in the new alluvial zone has the highest level of application of seed per hectare (69.0 kg/ha). In case of the application of chemical and inorganic fertilizers, the terai too have occupied the maximum rate (around 150.0 kg/ha) in context of the marginal small and medium farmers but for the large one, the tendency to use more fertilizer has been focused on paddy growers of the red lateratic zone (157.5 kg/ha). The tendency to apply organic manure has been focused mainly in the hilly region (50.0 q/ha) where there is no use of inorganic fertilizer. Irrigation has been viewed mainly in those progressive region where there are plenty opportunities to utilize the canal water, the submersible water and the availability of shallow pump and deep tube wells. Farmers of regressive zones like the coastal saline and the red lateratic zones suffer from an inadequate rainfall still largely depend on the rainfed farming system too for their *kharif* crop. Next to irrigation, farm mechanization has been viewed in all the progressive zones (New and Old Alluvial); where subsequently the bullock labour use was lower (73.0 pair hour and 72.0 pair hour respectively). The bullock labour use level was found to be very high in the hilly region (210.0 pair hour), as the zone is well acquainted with the terrace cultivation practices with the undulating land topography. Last but not least, the most important contributing factor is human labour, of which, unlike hill, almost all zones have used in average 155.0–160.0 man/days per hectare for the *kharif* paddy cultivation. The hill zone has a lower use of human labour, as the zone suffers from the low level of socio-economic livelihood strata of the farmers. Regarding economic return, progressive zones like the new and old alluvial have registered a higher economic return over cost (1.74 and 1.80 respectively). Problematic zones like the hill and coastal saline suffer in terms of economic return as much as 1.08 and 1.22, respectively (Table 4).

A spatial analysis of the total output index, the total input index and the total factor productivity index has been computed for all zones with respect to the hill, the ultimate problematic zone taken as the base. The results have envisaged the fact that for the output index, the new alluvial zone has occupied the highest TOI in all categories and the classes followed by the old alluvial, the red lateratic, the terai and the coastal saline region of the state. In case of the input indices, the red lateratic zone has registered the highest change over the hill followed by the new alluvial, the old alluvial, the coastal saline and the terai. Regarding the technology adoption by the farmers in different regions, the old alluvial has

Table 4. Comparative study on the productivity, input use, cost and economic return in paddy cultivation for different classes of farming community across all agro-climatic zones of West Bengal

Farm category	Zone	Average farm size (ha)	Productivity (kg/ha)	Farm gate price (Rs/Qtl)	Gross return (Rs/ha)	Seed		Fertilizer		Organic manure		Irrigation charges	Machine labour	PPC	Bullock labour		Human labour		Total operational cost (Rs/ha)	Economic return (B:C)
						Qty (kg)	Cost Rs	Qty kg	Cost Rs	Qty Qtl	Cost Rs	Cost Rs	Cost Rs	Cost Rs	Qty (hour)	Cost Rs	Qty (Man/days)	Cost Rs		
Marginal-Small	Hill	0.59	2 772.12	875.00	24 256.05	40.00	1 120.00	0.50	0.00	50.00	3 000.00	100.00	250.00	50.00	210.00	7 000.00	120.00	11 100.00	22 620.00	1.07
	Coastal saline	0.416	3 062.50	1068.33	32 717.61	62.63	751.50	116.25	2 087.65	26.56	796.87	150.00	1 000.00	562.50	107.00	2 125.00	153.75	19 987.50	27 461.02	1.19
	Terai	0.438	3 465.00	1092.00	37 837.80	69.00	855.60	154.50	2 008.50	5.57	167.15	200.00	1 050.00	967.50	72.00	1 350.00	148.50	22 275.00	28 873.75	1.31
	Red Lateritic	0.386	3 690.00	1 090.00	40 221.00	62.25	734.55	127.50	1 823.25	24.75	618.75	1 875.00	1 267.50	772.50	60.00	1 200.00	162.00	16 200.00	24 491.55	1.64
	Old Alluvial	0.324	4 443.75	1 120.00	49 770.00	62.81	769.45	140.62	1 933.59	19.21	576.56	675.00	1 312.25	468.75	75.00	1 500.00	159.38	20 718.80	27 954.40	1.78
	New Alluvial	0.506	4 719.00	1 110.00	52 380.90	64.50	967.50	138.00	2 152.80	22.50	675.00	1 800.00	1 218.75	742.50	82.50	1 650.00	148.50	20 790.00	29 996.55	1.75
Medium	Hill	0.766	2 787.15	875.00	24 387.56	40.00	1 120.00	0.50	0.00	50.00	3 000.00	100.00	250.00	50.00	210.00	7 000.00	135.00	11 100.00	22 620.00	1.08
	Coastal saline	0.778	3 100.00	1 086.67	33 686.77	62.50	687.50	112.50	2 137.50	25.15	754.50	150.00	1 250.00	1 000.00	75.00	1 500.00	155.00	20 150.00	27 629.50	1.22
	Terai	0.684	3 375.00	1 095.00	36 956.25	67.50	826.88	146.25	2 010.93	5.90	177.18	150.00	1 031.25	928.13	75.00	1 406.25	153.75	23 062.50	29 593.11	1.25
	Red Lateritic	0.783	3 770.00	1 090.00	41 093.00	64.21	866.95	135.00	1 822.50	23.44	585.93	1 875.00	1 284.37	675.00	63.75	1 275.00	165.00	16 500.00	24 884.75	1.65
	Old Alluvial	0.817	4 537.5	1 102.50	50 025.94	64.50	790.13	133.13	1 963.59	19.68	590.63	1 125.00	1 342.50	487.50	69.68	1 387.50	151.88	19 473.80	27 160.64	1.84
	New Alluvial	0.817	4 575.00	1 102.50	50 439.38	67.13	973.30	144.38	2 418.30	24.38	731.25	1 800.00	1 406.25	281.25	73.13	1 462.50	157.50	22 050.00	31 122.85	1.62
Large	Hill	1.60	2 799.90	875.00	24 499.13	40.00	1 120.00	0.50	0.00	50.00	3 000.00	100.00	225.00	50.00	210.00	7 000.00	120.00	11 100.00	22 595.00	1.08
	Coastal saline	1.06	3 225.00	1 100.00	35 475.00	63.75	892.50	127.50	2 295.00	22.50	675.00	150.00	300.00	975.00	112.50	2 250.00	157.50	20 475.00	28 012.50	1.27
	Terai	1.00	3 750.00	1 080.00	40 500.00	67.50	1080.00	150.00	2 100.00	22.50	562.50	1 125.00	1 312.50	937.50	60.00	1 200.00	165.00	16 500.00	24 817.50	1.63
	Red Lateritic	1.20	3 780.00	1 120.00	36 232.00	67.50	810.00	157.50	2 047.50	5.03	150.75	130.00	750.00	562.50	67.50	1 265.63	150.00	22 500.00	28 216.38	1.28
	Old Alluvial	1.00	4 612.50	1 080.00	49 815.00	62.81	690.00	153.75	2 306.25	20.25	607.50	787.50	1 331.25	825.00	75.00	1 500.00	146.25	19 012.00	27 059.50	1.84
	New Alluvial	1.06	4 987.50	1 050.00	52 368.75	68.85	895.00	150.00	1 800.00	26.25	787.50	900.00	1 875.00	937.50	67.50	1 350.00	142.50	19 950.00	28 495.00	1.84

Table 5. The TOI, TII and TFPI over the different agro-climatic zones in West Bengal

Category	Zone	Output index	Input index	TFP index
Marginal-small	Hill	100.00	100.00	100.00
	Coastal Saline	110.48	129.20	85.51
	Terai	124.99	110.94	112.67
	Red Lateritic	133.11	139.45	95.45
	Old Alluvial	160.30	125.05	128.19
	New Alluvial	170.23	133.05	127.94
Medium	Hill	100.00	100.00	100.00
	Coastal Saline	111.22	118.88	93.56
	Terai	121.09	104.85	115.49
	Red Lateritic	135.26	131.38	102.95
	Old Alluvial	162.80	116.20	140.10
	New Alluvial	164.15	126.82	129.43
Large	Hill	100.00	100.00	100.00
	Coastal Saline	115.18	133.34	86.39
	Terai	115.54	106.51	108.48
	Red Lateritic	133.93	140.16	95.56
	Old Alluvial	164.74	128.91	127.79
	New Alluvial	178.13	124.79	142.74

registered the highest TFP for the marginal-small (128.19%) and the medium (140.10%) farmers, while it was the highest (142.74%) among the large farming community in the new alluvial zones of West Bengal (Table 5).

CONCLUSION

The entire study attempts to judge the essence of the Green Revolution in rice cultivation and its actual reflection regarding the factor contribution over four decades in West Bengal. The study measures the extent of the technological change in rice cultivation, which has occurred in the state of West Bengal for the entire four decades, while its extent has not been equally disseminated in the decades. The effect of the productivity change was robust in the 2nd decade (1981–1982 to 1991–1992) with a 4.19% TFP growth rate indicating the good effect of the Green Revolution has began to start regarding the technological change in rice cultivation over West Bengal. Then, the TFP_{rice} results in the state have given a dismal picture in the later phases under study where it starts declining with change of time. At the end decade (2001–2002 to 2009–2010), the TFP growth has been found to be negative (–0.69) reflecting the ill effect of a higher use of inorganic fertilizers, insecticides and pesticides to corrupt the soil fertility status of the state. It is the quality HYV seed that dominate among all factor contributors for the overall TFP_{rice} change along with the human labour use. Farm mechanization enters after the 90s indicating a major reform in the context of the technology adoption by the rice growers in the state. The region-wise scenario of rice cultivation in the state has proved that the Gangetic Alluvial tract has a better technology adopting quality with a higher TFP indices as compared to the problematic regions like the Red Lateratic zone and the Coastal Saline belt, the reason of which might be the improved fertility status of soil with a large number of progressive paddy growers operating in terms of a better knowledge gaining, a better education and extension.

REFERENCES

Adlas J., Achoth L. (2006): Is the Green Revolution Vanishing? Empirical Evidence from TFP analysis for Rice. Poster paper prepared for presentation at the International Association of Agricultural Economics Conference. Gold Coast, Australia, Aug 12–18, 2006.

Anonymous (1991): Comprehensive Scheme for studying the cost of cultivation of Principal Crops in India. Directorate of Economics & Statistics, Department of Agriculture & Cooperation, Ministry of Agriculture, Government of India, Krishi Bhawan, New Delhi.

Anonymous (1996, 2000): Comprehensive Scheme for Studying the Cost of Cultivation of Principal Crops in India. Directorate of Economics & Statistics, Department of Agriculture & Cooperation, Ministry of Agriculture, Government of India, Krishi Bhawan, New Delhi.

Anonymous (2007): Reports of the Commission for Agricultural Cost and Prices for the Crops Sown during 2006–2007 Season. Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi.

Anonymous (2009a): Annual Report, 2005–06. Department of Agriculture, Government of West Bengal, Writers' Buildings, Kolkata.

Cassman K.G., Pingali P.L. (1995): Extrapolating trends from long-term experiments to farmers' fields: The case of irrigated rice system in Asia. In: Barnett V., Payne R., Steiner R. (eds.): Agricultural Sustainability: Economic, Environmental and Statistical Considerations. Johwiley & Sons Ltd., London; pp. 63–84.

Chand R., Kumar P., Kumar S. (2011): Total Factor Productivity and Contribution of Research Investment to

Agricultural Growth in India. Policy Paper 25. National Centre for Agricultural Economic and Policy Research, March 2011.

Chatterjee S. (2005): An Economic Analysis of Total Factor Productivity (TFP) in Agriculture with Reference to West Bengal. [Doctor of Philosophy (Agriculture) Thesis.] Department of Agricultural Economics, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur.

Dawe D.A., Dobermann P., Moya S., Abdulrachman P., Lal S.Y., Li B., Lin G., Panaullah O., Sariam Y., Singh A., Swarup P.S., Tan Q.X. Zhen. (2000): How widespread are yield declines in long-term rice experiments in Asia? Field Crops Research, *66*: 175–193.

Diewert W.E. (1976): Exact and superlative index numbers. Journal of Econometrics, *4*: 115–145.

Evenson R.E., Pray C.E. (1991): Research and Productivity in Asian Agriculture. Cornell University Press, Ithaca.

Flinn J.C., De Datta S.K. (1984): Trends in irrigated rice yields under intensive cropping at Philippines research stations. Field Crops Research, *5*: 201–216

Greenlands D.L. (1997): The Sustainability of Rice Farming. CAB International (UK) and International Rice Research Institute, Manila (Philippine).

Janaiah A., Hossain M. (2004): Partnership in the public sector agricultural R & D: Evidence from India. Economic and Political Weekly, *39*: 5327–5334.

Jha D., Kumar P. (1998): Rice production and impact of rice research in India: In: Pingali Prabhu L., Mahabub Houssain (eds.): Impact of Rice Research. Thailand Development Research Institute (TDRI), International Rice Research Institute (IRRI).

Kannan E. (2011): Total Factor Productivity Growth and Its Determinants in Karnataka Agriculture. Working Paper 265. The Institute for Social and Economic Change, Bangalore.

Kumar A., Yadav D.S. (2001): Long-term effects of fertilizers on the soil fertility and productivity of a rice-wheat system. Journal of Agronomy and Crop Science, *186*: 47–54.

Kumar P., Mittal S. (2006): Agricultural productivity trends in India: Sustainability issues. Agricultural Economics Research Review, *19*: 71–88.

Mukherjee A., Kuroda Y. (2001): Effect of Rural Nonfarm Employment and Infrastructure on Agricultural Productivity: Evidence from India. Discussion Paper No. 938. University of Tsukuba, Ibaraki, Japan.

Munir S., Hussain M., Nadeem N., Ali A., Javed Ishaq M. (2012): Comparison of total factor productivity growth of agriculture sector in different cropping systems of Punjab: 1981–2008. Journal of Agricultural Research, *50*: 433–444.

Murgai R. (1999): The Green Revolution and the Productivity Paradox – Evidence from the Indian Punjab. Policy Research Working Paper 2234. The World Bank Development Research Group, Rural Development, November 1999.

Nadeem N., Javed Ishaq M., Hassan I., Khurshid W., Ali A. (2012): Total Factor Productivity growth and performance of livestock sector in Punjab, Pakistan. Journal of Agricultural Research, *50*: 279–287.

Nambiar K.K.M. (1988): Annual Reports, Long-term Fertilizer Experiments in India (1971–1988). IARI, New Delhi.

Pingali P.L., Hossain M., Gerpacio R. (1997): Asian Rice Bowls: The Returning Crisis? CAB International IRRI. Los Banos, Philippines.

Rao N.C. (2005): Total factor productivity in Andhra Pradesh agriculture. American Economics Research Review, *18*: 1–19.

Yadav R.L., Dwivedi B.S., Pandey P.S. (2000): Rice-wheat cropping system: assessment of sustainability under green manuring and chemical fertilizer inputs. Field Crops Research, *65*: 15–30.

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