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ARTICLES

Agricultural Growth in West Bengal (1949-50 to 2009-10): Evidence from Multiple Trend Break Unit Root Test

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ABSTRACT

Some researchers have found an acceleration in the growth of agricultural production in West Bengal from the beginning of the 1980s, while other researchers have criticised the methodologies and findings of these studies and concluded that no significant acceleration in the production of foodgrains have occurred in West Bengal in the 1980s. In the present study, using modern time series techniques allowing for endogenous structural breaks in the growth path of the series under considerations, we have found the evidence of a statistically significant acceleration in the growth rate of productions of foodgrains, rice and aman rice in the 1980s, which was caused by a significant increase in the growth rate of yield of aman rice from 1980-81. However, this increase in the agricultural growth in West Bengal was rather short lived as the growth rate of yield of aman rice declined significantly in the state from 1986-87, which leads to a subsequent decline in the growth rate of production of foodgrains in the state from 1987-88.

Keywords: Acceleration, Growth, Structural break, Unit root.

JEL: C12, C22.

West Bengal has one of the lowest per capita net cultivated area (0.90 hectare in 1990-91) in the country and the 'small and marginal farmers' as a group constitute over 90 percent of the total farming community and cultivate around 63 per cent of total operational area in recent years. Agricultural growth in West Bengal was modest during the first three decades of the post-independence period. Boyce's (1987) estimates for the period 1949-1980 set out a meager 1.74 per cent annual growth in agricultural output in West Bengal, which trailed behind the rate of population growth during that period. However, a number of studies [e.g., Saha and Swaminathan (1994), Sawant and Achuthan (1995), Bhalla and Singh (1997)] have found a significant increase in the growth in agricultural production and productivity in West Bengal during the decade of the 1980s. But some other studies (e.g., Banerjee and Kundu (2001), Bhattacharyya and Bhattacharyya (2008)) have found that the growth rate in agricultural production and productivity tended to decline in West Bengal since the decade of the 1990s. However, all the above mentioned studies have analysed the increase or decline in the growth rate of production and productivity of crops in a deterministic trend curve fitting framework. Most of these studies have used analytical tools like exponential growth model and kinked exponential growth model for identifying any structural shift in the growth path of the variables under consideration. But use of kinked exponential growth model is appropriate only if the variable under consideration is trend stationary.

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Nelson and Plosser (1982) in their seminal paper have argued that most of the macroeconomic time series contains unit roots, which implies that the underlying data generating process is difference stationary instead of trend stationary for these series. If a time series variable contains unit root then analysing its growth rate using kinked exponential growth model can lead to erroneous results and false conclusions. Perron (1989), however, in his pioneering work has demonstrated that in the presence of exogenous structural break the standard unit root tests are not consistent against trend stationarity. He has pointed out that failure to account for structural breaks may lead to false acceptance of unit root null hypothesis by the Augmented Dickey-Fuller test in a time series exhibiting stationary fluctuations around a (deterministic) trend containing a structural break.

Perron's (1989) exogenous treatment of break point was criticised by subsequent studies [e.g. Banerjee *et al*., (1992), Christiano (1992), Zivot and Andrews (1992)]. Zivot and Andrews (1992) emphasised that the break point should be selected as the outcome of an endogenous procedure involving formal testing techniques. However, the Zivot and Andrews (1992) and Perron (1989) tests capture only one (the most significant) structural break in each variable. Lumsdaine and Papell (1997) extended the methodology of Zivot and Andrews (1992) to develop a test that allows for two endogenous structural breaks. They argued that unit root test that allows for two structural breaks (if significant) is more powerful than those which allow for one single break.

Mukhopadhyay and Sarkar (2001) have examined the time series behaviour of total foodgrains production, rice production and wheat production in West Bengal during the period 1950-51 to 1997-98 using the Augmented Dickey-Fuller test, Perron's (1989) test and Zivot and Andrews (1992) test. According to them production of foodgrains like rice and wheat in West Bengal is not trend stationary even after allowing for structural breaks. They have concluded that production of these crops follow a difference stationary process. They have also rejected the claim of any acceleration in the growth rate of foodgrains production in West Bengal in the 1980s.

Ghosh (2010, 2013) had examined the time series behaviour of net state domestic product from agriculture (NSDPA) and foodgrains production in the major states of India including West Bengal using Zivot and Andrews (1992) test. Ghosh (2010, 2013), however, while using the model C of Zivot and Andrews (1992) test designed for determining a singular (the most significant) endogenous structural break in the series under consideration, had reported the two most significant breakpoints (i.e., the year for which the t-statistics is the minimum and the year for which t-statistics is the next minimum) obtained from ZA test. Ghosh (2010), using the data from 1960-61 to 2006-07, had found that the growth rate of NSDPA in West Bengal increased significantly from 1983-84 but declined from 1991-92. Ghosh (2013), using the data from 1960-61 to 2009-10, had found 1983-84 as the first break year for foodgrains production in West Bengal with an upward shift in level and slope, and 1991-92 as the second break year with an upward shift in level but a downward shift in slope.

In view of the differences in findings between Mukhopadhyay and Sarkar (2001) and other studies claiming significant increase in agricultural growth in the state in the 1980s, a re-examination of this issue is needed. Mukhopadhyay and Sarkar (2001) and Ghosh (2010, 2013), however, have not analysed the growth of productivity for any crop. In view of the fact that owing to limited scope of expansion of area under cultivation, growth in productivity (i.e., production per unit of area) is the major source of growth in production for most of the major crops grown in West Bengal, examination of the time series behaviour of both production and yield (production per unit of area) of crops is relevant. Moreover, cultivation of non-foodgrain crops like potato, jute and oilseeds also gained importance in the state in the recent years, so an examination of time series behaviour of production and yield of these crops will provide a more complete description of agricultural growth scenario of West Bengal. It may also be observed in this connection that rice, the main crop grown in the state, can be classified into three categories according to sowing and harvesting period, viz. aus or autumn rice (which is sown during the months of May to July and harvested during July to November); aman or winter rice (sown during June to August and harvested during November-December) and boro or summer rice (sown during October to February and harvested during April-May) and analysing the growth of production and yield for each of these three categories of rice will provide additional insight into the agricultural growth scenario of West Bengal. Therefore, in the present paper, we intend to examine the time series behaviour of both production and yield of total foodgrains, rice, aman rice, aus rice, boro rice, wheat, pulses, potato, jute and oilseeds during the period 1949-50 to 2009-10. In this context, it may be noted here that most of the previous studies analysing agricultural growth in West Bengal focused primarily on testing for a single structural break in the growth path of the variable under consideration, e.g., Boyce (1987) tested for a positive structural break in the growth rate from 1965-66 onwards, Saha and Swaminathan (1994) and Mukhopadhyay and Sarkar (2001) tested for structural break from 1981-82 onwards while Banerjee and Kundu (2001) and Bhattacharyya and Bhattacharyya (2008) have found a negative structural break in the beginning of the 1990s. Hence it is quite likely that production and yield of at least some important crops grown in West Bengal are characterised by multiple structural breaks in their growth path. Ghosh (2010, 2013) have used ZA's model C to test for two breaks in the growth path of NSDPA in agriculture and foodgrains production in West Bengal. We have employed Lumsdaine and Papell (1997) test to examine the significance of such multiple structural breaks because Lumsdaine and Papell (1997) test is methodologically more powerful and suitable compared to Zivot and Andrews (1992) test for examining two structural breaks in the series under consideration. The Augmented Dickey-Fuller test and Zivot and Andrews test are also carried out for comparative purpose and for determining the nature of data generating process for the variables under consideration.

DATA AND METHODOLOGY

The study is based on analyses of secondary data collected from various issues of the *Statistical Abstract*, *West Bengal* and *Economic Review*, *Government of West Bengal*. The data to be tested in this paper are yields and production of total foodgrains, rice, aman rice, aus rice, boro rice, wheat, pulses, potato, jute and oilseeds over the period 1949-50 to 2009-10, expressed in natural logarithm.

For examining the time series properties of the variables under consideration, we begin with the 'Augmented' Dickey-Fuller (ADF) test suggested by Said and Dickey (1985), which involves estimating the following equation:

$$\Delta y_t = \mu + \beta t + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + \varepsilon_i \qquad \text{....(1)}$$

where y_t is the time series being tested, t is a time trend variable, Δ denotes the first difference operator, and k is the number of lags added to the model to ensure that residuals ε_i are white noise. The Akaike's information criterion (AIC) is used to determine the optimal lag length or k.

The null hypothesis of ADF test is $\alpha = 0$ against the alternative hypothesis of $\alpha < 0$. Non-rejection of null hypothesis implies that the time series under consideration contains an unit root so that the series is non-stationary, whereas rejection of the unit root null hypothesis implies the time series under consideration is stationary.

Perron (1989) showed that in the presence of structural break in time series, many perceived non-stationary time series are in fact stationary.

Zivot and Andrews (1992) emphasised that the break point should be selected as the outcome of an endogenous procedure involving formal testing techniques. Zivot and Andrews (ZA) test for a structural break in intercept (Model A) can be represented by the following equation (2):

$$\Delta y_t = \mu + \beta t + \theta DU_t + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + \varepsilon_i \qquad \text{....(2)}$$

while ZA test for a structural break in both intercept and slope (Model C) can be represented by the following equation (3):

$$\Delta y_t = \mu + \beta t + \theta DU_t + \gamma DT_t + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + \varepsilon_i \qquad \text{....(3)}$$

where DU_t = 1 if t > TB, otherwise zero; TB denotes the time of break, $DT_t = t - TB$ if t > TB, otherwise zero. In the present work the optimal lag length (k) is selected by the criteria advocated by Campbell and Perron (1991) and Ng and Perron (1995). For each value of TB, we have started with an upper bound on k chosen a priori. If the t-statistics of the last included lag is greater than or equal to 1.60, that upper bound is chosen. If the t-statistics of the last included lag is less than 1.60, k is reduced by one until the last lag becomes significant (t-statistics of the last lag greater than or equal to 1.60). If no lags are significant, we set k = 0. Following Perron (1989), we set the upper bound of k = 8. The 'trimming region' in which we have searched for TB cover the 0.15T – 0.85T period. Among all the possible values of TB, the break point (TB) that minimises the value of t-statistics of α is selected as the year of structural break.

Lumsdaine and Papell (LP, 1997) have argued that considering only one endogenous break may not be sufficient, and it could lead to a loss of information particularly when, in reality, there is more than one break. As an extension of the ZA test, they have introduced a modified version of the ADF test which is augmented by two endogenous breaks as follows:

$$\Delta y_t = \mu + \beta t + \theta_1 DU1_t + \gamma_1 DT1_t + \theta_2 DU2_t + \gamma_2 DT2_t + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + \varepsilon_i \quad ....(4)$$

The break dummy variables have the following values: $DUi_t = 1$ and $DTi_t = t - Tbi$ if t > Tbi; 0 otherwise (i = 1,2), $TB_2 \geq TB_1 + 2$. LP test for two breaks in intercept only (Model AA of LP) but not in the slope sets $\gamma_1 = \gamma_2 = 0$ in the above mentioned equation (4), while two breaks in both intercept and slope of the trend function (Model CC of LP) is measured by equation (4) without setting any restriction on the coefficients of the equation. The optimal lag length k is selected in the same manner as in equations (2) and (3).

RESULTS AND DISCUSSIONS

The area under the crops and crop groups under consideration is reported in the Table 1. From the table it may be observed that the area under foodgrains has increased from 4614 thousand hectares during 1949-52 (triennium) period to 6200 thousand hectares during 1971-74 (triennium) period and further to 6441 thousand hectares during the recent 2004-07 (triennium) period. However, area under foodgrains as a percentage of gross cropped area (GCA) has showed a moderate decline from more that 86 per cent during the 1949-52 (triennium) period to around 67 per cent during the recent 2004-07 (triennium) period, while area under non-foodgrain crops like potato and oilseeds has increased significantly during the same period. Area under potato has increased from 40 thousand hectares (around 1 per cent of GCA) during 1949-52 period to 361 thousand hectares (around 4 per cent of GCA) during 2004-07 period, while area under oilseeds increased from 125 thousand hectares (23 per cent of GCA) to 673 thousand hectares (7 per cent of GCA) during the same period. Among the foodgrain crops, area under boro rice increased significantly from a meagre 16 thousand hectares (0.3 per cent of GCA) during 1949-52 period to 297 thousand hectares (4.1 per cent of GCA) during 1971-74 period and further to 1387 thousand hectares (14.5 per cent of GCA) during the recent 2004-07 period, while area under aus rice and pulses declined during the same period. Area under aman rice, the main crop grown in West Bengal, also declined from more than 60 per cent of GCA during 1949-52 period to around 43 per cent of GCA during the recent 2004-07 period, although in absolute terms the area under aman rice had increased from 3421 thousand hectares during 1949-52 period to 3972 thousand hectares during 1971-74 period and 4067 thousand hectares during 2004-07 period.

TABLE 1. AREA (AND PERCENTAGE OF GROSS CROPPED AREA) CULTIVATED BY CROP/CROP GROUPS IN WEST BENGAL

('000 ha.)

Crops/Period (1)	1949-50 to 1951-52 (2)	1971-72 to 1973-74 (3)	1981-82 to 1983-84 (4)	1991-92 to 1993-94 (5)	2004-05 to 2006-07 (6)
Rice	3929 (73.5)	5092 (70.0)	5148 (69.4)	5671 (67.1)	5751 (60.1)
Aman	3421 (64.1)	3972 (54.6)	4068 (54.9)	4279 (49.8)	4067 (42.5)
Aus	483 (9.1)	822 (11.3)	684 (9.2)	538 (6.3)	298 (3.1)
Boro	16 (0.3)	297 (4.1)	387 (5.2)	945 (11.0)	1387 (14.5)
Wheat	46 (0.9)	374 (5.1)	270 (3.6)	276 (3.2)	372 (3.9)
Pulses	553 (10.4)	601 (8.3)	415 (5.6)	272 (3.2)	223 (2.3)
Total foodgrains	4614 (86.5)	6200 (85.2)	5941 (80.1)	6389 (74.4)	6441 (67.4)
Potato	40 (0.8)	76 (1.05)	127 (1.7)	227 (2.6)	361 (3.8)
Jute	273 (5.1)	416 (5.7)	469 (6.3)	514 (6.0)	574 (6.0)
Oilseeds	125 (2.3)	176 (2.4)	357 (4.6)	543 (6.3)	673 (7.0)
All of the crops taken into consideration	5052 (94.7)	6868 (94.35)	7673 (93.0)	7673 (89.3)	8049 (84.2)

Source: Computed from data collected from various issues of *Statistical Abstract, West Bengal*.
Figures in parentheses indicate the percentage of gross cropped area under the crop/crop group specified.

The data to be tested in this paper are yields and production of total foodgrains, rice, aman rice, aus rice, boro rice, wheat, pulses, potato, jute and oilseeds over the period 1949-50 to 2009-10 (for productions of aman rice, aus rice and boro rice, the period under consideration is 1949-50 to 2007-08 and for yields and production of potato, the period under consideration is 1949-50 to 2008-09) expressed in natural logarithm. In order to examine the time series properties of the variables under consideration, we begin our analysis with the ADF test, the results of which are reported in the following Table 2 (A) and Table 2 (B). ADF test results have shown that the null hypothesis of a unit root cannot be rejected even at the 10 per cent level of significance for 9 of the 10 series of the yield of crops and crop groups under consideration and 8 of the 10 series of the production of crops and crop groups under consideration. From the tables it may be observed that the unit root null can be rejected in favour of a stationary alternative only for the yield of foodgrains and for the productions of pulses and jute.

TABLE 2 (A). RESULTS FROM AUGMENTED DICKY – FULLER (ADF) TEST:

$$\Delta y_t = \mu + \beta t + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + \varepsilon_i$$

y_t (1)	μ (2)	β (3)	α (4)	k (5)	Nature of the series (6)
Ln of yield of foodgrains	4.6730 (3.26)***	0.0150 (3.40)***	-0.7062 (-3.25)*	4	S
Ln of yield of Rice	2.0819 (2.42)**	0.0068 (2.65)**	-0.3110 (-2.41)	4	N
Ln of yield of Aman rice	1.8459 (1.97)*	0.0056 (2.35)**	-0.2746 (-1.97)	4	N
Ln of yield of Aus Rice	1.4501 (2.47)**	0.0050 (2.53)**	-0.2254 (-2.46)	1	N
Ln of yield of Boro Rice	1.0957 (2.33)*	0.0013 (0.65)	-0.1442 (-2.11)	8	N
Ln of yield of Wheat	1.3240 (2.14)**	0.0037 (1.22)	-0.1934 (-2.01)	8	N
Ln of yield of Pulses	1.8459 (2.07)**	0.0012 (0.55)	-0.1639 (-2.10)	1	N
Ln of yield of Potato	1.4501 (-1.68)*	-0.017 (-2.33)**	0.5193 (1.77)	8	N
Ln of yield of Jute	1.0957 (1.21)	0.0054 (1.38)	-0.2780 (-1.18)	8	N
Ln of yield of Oilseeds	1.0544 (2.87)***	0.0058 (2.48)**	-0.3338 (-2.87)	1	N

TABLE 2 (B). RESULTS FROM AUGMENTED DICKY – FULLER (ADF) TEST:

y_t (1)	μ (2)	β (3)	α (4)	k (5)	Nature of the series (6)
Ln of Prodn. of Foodgrains	5.3338 (2.98)***	0.0166 (2.96)***	-0.6445 (-2.96)	4	N
Ln of Prodn. of Rice	3.0590 (2.38)**	0.0101 (2.38)**	-0.3747 (-2.35)	4	N
Ln of Prodn. of Aman rice	3.0771 (1.97)*	0.0078 (2.09)**	-0.3798 (-1.96)	4	N
Ln of Prodn. of Aus Rice	2.1276 (2.29)**	0.0026 (0.97)	-0.3411 (-2.20)	7	N
Ln of Prodn. of Boro Rice	0.3289 (2.09)**	0.0072 (1.01)	-0.0751 (-1.33)	1	N
Ln of Prodn. of Wheat	0.2959 (1.90)*	0.0047 (1.36)	-0.2254 (-1.83)	1	N
Ln of Prodn. of Pulses	2.3426 (3.29)***	-0.0080 (-3.22)***	-0.3799 (-3.29)*	1	S
Ln of Prodn. of Potato	1.2205 (1.52)	0.0109 (1.19)	-0.1970 (-1.37)	1	N
Ln of Prodn. of Jute	8.2225 (5.99)***	0.0314 (4.81)***	-1.115 (-5.99)***	1	S
Ln of Prodn. of Oilseeds	0.6836 (2.63)**	0.0125 (2.43)**	-0.2083 (-2.51)	4	N

('t' ratios are reported in parentheses. ***, ** and * implies corresponding null hypothesis is rejected at 1 per cent, 5 per cent and 10 per cent level of significance. In all the tables from table 2(a) to table 3(b) S implies the series under consideration is stationary or trend stationary process while N implies the series under consideration is a difference stationary process).

We have mentioned earlier that conventional unit root tests can have little power when the true data generating process contains structural break(s). It is already pointed out that previous studies (e.g., Boyce (1987), Saha and Swaminathan (1994), Mukhopadhyay and Sarkar (2001), Banerjee and Kundu (2001)) have found structural breaks in the growth path of important agricultural crops in West Bengal during different time periods so it is very much relevant to test for multiple structural breaks in the growth path of production and yield of crops under consideration. For this purpose, we employed the Lumsdaine and Papell (LP, 1997) test that allows for two endogenous structural breaks. We have estimated both models AA (allowing for two endogenous structural shift in intercepts) and CC (allowing for two endogenous structural breaks in both intercept and slope of the trend function), but assessing the significance of test statistics and coefficients of structural break dummies, model CC was found to be the most appropriate for the series under consideration. Model CC also enables us to examine structural breaks in the level as well as the growth rate, and testing for any change in the growth rate of the variables under consideration is our primary objective. We have also compared the results obtained from the Lumsdaine and Papell (LP, 1997) test with results obtained from Zivot and Andrews (ZA, 1992) test (model A and model C) for all of the series under consideration and found that LP test leads to more rejections of unit root null compared to ZA test for the variables under consideration. Taking all these points into consideration, model CC of LP test is selected as the appropriate model for our analyses, the results obtained from which are reported in Tables 3 (A) and 3 (B).

The results obtained from model CC of LP test bears the evidence of rejection of unit root null in favour of stationarity around a broken trend for eight of the ten crop yield variables (viz., for yields of foodgrains, rice, aman rice, boro rice, wheat, pulses, jute and oilseeds) and seven of the ten crop production variables (viz., for productions of foodgrains, rice, aman rice, boro rice, wheat, jute and oilseeds) under consideration.

From Table 3 (A) a significantly positive time trend (implying a significantly positive growth rate) is discernible for yields of all the crops except the yield of wheat and pulses. From the model CC of the LP test, two significant upward shifts in the level (but not in the growth rate) are discernible for the yield of foodgrains in the crop years 1983-84 and 1990-91 respectively. Thus, there is no evidence of any acceleration in the growth rate of foodgrains yield in the 1980s. For the yields of rice and aman rice, a significantly negative shift (crash) in level was observed in 1980-81, followed by a significantly upward shift in the growth rates. However, the growth rate drops significantly from 1993-94 for the yield of rice and from 1986-87 for the yield of aman rice. For the yields of boro rice and wheat, there occurs one significant upward shift in level in 1966-67 and 1967-68 respectively. For the yield of pulses, there occurred a significantly positive shift in level in 1976-77, followed by a positive (but statistically insignificant) shift in the growth rate and a significantly negative shift in level in 1987-88, followed by a negative (but not statistically significant) shift in the growth rate. Yield of jute showed a steady growth with a significant drop in level in 1964-65 and a significant rise in level in 1984-85, while yield of oilseeds showed a significant drop in both the level and the growth rate from 1972-73, which was reversed from 1986-87 by a significant rise in level.

From Table 3(B) a significantly positive time trend is discernible for production of all crops under consideration except for the production of wheat and pulses. Production of foodgrains, rice and aman rice depicts a significant drop in level of production in 1980-81, followed by a significant increase in the growth rate in the decade of the 1980s. However, growth rates of the production of aman rice and rice dropped significantly from the decade of the 1990s, while the growth rate of foodgrains production dropped significantly from 1987-88. Production of boro rice showed a significant drop in level in 1961-62 and a significant rise in level followed

TABLE 3 (A). RESULTS FROM MODEL CC OF LUMSDAINE AND PAPELL'S (LP) TEST

$$\Delta y_t = \mu + \beta t + \theta_1 DU1_t + \gamma_1 DT1_t + \theta_2 DU2_t + \gamma_2 DT2_t + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + \varepsilon_t$$

y_t (1)	TB_1 (2)	TB_2 (3)	μ (4)	β (5)	θ_1 (6)	γ_1 (7)	θ_2 (8)	γ_2 (9)	α (10)	k (11)	Nature of the series (12)
Ln of yield of foodgrains	1983	1990	7.3514 (8.46)***	0.0138 (5.99)***	0.1989 (2.23)**	0.0155 (-0.83)	0.2351 (2.89)***	-0.0151 (-0.79)	-1.0874 (-8.46)***	0	S
Ln of yield of rice	1980	1993	15.9496 (8.05)***	-0.0234 (7.57)***	-0.2856 (-5.78)***	0.0789 (8.16)***	-0.0276 (-0.61)	-0.0608 (-7.63)**	-2.3308 (-8.05)***	5	S
Ln of yield of aman rice	1980	1986	10.0682 (9.01)***	0.0101 (5.10)***	-0.3540 (-4.30)***	0.0917 (4.59)***	0.0834 (1.21)	-0.0723 (-3.70)**	-1.4550 (-9.01)***	1	S
Ln of yield of aus rice	1972	1987	4.8686 (6.45)***	0.0092 (3.26)***	-0.1426 (-2.54)**	0.0069 (1.26)	0.2388 (3.90)***	-0.0033 (-0.59)	-0.7403 (-6.46)	0	N
Ln of yield of boro rice	1964	1966	4.5485 (7.42)***	0.0126 (2.83)***	-0.1372 (-0.83)	0.1486 (1.46)	0.3467 (3.59)***	-0.1584 (-1.56)	-0.6686 (-7.48)***	0	S
Ln of yield of wheat	1964	1967	7.0006 (11.40)***	-0.0069 (-0.47)	0.1907 (1.28)	0.0158 (0.24)	0.8628 (7.70)***	-0.0018 (-0.03)	-1.0641 (-11.04)***	7	S
Ln of yield of pulses	1976	1987	7.1023 (10.24)***	-0.0014 (-0.34)	1.2896 (13.96)***	0.0207 (1.22)	-1.2673 (-11.30)***	-0.0117 (-0.60)	-1.1234 (-10.58)***	8	S
Ln of yield of potato	1965	1994	14.3372 (4.85)***	0.0326 (2.40)**	-0.1460 (-1.36)	0.0199 (1.30)	0.0414 (0.40)	-0.0875 (-5.05)**	-1.6025 (-4.91)	4	N
Ln of yield of jute	1964	1984	8.1588 (9.31)***	0.0143 (2.59)**	-0.1653 (-2.64)**	0.0033 (0.50)	0.1353 (2.41)**	0.0022 (0.49)	-1.1661 (-9.38)***	0	S
Ln of yield of oilseeds	1972	1986	9.3295 (7.27)***	0.0805 (6.35)***	-0.8934 (-7.54)***	-0.0556 (-3.03)***	0.4597 (3.89)***	-0.0018 (-0.13)	-1.6978 (-7.23)***	7	S

TABLE 3 (B). RESULTS FROM MODEL CC OF LUMSDAINE AND PAPELL'S (LP) TEST

y_t (1)	TB_1 (2)	TB_2 (3)	μ (4)	β (5)	θ_1 (6)	γ_1 (7)	θ_2 (8)	γ_2 (9)	α (10)	k (11)	Nature of the series (12)
Ln of prodn. of	1981	1987	9.0114	0.0252	-0.3013	0.0633	0.0811	-0.0694	-1.0830	0	S
foodgrains			(8.34)***	(7.31)***	(-3.40)***	(3.03)***	(1.09)	(-3.28)***	(-8.32)***		
Ln of prodn. of	1980	1990	13.9084	0.0346	-0.4464	0.0855	0.0558	-0.0922	-1.6916	1	S
rice			(10.29)***	(9.33)***	(-6.42)***	(7.81)***	(0.97)	(-8.03)***	(-10.27)***		
Ln of prodn. of	1980	1991	12.2953	0.0190	-0.3552	0.0697	-0.0818	-0.0642	-1.5036	1	S
aman rice			(8.59)***	(6.40)***	(-4.55)***	(6.16)***	(-1.10)	(-5.39)***	(-8.59)***		
Ln of prodn. of	1967	1987	6.2033	0.0312	0.3794	-0.0421	0.4658	-0.0097	-1.0778	7	N
aus rice			(6.07)***	(2.60)**	(3.70)**	(-3.10)***	(4.83)***	(-1.57)	(-6.17)		
Ln of prodn. of	1961	1966	0.8310	0.0886	-0.8128	0.0956	0.9258	-0.1516	-0.4850	4	S
boro rice			(2.87)***	(2.87)***	(-3.07)***	(1.37)	(4.42)***	(-2.33)**	(-7.51)***		
Ln of prodn. of	1961	1967	1.3586	0.0533	-0.3535	0.0638	1.1426	-0.1109	-0.5537	8	S
wheat			(1.57)	(0.64)	(-1.60)	(0.71)	(5.37)***	(-2.78)***	(-8.16)***		
Ln of prodn. of	1962	1998	4.4393	-0.0101	0.2726	-0.0149	0.2469	0.0037	-0.7420	8	N
pulses			(6.34)***	(-1.07)	(3.09)***	(-1.46)	(2.65)**	(0.29)	(-6.28)		
Ln of prodn. of	1963	1995	5.5335	0.0452	-0.1165	0.0275	0.1664	-0.0900	-0.9524	0	N
potato			(6.35)***	(3.13)***	(-0.98)	(2.09)**	(1.32)	(-5.11)***	(-6.32)		
Ln of prodn. of	1982	1985	9.8940	0.0359	-5.3609	1.9913	-0.5736	-1.9869	-1.3316	0	S
jute			(19.39)***	(8.14)***	(-15.28)***	(12.96)***	(-2.45)**	(-12.92)***	(-19.51)***		
Ln of prodn. of	1975	1986	5.8562	0.0409	-0.1846	0.1438	0.5474	-0.1319	-1.6382	8	S
oilseeds			(7.53)***	(4.98)***	(-1.76)*	(6.61)***	(4.34)***	(-6.05)***	(-7.43)***		

Critical values for t_α at 1 per cent, 5 per cent and 10 per cent level of significance are -7.19, -6.75 and -6.48, respectively [Ben-David *et al.*, (2003)].

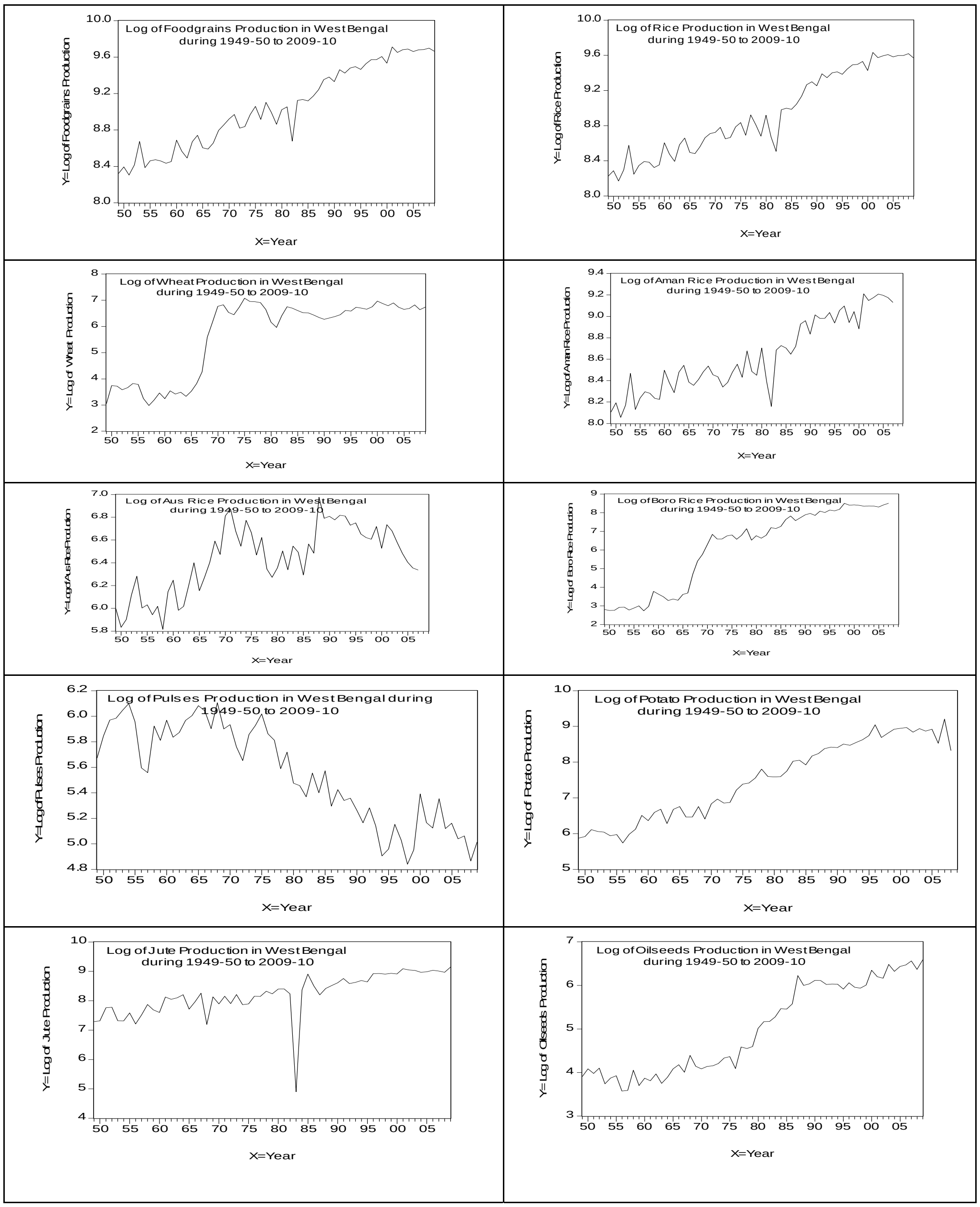

Figure 1. Plots of the Actual Data for the Productions of Selected Crops in West Bengal

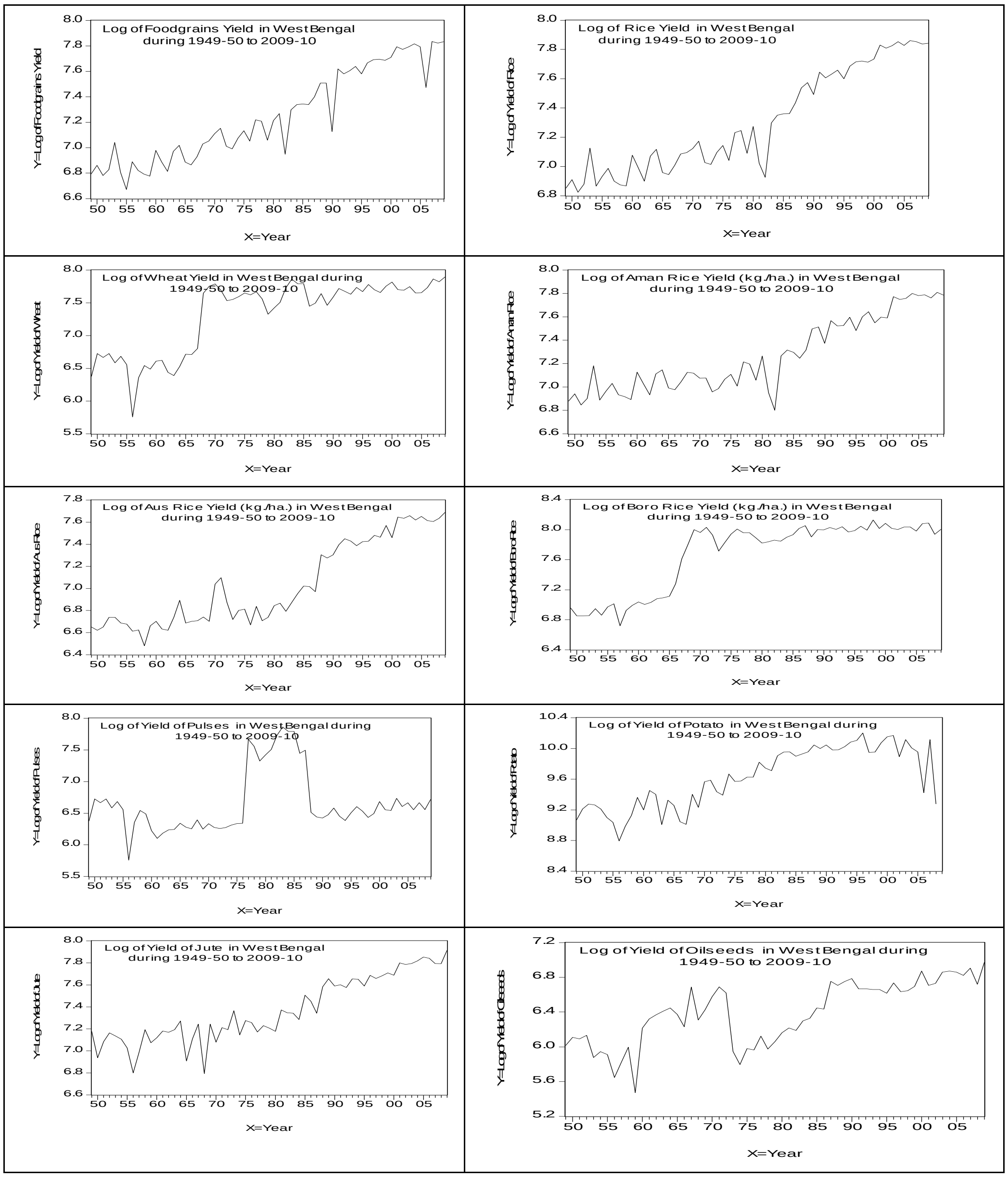

Figure 2. Plots of the Actual Data for the Yields of Selected Crops in West Bengal

by a significant drop in the growth rate from 1966-67 onwards. Production of wheat experienced a significant rise in level followed by a significant drop in the growth rate from 1967-68. Production of jute experienced a significant drop in level in 1982-83 followed by a sharp recovery, but jute production experienced a significant drop in both the level and the growth rate from 1985-86 onwards. Growth rate of the production of oilseeds also experienced a significant drop since 1986-87 after experiencing a significant increase in the growth rate during the period from 1975-76 to 1985-86.

LP test (model CC) found evidence of significant acceleration in growth rate from the beginning of the 1980s for the yields of aman rice and rice and for the production of foodgrains, rice and aman rice. However, from the same LP test (model CC) it is also revealed that the growth rates of production of foodgrains and production and yields of aman rice and rice dropped significantly in the late 1980s and the early 1990s. Thus, the acceleration in the growth rate of production and productivity of crops in West Bengal in the 1980s was limited to an increase in the growth rate of yield of aman rice from 1980-81, which results into a significant increase in the growth rates of production and yield of rice (from 1980-81) and production of foodgrains (from 1981-82). This is because area under aman rice accounted for almost 80 per cent of area under rice, 69 per cent of the area under total foodgrains and 55 per cent of the total area under cultivation in the early 1980s (Table 1), so that agricultural performance of the state during the period was greatly influenced by that of aman rice. A remarkable increase in the area under boro rice (from 387 thousand hectares during the triennium period 1981-84 to 945 thousand hectares during the triennium period 1991-94) in the decade of the 1980s, made possible by the rapid expansion of groundwater irrigation in West Bengal in the 1980s, also contributed to the increase in the growth rate of foodgrains production in the state in the 1980s (Table 1). Moreover, this increase in the agricultural growth in West Bengal was rather short lived as the growth rate of yield of aman rice declined significantly in the state from 1986-87, which led to a subsequent decline in the growth rate of production of foodgrains in the state from 1987-88. Ghosh (2013) also found similar results for foodgrains production in West Bengal.

The conclusions about the stationarity of all of the variables under consideration obtained from the model CC and model AA of LP test and model C and model A of ZA test are reported in Table 4. From the table, it may be observed that unit root null can be soundly rejected for the yields of foodgrains, boro rice, wheat, pulses, jute and oilseeds and for the production of aman rice, boro rice, wheat and jute by all these four models (i.e., by model CC and model AA of LP test and model C and model A of ZA test), while the unit root null cannot be rejected by any of these four models for the yield of potato and for the production of aus rice and potato. Generally, the LP test leads to more rejections of unit root null compared to ZA test. Unit root null is rejected for the production of foodgrains, rice (by model CC and model AA) and oilseeds (by model CC) by LP test while the ZA test fails to reject the unit root null for production of these crops. It may be noted here that Mukhopadhyay and Sarkar (2001) concluded that production of foodgrains and wheat in West Bengal contains unit root (difference stationary) even after allowing for structural break by Perron's and ZA procedure, while the present study found that productions of foodgrains and wheat are trend stationary in the presence of structural breaks.

TABLE 4. COMPARISON OF RESULTS FROM DIFFERENT MODELS

	Lumsdaine and Papell test		Zivot and Andrew test	
Variable	Model CC	Model AA	Model C	Model A
(1)	(2)	(3)	(4)	(5)
Ln of yield of foodgrains	Stationary	Stationary	Stationary	Stationary
Ln of yield of rice	Stationary	Non stationary	Non stationary	Stationary
Ln of yield of aman rice	Stationary	Non stationary	Stationary	Non stationary
Ln of yield of aus rice	Non stationary	Stationary	Non stationary	Stationary
Ln of yield of boro rice	Stationary	Stationary	Stationary	Stationary
Ln of yield of wheat	Stationary	Stationary	Stationary	Stationary
Ln of yield of pulses	Stationary	Stationary	Stationary	Stationary
Ln of yield of potato	Non stationary	Non stationary	Non stationary	Non stationary
Ln of yield of jute	Stationary	Stationary	Stationary	Stationary
Ln of yield of oilseeds	Stationary	Stationary	Stationary	Stationary
Ln of prodn. of foodgrains	Stationary	Stationary	Non stationary	Non stationary
Ln of prodn. of rice	Stationary	Stationary	Non stationary	Non stationary
Ln of prodn. of aman rice	Stationary	Stationary	Stationary	Stationary
Ln of prodn. of aus rice	Non stationary	Non stationary	Non stationary	Non stationary
Ln of prodn. of boro rice	Stationary	Stationary	Stationary	Stationary
Ln of prodn. of wheat	Stationary	Stationary	Stationary	Stationary
Ln of prodn. of pulses	Non stationary	Stationary	Stationary	Stationary
Ln of prodn. of potato	Non stationary	Non stationary	Non stationary	Non stationary
Ln of prodn. of jute	Stationary	Stationary	Stationary	Stationary
Ln of prodn. of oilseeds	Stationary	Non stationary	Non stationary	Non stationary

SUMMARY AND CONCLUSIONS

The present study found the evidence of a statistically significant acceleration in the growth rate of productions of foodgrains, rice and aman rice in the 1980s by employing modern time series techniques. This was caused by a significant increase in the growth rate of yield of aman rice from 1980-81. However, this increase in the agricultural growth in West Bengal was rather short lived as the growth rate of yield of aman rice declined significantly in the state from 1986-87, which led to a subsequent decline in the growth rate of production of foodgrains in the state from 1987-88. The growth rate of production of jute and oilseeds also declined significantly in West Bengal from 1985-86 and 1986-87, respectively. The findings from the present study differs from that of Mukhopadhyay and Sarkar (2001) as the study found no evidence of acceleration in foodgrains production in West Bengal in the 1980s. Moreover, Mukhopadhyay and Sarkar (2001) concluded that productions of ‘total foodgrains’, ‘rice’ and ‘wheat’ are difference stationary, while we have found productions of both ‘total foodgrains’ and ‘rice’ trend stationary by LP test and production of wheat was found trend stationary by both ZA and LP tests. Allowing for two endogenous structural breaks in both intercept and slope by applying LP test, the present study has indicated that production and yields of foodgrains, rice, aman rice, boro rice, jute and oilseeds are trend stationary while production and yield of wheat was found stationary without any significant time trend. In the presence of endogenous structural break(s), a difference stationary process is maintainable for production and yields of aus rice and potato.

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