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Total Factor Productivity Growth in West Bengal Agriculture- A DEA Approach

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Abstract

The present study seeks to estimate the total factor productivity growth of West Bengal agriculture considering five major crops- paddy, wheat, rapeseed-mustard, potato and, jute for the period 2005-06 to 2018-19. The total factor productivity (TFP) growth is estimated using data envelopment analysis (DEA) and, further TFP growth is decomposed into the components of technical change, efficiency change and, scale change to identify the sources of productivity growth. The study draws motivation from the lack of research evidence to show the total productivity growth in the crop sector in the post-2000s. The estimation of TFP growth revealed that the TFP growth of West Bengal agriculture (all the selected crops taken together on average) is positive during the period 2005-06 to 2018-19. It is observed that all the selected crops except jute experienced positive TFP growth during the period under study. The decomposition of TFP highlights that all the crops except jute and potato have undergone a positive technical change. Pure technical efficiency change is zero for all the selected crops whereas scale efficiency change is positive for all the crops except jute. Thus, TFP growth occurred due to both technical change and scale efficiency changes for all the crops except jute.

Key words: West Bengal Agriculture, Growth, Total factor productivity, Data envelopment analysis

The agriculture sector plays an important role for the growth and development of the economy. It not only provides food to the large people and fast-growing people but also raw materials to various agro-based industries. It has a crucial role in employment and thus inclusive growth. Almost 61.5 percent rural working population and 45.6 percent (urban plus rural) working population was engaged in agriculture and allied activities [1]. Although foodgrain production significantly increased in India after the successful implementation of the high yielding variety technology in the mid-1960s. However, in the post-reform period of the 1990s, the foodgrain production increased at the rate of 1.7 percent [2], which was below the population growth rate of 1.9 percent [2]. Thus, there is a gap between the growth rate of food production and population growth which can lead to food insecurity. Another major concern in recent years is acute food price inflation. If we look per capita availability of cultivable land at 0.20 hectares (ha), which is much lower than many developed countries in the world. Thus, the immense pressure of population on land and overcrowding of agriculture has resulted in zero or even negative marginal productivity of labour.

Given the limited scope in raising the net sown area, it is very important to meet the food demand. So, there is a viable option for an increase in productivity to ensure food security. To maintain the food demand, the efficiency of agriculture productivity with sustainability is very crucial. Sustainable development asks not only for the expansion of output through using greater inputs but also enhancement of total factor productivity growth (TFPG). It is generally acknowledged that growth no matter how impressive will not be sustainable without improvement in total factor productivity growth. TFPG is defined as the residual growth in outputs not explained by the input growth [3]. It is the combined result of technical progress and improvements in efficiency. As a result, the movement of TFPG can be decomposed into technical change, technical efficiency change and scale efficiency change. Under these circumstances, there is a need for measurement of TFPG and, the decomposition of TFPG. Decomposition of TFPG gives us the sources of TFPG that account for TFPG changes.

The present study estimates the TFPG of West Bengal agriculture as well as the decomposition of TFPG. A disaggregated crop-specific TFPG is estimated which primarily enables us to make a distinction between crops that remain ahead in terms of TFPG and those lagging behind. It is also helpful in framing policies toward improvement in TFPG. Specifically, the focus is on five major crops produced in West Bengal: paddy, wheat, rapeseed-mustard, potato, and jute. The reason behind the choice of the West Bengal economy is that among the Indian states, West Bengal is one of the most fertile regions in the country with characterized by fragmented small landholding by a large number of farmers. West Bengal has accounted for an important position in terms of the average

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annual rate of growth of the gross state domestic product (GSDP) from agriculture over the 10 years from 1994 to 2004 at 3.64 percent—much higher than the all-India average (1.53%) [4]. About 70 percent of the working population is directly or indirectly engaged in West Bengal agriculture. The contribution of Agriculture and Allied in GSDP of West Bengal was 23.93% at a constant price for the year 2004-05. But the contribution slips to 16.34% in GSDP of West Bengal at constant prices for the year 2013-14 [5]. Although the contribution decreases over the years still it is higher compared to the All-India level accounted for 13.9% in the year 2013-14. Although the substantial improvement is occurred in agricultural production in West Bengal, still there is a considerable scope for the improvement of agricultural production and productivity. The production of crops such as jute, wheat, potato, and rapeseed-mustard increased significantly. With respect to some of the crops such as jute and potato, West Bengal's contribution to all-India production is quite large. As per 2007-08 estimates West Bengal accounts for approximately 15.3 percent of total rice production, 1.2 percent of total wheat production, 6.2 percent of total rapeseed-mustard production, 34.8 percent of total potato production, and 74.2 percent of total jute production in India [6]. The five crops were selected based on their percentage shares in total area under respective categories in West Bengal, and the trend growth rates of their outputs. Almost 98 percent of the area under fibers is comprised of jute. Paddy and wheat together contribute about 99 percent to the total area under cereals and 95 percent of the total foodgrains area. Potato comprises about 71 percent of the area in the miscellaneous crop category. Almost three-fourths (72%) of the area under oilseeds is comprised of rapeseed mustard.

The objectives of the present study are as follows:

i) To estimate the rate of growth in production and area of five major crops in West Bengal agriculture.

ii) To estimate the TFP growth of five major crops in West Bengal agriculture for the period 2005-06 to 2018-19.

iii) To identify the sources of TFP growth whether it occurred due to technical change and/or efficiency change and/or scale efficiency change.

Thus, the TFP growth is estimated using the data envelopment analysis (DEA), which is a non-parametric approach. More specifically, the Malmquist productivity index (MPI), introduced by Caves, Christensen, and Diewert [7] is constructed to estimate the TFP index. The MPI has a few advantages over other conventional measures as it requires neither any explicit specification of production technology nor any econometric estimation. It only requires data on input and output quantities. Furthermore, with the use of the distance function, it is possible to directly measure changes in the level of technical efficiency which is an important component of productivity changes between years, and, thus, it helps to isolate two components of productivity growth—catching up to the frontier (changes in technical efficiency over time) from shifts in the frontier (technical change over time).

MATERIALS AND METHODS

The Malmquist productivity index was introduced as a theoretical index by Caves, Christensen and Deiwert [7] and was popularized as an empirical index by Fare *et al*. [8]. This index is defined using distance functions. Here, an output distance function is used to consider a maximum proportional expansion of the output, given the inputs. More specifically, the Malmquist TFP index measures the TFP growth change between two data points by calculating the ratio of the distances of each data point relative to a common technology. Following Fare *et al*. [8], the output-oriented Malmquist TFP change index between period t and period $(t+1)$ is given by:

$$m_c\,(x^t, y^t, x^{t+1}, y^{t+1}) = \left[\frac{D_c^t(x^{t+1},y^{t+1})}{D_c^t(x^t,y^t)} \cdot \frac{D_c^{t+1}(x^{t+1},y^{t+1})}{D_c^{t+1}(x^t,y^t)} \cdot\right]^{1/2} \quad \text{.....(1)}$$

Where the notation $D_c^t\,(x^{t+1}, y^{t+1})$ represents the distance from the period $(t+1)$ observation to the technology of t period, c represents the technology under constant returns to Scale (CRS), y represents output and x represents input. A value of m_c greater than one indicates positive TFP growth from period t to period $(t+1)$ while a value less than one indicates a decline in TFP growth. Fare *et al*. [8] provided an initial decomposition of the productivity as:

$$m_c\,(x^t, y^t, x^{t+1}, y^{t+1}) = \left[\frac{D_c^{t+1}(x^{t+1},y^{t+1})}{D_c^t(x^t,y^t)}\right] \times \left[\frac{D_c^t(x^{t+1},y^{t+1})}{D_c^{t+1}(x^{t+1},y^{t+1})} \cdot \frac{D_c^t(x^t,y^t)}{D_c^{t+1}(x^t,y^t)} \cdot\right]^{1/2} \quad \text{........(2)}$$

where the ratio outside the square brackets measures the change in the output-oriented measure of Farrell technical efficiency between periods t and $(t+1)$. That is, the efficiency change is equivalent to the ratio of the Farrell technical efficiency of period t to that of period $(t+1)$. The remaining part of the index in Eq. (2) is a measure of technical change which is the geometric mean of the shift in technology between the two periods, evaluated at x^t and x^{t+1}. In other words, TFP growth can be decomposed as:

TFP Growth = Technical Efficiency Change (Catching up Effect) × Technical Change (Frontier Effect)

Here both components of TFP growth are measured under CRS technology. Since the best practice technologies may exhibit variable returns to scale (VRS), it is desirable to redefine both components on best technologies. Fare *et al*. [8] redefined the Technical Efficiency component in the following way:

$$\left[\frac{D_c^{t+1}(x^{t+1},y^{t+1})}{D_c^t(x^t,y^t)}\right] = \left[\frac{D^{t+1}(x^{t+1},y^{t+1})}{D^t(x^t,y^t)}\right] \times \left[\frac{D_c^{t+1}(x^{t+1},y^{t+1})}{D^{t+1}(x^{t+1},y^{t+1})} \cdot \frac{D^t(x^t,y^t)}{D_c^t(x^t,y^t)}\right] \quad \text{------------ (3)}$$

Technical Efficiency Index $_{\text{CRS}}$ = Technical Efficiency Index $_{\text{VRS}}$ × Scale Efficiency Index.

Thus, they decomposed the catching up effect (given by technical efficiency change under the CRS technology) into 'pure' technical efficiency change (given by technical efficiency change under the VRS technology) and scale efficiency change. That is:

Technical Efficiency Change Index = Pure Technical Efficiency Change Index × Scale Efficiency Change Index

Therefore substituting (3) into (2) gives the Fare *et al*. [8] decomposition of the Malmquist productivity index (MPI)

$$m_c\,(x^t, yt, xt^{+1}, yt^{+1}) = \left[\frac{D^{t+1}(x^{t+1},y^{t+1})}{D^t(x^t,y^t)}\right] \times \left[\frac{D_c^{t+1}(x^{t+1},y^{t+1})}{D^{t+1}(x^{t+1},y^{t+1})} \cdot \frac{D^t(x^t,y^t)}{D_c^t(x^t,y^t)}\right] \times \left[\frac{D_c^t(x^{t+1},y^{t+1})}{D_c^{t+1}(x^{t+1},y^{t+1})} \cdot \frac{D_c^t(x^t,y^t)}{D_c^{t+1}(x^t,y^t)}\right]^{1/2}$$

TFP Change Index = Pure Technical Efficiency Change Index × Scale Efficiency Change Index × Technical Change Index ------------ (4)

In this decomposition technical efficiency change is measured relative to the best practice technology but technological change or shifts of frontier remains measured under CRS.

The required distance measures for the decomposition in Eq. (3) and (4) can be calculated using a mathematical linear programming (LP) technique called DEA. This requires the solving of four LPs. under the constant returns to scale technology. In this consisting of time Period (t) is equal to 14 years, inputs (x) = 4 and output (y) = 1. λ's are intensity parameters. The four LP's mentioned below are for each production unit. Thus, suppose one has data on i no of DMUs and t time periods, then one must solve i x (4t-2) LP's to solve for the estimation of Malmquist TFP indices.

$$[D^t_c(y^t, x^t)]^{-1} = \max_{\varphi\lambda} \varphi,$$
$$\text{st} \quad -\varphi y^t_i + Y^t\lambda \geq 0, \quad x^t_i - X^t\lambda \geq 0, \quad \lambda \geq 0,$$

$$[D^{t+1}_c(y^{t+1}, x^{t+1})]^{-1} = \max_{\varphi\lambda} \varphi,$$
$$\text{st} \quad -\varphi y_i^{t+1} + Y^{t+1} \geq 0, \quad x_i^{t+1} - X^{t+1}\lambda \geq 0, \quad \lambda \geq 0,$$

$$[D^t_c(y^{t+1}, x^{t+1})]^{-1} = \max_{\varphi\lambda} \varphi,$$
$$\text{st} \quad -\varphi y_i^{t+1} + Y^{t+1} \geq 0, \quad x_i^{t+1} - X^{t+1}\lambda \geq 0, \quad \lambda \geq 0,$$

$$[D^{t+1}_c(y^t, x^t)]^{-1} = \max_{\varphi\lambda} \varphi,$$
$$\text{st} \quad -\varphi y_i^t + Y^t \geq 0, \quad x_i^t - X^t\lambda \geq 0, \quad \lambda \geq 0,$$

Where;

y_i^t is a M×1 vector of output quantities for the i-th industry in the t-th year

x_i^t is a K×1 vector of input quantities for the i-th industry in the t-th year

Y^t is a N×M matrix of output quantities for all N industries in the t-th year

X^t is a N×K matrix of output quantities for all N industries in the t-th year

λ is a N×1 vector of weights

φ is a scalar

In this study, TFP is estimated taking into one output with four inputs. Output is measured as the level of production (in thousand tons). The inputs are (1) irrigated area (IRG) (thousand hectares). (2) human labour (HL) (man-hours), (3) fertilizer (FRT) (thousand tons), and (4) seeds (thousand tons). We have selected five major crops viz., paddy, wheat, rapeseed mustard, jute and potato to study the agricultural productivity in West Bengal for the period 2005-06 to 2018-19. Compiled data on output and inputs are drawn from Agricultural Statistics of India, Economic & Political Weekly (EPW) Research Foundation.

RESULTS AND DISCUSSION

Annual average growth of output production and area under cultivation

Data in (Table 1) depicts the annual average growth rate of production and area under cultivation. Potato accounted for the maximum annual average growth of production (8.5%) followed by rapeseed mastered (6.5%), paddy (1.4%), and jute (0.03%) respectively. Wheat accounted for the negative growth of production by -1.2%. The annual average growth of output production in average agriculture of West Bengal is 1.1% during the period 2005-06 to 2018-19. In the case of annual average growth of the area under cultivation, rapeseed mastered and potato accounted for positive growth by 3.2% and 1.8% respectively whereas wheat, paddy, and jute registered negative growth in the area under cultivation by -6.1%, 0.21%, and -0.49% respectively. The annual average growth of area under cultivation in average West Bengal agriculture also accounted for negative growth by -0.22% during the years 2005-06 to 2015-16.

Table 1 Annual Growth rate of output production and area cultivation during the year 2006-07 to 2018-19 in West Bengal Agriculture

Crops	Annual growth of production	Annual growth of area cultivation
Paddy	0.0104	-0.0021
Wheat	-0.1246	-0.0612
Rapeseed & Mustard	0.0653	0.0318
Potato	0.0847	0.0178
Jute	0.0003	-0.0049
Average West Bengal Agriculture	0.0107	-0.0022

Total factor productivity estimates

The results of the total factor productivity index (MPI) are estimated by using the data envelopment analysis program (DEAP) introduced by Coelli [9]. The sample averages of the total factor productivity (TFP) index for the individual crops and the average annual growth rates of total factor productivity for these crops are presented in (Table 1-2) respectively. The TFP index in any one year treats the year immediately prior to it as the base so the difference between the value of the TFP index and unity shows the total factor productivity growth (TFPG) rate over the previous year. From the disaggregated crop-wise analysis, it is evident that all selected crops except jute, experienced positive total factor productivity growth. It is observed across different crops that wheat accounted for the highest productivity growth of 4.1 percent followed by paddy (3.7%), rapeseed and mustard (2.0%), and potato (0.4%) respectively. All the selected crops taken together have an annual average TFP growth rate of about 1.8 percent. Now TFP growth can be caused by technical change and/or technical efficiency change and/or scale efficiency change. While (Table 1) depicts the TFP change index, level of technical change index, technical efficiency change index, and scale efficiency change index by selected crops.

Data in (Table 2), on the other hand, shows the rates of TFP growth, rate of technical progress, and rate of technical efficiency change along with the rate of scale efficiency change for the selected crops. (Table 2) shows that all the crops except jute and potato have undergone positive technical changes. The highest technical progress occurred for wheat (2.7%), followed by paddy (2.6%), and rapeseed-mustard (1.1%) respectively. The rate of technical progress for potato is zero whereas it is negative for jute (-1.0%).

So, for jute, there is technical regress. It is observed that for all the selected crops the rate of pure technical efficiency change is zero which indicates there is no role of technical efficiency change causing the rate of change in TFP. The rate of scale efficiency change for all selected crops except jute are positive and wheat accounted for the highest rate of scale efficiency change (1.4%) followed by paddy (1.1%), rapeseed and mustard (0.9%), and potato (0.4%) respectively. The positive growth rate of TFP of all selected crops except jute has been accompanied by the positive growth rate of technical change and scale efficiency change but the rate of technical change is higher compared to the rate of scale efficiency change. In the case of jute, the negative rate of growth of TFP (-1.0%) is caused by a purely negative rate of growth of technical change as the rate of change in technical efficiency and scale efficiency are zero for this crop. The annual average growth rate of TFP for all selected crops is caused by a positive rate of growth both for technical change and scale change but the rate of technical change (1.1%) is higher compared to the rate of scale efficiency change (0.8%). The level of pure technical efficiency change for all the selected crops has reached close to 100 percent. Therefore, there is little scope for further improvement in efficiency for these crops. However, it is observed in Table 1 that jute has experienced technical regress that causes the respective frontier to shift below. As a result, the apparent improvement in the technical efficiency (reaching the 100 percent mark) for jute cannot be explained in terms of the movement towards the frontier or the efficiency gain (catching up effect). The proximity of observations to the frontier or 'catching-up' is explained by the downward shift of the frontier itself.

Table 1 Average total factor productivity index and average efficiency change index and technical change index for the period

Crops	Efficiency change index	Technical change index	Pure efficiency change index	Scale efficiency change index	Total factor productivity change index
Paddy	1.011	1.026	1	1.011	1.037
Wheat	1.014	1.027	1	1.014	1.041
Rapeseed & Mustard	1.009	1.011	1	1.009	1.020
Potato	1.004	1	1	1.004	1.004
Jute	1.000	0.99	1	1	0.990
Mean	1.008	1.011	1	1.008	1.018

Table 2 Average annual rates of total factor productivity growth, technical progress, technical efficiency change and scale efficiency change for the period

Crops	Efficiency change	Technical change	Pure efficiency change	Scale efficiency change	Total factor productivity change
Paddy	0.011	0.026	0.000	0.011	0.037
Wheat	0.014	0.027	0.000	0.014	0.041
Rapeseed & Mustard	0.009	0.011	0.000	0.009	0.020
Potato	0.004	0.000	0.000	0.004	0.004
Jute	0.000	-0.010	0.000	0.000	-0.010
Mean	0.008	0.011	0.000	0.008	0.018

Fig 1 Total factor productivity index of West Bengal agriculture during the period 2005-06 to 2018-19

It is observed from (Fig 1) that the total factor productivity index of the average of five crops of West Bengal agriculture is fluctuating and slightly decreasing over the period 2006-07 to 2018-19. Data in (Table 4-5) show the total factor productivity (TFP) index and the rate of the total factor productivity (TFP) change with its different components of the average five crops of West Bengal agriculture over the period 2006-07 to 2018-19.

Table 3 Annual levels of total factor productivity change (tfpch) index, efficiency change (effch) index, pure efficiency change (pech) index, technical change (techch) index, and scale change (sech) index in average West Bengal agriculture

Year	effch	techch	pech	sech	tfpch
2006-07	1.016	1.011	1	1.016	1.027
2007-08	1.012	1.012	1	1.012	1.024
2008-09	1.018	1.014	1	1.018	1.032
2009-10	1.008	1.017	1	1.008	1.025
2010-11	0.986	1.011	1	0.986	0.997
2011-12	1.015	0.980	1	1.015	0.995
2012-13	0.989	1.007	1	0.989	0.996
2013-14	1.016	1.011	1	1.016	1.027
2014-15	1.019	1.014	1	1.019	1.033
2015-16	1.011	1.016	1	1.011	1.027
2016-17	0.990	1.011	1	0.990	1.001
2017-18	1.006	1.015	1.0001	1.006	1.021
2018-19	1.015	1.019	1.0001	1.015	1.034
mean	1.008	1.011	1.000	1.008	1.018

Table 4 Annual growth rate of total factor productivity change (tfpch), efficiency change (effch), pure efficiency change (pech), technical change (techch), and scale change (sech) in average West Bengal agriculture

Year	effch	techch	pech	sech	tfpch
2006-07	0.016	0.011	0.000	0.016	0.027
2007-08	0.012	0.012	0.000	0.012	0.024
2008-09	0.018	0.014	0.000	0.018	0.032
2009-10	0.008	0.017	0.000	0.008	0.025
2010-11	-0.014	0.011	0.000	-0.014	-0.003
2011-12	0.015	-0.020	0.000	0.015	-0.005
2012-13	-0.011	0.007	0.000	-0.011	-0.004
2013-14	0.016	0.011	0.000	0.016	0.027
2014-15	0.019	0.014	0.000	0.019	0.033
2015-16	0.011	0.016	0.000	0.011	0.027
2016-17	-0.010	0.011	0.000	-0.010	0.001
2017-18	0.006	0.015	0.000	0.006	0.021
2018-19	0.015	0.019	0.000	0.015	0.034
Mean	0.008	0.011	0.000	0.008	0.018

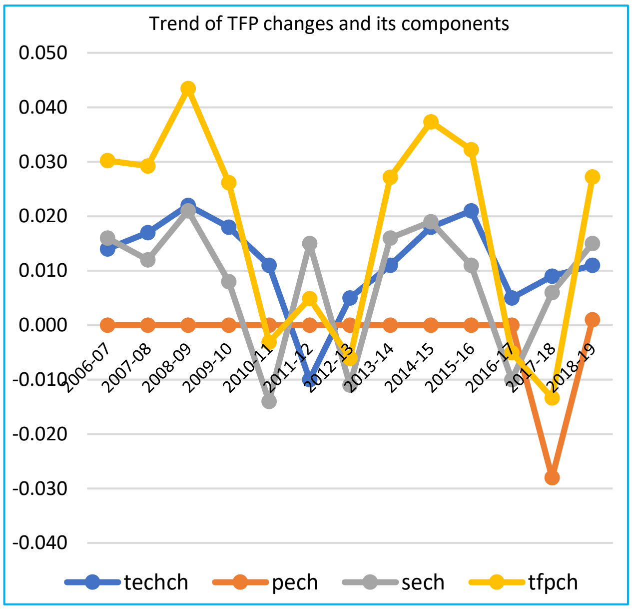

Fig 2 Trend of total factor productivity growth rate and its components of West Bengal agriculture during the period 2005-06 to 2018-19

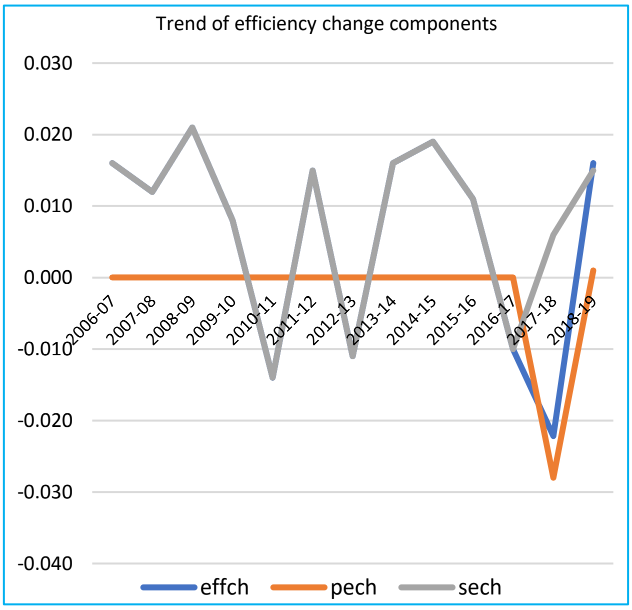

Fig 3 Trend of efficiency change growth rate and its components of West Bengal agriculture during the period 2005-06 to 2018-19

Data in (Fig 2) shows the fluctuating growth rate of TFP change but there is a slightly decreasing trend in TFP growth rate change in average West Bengal agriculture over the period 2006-07 to 2018-19. In the case of technical change, the rate is fluctuating with a slightly decreasing trend during the period 2006-07 to 2018-19. Both the growth rate of efficiency change and scale efficiency change are fluctuating at a similar pattern as the rate of pure technical efficiency change is constant shown in Figure 3. The trend of efficiency change and scale change in average West Bengal agriculture is more or less constant during the period under study depicted in (Fig 3).

CONCLUSION

The total factor productivity analysis revealed that all the selected crops taken together have an annual average productivity growth of about 1.8 percent. The crops differ remarkably from each other so far as their TFP growth is concerned. All selected crops except jute experienced positive productivity growth. Wheat registered the highest total factor productivity growth of about 4.1% while potato recorded the lowest positive productivity growth. The decomposition of the TFPG, explains that all the crops except jute and potato showed positive technical progress and technical efficiency change. Jute has experienced technical regress whereas potato showed zero-improvement technical change. For all the selected crops, there is no role of pure technical efficiency changes causing for efficiency change and thus TFP changes. Only Scale efficiency changes cause technical efficiency changes. Thus, the TFP changes occurred due to both technical change and scale efficiency change for all the crops except jute where TFP changes due to a purely technical change. From the trend line analysis, it is concluded that although the TFP growth of West Bengal agriculture (on average) is positive and fluctuating, there is a slightly downward trend observed during the period under study.

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