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HAS THERE BEEN AN ACCELERATION IN THE GROWTH OF AGRICULTURE IN WEST BENGAL?: A FRESH LOOK USING MODERN TIME SERIES TECHNIQUES

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SUMMARY. Of late several researchers have studied the performance of agriculture in West Bengal, and most of them have found that there has been acceleration in the growth of agriculture in the early eighties. It may be pointed out that all these studies are essentially based on somewhat naive and conventional econometric approach of curve fitting, and not on the rigorous trend analysis procedure developed in the last two decades. Since it is now recognized that the conventional procedure may be inadequate, conclusions based on such an approach may yield misleading inferences. In this paper we first present a brief yet comprehensive and up-to-date review of the methodology of modern trend analysis. We then apply this procedure in analysing the time series behaviour of total foodgrains production, rice production and wheat production in West Bengal, and observe that our findings on the actual trend process, occurence of breaks in the time series, the nature of such breaks, if any, and finally their effects on the trend process, are somewhat different from those reported by previous researchers. In particular, we have found no statistical support for acceleration in growth of total foodgrains production and wheat production, and some evidence of acceleration in growth of rice production only.

1. Introduction

A major debate on the performance of agriculture in West Bengal, one of the states of India, in the early eighties, which has been termed "spectacular" by some analysts, has been continuing since Saha and Swaminathan published their paper in 1994 in which they studied what they called "changing trajectories" of agricultural growth in West Bengal. In that paper the authors considered two deterministic trend functions viz., exponential and log-quadratic, and estimated these using time series data on total foodgrains production in West Bengal spanning the period 1965

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to 1990, and finally concluded that West Bengal experienced accelerated growth in agriculture during the eighties. They attributed this performance to the implementation of land reforms and establishment of Panchayati Raj system (i.e., decentralized administration at the local level) in the state. Following this work, Bhalla and Singh (1997) also analysed the agricultural growth experienced by the eastern region in general and West Bengal in particular, and found evidence of agricultural growth, the occurrence of which was explained by them in terms of substantial increase in area under irrigation through private initiative.

In this debate on agricultural growth in West Bengal, some researchers have also examined whether there has been a shift in the trend curve which might help in better understanding of this phenomenon of growth with acceleration. In this context reference may be made of the paper by Chattopadhyay *et al.* (1993) who used standard curve fitting techniques and found no statistical evidence in support of break in total foodgrains production during the period 1950-51 to 1987-88 in all states in eastern region barring Orissa primarily because of diminished/constant rate of growth of cropped area under the major crops in this region. Somewhat contrary to the findings of Chattopadhyay *et al.* is the observation made by Sen and Sengupta (1995) who noted a positive break in trend in the rate of growth of total foodgrains production in West Bengal in the year 1981-82. In this ongoing debate the latest contribution is by Rawal and Swaminathan (1998) who have used deterministic trend of exponential form and concluded on the basis of time series data spanning about 50 years that West Bengal has experienced acceleration in growth during and after major changes in agrarian institutions and land relations.

We thus note that researchers have made similar yet sometimes conflicting conclusions on the actual situation regarding agricultural growth in West Bengal in the '80s. It is also somewhat difficult from the plots of these data sets to explain as to why most of these studies have found evidence of accelerated growth in agriculture in the early eighties. Since all these studies have used essentially the same methodology viz., deterministic trend curve fitting, and the same database with some variations only in span of the series, it is reasonable to suggest that explanations may lie in the fact that such conventional econometric approach of curve fitting for analysing trend is inadequate. We discuss in this paper that this is indeed so, and hence we argue that appropriate modern time series techniques must be used so that valid inferences could be drawn about the true but unknown growth process.

It is well known that there has been a phenomenal growth in the literature on time series techniques since the mid-seventies. The old and somewhat naive concept of trend being only deterministic in nature has been challenged and the concept of variable/stochastic trend having consideration to long-term growth and its recurrent fluctuations around this growth path, has been suggested. This has led to a veritable explosion of research on this and allied topics, and consequently to the development of a statistically rigorous methodology for trend analysis. It may be noted that the assumption of deterministic trend is quite restrictive since the fact is that over a reasonably long period of time economic variables are most likely to change in their mean and often in their variance so that their first two moments would be far from being constant over time (*cf.* Hendry (1986)), and consequently the trend might often be stochastic in nature. Hence, as noted by Nelson and Plosser (1982) and Nelson and Kang (1984), the method applied for trend elimination becomes quite important for inference and forecasting purposes. In fact, Stock and Watson (1988, p.149) had rightly stated that "Variable trends provide numerous econometric pitfalls and raise difficult methodological issues. Time series analysts have long recognized that regression analysis can be highly misleading when applied to series with variable trends. In some cases the result can be dramatic errors in forecasting. In other cases, an improper treatment of variable trends can result in false conclusions about how the economy works."

A decade has since passed, and the "numerous econometric pitfalls" and "difficult methodological issues" have been carefully investigated by theoretical researchers, and appropriate inferential procedures have been developed. In the context of trend analysis one of the most important contributions has been the development of unit root tests and their modifications and generalisations from consideration of structural break and power performance. It is, therefore, important that such a rigorous and comprehensive time series methodology be used for analysing the growth of agriculture in West Bengal so that it becomes known - at least from academic point of view- which trend model is best supported by the data. This is precisely what we have attempted at doing in this paper. The plan of the paper is as follows. We give a brief but comprehensive review of the methodology in the next section. The findings of the application of this methodology on the production of total foodgrains as well as two major crops viz., rice and wheat, in West Bengal are discussed in Section 3. The paper ends with some concluding remarks in Section 4.

2. Methodology

It has long been known that many economic time series, especially macroeconomic time series, are non-stationary. However, macroeconomic time series were earlier characterized as stationary fluctuations around a deterministic trend. But this traditional view of treating macroeconomic variables, which is now known in the literature as trend stationary process, was challenged by Nelson and Plosser in their seminal work in 1982. On the basis of empirical evidences found from the application of unit root test of Dickey and Fuller (1979, 1981) to a wide range of historical time series for the U.S. economy, they inferred that all the series, with the sole exception of unemployment rate, had unit roots, and hence the underlying processes were difference stationary processes and not trend stationary processes, as characterized in all the earlier studies. A large number of papers following this study, in general, supported the conclusions of Nelson and Plosser (1982) viz., difference stationary process is more appropriate for most macroeconomic time series.

The debate concerning whether a macroeconomic time series is trend stationary or difference stationary has profound implications in economic policies and decisions. A trend stationary process (TSP) implies that the effect of any random shock is temporary around a stable trend whereas a difference stationary process (DSP) means that any random shock has a permanent effect to the series. There are two important statistical implications as well. The first one is about the trend removal method used (by differencing or by regressing). As pointed out by Nelson and Kang (1981), spurious autcorrelation results whenever a time series generated by DSP is de-trended by regressing on time, or a TSP is de-trended by differencing. The second statistical problem is that the distribution of the least squares estimator of the autoregressive parameter has a non-standard distribution (not the usual normal, t or F) when there is a unit root (*cf.* Dickey and Fuller(1979)). It is therefore imperative that unit root tests are carried out for trend analysis of macroeconomic time series. Even in these testing exercises one has to be extremely careful, as described below, with regard to issues like break in time series including whether breaks are endogenously or exogenously determined, power of the tests etc.; otherwise conclusions could be misleading.

Unit root tests and trend stationarity versus difference stationarity: In the unit root testing procedure the implicit null hypothesis is that the series is generated as a driftless random walk with possibly a serially correlated error. In the terminology of Mills (1993), such a time series y_t is said to be difference stationary *i.e.*,

$$\Delta y_t = \epsilon_t, \quad t = 1, 2, \ldots, T \tag{1}$$

where $\Delta y_t = y_t - y_{t-1}$ is the first difference of y_t and $\epsilon_t = \theta(B)a_t$ denotes the stationary process generating serial correlation, $\theta(B)$ being an appropriate polynomial in backshift operator B, a_t is a white noise (WN) process and T is the total number of observations. The alternative in this case is that y_t is stationary in levels i.e.,

$$y_t = \phi y_{t-1} + \epsilon_t, \quad |\phi| < 1 \tag{2}$$

or, equivalently, $\Delta y_t = (\phi - 1)y_{t-1} + \epsilon_t$. A test of model (1) against model (2) i.e., the null $H_0 : \phi = 1$ *versus* the alternative $H_1 : |\phi| < 1$, under the assumption that ϵ_t is Gaussian white noise is carried out by taking the usual t-ratio of the estimate of $(\phi - 1)$ to its standard error. But, as already mentioned, Dickey and Fuller (DF) have shown that this statistic does not have a Student's t-distribution under H_0. Fuller (1976) has, however, obtained the appropriate distribution of the test statistic , called τ, and computed its critical values at selected significance levels. These tabulated values are used to conclude on this test. This test has been modified by Said and Dickey (1985), Phillips (1987), and Phillips and Perron (1988) for the case where ϵ_t is not white noise. The "augmented" Dickey and Fuller (ADF) test suggested by Said and Dickey (1985) is the most widely used unit root test. This test involves estimating the following equation

$$\Delta y_t = (\phi - 1)y_{t-1} + \sum_{j=1}^{k} \delta_j \Delta y_{t-j} + a_t, a_t \sim WN(0, \sigma^2) \tag{3}$$

and then testing for the significance of $(\phi - 1)$. Said and Dickey have shown that the underlying test statistic has the same asymptotic distribution τ as in the original

DF τ test. Insofar as the generalisations by Phillips (1987) and Phillips and Perron (1988) are concerned, it allows for a wide range of serial correlation and heterogeneity patterns in ϵ_t. This statistic $Z(\tau)$ can be compared to the DF τ table. However, its power performance is not exactly known; it also suffers from size distortions. Hence, we confine ourselves to applying only the ADF test.

As discussed in Mills (1993), while the null hypothesis of a driftless random walk is appropriate for some series, many often contain a drift parameter so that the relevant null hypothesis becomes

$$\Delta y_t = \beta_0 + \epsilon_t \tag{4}$$

where β_0 denotes the drift parameter. In this case, the plausible alternative is that y_t is generated by a linear trend buried in stationary noise i.e., y_t is a trend stationary process given by

$$y_t = \beta_0 + \beta_1 t + \epsilon_t. \tag{5}$$

Now, as far as testing the model in (4) against the model in (5) is concerned, Perron (1988) has shown that τ statistic is not capable of distinguishing between the two models. However, an appropriate test may be suggested by way of an extension of the testing methodology described above. Here we test for the significance of the coefficient $(\phi - 1)$ associated with y_{t-1} in the following regression

$$\Delta y_t = \beta_0 + \beta_1 t + (\phi - 1) y_{t-1} + \sum_{j=1}^{k} \delta_j \Delta y_{t-j} + a_t. \tag{6}$$

The computed value is compared with the tabulated value of τ^* statistic[1] due originally to Fuller (1976) and later extended by Guilkey and Schmidt (1989) and MacKinnon (1990).

It may be noted that strictly speaking, the unit root null hypothesis requires that not only $\phi = 1$ in (6) but also $\beta_1 = 0$ because if $\beta_1 \neq 0$ with $\phi = 1$, y_t will contain a quadratic trend; also, if y_t is in logarithms which is often the case, a non-zero β_t under the null of unit root implies an ever increasing (or decreasing) rate of change Δy_t. Although such a possibility should best be avoided, the point to note is that τ^* is not invariant with respect to β_1, even asymptotically. If $\beta_1 \neq 0$ under the null, the variance of y_t would be dominated by a quadratic term and τ^* will be asymptotically normal. To overcome such complications, Dolado, Jenkinson and Sosvilla- Rivero (1990) have proposed the following procedure for testing the unit root in the presence of possible trend.

Step I: Equation (6) is estimated and τ^* statistic used to test the null hypothesis $H_0 : \phi = 1$. If the null is rejected, there is obviously no need to proceed further ; otherwise the next step is followed.

Step II: We test the significance of β_1 from the following equation using the conventional testing procedure:

$$\Delta y_t = \beta_0 + \beta_1 t + \sum_{j=1}^{k} \delta_j \Delta y_{t-j} + a_t. \tag{7}$$

If β_1 turns out to be significant, we compare τ^* with the standard normal distribution and make our inference about the unit root null accordingly; otherwise we go on to the next step.

Step III: We estimate

$$\Delta y_t = \beta_0 + (\phi - 1)y_{t-1} + \sum_{j=1}^{k} \delta_j \Delta y_{t-j} + a_t \tag{8}$$

and test the null hypothesis of $\phi = 1$ using τ statistic. If the null is rejected, the conclusion is that y_t is stationary in levels and the testing procedure is terminated. If, however, the null is not rejected, we carry out the final step.

Step IV: The significance of β_0 in the following regression is tested using conventional testing procedure:

$$\Delta y_t = \beta_0 + \sum_{j=1}^{k} \delta_j \Delta y_{t-j} + a_t. \tag{9}$$

If β_0 is found to be insignificant, we conclude that y_t contains a unit root and there is no drift parameter. Otherwise, i.e., if $\beta_0 \neq 0, \tau$ is compared with the standard normal and the inference is made accordingly.

As regards the determination of the optimum lag k, we may consider information-based criteria like Akaike's information criterion (AIC), Bayesian information criterion (BIC), corrected AIC (AICC) etc. Schwert(1987) has also suggested k to be equal to either $[4(/100)^{0.25}]$ or $[12(/100)^{0.25}]$ where [.] denotes the integer part of the argument. There is also a 'rule of thumb ' by Diebold and Nerlove (1990) which simply states k to be set to $[T^{0.25}]$. Besides, one may follow Hall's (1994) criterion which suggests starting with a large value of k and testing the significance of the last coefficient and reducing k iteratively until a significant statistic is encountered.

Finally, we should carry out diagnostic testing with the residuals of the regressions to ensure that the errors are indeed Gaussian white noise, as assumed. This is essentially done by using Ljung-Box (1978) statistic test which is given by

$$Q(m) = T(T+2) \sum_{j=1}^{d} r_j^2/(T-j) \tag{10}$$

where r_j is the sample autocorrelation of lag j of the residuals. Under the null of white noise errors, $Q(m) \sim \chi^2_m$, asymptotically, where $m = d - d^*, d^* (< d$ obviously) being the number of estimated parameters.

Test for exogenous structural break. In his pioneering work, Perron (1989) has shown that in the presence of exogenous structural break the standard unit root tests are not consistent against trend stationarity. He has also provided evidence to the effect that these tests may be biased towards accepting the false null hypothesis of a unit root if a time series exhibits stationary fluctuations around a trend containing a structural break. This is an important finding, especially because the span of time series data in any empirical work is usually long enough to have had structural breaks. In his paper, Perron has suggested a procedure which is appropriate for testing unit roots in presence of a one-time structural break in the series. The structural break is assumed to be exogenously determined from consideration of visual examinations of the plots of the data and/or consultations with the researchers having knowledge on the nature of the series.

Perron's (1989) method of unit root testing in the presence of an exogenous structural break, which is essentially based on the approach of 'intervention analysis' of Box and Tiao (1975), considers the following three models:

$$\text{Model A}: \quad \Delta y_t = \mu^A + \theta^A DU_t + \beta^A t + \alpha^A D(TB)_t + (\phi^A - 1)y_{t-1} + \sum_{j=1}^{k} \delta_j \Delta y_{t-j} + a_t \tag{11}$$

$$\text{Model B}: \quad \Delta y_t = \mu^B + \theta^B DU_t + \beta^B t + \gamma^B D(TS)_t + (\phi^B - 1)y_{t-1} + \sum_{j=1}^{k} \delta_j \Delta y_{t-j} + a_t \tag{12}$$

$$\text{Model C}: \quad \Delta y_t = \mu^C + \theta^C DU_t + \beta^C t + +\gamma^C DT_t + \alpha^C D(TB)_t + (\phi^C - 1)y_{t-1} + \sum_{j=1}^{k} \delta_j \Delta y_{t-j} + a_t. \tag{13}$$

where $DU_t = 1$ if $t > T_B$ and 0 otherwise; $D(TB)_t = 1$ if $t = T_B + 1$ and 0 otherwise; $D(TS)_t = t - T_B$ if $t > T_B$ and 0 otherwise; $DT_t = t$ if $t > T_B$ and 0 otherwise, $T_B(1 < T_B < T)$ refers to the time of break i.e., the period at which the change in the parameters of the trend function occurs and a_t is assumed to be independently and identically distributed (iid) with mean 0 and variance σ^2. It may be noted that Model A permits an exogenous change only in the level of the series whereas Model B allows for an exogenous change only in the rate of growth and Model C permits both. These models are now appropriately nested in the testing framework under the null of unit root, the alternative being trend stationarity.

Test for endogenous structural break. Perron's (1989) exogenous treatment of break point came under criticism from Christiano (1992) and later by Zivot and Andrews (1992). Christiano argued that Perron's exogenous choice of break points which is essentially based on data plots, suffer from the problem of data mining and pre-testing. Likewise, Zivot and Andrews demonstrated that the major problem with Perron's procedure is that the choice of break point is somewhat arbitrary. Therefore, they advocated that the break point ought to be selected as the outcome of an endogenous procedure involving formal testing techniques. Zivot and Andrews (1992) considered the null hypothesis to be simply that y_t is difference stationary possibly with a non-zero mean but without an exogenous structural break and viewed the determination of the break point $\lambda = T_B/T$ as the outcome of an estimation procedure designed to fit y_t to an alternative hypothesis which stipulates that y_t can be represented by a trend stationary process with a single break in trend occuring at an unknown point of time. Their approach is to choose that λ which minimizes the unit root test statistic computed from the regressions given in (11) through (13). Note that since under the null y_t is difference stationary with no structural break, the dummy $D(TB)$ no longer needs to be present in the three equations. Finally, Perron's critical values can no more be used since selection of λ is here treated as the outcome of an estimation procedure; the critical values for the limiting distribution of these 'minimum t-ratios', as provided by Zivot and Andrews, are instead used for the purpose of comparision with the computed values.

Test for null of stationarity. It is now established that the standard unit root tests (i.e.,DF and ADF tests) often have low power against relevant trend stationary alternatives. Hence, for confirming the inferences drawn by standard ADF test another test where the null hypothesis of stationarity is tested against the alternative of unit root, should be performed. While this problem has been considered by some researchers like Tanaka (1983) and Leybourne and McCabe (1989), the most well-known of these tests is due to Kwiatkowski *et al.* (1992)(hereafter KPSS). This test assumes that the series $\{y_t\}$ can be decomposed into the sum of a linear trend, a random walk process and a stationary error i.e.,

$$y_t = \beta t + w_t + \epsilon_t \tag{14}$$

where w_t is a random walk process given by $w_t = w_{t-1} + u_t$ and u_t's are independently and identically distributed with mean zero and variance σ_u^2. The stationarity hypothesis is simply $H_0 : \sigma_u^2 = 0$. Since ϵ_t is assumed to be stationary, y_t is trend stationary under the null hypothesis. This test also considers the case under weaker assumptions about ϵ_t. This is important since ϵ_t's are likely to be highly time dependent. The performance of the test depends on l, the lag truncation parameter. From consideration of avoidance of size distortions and ensuring high power of the test, the test recommends that the value of l may be 8 at the most if T is large. Therefore, the value of l to be chosen in empirical work would be less than 8; in fact, it is likely to be much less than 8 when the number of observations is not large enough.

Very recently, Lee *et al.* (1997) have examined the effect of a structural break on KPSS test. They have shown that the test suffers from size distortions problem if a structural break is present but it is ignored. This problem is analogous to the problem of loss of power of unit root tests ignoring an existing break. Incorporating a structural break in the intercept they have shown that the presence of a structural break, however, does not necessarily imply stationarity, since tests for stationarity are invariant to a break if the alternative of a unit root is true. We conclude this section by referring to the most recent paper on this topic by Leybourne *et al.* (1998) in which they have shown that if the structural break occurs early in the series where the data generating process is integrated of order one i.e., Δy_t is stationary, but with a break, then routine application of standard DF test can lead to a very serious problem of spurious rejection of the unit root null hypothesis.

3. Empirical Results

In this section we report the results of the application of this comprehensive methodology for studying the growth of agriculture in the state of West Bengal and obtaining the most appropriate trend model for the relevant variables. Towards these ends we consider the time series data of total foodgrains production as also of two major crops of the state viz. rice and wheat. Although other variables like area under cultivation, productivity etc. may also be relevant for studying the agricultural growth, we confine ourselves to production only since it is the most important amongst all these variables from consideration of growth. For this study we have taken annual data spanning the period 1950-51 to 1997-98; these data were collected from successive volumes of Statistical Abstracts, upto 1978-79 and thereafter of Economic Review, both of the Government of West Bengal. Other researchers and analysts have also used the same series, although obviously of varying lengths. From the plots of these series (see Figure 1 below), it is evident that for both total foodgrains and rice there appear to have perceptible trend with tendency to drift upwards excepting for the years 1981-82 and 1982-83, with major "wanderings" about the trend line. The considerable decline in the figures for these two years indicates that there has been "crash" in the series in one or both of these two years; the subsequent rise in the next year and the nature of movement of the two series thereafter seem to give some indication that there might have been a break in the series either in 1981-82 or in 1982-83 or in both the years. A formal conclusion on the actual occurrence of breaks and their natures must, however, be based on proper statistical tests. As for the time series in wheat, the plot seems to suggest very mild trend without any break. It may be noted that for the purpose of this study the observations have been changed to their logarithmic values from usual considerations like stability of unconditional variance and the distribution being well-shaped(often close to normality). We now discuss the empirical results -first with the series of total foodgrains production.

Identification of the time series process-total foodgrains. Following the ADF test procedure outlined in the preceding section, we estimate the regression equations specified in (6) through (9) by least squares, and the estimated equations are given below (with absolute value of the test statistic in the parentheses).

$$\Delta y_t = \underset{(2.294)}{3.694} + \underset{(2.327)}{0.012}\, t - \underset{(2.275)}{0.444}\, y_{t-1} - \underset{(0.819)}{0.145}\, \Delta y_{t-1} - \underset{(2.081)}{0.311}\, \Delta y_{t-2} + \hat{a}_t \quad (15)$$

$$\Delta y_t = \underset{(0.837)}{0.032} + \underset{(0.474)}{0.001}\, t - \underset{(3.071)}{0.418}\, \Delta y_{t-1} - \underset{(3.570)}{0.482}\, \Delta y_{t-2} + \hat{a}_t \quad (16)$$

$$\Delta y_t = \underset{(0.192)}{0.089} - \underset{(0.087)}{0.005}\, y_{t-1} - \underset{(2.938)}{0.414}\, \Delta y_{t-1} - \underset{(3.470)}{0.478}\, \Delta y_{t-2} + \hat{a}_t \quad (17)$$

$$\Delta y_t = \underset{(2.716)^*}{0.048} - \underset{(3.090)}{0.417}\, \Delta y_{t-1} - \underset{(3.587)}{0.480}\, \Delta y_{t-2} + \hat{a}_t. \quad (18)$$

(* *indicates significance at 1% level*)

We observe from regression (15) that the absolute value of τ^* statistic is 2.275, which is compared with the appropriate tabulated values viz., -3.50 and -4.15 at

5 percent and 1 percent levels of significance, respectively, and hence we conclude that the underlying null hypothesis i.e., difference stationary (DS) process cannot be rejected. This necessitates that Step II be carried out. We find from equation (16) that the value of t-ratio for β_1 is 0.474. This computed value is compared with the critical value of t-distribution with d.f. 44 and we find that β_1 is highly insignificant. We then carry out the estimation of regression equation (8). The estimated equation given in (17) suggests, on the basis of the τ statistic value corresponding to the coefficient of y_{t-1}, that the null of unit root cannot be rejected even at 5 percent level of significance, the observed absolute value of τ statistic corresponding to the coefficient of y_{t-1} in equation (17) being merely 0.087. Finally, from (18) we note that β_0 is significant at 1 percent level. We, therefore, conclude that the time series of total foodgrains in West Bengal follows a DS process with a non-zero drift. In other words, the conclusion is that there is a trend in the series, but the trend is stochastic and not deterministic in nature, thereby implying that both the mean level and the variance are affected. It is thus clearly estabilished that proper analysis, based on the entire data set spanning the period 1950-51 to 1997-98, does not lend any statistical support to the assumption of deterministic trend for the time series of total foodgrains production in West Bengal. Further, the series exhibits no acceleration (or deceleration) in the growth since we have found that β_1 is insignificant under the null of unit root (*cf.* equation (16)).

Table 1. LJUNG-BOX STATISTIC $Q(m)$ VALUES BASED ON RESIDUALS OF ADF TEST

Lag(m)	Test statistic value		
	Total foodgrains	Rice	Wheat
1	0.361×10^{-3}	0.380×10^{-2}	0.907×10^{-3}
2	0.672×10^{-2}	0.014	0.211
3	0.158	0.027	0.951
4	1.655	0.324	0.955
5	1.753	0.343	0.998
6	1.801	0.499	1.976
7	2.249	1.079	6.297
8	2.419	1.288	6.394

(*The null of no autocorrelation can not be rejected even at 5% level of significance for all the above test statistic values*)

In order to check if the residuals of the chosen model have indeed become white noise, we carried out Ljung-Box test as described in Section 2, and the results are given in Table 1. It may be noted at this stage that the optimum value of k was found to be 2 following Hall's (1994) procedure of lag determination ; this choice of k was also confirmed by standard information-based criteria like AIC, AICC, BIC etc. The value of $Q(m)$ test statistic was computed for m up to 8, and as evidenced from Table 1 the computed values are very small as compared to the tabulated χ^2 values indicating thereby that the null of Gaussian white noise for the errors is strongly supported by Ljung-Box test. We also checked the normality of the residuals by using Jarque-Bera (1980) test (JB) for normality. For the series of total foodgrains, JB test statistic value for the chosen model was found to be 0.1164 only. Thus, the test fails to reject the null of normality even at 5 percent level of significance.

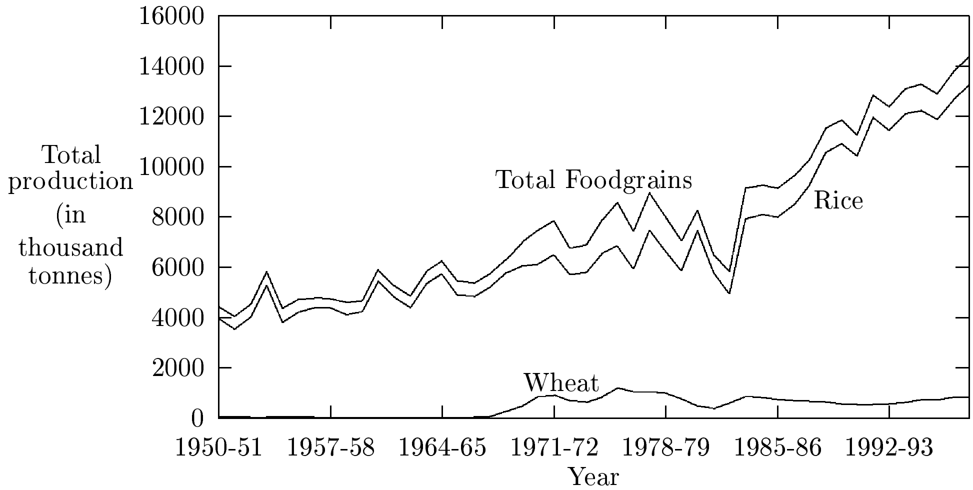

Figure 1. Trends in production of major crops in West Bengal

Unit root test with structural break. We now examine the nature of trend in the series from the standpoint of structural break by applying Perron's test (1989). Since the plot suggests that there was a sharp fall in 1981-82 as compared to 1980-81 and a further fall in 1982-83 and then a rise in the next year, we assumed three possible one-time exogenous breaks in the series viz., 1981-82,1982-83 and 1983-84, so that the possibility of occurrence of break(s) in the series in the early eighties is duly considered in the analysis.

Perron's procedure which is essentially based on ADF test was carried out for these 3 years separately, and we found that a break indeed occurred in 1981-82, but not in the other two subsequent years. Further, the nature of the break in 1981-82 is a one-time "crash" in level i.e., the relevant coefficient estimate is negative and significant. This is clearly borne out by the fact that the estimate of the coefficient α^A in Model A in (11) is –0.395 (*cf.* the estimated equation (19) below), which is significant at 1 percent level of significance (The absolute values of the test statistic are given in parentheses).

$$\begin{aligned}\Delta y_t \;=\; & \underset{(3.167)^*}{4.836} + \underset{(2.093)}{0.118}\; DU_t - \underset{(2.171)}{0.012}\; t - \underset{(3.572)^*}{0.395}\; D(TB)_t - \underset{(3.101)}{0.576}\; y_{t-1} \\ & - \underset{(1.862)}{0.202}\; \Delta y_{t-1} - \underset{(1.280)}{0.254}\; \Delta y_{t-2} + \hat{a}_t. \qquad (19)\end{aligned}$$

(∗ *indicates significance at 1% level*)

Thus, we may conclude from the above estimated equation that there was a significant fall in the level of foodgrains production in 1981-82. This finding may be attributed to the fact that during 1981-82, West Bengal experienced a spell of severe drought (*cf.* Saha and Swaminathan (1994)) as a result of which the total foodgrains production recorded a significant fall in that year. It may be noted that this inference is quite in contrast with the findings of other researchers in that they had found statistical evidence towards the existence of a positive break in the rate of growth in 1981-82 leading them to conclude that an acceleration in the growth of total foodgrains production in West Bengal occurred in 1981-82. In fact, it is evident from (19) that the τ-statistic corresponding to the coefficient of y_{t-1} is insignificant when compared with the tabulated τ-values in Perron (1989,Table IV, p.1376)[2]. Further, the intercept μ^A is significant with the test statistic taking value 3.167. Thus, we may conclude that even in the presence of a one-time break in level (in the sense of a "crash"), the underlying time series process is DS with drift same as in the case without consideration to any break in the series. Finally, we report the Ljung-Box test statistic, $Q(m)$, values of the estimated model in (19) in Table 2 below. We observe from this table that $Q(m)$ values are insignificant for all values of lags considered up to 8 for total foodgrains production. This diagnostic test, therefore, suggests that the assumption of Gaussian white noise error in Perron's test is statistically acceptable for this series.

Table 2. Ljung-box statistic values based on residuals of time series models with break

Lag(m)	Exogenous structural break			Endogenous structural break	
	Total foodgrains (slope break) 1981-82	Rice (level break) 1981-82	Rice (slope break) 1981-82	Total foodgrains (level break) 1981-82	Rice (slope break) 1991-92
1	0.520×10^{-02}	0.882	0.151	0.014	0.270×10^{-02}
2	0.622×10^{-02}	1.064	0.217	0.021	0.150
3	0.026	1.077	1.922	0.028	0.237
4	1.208	1.568	3.262	0.785	0.373
5	1.355	1.591	3.755	0.878	0.376
6	1.390	2.317	4.290	0.900	0.437
7	1.766	2.921	4.294	1.523	0.926
8	1.785	3.012	2.076	1.593	1.014

(The null of no autocorrelation can not be rejected even at 5% level of significance for all the above test statistic values)

We also carried out the same exercise from consideration of the break point being endogenously determined, rather than exogenously as in Perron. This was done by following the approach of Zivot and Andrews (1992), discussed in Section 2. For this exercise we had $T-2$ i.e.,46 regressions corresponding to as many break fractions, and found that the break point determined through this procedure came out to be the same as in Perron's case *viz.*, 1981-82. The estimated equation corresponding to Model A in (11)[3] for the year 1981-82 was obtained as (absolute values of the test statistic are given in parentheses)

$$\Delta y_t = \underset{(1.891)}{3.128} + \underset{(1.299)}{0.082}\, DU_t + \underset{(1.224)}{0.007}\, t - \underset{(1.840)}{0.371}\, y_{t-1} + \sum_{j=1}^{2} \hat{\delta}_j \Delta y_{t-j} + \hat{a}_t. \quad (20)$$

By comparing the test statistic value for the coefficient of y_{t-1} with the critical value computed by Zivot and Andrews (1992, Table 2, p.256), we come to the conclusion that the null of DS process cannot be rejected even at 5 percent level of significance. We also find from (20) that the constant is significant, although at a level slightly higher than the usual 5 percent level of significance. Thus, the conclusion about the time series when the break point is determined endogenously, is the same as that with exogenously determined break point *viz.*, there is a break in level (in the nature of "crash" or significant fall in the intercept) in 1981-82, and the underlying time series follows a DS process with a drift. The diagnostic checks on the residuals yield, as before, Gaussian white noise errors as evidenced from the values of $Q(m)$ statistic presented in Table 2 for this case.

Lastly, we report the results of the application of KPSS test with this data. As already mentioned in Section 2, this test is in the nature of a confirmatory test for ADF testing procedure, and is designed to test the null hypothesis of level stationarity/trend stationarity against the alternative of unit root. The computed values of KPSS test statistic with as well as without a linear trend term are given in Table 3. These values are then compared with the tabulated values (*cf.* Kwaitkowski et al.(1992), Table 1,p.166) to conclude on the outcome of the test. Since the number of observations is small as compared to the sample size required for time series modelling, we decided to fix the value of the lag truncation parameter l at reasonably small value, say 3 or 4. From Table 3 we observe that the null is rejected in favour of the alternative of DS at 1 percent level of significance for the case where there is no linear trend.

Table 3. KPSS TEST STATISTIC VALUE UNDER THE NULL OF LEVEL/TREND STATIONARITY

Lag truncation	Total foodgrains		Rice		Wheat	
parameter (ℓ)	Etamu	Etatau	Etamu	Etatau	Etamu	Etatau
1	4.307*	0.197*	4.204*	0.380*	3.676*	0.661*
2	2.290*	0.144**	2.248*	0.275*	1.879*	0.344*
3	1.595*	0.127***	1.569*	0.232*	1.281*	0.240*

(* *denotes rejection of null of stationarity at 1 percent levels of significance,* ** *denotes rejection at 5 percent only,* *** *denotes rejection at 10 percent only; Etamu is KPSS test statistic without linear trend and Etatau stands for the statistic with linear trend*)

Table 4. KPSS TEST STATISTIC VALUE WITH BREAK IN 1981-82

Lag truncation parameter (ℓ)	Total foodgrains (level break) 1981-82		Rice (level break) 1981-82	
	Etamu	Etatau	Etamu	Etatau
1	1.348*	0.171**	1.919*	0.054
2	0.798*	0.126***	1.145*	0.051
3	0.597**	0.111	0.853*	0.059

(* , ** , ***, *Etamu and Etatau are the same as in Table 3*)

As for the case with the linear trend term, we note that TS is rejected in favour of DS at 10 percent level of significance for the values of l up to 3. Hence, we may conclude that KPSS test confirms the inference drawn by ADF test regarding the series of total foodgrains production viz., the time series is a DS process. Finally, we briefly report the performance of KPSS test in presence of structural break (*cf.* Lee *et al.* (1997)) in Table 4. The exercise was done taking 1981-82 as the break point since an exogenous break in level (in the sense of significant fall in value) was found in 1981-82 by Perron's method. We find from the performance of this test that even in the presence of an intercept break in 1981-82, the conclusion of DS process is confirmed.

Thus, combining the findings of all the tests, we may sum up that the series of total foodgrains production in West Bengal is a DS process with a drift when the exercise is carried out for the entire series irrespective of any consideration to structural break in the series. The assumption of TS process is not supported by modern techniques of trend analysis. As regards the presence of a break, we have observed, like other analysts of this data, that a break indeed occurred in 1981-82. However, the nature of the break is different in the sense that while they found a positive break in slope (leading them to conclude that there was an acceleration in growth of total foodgrains production in 1981-82), which was attributed to institutional effects brought about by Panchayati Raj system in rural Bengal, we have found the existence of a one-time negative break in intercept only, which may be attributed to the drought in 1981-82. Thus, we may conclude that these statistical evidences do not give support to the hypothesis of increasing growth rate in total foodgrains production since 1981-82, as observed by previous researchers.

Identification of the series – rice. It has been already stated that apart from total foodgrains production, we have also analysed the time series of production of two other major crops in West Bengal *viz.*, rice and wheat. Since time series modelling for total foodgrains production has been discussed in details, we report the findings for these two series very briefly. Assuming y_t represents total rice production in logarithmic scale the estimated equations for ADF test for the series are as follows. (The figures in parentheses denote absolute values of the test statistic).

$$\Delta y_t = \underset{(1.674)}{2.388} + \underset{(1.793)}{0.008}\, t - \underset{(1.653)}{0.290}\, y_{t-1} - \underset{(2.017)}{0.335}\, \Delta y_{t-1} - \underset{(3.386)}{0.471}\, \Delta y_{t-2} + \hat{a}_t \quad (21)$$

$$\Delta y_t = \underset{(0.805)}{0.031} + \underset{(0.716)}{0.001}\, t - \underset{(4.114)}{0.519}\, \Delta y_{t-1} - \underset{(4.647)}{0.581}\, \Delta y_{t-2} + \hat{a}_t \quad (22)$$

$$\Delta y_t = -\underset{(0.102)}{0.046} + \underset{(0.225)}{0.012}\, y_{t-1} - \underset{(3.971)}{0.524}\, \Delta y_{t-1} - \underset{(4.539)}{0.581}\, \Delta y_{t-2} + \hat{a}_t \quad (23)$$

$$\Delta y_t = \underset{(3.100)^*}{0.055} - \underset{(4.115)}{0.516}\, \Delta y_{t-1} - \underset{(4.642)}{0.576}\, \Delta y_{t-2} + \hat{a}_t. \quad (24)$$

(∗ *denotes significance at 1% level*)

It is obvious from the above results that ADF test suggests that the time series process is described by a DS process with a drift and not a TS process as assumed by other researchers. It is also confirmed from the values of $Q(m)$ statistic shown in Table 1 that the residuals are indeed Gaussian white noise.

As regards Perron's test, the findings are somewhat mixed. When we consider 1981-82 as the break year, we observe either a negative one-time break in intercept (a "crash" in the level of production as shown in equation (25)) or a positive break in slope (as shown in equation (26)) but both are not simultaneously present as evidenced from equation (27). (The figures in parentheses denote absolute values of the test statistic).

$$\begin{aligned}\Delta y_t &= \underset{(3.415)}{4.174} - \underset{(4.212)^*}{0.446}\ D(TB)_t + \underset{(3.446)}{0.181}\ DU_t + \underset{(2.011)}{0.008}\ t - \underset{(3.330)}{0.500}\ y_{t-1} \\ &\quad - \underset{(2.498)}{0.335}\ \Delta y_{t-1} - \underset{(3.202)}{0.374}\ \Delta y_{t-2} + \hat{a}_t \qquad (25)\end{aligned}$$

$$\Delta y_t = \underset{(3.951)}{22.104} - \underset{(2.350)}{0.311}\ DU_t + \underset{(3.695)^*}{0.069}\ D(TS)_t - \underset{(3.927)^*}{2.700}\ y_{t-1} + \sum_{j=1}^{8} \hat{\delta}_j \Delta y_{t-j} + \hat{a}_t \qquad (26)$$

$$\begin{aligned}\Delta y_t &= \underset{(3.018)^*}{7.243} + \underset{(2.448)}{0.015}\ t - \underset{(3.826)^*}{0.410}\ D(TB)_t - \underset{(1.044)}{0.445}\ DU_t + \underset{(1.478)}{0.017}\ DT_t \\ &\quad - \underset{(2.985)}{0.873}\ y_{t-1} - \underset{(0.472)}{0.098}\ \Delta y_{t-1} - \underset{(1.502)}{0.228}\ \Delta y_{t-2} + \hat{a}_t. \qquad (27)\end{aligned}$$

(* *denotes significance at 1% level and ** at 5% level*).

This means that while a break in 1981-82 is supported by the data analysis, the nature of the break is either a negative one-time break in intercept or a positive break in slope but not both. The relevant Ljung-Box test statistic values are shown in the Table 2. It may be mentioned here that unlike the case with total foodgrains production, we found evidence of a one-time positive trend break in slope only in rice production separately in 1982-83 and 1983-84 as well. In both these cases, however, the DS process was found to be acceptable and not TS process as with 1981-82 break. For reasons of brevity and space the estimated equations with breaks in 1982-83 and 1983-84 are omitted here. Although the above results lend support to the hypothesis of an acceleration in the production of rice in the early '80's, one has to be cautious in drawing inferences on the nature of the break since in the year 1981-82 when occurence of a positive break in slope was observed by others, we have found that the break could be explained in terms of either intercept (negative) or slope (positive).

Insofar as the determination of endogenous break is concerned, we have found 1991-92 as the break year for the series of rice production, by applying Zivot and Andrew's (1992) "minimum t-ratio rule". This finding is somewhat surprising given the nature of the plot and the prevailing economic scenario in and around 1991-92. However, since this procedure is based on the magnitude of some descriptive statistic-based measure, we need not attach much importance to this finding. The estimated equation is shown below:

$$\Delta y_t = \underset{(1.477)}{2.540} + \underset{(1.710)}{0.008}\ t + \underset{(0.163)}{0.003}\ D(TS)_t - \underset{(1.466)}{0.302}\ y_{t-1} + \sum_{j=1}^{2} \hat{\delta}_j \Delta y_{t-j} + \hat{a}_t. \qquad (28)$$

We also carried out KPSS confirmatory test on the conclusions drawn on the basis of ADF test for the series of rice production. The conclusion of DS with drift is confirmed even allowing lag up to 6 at 5 percent level of significance. Finally, the results concerning this test with consideration of break in the series (*i.e.*, Lee *et al.*) are shown in Table 4.

Identification of the series – Wheat. The estimated equations for testing whether the time series data on wheat production in West Bengal exhibited a unit root with/without a drift parameter are as follows.

$$\Delta y_t = \underset{(1.950)}{0.354} + \underset{(1.185)}{0.007}\ t - \underset{(1.741)}{0.091}\ y_{t-1} + \underset{(3.443)}{0.521}\ \Delta y_{t-1} - \underset{(0.081)}{0.013}\ \Delta y_{t-2} + \hat{a}_t \quad (29)$$

$$\Delta y_t = \underset{(0.868)}{0.083} - \underset{(0.493)}{0.002}\ t + \underset{(3.312)}{0.513}\ \Delta y_{t-1} - \underset{(0.671)}{0.104}\ \Delta y_{t-2} + \hat{a}_t \quad (30)$$

$$\Delta y_t = \underset{(1.571)}{0.253} - \underset{(1.365)}{0.039}\ y_{t-1} + \underset{(3.380)}{0.513}\ \Delta y_{t-1} - \underset{(0.441)}{0.068}\ \Delta y_{t-2} + \hat{a}_t \quad (31)$$

$$\Delta y_t = \underset{(0.952)}{0.410} + \underset{(3.360)}{0.515}\ \Delta y_{t-1} - \underset{(0.663)}{0.102}\ \Delta y_{t-2} + \hat{a}_t. \quad (32)$$

It is obvious from the equations in (29) and (31) that the null of unit root cannot be rejected even at 5 percent level of significance without as well as with trend. The linear trend component and the drift are insignificant as shown in the equations (30) and (32), respectively. On the basis of these results, we may thus conclude that the time series of wheat production follows a DS process without drift. The relevant computations on diagnostic test are shown in Table 1. As regards occurence of any break in the series, we found no such statistical evidence during the early eighties. The results of KPSS test given in Table 3 also confirms that the series follows a DS process without drift. Thus, the final conclusion on the series of wheat production in West Bengal is that it follows a DS process without drift and without any structural break.

4. Concluding Remarks

In this paper we have applied the modern time series techniques to study the performance of agriculture in West Bengal. This study has been motivated by the fact that all the existing studies on this topic seem to suffer from some methodological limitations. Since it is now recognized that the conventional econometric approach of curve fitting may not often be adequate for trend analysis, it is important to examine the performance of agriculture in West Bengal by using the rigorous procedure of trend analysis.

Our findings in this study are somewhat different from those of the previous studies. The actual trend process in each of these variables *viz.*, total foodgrains production, rice production and wheat production, has been found to be difference stationary (DS) (with drift parameter for the first two variables only) when the entire series covering the period 1950-51 to 1997-98 was considered without consideration to any break in the series. This finding is in contrast with the previous studies in all of which the underlying trend processes were assumed to be trend stationary. Insofar as structural breaks are concerned, we have found evidence of a one-time break in 1981-82 for total foodgrains production, a one-time break in early eighties (1981-82/1982-83/1983-84) for rice production and no break at all for wheat production. While these findings of ours on the occurence of break are the same as those of the studies by previous researchers, the main difference lies in the nature of these breaks and their effects on the actual trend process. For total foodgrains, we have observed a one-time negative break in intercept which may be attributed to the prevalence of severe drought in that year; but earlier researchers found a positive break in slope (implying an acceleration) in the same variable, which has been explained by them in terms of institutional reforms initiated in the early eighties in rural West Bengal. Our observation on break in rice production is similar to the observations made by other researchers in the sense that the hypothesis of acceleration in growth of rice production during the early eighties is acceptable by the modern time series methodology. With regard to the actual trend process in presence of breaks, we have found that the DS model with a drift parameter still holds for total foodgrains production as well as for rice production. However, a trend stationary process is acceptable when the break year is taken to be 1981-82. As already mentioned, the series of wheat production follows a driftless DS process without statistical evidence of any structural break.

Notes

1. Because of the presence of time trend t as an additional regressor, the distribution of the τ-statistic changes and hence the change in the notation.

2. In the presence of a break the usual DF τ or τ^*-statistic critical values are not valid. Perron (1989) has computed the critical values after obtaining the appropriate distribution of the test statistic.

3. Since a one-time break only in level was found when the break point is taken to be exogenous, for this case of endogenously determined break point we have considered Zivot and Andrew's (1992) approach for Model A only.

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