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Is the rice cultivation in west Bengal sustainable?

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Abstract
The present study was conducted to measure total factor productivity and its sources of growth of rice cultivation in West Bengal for the period of 1994-95 to 2013-14. Törnqvist Theil Index was applied to measure total factor productivity using output and input data of rice crop. The study was based on secondary data collected from various sources. The results of study revealed that there was a declination of area under rice cultivation. Maximum share of human labour to total variable cost indicates rice cultivation was labour intensive. Fall of growth rate of bullock labour and sharp increase of machine labour showed the awakening of mechanization. Declination of fertilizer productivity supported the fact that there was need of concerned for effective use of this input. The state had positive and significant total factor productivity growth throughout the studied periods. Expenditure on agricultural research and education, number of tractors had positive and significant effect on total factor productivity growth, indicating this factor should be maintained as it is showing a prospect in future growth of TFP in this state.

Keywords: Total factor productivity, Törnqvist Theil Index, Rice, West Bengal

Introduction

In 2015, the United Nations (UN) committed to achieve zero hunger by 2030 as the second of the Sustainable Development Goals (SDGs). An important element of this goal is to end all forms of malnutrition, including agreed targets on childhood stunting and wasting. India's nutritional problems are extensive. In 2016, 38.7% of children under five were defined as 'stunted' (of below average height) (Klaus, 2016) [6], a strong indicator of chronic malnourishment in children and pregnant women, and a largely irreversible condition leading to reduced physical and mental development (Jeyaseelan *et al.* 2016) [5]. Malnourishment within the adult population is also severe, with approximately 15% of the total population defined as malnourished. Rice is the world's most important crop, and the food security in Asia has traditionally been defined as having stable prices for rice in the major urban markets of a country. Therefore, food security is essentially a reflection of rice security in this region. Rice is the cheapest and most effective staple food crop available in this region that is likely to eradicate acute under nutrition. Rice protein ranks high in nutritional quality among cereals, though protein content is modest. Unmilled rice (brown rice) provides 4.3 to 18.2 per cent protein, averaging 9.5 per cent based on 17,587 cultivars in the IRRI germplasm (Singh & Singh, 1997) [13].

India is one of the world's largest producers of rice accounting for 20 per cent of all world rice production. Most outstanding states in India for the production of rice are West Bengal (15.80 per cent), Andhra Pradesh (12.71 per cent), Uttar Pradesh (11.91 per cent), Punjab (10.86 per cent), Orissa (7.31 per cent), Tamil Nadu (7.08 per cent), Chhattisgarh (5.40 per cent), Bihar (5.34 per cent), Karnataka (3.70 per cent) and Haryana (3.61 per cent) during the period 2011-12 (Anonymous, 2013) [1]. Rice plays vital role in the national food grain supply. Rice is the major component of food grain and cereal in the country contributes 43% and 46% of the total food grain and cereals respectively. West Bengal is known as Bowl of rice because it constitute major food item and is being cultivated in major portions of agricultural area. The state is the highest rice producing state in India. Rice production of this state need to be sustained in order to meet nutritional security of the country.

Total factor productivity (TFP) growth is a widespread quantitative economic instrument used to evaluate the performance and sustainability of agricultural systems over time, which has proven valuable for policy measures geared towards fostering agricultural development. Empirical studies of the TFP on developing countries in agriculture are becoming increasingly important in providing a complex picture of technological change. The TFP for Indian crop sector had been analysed by measuring the total factor productivity (TFP) for the Indian crops sector as a whole (Rosegrant and Evenson 1992) [10] but the results of the sectoral approach cannot be used precisely for policy decisions with respect to individual crops because technological change varies across crops. Thus TFP growth has to be examined for individual crops (Kumar and Rosegrant, 1994) [9]. For last few decades there were a number of studies for TFP estimation in different crop sectors like rice (Kumar and Rosegrant, 1994) [9], wheat (Kumar and Mruthyunjaya, 1992) [8] and (Bhusan, 2005) [2], major pulses (Suresh and Reddy, 2016) [14], oilseeds (Chandel, 2007) [3]. Besides there was another study on pigeon pea in Maharashtra (Sanap *et al*, 2015) [11]. Sidhu and Byerlee (1992) [12] had ably analysed technical change and wheat productivity in the Indian Punjab in the post-green revolution period. As rice plays an important role in national security and West Bengal got the highest production in rice cultivation, thus main focus of study was to measure growth of total factor productivity and also determine its sources of rice in West Bengal for effective policy implication.

Data and Methodology

Collection of data: The study was undertaken on a macro framework based on secondary data. To meet the objectives of this study, data of yield of rice of those two states were collected from India stat.com and statistical abstracts of the state. Farm level data on use of inputs and their prices of paddy from 1994-95 to 2013-14 was collected from the "Comprehensive Scheme for the Study of Cost of Cultivation of Principal Crops", Directorate of Economic and Statistics (DES), Ministry of Agriculture, Government of India (GOI). The time series data on infrastructural variables, source wise irrigated area, literacy rate, annual average rainfall, proportion of area under HYV, number of tractors and pump sets, ratio of P and N nutrients, expenditure on agricultural education and research for the same time periods were taken for West Bengal from various publication of Government of India and also from India stat.com.

Measuring TFP using Törnqvist Theil Index: Törnqvist Theil Index which is an index number approach had been used to measure TFP. Output index comprised with yields of both grain and straw of rice. Share of value main product and by-product to total revenue was applied as weight age of output index. Seed, fertilizer, manure, insecticide/pesticide, human labour, animal labour, machine labour and irrigation were included in input index and their share of cost to total cost of cultivation was considered to give weight age the input index. Finally TFP index was calculated by dividing output index with input index. This method can be found in wide range of empirical studies for analysing TFP in different crop sectors like rice (Kumar and Rosegrant, 1994) [9], wheat (Kumar and Mruthyunjaya, 1992) [8], oilseeds (Chandel, 2007) [3]. Besides there was another study on pigeon pea in Maharashtra (Sanap *et al*, 2015) [11] who used this same method.

The general formula used for construction of index is as follows:

Total output index (TOI)

$$TOI_t/TOI_{t-1} = \Pi_j\left(Q_{jt}/Q_{jt-1}\right)^{\left(R_{jt}+R_{jt-1}\right)^{\frac{1}{2}}} = A_t \ldots \quad (1)$$

Where

$$R_{jt} = Q_{jt} * P_{jt}/\sum_{j=1}^{n} Q_{jt} * P_{jt}$$

Total input index (TII)

$$TII_t/TII_{t-1} = \Pi_i\left(X_{it}/X_{it-1}\right)^{\left(S_{it}+S_{it-1}\right)^{\frac{1}{2}}} = B_t \ldots \quad (2)$$

Input price index (IPI)

$$IPI_t/IPI_{t-1} = \Pi_i\left(P_{it}/P_{it-1}\right)^{\left(S_{it}+S_{it-1}\right)^{\frac{1}{2}}} = C_t \ldots \quad (3)$$

Where,

$$S_{it} = Q_{it} * P_{it}/\sum_{j=1}^{m} Q_{it} * P_{it}$$

R_{jt} is the share of jth crop output in total revenue in year t,
Q_{jt} is the output of jth crop in year t,
j varies from 1 to n outputs
S_{it} is the share of input i^{th} in the total input cost in year t, and
X_{it} is the quantity of input i^{th} in year t.
i varies from 1 to m inputs used in the production.
In the case of TFP for a single crop, revenue share refers to the share of main product and by-product in total revenue from the crop, while output includes main product and by-product.
Total output index (TOI) and total input index (TII) for the year t were computed from Equations (1), (2) are as follows:

$$TOI\ (t) = A_1\ A_2 \ldots\ldots\ldots A_t \ldots \quad (1)$$

$$TII\ (t) = B_1\ B_2 \ldots\ldots\ldots B_t \ldots \quad (2)$$

This way, streams of total output index (TOI) and total input index (TII) for different years (t) were computed from Equations (1) and (2) respectively.
The total factor productivity (TFP) index was computed from TOI and TII as under:

TFPt = {TOI (t) / TII (t)}*100

Factors influencing TFP: To know the influence of infrastructural, socio-economic and technological variable on the productivity of rice a multi-variable model in the form of log linear was estimated as follows. The time series data from the year 1994-95 to 2013-14 were considered for the present study.

$$LnY = Lna + b_1 1 lnX_1 + b_2 lnX_2 + \ \ldots\ldots\ldots + b_n lnX_n$$

Where
Y = TFP indices
a = Intercepts
$b_1, b_2 \ldots b_n$ = Coefficients
Research (X_1) = Expenditure in research and education/'000

ha of rice cropped area.
MARKETS (X_2) = Number of regulated market and sub market yard/'000 ha of rice cultivated area.
Electrification (X_3) = Number of village electrified/'000 ha of rice cultivated area.
HYV (X_4) = Proportion of high yielding variety rice area to total rice cropped area.
TRACTOR (X_5) = Number of tractors/'000 ha of rice cultivated area.
JJA RAINFALL (X_6) = June, July, August rainfall.

Results and Discussion

Rice cultivation scenario: From Table 1 it was clear that, in West Bengal during period I (1994-04) growth of production (2.35%) was due to growth in yield (2.29%) because growth of area was almost stagnant at that time (0.011%). But during period II (2004-16) stagnation of production (0.38%) was solely due to declination of area (-0.72%). In period III (1994-16) growth of production was mainly effected by growth in yield (1.44%). Significant declination of area was quite frightening as these might be due to a huge distress sale by the farmers shifted the area under rice to other crops or might be due to delayed monsoon the farmers became reluctant to put the area under cultivation as most of the area under rice in West Bengal are under rain fed condition and largely depends upon monsoon.

Table 1: Compound annual growth rate of area, production and yield of rice in West Bengal (% per annum)

Years	Area	Production	Yield
Period I (1994-04)	0.011 (0.004)	2.35**(0.006)	2.29***(0.003)
Period II (2004-16)	-0.72*(0.0035)	0.38(0.003)	1.25***(0.002)
Period III (1994-16)	-0.48***(0.001)	1.06***(0.002)	1.44***(0.001)

Note: *** significant at 1 % level, ** significant at 5% level, * significant at 10 % level
Figures in the parenthesis are standard errors

Input share and growth rate of input use of rice cultivation: The perusal of Table. 2 shows that total cost of cultivation along with total variable cost and total fixed cost increased with time for this state, but share of variable cost to total cost was more than fixed cost throughout study periods. Highest cost incurred in human labour among the variable cost items and rental value of owned land among fixed cost items. Share of human labour to total cost was almost half (47.25%) in 2013-14, showing that agriculture in West Bengal was still human labour intensive. Share of other inputs like seed, manure, insecticide, fertilizers to the total cost did not change much for this state. Share of irrigation to total cost of cultivation declined in 2013-14.

Table 2: Costs of different inputs of rice in different time periods in West Bengal (Rs/ha)

Inputs	Period I (1994-95)	Period II (2004-05)	Period III (2013-14)
Seed	423.62(3.32)	686.78(2.81)	1813.24(2.98)
Manure	277.37(2.18)	362.60(1.49)	1201.56(1.97)
Human labour	4774.17(37.46)	9346.30(38.30)	28788.19(47.25)
Animal labour	971.63(7.62)	2392(9.80)	2600.59(4.27)
Fertilizer	645.64(5.07)	1660.60(6.80)	4044.39(6.64)
Insecticide	110.78(0.87)	171.76(0.70)	688.82(1.13)
Irrigation	562.32(4.41)	1353.83(5.55)	1822.28(2.99)
Machine labour	227.42(1.78)	823.71(3.38)	2722.48(4.47)
Miscellaneous cost	2.87(0.00)	15.72(0.06)	34.23(0.06)
Interest on variable cost	188.24(1.48)	366.30(1.50)	929.97(1.53)
Total variable cost	8181.19(64.19)	17179.6(70.40)	44645.75(73.28)
Rental value of owned land	3834.52(30.09)	5524.92(22.64)	13848.82(22.73)
Rent paid for lease-in-land	46.09(0.36)	64.77(0.27)	407.91(0.67)
Land revenue, taxes and cess	16.25(0.13)	38.32(0.16)	49.95(0.08)
Dep. on implements & buildings	164.37(1.29)	490.32(2.01)	680.33(1.12)
Interest on fixed capital	502.82(3.95)	1105.52(4.53)	1291.43(2.12)
Total Fixed Cost	4564.05(35.81)	7223.85(29.60)	16278.44(26.72)
Total Cost of Cultivation	12745.14(100.00)	24403.45 (100.00)	60924.19(100.00)

***Source*:** Directorate of Economics and Statistics, Govt. of India
Figures in parentheses are the percentage of their respective total cost of cultivation

The growth rate of traditional inputs were either stagnant of declining for this state, except manure which showed increasing trend during 2004-14 (Table 3). Fall of growth rate of bullock labour and sharp increase of machine labour showed the awakening of mechanization, and replacement of bullock labour with machine labour in various operation especially in the preparation of fields and harvesting of paddy. This triggering of mechanization had significant and positive effect on yield and it depicted positive significant growth rate throughout the periods. Sharp increase of modern inputs like fertilizer and insecticides showed intensive use excessive dependence on those inputs.

Table 3: Compound Annual Growth Rate of input use of rice cultivation in West Bengal (% per annum)

Inputs	Period I (1994-04)	Period II (2004-14)	Period III (1994-14)
Traditional inputs			
Seed (kg/ha)	-0.84***(0.002)	-1.24***(0.002)	-1.07***(0.0008)
Manure (kg/ha)	-6.56(0.04)	2.81(0.02)	-2.60**(0.01)
Human labour (man-hrs/ha)	0.78 (0.006)	-0.95* (0.004)	0.01 (0.002)
Animal labour (pair-hrs/ha)	-2.09*(0.01)	-8.64***(0.01)	-4.76***(0.006)
Modern inputs			
Fertilizer (kg nut/ha)	6.68***(0.02)	3.62**(0.013)	4.01***(0.006)
Insecticide (kg/ha)	9.02***(0.02)	14.85***(0.016)	8.87***(0.008)
Irrigation charges (Rs/ha)	9.81***(0.02)	8.96***(0.02)	6.33***(0.009)
Machine labour (hr/ha)	14.15***(0.01)	18.98***(0.02)	13.90***(0.007)
Total cost of cultivation (Rs/ha)	7.34***(0.01)	10.47***(0.009)	7.59***(0.004)
Yield (q/ha)	0.98(0.01)	0.95***(0.002)	1.00***(0.002)`

*** Significant at 1 % level, ** significant at 5% level, * significant at 1% level
Figures in the parenthesis are standard errors

Partial factor productivity of rice in West Bengal: The trend in yield per unit of land, labour and fertilizer were estimated for Period I (1994-04), Period II (2004-14) and period III (1994-14) (Table 4). Positive and significant growth rate of labour productivity was a result of reduced use of labour on account of mechanization and in case of land productivity positive growth showed the increase the use of land saving modern inputs particularly fertilizer and irrigation. It was to be noted that there was a significant fall in the productivity of fertiliser in this state was because of poor irrigation management in the eastern region (Kumar 1977) which resulted the nutrient removal from the soil at a rate that had not been matched by balance growth in the supply of nutrients through chemical and organic fertilizers.

Table 4: Trend of growth rates of partial factor productivity of different factors of rice cultivation in West Bengal (% per annum)

Years	Land	Labour	Fertilizer
Period I (1994-04)	2.27***(0.005)	1.49**(0.005)	-4.11**(0.02)
Period II (2004-14)	2.19**(0.007)	2.20***(0.006)	-2.31(0.01)
Period III (1994-14)	1.98***(0.002)	1.47***(0.002)	-2.42***(0.005)

Note: *** significant at 1 % level, ** significant at 5% level, * significant at 10 % level
Yield per unit of input is use as the measure of average productivity

Total factor productivity of rice in West Bengal

In this section Total factor productivity has been estimated for this state which give us an idea about sustainability of rice cultivation of the state. The analysis had been carried out for the post-liberalization period of 1994-95 to 2013-14, which was also divided into two sub-periods, *viz*. Period I (19494-95 to 2003-04) and Period II (2004-05 to 2013-14). The first period broadly corresponded to the period of turbulence in the economy characterized by dwindling of public expenditure in agriculture. The second period was characterized by sharp reversal of the public investment and agricultural performance.

Trends in total output index, total input index and total factor productivity indices in West Bengal are shown in Table 5. In period I there were seven favourable years for West Bengal. During period II West Bengal showed tremendous increase in total factor productivity index. During period II all the years in West Bengal all the years showed favourable TFP growth. A rising trend in TFP from 2010-11 to 2013-14 was due to increase in output index which pushed the TFP curve upward.

Table 5: Törnqvist Theil index of output, input and TFP of rice in West Bengal

Years	TOI	TII	TFP
Period I			
1994-95	100	100	100
1995-96	94.20	89.73	104.98
1996-97	102.78	103.29	99.51
1997-98	105.80	104.48	101.27
1998-99	106.37	106.52	99.86
1999-00	105.52	99.61	105.94
2000-01	107.88	96.61	111.66
2001-02	118.58	99.55	119.12
2002-03	116.18	106.37	109.22
2003-04	118.11	106.45	110.95
Period II			
2004-05	121.42	102.04	118.98
2005-06	113.07	101.45	111.45
2006-07	122.31	104.50	117.05
2007-08	121.37	104.30	116.36
2008-09	119.48	104.36	114.49
2009-10	120.14	105.85	113.50
2010-11	127.74	103.72	123.15
2011-12	126.79	100.51	126.15
2012-13	129.48	94.85	136.51
2013-14	131.56	91.67	143.51

Table 6 depicts average annual growth of output, input and TFP indices of rice. Throughout the periods the TFP growth rate was positive and significant. During period I contribution of TFP growth was 65.22 percent in total output growth. But in Period II TFP growth tremendously (182.8%). This might be the combine result of 'National Food Security Mission' (2007), where the mission intervention consists of a judicious mix of proven technological components covering seeds of improved variety, soil ameliorants, plant nutrients, farm machines/implements, and plant protection measures; and 'Rashtriya Krishi Vikas Yojana' (2007-08), which incentivized the state to enhance public investment. For period III TFP contribution was 101 % which showed promising future for rice cultivation in this state.

Table 6: Average annual growth of output, input and TFP indices of rice in West Bengal (% per annum)

Years	Input	Output	TFP	Share of TFP to the Output growth (in percentage)
Period I (1994-04)	0.77	2.3***	1.50**	65.22
Period II (2004-14)	-0.98**	1.22***	2.23**	182.8
Period III (1994-14)	-0.02	1.48***	1.50***	101

*** Significant at 1 % level, ** significant at 5% level, * significant at 10 % level

Analysing factors affecting total factor productivity of rice in West Bengal

The estimated parameters of TFP decomposition equation for rice were presented in Table 7. Expenditure on agricultural research and education from revenue and capital expenditure (RESEARCH) of this state are another important factors which determines TFP. Education help the educated rural youth to remain in agriculture and contribute their knowledge for the efficient use of inputs and research helps to understand the condition of the state's agriculture, this variable had both positive and significant impact showing for the future growth in TFP, this factor has to be maintained. Ghose and Bhattacharyya (2011) [4] also found similar positive impact of this factor in wheat, rapeseed-mustard and potato cultivation in West Bengal. Kumar and Rosegrant (1994) [9] in their study of 'Productivity and sources of growth for rice in India' and Kumar and Mruthyunjaya (1992) [8] in their study of 'Measurement and Analysis of Total Factor Productivity Growth in Wheat' had also found that research had same positive and significant impact on overall country for the period 1970-71 to 1988-89 showing not only for those two states this factor was also important for total factor productivity growth of wheat and rice in overall country.

The development of rural infrastructure (such as roads, communications, institutional support, and provision of storage and warehousing) are closely associated with the establishment of regulated markets and its connected sub market yards, so the latter variable is used as a proxy for the level of infrastructure development (MARKETS), this variable had positive but insignificant effect on TFP.

Another variable ELECTRFICATION had taken as a proxy of development of rural infrastructure. This variable had negative and significant effect on TFP.

Proportion of HYV rice area to total rice cropped area had also taken as a variable to measure the effects of high yielding varieties in TFP, although it had positive effect but it was insignificant. Number of tractors per thousand hectare of rice cultivated area (TRACTOR) had taken to capture the effect of mechanization on TFP. This variable had show positive and significant effect.

To capture the effect of weather on TFP, JJA RAINFALL variable had taken. It had negative but insignificant effect.

Table 7: Factors affecting Total Factor Productivity of rice in West Bengal from 1994-95 to 2013-14

Variables	Parameter Estimates	Standard Error	T-Ratio
Intercept	8.17**	2.846	2.87
Research	0.152*	0.077	1.97
Market	0.664	0.459	1.45
Electrification	-0.952*	0.489	-1.95
HYV	0.102	0.177	0.579
Tractor	0.125*	0.068	1.83
JJA rainfall	-0.034	0.065	-0.51
R^2= 0.80, D.F = 19			

*** Significant at 1 % level, ** significant at 5% level, * significant at 10 % level

Summary and Conclusions

Rice is an important crop to achieve sustainable development goal in zero hunger. The study had revealed that there was a significant declination of area under rice cultivation from 1994-2016. Main factors for this declination was delayed monsoon and distress sale by the farmers. So government should pay attention to cover more area under irrigation and on effective procurement policy. Share of human labour was almost half (47.28%) of total cost of cultivation in 2013-14, showing rice cultivation was labour intensive. Productivity of land and labour was positive throughout the studied periods but productivity of fertilizer was declining (-2.45%) from 1994-2014. This was mainly due to poor irrigation management so this inefficiency need to be cared of by promoting more efficient method. Growth rate of TFP was positive and significant throughout the studied periods. RESEARCH and TRACTOR were the only variables which had significant and positive effect on TFP. So, growth of these factors should be maintained for future growth of TFP.

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