Total Factor Productivity Growth and its Determinants for West Bengal Agriculture

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ABSTRACT

The present study is concerned with the measurement of total factor productivity growth (TFPG) using the non-parametric approach for seven major crops--aus, aman, boro, jute, wheat, rapeseed-mustard, and potato--in West Bengal, from 1980 to 2003. TFPG is decomposed into the components of technical change, efficiency change, and scale change. A second stage regression analysis highlights the favorable role of factors (i.e., public expenditure, credit, irrigation, regulated markets, and inequality reduction in the distribution of operational land holdings) in fostering TFPG.

INTRODUCTION

Sustainable agricultural development calls not only for output expansion through increasing inputs but also enhancement of total factor productivity growth (TFPG). India, with 1.21 billion people is the second most populous country in the world. In 2001, almost 57 percent of the working population was engaged in agriculture and allied activities. Overcrowding has resulted in zero or even negative marginal productivity of labor. The immense pressure of population on land is reflected in the per capita availability of cultivable land at 0.20 hectares (ha), which is much lower than many developed countries in the world.[1] India attained self-sufficiency in foodgrain production and also became a net exporter of foodgrain 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, which was below the population growth rate of 1.9 percent. Thus, a large section of the Indian population is still suffering from food insecurity. Another major concern in recent years is acute food price inflation in 2010. The Wholesale Price Index increased by about 15.6

[1] Per head availability of cultivable land is 4.48 ha in the U.S.A., 0.43 ha in the U.K., and 0.35 ha in Japan.

percent (from 155.39 percent in 2010 to 179.63 percent in 2011). Given the limited scope in raising the net sown area,[2] it seems viable to opt for an increase in TFPG to ensure food security.

TFPG is the combined result of technical progress and improvements in efficiency, and captures that part of output growth not taken care of by input growth. As a result, movement of TFPG can be decomposed into technical change and scale efficiency change. Under these circumstances, there emerges a need for measurement of TFPG and the identification of the factors that account for productivity changes.

A disaggregated crop-specific analysis of TFPG 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 towards improvement in TFPG. Given the dearth of crop-wise analysis in the existing literature, the present study performed a crop-wise analysis for West Bengal. Specifically, the focus is on seven major crops produced in West Bengal: aman (*kharif* paddy), aus (pre-*kharif* paddy), boro (*rabi* paddy), jute, wheat, potato, and rapeseed-mustard.[3]

The reason behind the choice of the West Bengal economy is that among the Indian states, West Bengal acquires an important position in terms of the average annual rate of growth of the gross state domestic product from agriculture over the 10 year period from 1994 to 2004 at 3.64 percent—much higher than the all-India average (1.53%) and also the highest among all states (Government of West Bengal 2009; Planning Commission and Central Statistical Organization 2008). Apart from the three varieties of paddy (i.e., *aman*, *aus*, and *boro*), the substantial improvement in agricultural production in West Bengal is attributable to the production of crops such as jute, wheat, potato, and rapeseed-mustard. With respect to some of these crops (i.e., jute, potato) West Bengal's contribution to all-India production is quite large. As per 2002 estimates West Bengal accounts for approximately 18 percent of total rice production,[4] 1.2 percent of total wheat production, 4.5 percent of total rapeseed-mustard production, 30 percent of total potato production, and 77 percent of total jute production in India.

The seven crops were selected based on their percentage shares in total area under respective categories in West Bengal, the consumption pattern, and the trend growth rates of their outputs. Almost 98 percent of the area under fibers is comprised of jute. Aman, aus, boro, and wheat together contribute about 99 percent to the total area under cereals and 95 percent of 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. State-wise data on the consumption pattern of various crops (Ministry of Statistics and Program Implementation 2005) show that in 2004, monthly per capita consumption of rice, wheat, and potato stood at around 19.04 kilograms (kg), 3.06 kg, and 5.54 kg, respectively. Rice accounts for more than 80 percent of total cereal consumption in the state,

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[2] Net area sown was 140.29 million ha in 1980-81, 142.82 million ha in 1996-97 and 140.86 million ha in 2007-08.

[3] Aus and jute are pre-kharif crops. The pre-kharif season refers to the period from March-April to June-July. Aman is the kharif crop. The kharif period starts with the onset of the monsoon in June-July and lasts till October-November. Crops such as boro, wheat, potato, and rapeseed-mustard are planted in the rabi season which spans the period from October-November to February-March.

[4] Secondary data for three different categories of rice (i.e., aus, aman, and boro) are not available on an all-India basis so the comparison is restricted to the total rice production figure.

while wheat accounts for about 13 percent of the total. Potato is the most important vegetable in terms of absolute consumption.[5] The consumption data for the three categories of rice (i.e., aus, aman, and boro) were not available as the distinction is made on the basis of sowing and harvesting seasons and, hence, is more valid and useful for production decisions than for gauging consumption. Consumption figures for rapeseed-mustard were not available. However, consumption data on mustard oil and oilseeds were available and the respective figures for the same year are 1.072 kg and 0.04 kg. As rapeseed-mustard is the most commonly used oilseed, either in seed form or as cooking oil, the oilseed consumption figure can also be taken to represent the consumption pattern of rapeseed-mustard. The consumption data for jute (as sum total of internal consumption and exports of jute goods) was obtained from the Jute Corporation of India. Available data suggest that in 2004-05, internal consumption of jute stood at 1394.2 megatons while exports of jute goods were 321.8 megatons. Therefore, total consumption of jute was around 1716 megatons in 2004-05. An estimate by the authors puts the trend rates of growth in production for aman, aus, and boro at 2.72 percent, 1.10 percent, and 6.72 percent, respectively. The respective figures for wheat, jute, rapeseed-mustard, and potato are 2.34 percent, 3.41 percent, 4.13 percent, and 5.6 percent.

The present study estimates TFPG using the data envelopment analysis (DEA), which is a non-parametric approach.[6] More specifically, the paper resorts to the Malmquist productivity index (MPI), introduced by Caves, Christensen, and Diewert (1982).

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 distance function, it is possible to directly incorporate changes in the level of technical efficiency as an important component of productivity changes between years, and, thus, it helps to isolate two mutually exclusive and exhaustive components of productivity growth—catching up to the frontier (changes in technical efficiency over time) from shifts in the frontier (technical change over time). Finally, the second stage regression analysis is performed to find out the determinants of TFPG.

METHODOLOGY

Theoretical Framework: Measurement and Decomposition of Multi-Factor Productivity Growth

The DEA being a non-parametric analysis does not require any explicit specification of production function. The analysis involves construction of a benchmark technology reflecting the maximum producible output on the basis of the sample observations and a few assumptions about the production technology such as feasibility, convexity of the production possibility set (PPS), free disposability of both inputs and outputs, and constant returns to scale (CRS) or variable returns to scale (VRS).

In a single input-output framework, a productivity index for k^{th} farm at time 't+1', with period t as the base, can be written as

$$\pi_k = \frac{AP_k^{t+2}}{AP_k^t} \tag{1}$$

[5] Data on quantity consumed for total vegetables are not available. Hence, the relative share of potato in vegetable consumption cannot be computed.

[6] There are four different approaches in TFPG measurement. These are (1) Growth Accounting Approach, (2) Econometric Estimation of Production and Cost Functions, (3) Production Frontier Approach, and (4) Non-Parametric Approach.

where: $$AP_k^t = \frac{y_k^t}{x_k^t}$$

is average productivity of say, k^{th} farm, at time '*t*'. y_k^t and x_k^t are output and input quantities of the k^{th} farm, at time *t*.

The index π_k does not require assumptions about returns to scale. However, in order to decompose the changes in productivity into its components, the concept of returns to scale assumption becomes important. Also, in the multiple-output multiple-input case, it is needed to arrive at composite input and output levels to carry out the productivity measurement.

Given the above assumptions, the free disposal convex hull of the observed input-output vectors gives an inner approximation of the true underlying PPS. With CRS assumption, all non-negative input-output combinations, which are proportional to any feasible input-output combination, will also be feasible. Then the PPS becomes a convex cone (Varian 1984). Figure1 depicts the diagrammatic representation of such a construction.

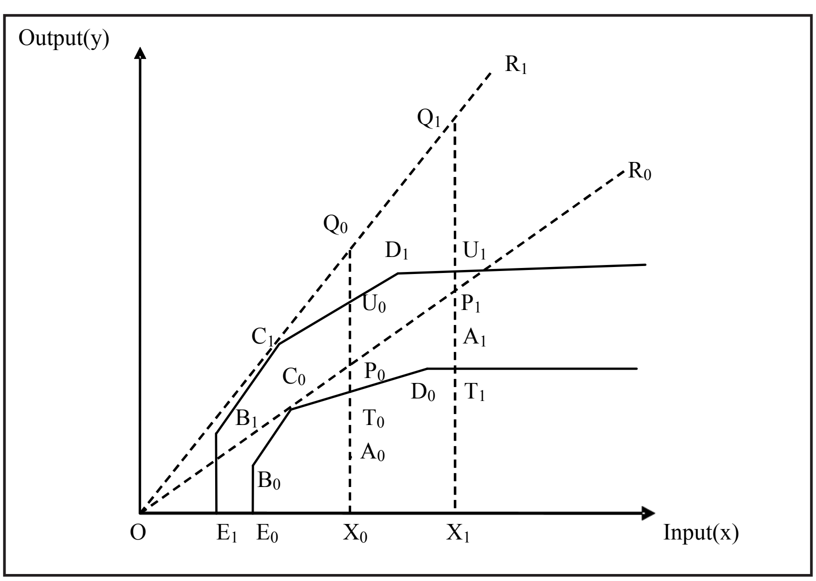
Let us begin with the case of four farms—A, B, C, and D. The observed input-output levels are shown by points A_0 through D_0 in period '0'. Similarly, points A_1 through D_1 represent input-output levels in period '1'. For farm *A,* input $0X_0$ is required to produce A_0X_0 in period '0' and input $0X_1$ to produce A_1X_1 in period '1'. Therefore, the productivity index for farm *A* in period '1' is

$$\pi_A = \frac{\frac{A_1X_1}{0X_1}}{\frac{A_0X_0}{0X_0}} \tag{2}$$

Given the convexity assumption, all input-output combinations in the convex hull of the points A_0, B_0, C_0, and D_0 are feasible in period '0'. The free disposal convex hull is the set of points bounded by the horizontal axis and the extended broken line $E_0B_0C_0D_0$. Under CRS, all radial expansion and (non-negative) contraction of feasible input-output bundles are all feasible. Thus, the PPS in case of CRS in period '0' is the cone formed by the horizontal axis and the ray $0R_0$ through point C_0. Similarly, in period '1' the CRS frontier is the ray $0R_1$ through the point C_1.

For any (not necessarily feasible) input

Figure 1.Construction of PPS based on the observed input-output vectors



vector x^t and the output vector y^t in period t, (t=1,… T), the production possibility set is defined as

$$S^t = \{(x^t y^t) : y^t \text{ can be produced from } x^t\},$$
$$x^t \in R^N + t = 1, \dots \mathrm{T}$$

The PPS is assumed to satisfy certain axioms required to define meaningful output distance functions. The set should be closed, bounded, and convex and satisfy strong disposability of outputs. Then the output distance function as provided by Shephard (1970) can be written as

$$D^t = (x^t, y^t) = \min \delta : \left(\frac{x^t, y^t}{\delta}\right) \in S^t, t = 1, \dots T$$

It is to be noted that

$$D_0^t(x^t, y^t) \leq 1, \text{if and only if } (x^t, y^t) \in S^t$$

and

$$D_0^t(x^t, y^t) = 1, \text{if and only if } (x^t, y^t)$$

is on the frontier of technology. This occurs when production is technically efficient (Farrell 1957).

Under the CRS assumption, in period ‘0’, the maximum producible output from input $0X_0$ is P_0X_0. Similarly, P_1X_1 is the maximum producible output from input $0X_1$, in period ‘0’. Hence, the distance functions are:

$$D_c^0(x_0 y_0) = \frac{A_0X_0}{P_0X_0} \tag{3}$$

$$D_c^0(x_1 y_1) = \frac{A_1X_1}{P_1X_1} \tag{4}$$

in period ‘0’. So, the productivity index for farm A in period ‘0’ can be written as,

$$\pi_A^1 = \frac{\frac{A_1X_1}{0X_1}}{\frac{A_0X_0}{0X_0}} = \frac{\frac{A_1X_1}{P_1X_1} * \frac{P_1X_1}{0X_1}}{\frac{A_0X_0}{P_0X_0} * \frac{P_0X_0}{0X_0}} = \frac{D_C^0(x_1, y_1)}{D_C^1(x_0, y_0)} \tag{5}$$

Following the same logic,

$$\pi_A^1 = \frac{\frac{A_1X_1}{0X_1}}{\frac{A_0X_0}{0X_0}} = \frac{D_C^1(x_1, y_1)}{D_C^1(x_0, y_0)} \tag{6}$$

According to Färe, Grosskopf, Norris, and Zhang (1994) one may calculate productivity indices relative to any technology. In this paper, the Malmquist productivity index is calculated for VRS technology. Following Ray and Desli (1997), the productivity index is decomposed into three separate components: technical change, technical efficiency change, and scale efficiency change.

Referring to Figure 1, points such as T_0 and T_1 in period ‘0’, are on the VRS frontier and, hence, technically efficient. It is obvious that average productivity at T_1 is lower than that at T_0. The point C_0 is the maximum observed average total factor productivity along the VRS frontier. According to Banker, Charnes, and Cooper (1984), points such as C_0 is the point of most productive scale size (MPSS). Such a point is common to both VRS and CRS frontiers as the constant average productivity at any point on the latter (such as P_0 or P_1) equals the average productivity at the MPSS on the VRS frontier.

The scale efficiency at any point on the frontier captures the deviation (upward or downward) of that particular observation from the MPSS and is measured by the ratio of the average productivity at that point to the average productivity at the MPSS. Thus,

$$\pi_A^1 = \frac{\frac{A_1X_1}{0X_1}}{\frac{A_0X_0}{0X_0}} = \frac{D_C^1(x_1, y_1)}{D_C^1(x_0, y_0)} \tag{7}$$

$$SE^0(x_1, y_1) = \frac{AP_{T1}}{AP_{C1}} = \frac{D_C^0(x_1, y_1)}{D_v^0(x_1, y_1)} \tag{8}$$

Hence, equations (5) and (6) can be rewritten as

$$\pi_A^0 = \frac{D_v^0(x_1, y_1)}{D_v^0(x_0, y_0)} \frac{SE^0(x_1, y_1)}{SE^0(x_0, y_0)} \quad (9)$$

$$\pi_A^1 = \frac{D_v^1(x_1, y_1)}{D_v^1(x_0, y_0)} \frac{SE^1(x_1, y_1)}{SE^1(x_0, y_0)} \quad (10)$$

Now, the Malmquist productivity change index as specified by the geometric mean of the two Malmquist productivity indices (Caves, Christensen, and Diewert 1982) is given as

$$\pi_A = \left[\left\{\left(\frac{D_v^0(x_1, y_1)}{D_v^0(x_0, y_0)}\right)\left(\frac{SE^0(x_1, y_1)}{SE^0(x_0, y_0)}\right)\right\} * \left\{\left(\frac{D_v^1(x_1, y_1)}{D_v^1(x_0, y_0)}\right)\left(\frac{SE^1(x_1, y_1)}{SE^1(x_0, y_0)}\right)\right\}\right]^{1/2} \quad (11)$$

$$= \left\{\left(\frac{D_v^0(x_1, y_1)}{D_v^0(x_0, y_0)}\right)\left(\frac{D_v^1(x_1, y_1)}{D_v^1(x_0, y_0)}\right)\right\}^{1/2} \left\{\left(\frac{SE^0(x_1, y_1)}{SE^0(x_0, y_0)}\right)\left(\frac{SE^1(x_1, y_1)}{SE^1(x_0, y_0)}\right)\right\}^{1/2}$$

$$= \left\{\left(\frac{D_v^0(x_0, y_0)}{D_v^1(x_0, y_0)}\right)\left(\frac{D_v^0(x_1, y_1)}{D_v^1(x_1, y_1)}\right)\right\}^{\frac{1}{2}} \left\{\frac{D_v^1(x_1, y_1)}{D_v^0(x_0, y_0)}\right\}\left\{\left(\frac{SE^0(x_1, y_1)}{SE^0(x_0, y_0)}\right)\left(\frac{SE^1(x_1, y_1)}{SE^1(x_0, y_0)}\right)\right\}^{1/2}$$

Thus,

$$\pi_A = (TECHCH) * (PEFFCH) * (SCH) \quad (12)$$

where:

$$TECHCH = \left\{\left(\frac{D_v^0(x_0, y_0)}{D_v^1(x_0, y_0)}\right)\left(\frac{D_v^0(x_1, y_1)}{D_v^1(x_1, y_1)}\right)\right\}^{1/2} \quad (13)$$

measures technical change,

$$PEFFCH = \frac{D_v^1(x_1, y_1)}{D_v^0(x_0, y_0)} \quad (14)$$

measures pure (technical) change, and

$$SCH = \left\{\left(\frac{SE^0(x_1, y_1)}{SE^0(x_0, y_0)}\right)\left(\frac{SE^1(x_1, y_1)}{SE^1(x_0, y_0)}\right)\right\}^{1/2} \quad (15)$$

measures change in scale efficiency.

The Nonparametric Methodology

In order to decompose the MPI into the above components, we need to construct the reference technology from sample observations. Let y_j^t and x_j^t represent, respectively, the output and input vectors of farm *j* (*j* = 1,2, …*N*) in period *t*. Then, as shown by Varian (1984), an inner approximation of the underlying production possibility set in period *t* will be:

$$S^t = \{x^t, y^t\}\colon \sum_{j=1}^{N} \gamma_j x_t^j \leq x;\ \sum_{j=1}^{N} \gamma_j y_t^j \geq y;\ \sum \gamma_j = 1;\ \gamma_j \geq 0\ (j = 1, 2, \ldots N) \quad (16)$$

Now given the feasibility and the convexity assumptions as mentioned earlier: (1) any observed input-output bundle (x_t^j, y_t^j) is feasible, and (2) any input–output pair $(\overline{x}, \overline{y})$ satisfying

$$\overline{x} = \sum_{j=1}^{N} \gamma_j x_t^j \leq x;\ \overline{y} = \sum_{j=1}^{N} \gamma_j y_t^j,\ \sum \gamma_j = 1;\ \gamma_j \geq 0\ (j = 1, 2, \ldots N)$$

is also feasible. Further by free disposability, any $x \geq \overline{x}$ can produce $\overline{y}$.

Hence, x can also produce y if $y \leq \overline{y}$.

Therefore, the output oriented distance function under VRS is obtained as

$$D_v^t(x_k^j, y_k^j) = \frac{1}{\varphi^*}, \text{where } \varphi^* = \max \varphi \quad (17)$$

subject to:

$$\sum_{j=1}^{N} \gamma_j x_t^j \leq x_k^t; \sum_{j=1}^{N} \gamma_j y_t^j \geq y_k^t, \quad \sum \gamma_j = 1; \gamma_j \geq 0 \; (j = 1, 2, \dots N) \tag{18}$$

For $t = k$, we get the period distance functions, while $t \neq k$ would define the cross period distance functions.

Data

This study considers single-output four-input production technology for West Bengal agriculture. The reference period of the analysis is from July 1980 to June 2003. The levels of production (in megatons) of the seven selected crops—aus, aman, boro, jute, wheat, rapeseed-mustard, and potato are considered as output. The inputs included are: (1) human labor (*HL*) (man-days), (2) fertilizer (*FRT*) (megatons), (3) pesticides (*PST*) (metric tons), and (4) irrigated area (*IRG*) (thousand hectares).

The annual production figures are taken from the various publications of the Economic Review of West Bengal Agriculture (Government of West Bengal 1978; 2006). Data on inputs other than irrigation are collected from the yearly Farm Management Survey on the Cost of Cultivation of West Bengal (Government of West Bengal 1981; 2003). The cost figures for these inputs are deflated by the average wage rate and the respective wholesale price indices for fertilizers and pesticides to get the physical quantity of inputs. The crop-wise irrigation figures are taken from the West Bengal Agricultural Census (Government of West Bengal 1971; 1977; 1981; 1986; 1991; 1996; 2001; 2006) for various years and are then interpolated to get the entire series.

RESULTS

The results on MPI are obtained by using the data envelopment analysis program (DEAP) introduced by Coelli (1996). The sample averages of MPI for the individual crops and the average annual growth rates of productivity for these crops are presented in Table 1. The productivity index in any one year treats the year immediately prior to it as the base so the difference between the value of the MPI and unity shows the productivity growth rate over the previous year.

From the disaggregated crop-wise analysis, it is evident that all selected crops except aus and jute, experienced positive productivity growth. However, there exist wide differences in TFPG across different crops and also among the three types of rice—aus, aman, and boro. Boro registered the highest productivity growth of 6.6 percent followed by rapeseed-mustard (5.5%), potato (4.7%), and wheat (4.5%). Aman recorded the lowest TFPG rate of 0.023 percent. All the selected crops taken together have an annual average productivity growth of about 2.6 percent.

Now productivity growth can be caused by technical change and/or efficiency change factors. While Table 1 depicts the MPI, level of technical change, and technical efficiency change by crop, Table 2, on the other hand, shows the rates of productivity growth, technical progress, and efficiency change along with the scale efficiency change for the selected crops. For all the crops except aus and jute, the growth rate of MPI is positive. This positive growth rate of MPI has been accompanied by positive growth rates of technical change, technical efficiency change, and scale efficiency change. However, the extent of the growth rate of MPI, technical change, technical efficiency change,

Table 1. Average MPI and average annual levels of technical change and efficiency change

Crops	MPI	Level of Technical Progress	Level of Technical Efficiency Change
Aus	0.990	0.997	0.992
Aman	1.000	1.000	1.000
Boro	1.066	1.027	1.038
Jute	0.981	0.981	1.000
Wheat	1.045	1.009	1.035
Rapeseed-mustard	1.055	1.025	1.029
Potato	1.047	1.000	1.046

Table 2. Average annual rates of productivity growth, technical progress, technical efficiency change, and scale efficiency change

Crops	TFPG Rates	Rate of Technical Progress	Rate of Technical Efficiency Change	Rate of Scale Efficiency Change
Aus	-1.024	-0.254	-0.772	-6.000
Aman	0.023	0.023	0.000	0.000
Boro	6.643	2.749	3.789	0.400
Jute	-1.909	-1.909	0.000	0.000
Wheat	4.491	0.925	3.534	3.600
Rapeseed-mustard	5.483	2.509	2.901	2.901
Potato	4.669	0.041	4.625	0.900

and scale efficiency change varies across different crops.

The negative productivity growth rate for aus (-1.02) is attributable to technical regress along with negative rates of technical efficiency change. Negative scale efficiency change for aus implies movement away from the most productive scale size. The negative productivity growth rate for jute (-1.91) is explained mainly by technical regress, as the rate of technical efficiency change is zero for this crop.

All the crops except aus and jute have undergone technical progress. The highest technical progress occurred for boro (2.75%), followed by rapeseed-mustard (2.51%), and wheat (0.93%). The rates of technical progress for aman (0.02%) and potato (0.04%), though positive, are close to zero. For aus and jute, there is technical regress. The observation for aus, aman, jute, boro, and rapeseed-mustard are perfectly consistent with the productivity growth of these crops. However, for wheat and potato, although the TFPG rates are quite high (more than 4%), the annual rates of technical progress are below one percent.

The level of technical efficiency for aus is close to 100 percent and crops other than aus have reached the 100 percent mark. There is therefore, little scope for further improvement in efficiency for these crops. However, as shown by Table 1, aus and jute have experienced technical regress that causes the respective frontier to shift below. As a result, the apparent improvement in the level of efficiency (reaching the 100% mark) for aus and jute cannot be explained in terms of the movement towards the frontier or the efficiency gain (catching up). The proximity of observations to the frontier or the ‘catching- up’ is explained by the downward shift of the frontier itself. A simple estimation of the compound annual growth rates for aus and jute production for the period under study shows the rates to be 1.10 percent and 3.41 percent, respectively. Input usage remained the main contributing factor behind this positive output growth as both these crops witnessed negative rates of TFPG for the reference period.

The share of TFP in output growth differs widely among the selected crops. The approximate percentage contribution of TFPG in output growth of aus, aman, boro, jute, wheat, rapeseed-mustard, and potato are -93.09, 0.85, 98.85, -55.98, 191.92, 132.76, and 83.38, respectively. Very high figures for wheat and rapeseed-mustard are suggestive of very small output growth in relation to the TFP growth of these crops. Output growth rate being lower than the TFPG rate, raises the ratio representing the share of TFP in output growth. The negative contribution of aus and jute in their respective output growths is compatible with the negative TFPG rates for these two crops and implies that TFP growth has no positive role in explaining output expansion. Whatever output growth is possible for these two crops, it is only through input usage. For crops such as boro and potato, most of the output growth is caused by TFP.

The Determinants of TFPG

A second-stage regression analysis was carried out to identify the factors explaining the movement of TFPG for each crop. The exercise was performed also on the basis of average measure of TFPG. Variation in TFPG was explained in terms of the following explanatory variables:[7]

Expenditure on education and research in West Bengal (XER)

The role of R&D in agriculture is unquestionable because these are largely public goods (Stiglitz 1987). Previous studies (Rao and Gulati 1996; Pal, Jha, and Singh 1997; Evenson, Pray, and Rosegrant 1999; Huffman and Evenson 2006) highlight the prominence of public-sector research and extension in explaining TFPG. The present paper included the amount of government expenditure on education and research as an explanatory variable, which was expected to have a positive relation with TFPG.

Planned state expenditure on agriculture and rural development (XAD) and planned state expenditure on irrigation and flood control (XIR)

The rapid decline in public investment in agriculture for almost all the Indian states, including West Bengal, since 1981 (Gulati and Bathla 2001; Chand 2001) could not be compensated even by some increase in private investment, implying the importance of public expenditure on agricultural growth. While *XAD* captures the overall effect of state expenditure on the rural sector on TFPG, *XIR* shows the effect of government irrigation expenditure on TFPG. The expected signs of both the variables were positive.

All three expenditure variables mentioned above were deflated by the wholesale price index number for the primary articles to arrive at the real figure.

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[7] Amounts used for variables *XER, XAD, XIR, LB*, and *BN* were in crores. INR 1 crore is equivalent to INR 10 million.

Number of regulated agricultural sub-markets in West Bengal (MKT)

Developing the marketing facilities not only helps meet the demand side but is also essential for assuring adequate price support to the farmers. Apart from building an effective and integrated three-tier marketing infrastructure for marketing of agricultural produce, one of the objectives of the West Bengal State Marketing Board has been to ensure remunerative prices of agricultural produce for the farmers. Much of the agricultural produce in the state is marketed through the regulated markets.[8] To capture the effect of developing marketing facilities, the number of regulated sub-markets was included as a proxy since the variable *MKT* was likely to have positive effects on the productivity growth (Evenson, Pray, and Rosegrant 1999).

The Gini ratio in West Bengal (GN)

Gini ratio captures the inequality in the distribution of operational land holdings. A number of country-specific studies (Besley and Burgess 2000; Banerjee and Iyer 2005; Vollrath 2007) explore the possible connection of land distribution and productivity. A fall in the ratio implies a move towards a more equal distribution of land so the Gini ratio is expected to affect the TFPG indirectly. For calculation of Gini coefficient, the data on the number of farmers and the area of their holdings were obtained for the five different size-classes: marginal (less than 1 ha), small (1-2 ha), semi-medium (2-4 ha), medium (4-10 ha), and large (10 ha and above).

Loan advances by the land development banks in West Bengal (LB)

Land development banks are an important part of the cooperative banks.[9] The cooperative sector is a major source of credit for the Indian agricultural sector particularly when it comes to credit flow to the small and marginal farmers. The variable *LB* was expected to be positively related to productivity growth.

Loan advances from scheduled commercial banks to the rural area in West Bengal (BN)

The commercial banks come after the cooperative banks in disbursing credit to the rural sector. A positive relationship was expected to exist between the TFP growth and the variable *BN*. Both types of loan advances have been deflated by the wholesale price index number for the primary articles to arrive at the real figure.

Proportion of area irrigated through sources other than government canals (OTHIR)

Though the need for public investment in irrigation is crucial (Rao 1989; Rawal and Swaninathan 1998), the complementary role of private irrigation cannot be totally ignored. Given the large percentage of small and marginal holdings, the spread of minor irrigation in West Bengal since the 1980s has particularly contributed to the agricultural development of the state. The proportion of area irrigated through sources other than government canals was considered here as an explanatory

[8] As of October 2002, there were 44 principal markets and 617 sub-market yards under the Regulated Market Committee in different districts. These markets include storage facilities, auction platforms, market shades and stalls, and other related infrastructure.

[9] Regression analysis involving the loan advances by the cooperative banks as one of the regressors did not yield meaningful results so they are not reported here.

variable of TFPG. It was expected that there exists positive relationship between *OTHIR* and TFPG. Other included variables were:

Area under canal irrigation in the state (CNL)

Irrigation is an important infrastructure variable. Canal irrigation[10] being an important component, was expected to be positively related to TFPG.

Consumption of fertilizers (tons) in West Bengal (FRT)

Fertilizer is an important factor of modern intensive agricultural practices. The expected sign of this variable with TFPG was positive.

Number of bargadars (sharecroppers) in the state (BGN)

West Bengal is one of the very few Indian states where land reforms have been successfully implemented. 'Operation Barga' as an important stage of the land reform program involved recording the names of *bargadars*. The number of *bargadars* was taken here as a proxy for the land reform factor, which was also expected to affect the TFPG directly.

While performing the regression analysis, various combinations of the above-mentioned policy variables along with the different lags of expenditure variables were tested. All the explanatory variables were normalized using two alternative deflators—the gross cropped area and the gross irrigated area. Among the alternative specifications, the equation that provided the best fit is reported.

The data on public expenditure on education and research in West Bengal was obtained from different publications of Finance Accounts, Government of India. For calculation of the Gini ratio, the requisite data on number of farmers and the area of holdings for different size-classes were taken from West Bengal Agricultural Census data. The data on the remaining variables were obtained from various issues of the Government of West Bengal Economic Review.

Table 3 depicts the results of the regression analysis. The chosen models for boro, wheat, potato, and the aggregate include the public expenditure variables with three-year lags. The explanatory variables were measured in terms of per unit gross cropped area for aus while for the other crops, the variables were measured in terms of per unit gross irrigated area. Factors affecting the TFPG of individual crops and also the average TFPG differ substantially.[11] The real value of the expenditure on education and research in the state (the current value/the three-year lagged value) was found to be a significant explanatory variable for the TFPG of rapeseed-mustard ($p < .01$), wheat ($p < .01$), and the average TFPG ($p < .10$). The real value of planned expenditure on irrigation and flood control (the current value/the three-year lagged value) was a significant factor for the TFPG of aman ($p < .01$), boro ($p < .01$), and potato ($p < .01$). The state plan expenditure on agriculture and rural development (the three-year lagged value) turned out to be significant only for potato ($p < .05$).

Three different forms of public expenditure were positively related to the TFPG of different crops. Loan advances by the land development banks were positive and significant determinants of TFPG for rapeseed-mustard ($p < .01$), wheat ($p < .05$), and of the average TFPG ($p < .05$). The coefficients of advances by the scheduled commercial banks to the rural area (*BN*) were

[10] Source: Agricultural Census of West Bengal
[11] For jute, the study failed to identify any significant explanatory variable.

Table 3. Coefficients of the regression equation identifying the factors behind TFPG

Crop Variables	Aman	Aus	Boro	Rapeseed-mustard	Potato	Wheat	TFP Average (AM)
(Constant)	0.034 (0.176)	14.275 (2.033)*	-0.254 (2.572)**	2.190 (8.022)***	-0.354 (3.571)***	-1.583 (2.447)**	0.433 (2.447)**
XER				3710.987 (3.543)***			
XIR	1868.505 (3.669)***						
XERt-3					969.309 (1.311)	108.896 (3.374)***	1779.988 (2.010*)
XADt-3					884.553 (2.922)**		
XIRt-3			1603.613 (3.482)***		656.339 (3.331***)		
LB				7.681 (4.691)***		16.685 (2.782)**	3.301 (2.943)**
BN		-8.645 (3.534***)		-8.789 (7.257)***			-4.217 (4.777)*
GN	-1645.939 (1.788*)	-382111.97 (3.657***)		-20182.345 (7.235)***			
MKT				45.356 (6.189)***			18.994 (4.473)***
OTHIR							7.118 (4.701)***
CNL						4.940 (1.600)	
FRT		12.776 (2.739**)					4.244 (2.782)**
BGN		126.062 (1.761)					
Adj. R-Sq.	0.354	0.574	0.382	0.805	0.494	0.457	0.633

Note: Figures in parentheses are the absolute critical values of the t-ratio; *, **, and *** denote significant at 10%, 5% and 1% levels, respectively.

found to be negative, but statistically significant for aus ($p < .01$), rapeseed-mustard ($p < .01$), and the average TFPG ($p < .01$). The Gini ratio had a statistically significant inverse relationship with the respective rates of productivity growth for aman ($p < .10$), aus ($p < .01$), and rapeseed-mustard ($p < .01$). The coefficients of the number of regulated sub-markets (*MKT*) were found to bear expected positive and statistically significant relationship with rapeseed-mustard ($p < .01$) and the average TFPG ($p < .01$). One of the factors having a significant positive relationship ($p < .01$) with the average productivity growth is *OTHIR* or the proportion of area irrigated through sources other than government canals. Fertiliser consumption (*FRT*) bears positive and significant relationship ($p < .05$), with the TFPG of aus and the average TFPG. As revealed by Table 3, the goodness-of-fit of the model is quite satisfactory, varying from about 35 percent in the case of aman to about 81 percent in the case of rapeseed-mustard.

The negative and significant coefficients of advances by the scheduled commercial banks to the rural area (*BN*) for the TFPG of aus, rapeseed-mustard, and the average TFPG can be explained by the fact that these advances are made to the rural sector as a whole and not specifically to the agricultural sector. It may be possible that a major portion of these advances goes to finance non-agricultural activities including self-consumption and, thus, fails to increase the total factor productivity growth. Perhaps, this is one reason behind the negative relationship between advances to the rural area from scheduled commercial banks and the average annual productivity growth rate. The plots of TFPG rates for aus and rapeseed-mustard and the average TFPG (shown in Figures 2 and 3, respectively) are contrasted with separate plots of *BN* for the shortened dataset used for aus and related to rapeseed-mustard/average TFPG rates (Figure 4). The bank advances show a slow but continuous tendency to rise while the TFPG rates show a fluctuating and a slightly declining trend. On the basis of these opposite trends indicating an inverse relationship between the aforementioned variables, it cannot be claimed

Figure 2. Total productivity growth rate of aus and rapeseed-mustard

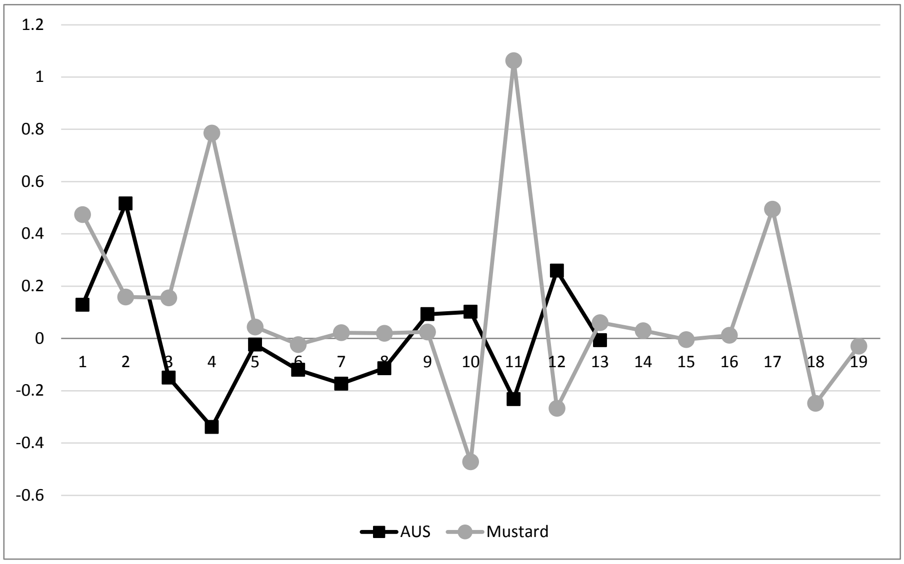


Figure 3. Average total productivity growth rate of the seven crops

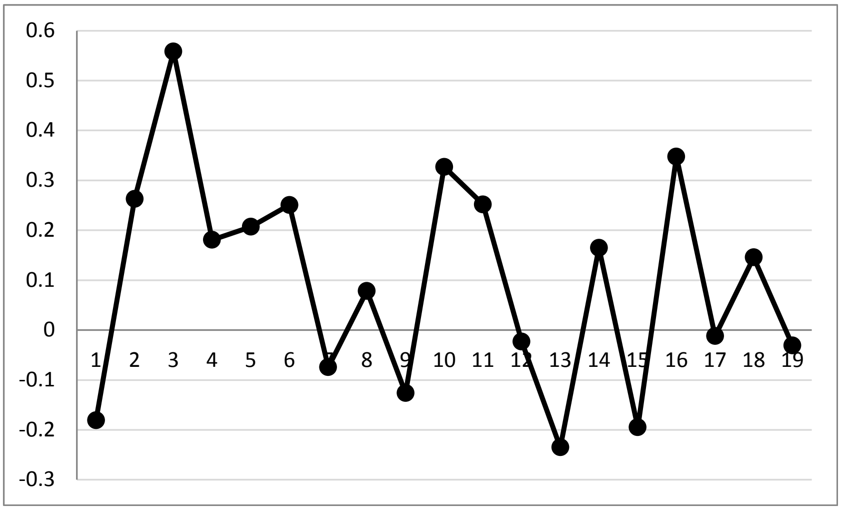
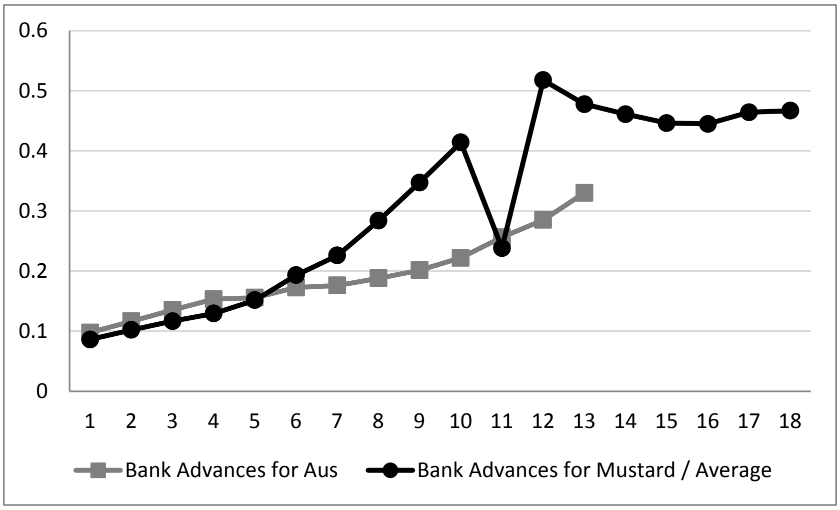


Figure 4. Advances to the rural areas from the scheduled commercial banks for aus and rapeseed-mustard/average



that loan advances to the rural area by the scheduled commercial banks have a significant favorable effect on TFPG.

The selected crops also differ in terms of the respective elasticities with respect to the different relevant variables (Table 4).

CONCLUSIONS AND POLICY RECOMMENDATIONS

The nonparametric analysis revealed that all the selected crops taken together have an annual average productivity growth of about 2.6 percent. The crops differ remarkably from each other so far as their TFP growth is concerned. All selected crops except aus and jute experienced positive productivity growth. Boro registered the highest productivity growth of about 6.6 percent while aman recorded the lowest positive productivity growth of about 0.02 percent. All crops except aus and jute showed technical progress and an improvement in the level of technical efficiency. For aus and jute, there is technical regress accompanied by high level of efficiency. However, the downward shift of the frontier (as manifested through technical regress) in the case of these two crops explains the high level of efficiency.

The regression results from the present study underline the indispensable role of the public sector in augmenting the TFP growth as public expenditure, in one form or another, turns out to be a significant explanatory factor for all crops except aus. The share of the public sector in gross capital formation for agriculture (in India and in West Bengal, as well)[12] has declined for

Table 4: Elasticities of TFPG with respect to the regressors

TFPG Elasticity	Aus	Aman	Boro	Wheat	Rapeseed-mustard	Potato
Expenditure on education and research				2.82	1.46	0.95
Expenditure on irrigation		10.91	7.96		3.42	
Expenditure on agriculture and rural development						6.83
Advances from land development banks				1.09	1.32	
Advances from scheduled commercial banks	364.8				-24.86	
Gini coefficient	7613.74	-10.85			-48.52	
Number of regulated sub-markets					49.73	
Area under canal irrigation				2.53		
Fertilizer	-293.44					
Number of bargadars	-4539.65					

[12] Public sector's share in total capital formation in Indian agriculture has declined from 54 percent in 1980 to 30 percent in 1990, and further to 25 percent by the late 1990s. Public investment in agriculture (as capital expenditure per hectare of net sown area at constant prices) in West Bengal registered an average growth rate of (-) 3.39 percent per annum over the period from 1974 to 1997 (Chand 2001).

more than two decades accompanied by a sharp decline in the average annual growth rates in the index of agricultural production over the same period.[13] Given the positive relationship between public expenditure and agricultural growth, there is a need to increase public investment in agriculture. The negative but significant role played by the Gini coefficient signifies that reduced inequality in land distribution in West Bengal[14] has favorable effect on the productivity growth. The role of the irrigation factor is also worth mentioning. In this paper, the average TFPG depends significantly on the sources other than canal irrigation, and these comprise mainly of various sources of minor irrigation. Though the proportion of net irrigated area to net cropped area stood at 70.5 percent in 2007-08, there is still space for creating new irrigation potential and utilizing them. The target set for raising the proportion of net irrigated area is 80 percent by the end of the Eleventh Plan in 2012 (Government of West Bengal 2009). To achieve these targets, special emphasis has been placed on minor irrigation facilities. A well-developed marketing network is a pressing need in the face of growing competition in the globalized era. As seen in the above regression analysis, one of the ways through which the TFPG in agriculture can be improved is the development of marketing infrastructure.

The negative relationship between the advances by the scheduled commercial banks and the productivity growth, points towards the diversion of these funds to finance non-agricultural activities. Thus, it calls for filling the gaps between the disbursement of developmental funds and its utilization. Had the lacuna in fund management been absent, and had the decline in public sector investment in the agricultural sector been arrested, perhaps a productivity growth rate higher than a mere 2.6 percent could have been achieved.

To sum up, the regression analysis reflects the importance of the public sector (through various expenditures), of disbursement of credit, of infrastructure such as improved marketing facilities, and also of more equal distribution of operational holdings. From the regression equation for the average TFPG, it follows that compared to irrigation through government canals, other sources of irrigation are more effective in fostering productivity growth. However, differences persist among the crops with respect to the set of factors explaining the TFPG. Besides, the explanatory powers of the selected models also vary noticeably among the crops. These factors emphasize the need for taking some crop-specific measures for improving the TFP.

Future research can effectively address some issues with respect to the analyses of TFPG and its determinants for different crops. A farm-level analysis is expected to provide a more disaggregated picture of inefficiency and productivity analyses of crop production in the state. This will help in better specification of the variables affecting inefficiencies and total factor productivities at the farm level. Due to paucity of data, however, the present study could not carry out a farm-level analysis. Also, due to the short span of the post-liberalization period (less than a decade), any sub-period analysis could not be done as this would adversely affect the degree of freedom. Future research therefore, can focus on the farm- level TFPG analysis and can also take care of the developments in the post-liberalization period.

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[13] The growth rate of foodgrains production decelerated to 1.2 percent from 1990 to 2007.
[14] West Bengal is one of the few states that implemented tenancy laws rigorously.

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