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ARTICLES

Structural Breaks and Performance in Indian Agriculture

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I

INTRODUCTION

The comprehensive economic reforms since 1991 and their impacts on various aspects of the Indian economy have been an important subject of extensive research and intense debate. There are many studies that have examined the performance of the Indian economy, particularly after the large-scale economic reforms involving liberalisation and structural adjustment programmes since 1991. In order to investigate whether the Indian economy has undergone any significant structural break after the economic reforms, a number of studies have tried to locate structural break in Indian macroeconomic data. These studies have identified structural break in the long-term growth trend in gross domestic product (GDP) around 1980-81 (see, for example, Dholakia, 1994; Kumar, 1992; Sinha and Tejani, 2004, among others). However, Balakrishnan and Parameswaran (2007a) (henceforth, B-P (2007a)) have observed significant acceleration of GDP growth rate in 1978-79, and Ghosh (1999, 2008) has reported evidence of structural break in real GDP in 1988-89 and in real gross national product (GNP) in 1993-94.

At the sectoral level, a number of empirical studies have evaluated the performance of Indian agriculture, and identified significant turning points, particularly after the introduction of new high-yielding variety (HYV) technology in the mid-1960s (see, for example, Bhalla, 2007; Bhalla and Singh, 1997, 2001). It is argued that the adoption of new seed-fertiliser technology has ushered in an era of green revolution in Indian agriculture, as it has led to a marked increase in the growth rate of agricultural output in several parts of India. And growth in productivity rather than in area has been the predominant source of growth in agricultural output.

The Indian economy has also been undergoing significant changes due to implementation of the large-scale economic reforms since 1991. The policies that have direct and indirect bearing on agriculture are likely to have far reaching consequences for agricultural development. The on-going economic reforms and gradual opening up of Indian agriculture to world economy through the liberalisation of both internal and external trade are expected to have significant impact on agricultural production. The reduction of protection to industry and the exchange rate

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depreciation are expected to shift inter-sectoral terms of trade in favour of agriculture which is likely to boost agricultural exports. Consequently, agricultural production is expected to rise significantly, and its trend function is likely to undergo structural break after the economic reforms. Against this background, it seems pertinent to identify the critical turning points and evaluate the growth performance in Indian agriculture.

While evaluating the performance of agriculture during different phases, the researchers have chosen the sub-periods exogenously on the basis of prior information about the timing of significant changes. The turning points are also considered uniformly for all the Indian states, with the implicit assumption that all the states have undergone structural breaks in the same year as observed at the all-India level. It may, however, be possible that the states might have undergone significant structural breaks in agriculture in different years.

However, there is hardly any comprehensive study, involving advanced econometric technique, to address the question of estimating endogenously the critical turning points in agriculture in the Indian state economies. Dholakia's (1994) study is perhaps the first attempt to identify structural breaks endogenously during 1960/61–1989/90, applying the switching regression technique to Indian state-level data. However, as Dholakia (2007) rightly pointed out in the context of his comments on B-P (2007a), some of the estimates of breakdates could change with more recent data, different base year and advanced methodology. Under this condition, and since the Indian economy has undergone several important changes after 1991, it seems important to estimate the critical turning points in the state economies, applying advanced econometric technique to more recent data available with a different base year. Moreover, from the policy standpoint, it seems useful to estimate endogenously the timing of structural break, and evaluate agricultural performance looking into the nature of structural break in the states. It may be of interest to see whether the states also experience the shift in their growth path in the same year in which the economy as a whole experienced it. This helps in identifying the states, which might have been responsible for acceleration/deceleration of agricultural growth. The results may be useful for understanding the process of growth in agriculture during different periods.

II

OBJECTIVE AND DATABASE

This paper estimates the critical turning points, and evaluates the growth performance of agriculture in fifteen major Indian states during 1960/61–2006/07. The growth performance has been evaluated during different periods, particularly during the pre- and post-reforms ones. Moreover, utilising the methodology suggested by Zivot and Andrews (1992) [henceforth, Z-A], we have endogenously estimated the critical turning points in the agricultural sector of the states. For this purpose, we have first evaluated the univariate time-series properties (stationarity and non-stationarity) of time series data with the assumption that there is no structural break. Applying the Augmented Dickey-Fuller (ADF) test for a unit-root, we have examined if the data are better represented by a difference stationary (DS) or a trend stationary (TS) process.

Moreover, in view of the fact that random shocks occur less frequently than the DS process assumes, and in view of the observation that there are several sudden changes in the trend functions, we have examined the unit-root hypothesis incorporating appropriate structural break in an endogenous manner. We have employed the Z-A's method of unit-root test that does not require prior information about the timing of break. This method, developed in the spirit of Banerjee *et al.*, (1992) and Christiano (1992), considers the selection of the breakpoints (structural breaks) as the outcome of an estimation procedure, and thus, identifies the breakpoints in time-series data in an endogenous manner. The data used here were compiled from EPW Research Foundation (2003, 2004), Government of India (2006, 2007, 2008a, 2008b) and Reserve Bank of India (2007).

The rest of the paper is organised as follows. Section III outlines the methodology used for estimating endogenously the critical turning points in the trend functions. Section IV discusses the results: it evaluates the performance of agriculture during the pre- and post-reform periods, investigates the univariate time-series properties of the variables using the ADF test for a unit root, and then estimates endogenously the critical turning points in agriculture applying the Z-A's method of unit-root test. Section V summarises the main findings and draws conclusions.

III

METHODOLOGY

This section outlines the methodology for evaluating the univariate time series properties of the variables and for estimating endogenously the critical turning points in the trend functions of the variables. It first describes the ADF test for a unit root with no structural break, and then outlines the Z-A's method of unit root test incorporating appropriate structural break in the trend functions.

III.1 *The ADF Test for a Unit Root*

The ADF test for a unit root, developed by Dickey and Fuller (1979, 1981), is based on the statistics obtained from applying the ordinary least squares (OLS) method to the following regression equation.

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

where y_t = time series variable; t = trend variable;

$\Delta y_{t-i} = y_{t-i} - y_{t-i-1}$;

$e_t \sim \text{i.i.d.}(0, \sigma^2)$.

The t-statistic, $\hat{\tau} = \frac{\hat{p} - 1}{\text{s.e}(\hat{p})}$, is used to test for the unit-root null hypothesis $H_o : \rho = 1$. Since $\hat{\tau}$ does not have the usual properties of Student-t distribution, we have used the critical values tabulated by Fuller (1976, Table-8.5.2, p.373) for testing the level of significance. The lagged first difference terms are included in the equation to take care of possible correlation in the residuals.

III.2 *The Z-A's Method of Unit Root Test*

The Z-A's test for a unit root with an endogenous structural break in the data specifies the null hypothesis as:

$$y_t = \mu + y_{t-1} + e_t \qquad \text{....(2)}$$

Three plausible models under the alternative hypothesis allowing for structural break in the trend function are specified as:

$$\text{Model A: } y_t = \mu_1 + \beta t + (\mu_2 - \mu_1) DU_t + e_t \qquad \text{....(3)}$$

$$\text{Model B: } y_t = \mu_1 + \beta_1 t + (\beta_2 - \beta_1) DT_t^* + e_t \qquad \text{....(4)}$$

$$\text{Model C: } y_t = \mu_1 + \beta_1 t + (\mu_2 - \mu_1) DU_t + (\beta_2 - \beta_1) DT_t^* + e_t \qquad \text{.... (5)}$$

While Model A allows for structural break in the level and Model B in the slope, Model C specifies structural change in both the level and slope of the trend function. Specifically, the Z-A's method of unit-root test involves estimation of the following regression equations, which are constructed by nesting the models under the null and alternative hypotheses:

$$\text{Model A: } y_t = \mu^a + \beta^a t + \theta^a DU_t(\hat{\lambda}) + \rho^a y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + e_t \qquad \text{....(6)}$$

$$\text{Model B: } y_t = \mu^b + \beta^b t + \gamma^b DT_t^*(\hat{\lambda}) + \rho^b y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + e_t \qquad \text{....(7)}$$

$$\text{Model C: } y_t = \mu^c + \beta^c t + \theta^c DU_t(\hat{\lambda}) + \gamma^c DT_t^*(\hat{\lambda}) + \rho^c y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + e_t \qquad \text{....(8)}$$

where $DU_t(\lambda) = 1$ if $t > \lambda T$, 0 otherwise; $DT_t^*(\lambda) = t - \lambda T$ if $t > \lambda T$, 0 otherwise. $\hat{\lambda}$ is the estimated value of the break fraction. While Model A may be treated as level shift one as it allows for a change in the level of the trend function, and Model B as growth shift one, Model C may be considered as level-cum-growth shift one in which both the level and slope of the trend function are allowed to change after the structural break.

The Z-A's method provides an estimation procedure for determining the break fraction (breakpoint) $\lambda = T_B/T$ in a manner that gives the least favourable weight to the unit-root hypothesis, using the test statistics for $\rho^i = 1 (i = a, b, c)$. That is, λ is chosen in such a manner that the one-sided t-statistic for testing $\rho^i = 1$ is minimised. If λ^i_{inf} represents such a minimising value for model i, then the criterion for estimating the point of structural break endogenously is given by:

$$t_{\hat{\rho} i}\left[\hat{\lambda}^i \inf\right] = \inf_{\lambda \Lambda} t_{\hat{\rho} i}(\lambda) \qquad \text{....(9)}$$

where Λ is a specified closed subset of (0, 1). T_B refers to the time of break, i.e., the year in which a change in the parameters of the trend function occurs. The estimated break year $\hat{T}_\beta (= \hat{\lambda} T)$ corresponds to the minimum value of $t_{\hat{\rho} i}(\lambda)$ The significance of $t_{\hat{\rho} i}\left(\hat{\lambda}^i \inf\right)$ is assessed by using the asymptotic estimated-breakpoint critical values reported by Zivot and Andrews (1992).

IV

RESULTS AND DISCUSSION

IV.1 *Performance of Agriculture*

The performance of agriculture is evaluated against the background of structural transformation of the economy and the consequent changes in the position of the agricultural sector vis-à-vis the other sectors. Since the structure of an economy is viewed in terms of sectoral composition of output, structural transformation may be examined by looking into the nature and direction of changes in the contribution of different sectors to gross domestic product.

IV.1.1 *Changes in the Sectoral Composition of Output*

During the process of growth, the Indian states have experienced significant changes in the shares of output originating from different sectors. The data on sectoral composition of output, presented in Table 1, reveal that at the all India level, the share of agricultural and allied activities in real GDP declined gradually from 46.3 per cent in 1970-71 to 32.2 per cent in 1990-91, and then sharply to 18.49 per cent in 2006-07. In contrast, the share of industry increased from 21.5 per cent in 1970-71 to 27.2 per cent in 1990-91, but declined to 26.77 per cent in 2006-07. The

TABLE 1. SHARE OF GSDP AT FACTOR COST BY INDUSTRY ORIGIN AT CONSTANT PRICES

(*per cent*)

State	Agriculture and Allied			Industry			Services		
	1970/71	1990/91	2006/07	1970/71	1990/91	2006/07	1970/71	1990/91	2006/07
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Andhra Pradesh	56.58	36.66	27.76	14.02	22.15	24.49	29.4	41.19	50.75
Assam	61.37	38.32	27.82	16.52	16.95	20.68	22.12	44.73	51.50
Bihar	58.01	38.23	33.04	21.59	31.29	13.67	20.41	30.48	53.29
Gujarat	47.96	25.24	18.27	21.77	37.52	40.28	30.26	37.24	41.45
Haryana	64.64	44.87	21.74	15.35	24.42	30.59	20.01	30.71	47.67
Karnataka	54.2	32.63	19.72	23.63	26.19	26.45	22.17	41.18	53.83
Kerala	49.36	31.18	17.71	16.40	24.00	21.69	34.24	44.81	60.60
Madhya Pradesh	59.70	41.04	25.58	17.19	28.55	24.37	23.11	30.42	50.05
Maharashtra	28.41	21.37	12.71	34.40	36.31	26.71	37.19	42.32	60.58
Orissa	65.46	35.80	23.08	12.21	26.69	30.01	22.34	37.51	46.91
Punjab	58.33	47.06	31.93	15.35	24.17	25.90	26.32	28.77	42.17
Rajasthan	60.98	44.99	29.35	13.49	22.24	27.11	25.53	32.77	43.54
Tamil Nadu	39.32	21.58	12.91	26.66	35.15	28.74	34.02	43.27	58.35
Uttar Pradesh	58.40	41.16	28.54	8.91	22.01	26.26	32.69	36.82	45.20
West Bengal	43.51	29.02	24.66	24.27	29.45	20.96	32.22	41.54	54.38
India*	46.30	32.20	18.49	21.50	27.20	26.77	32.20	40.60	54.74
CV (per cent)	19.11	23.44	26.99	34.99	21.73	22.63	20.80	15.09	12.35

Sources: EPW Research Foundation (2003, 2004); Government of India (2008a,).

Notes: *For India, the figures are shares of gross domestic product (GDP) at factor cost by industry origin at constant prices; GSDP = Gross state domestic product.

biggest increase in the GDP share occurred in the services sector – from 32.2 per cent in 1970-71 to 40.6 per cent in 1990-91, and further to 54.74 per cent in 2006-07. Thus, the emerging structural change in GDP shares witnessed a big decline in the share of agriculture, accompanied by a modest increase in the share of industry, and a much sharper increase in the share of services.

Although there have been significant differences in the structure of the state economies, the states experienced a similar process of structural change. Table 1 shows that while the share of the agricultural and allied sector in gross state domestic product (GSDP) has declined substantially in all the states during 1970/71–2006/07, the share of the industrial sector has increased modestly in all the states except Bihar, Maharashtra and West Bengal, and the share of the services sector has increased substantially in all the states. The inter-state variations in the structure of the state economies, measured in terms of the coefficient of variation (CV), has consistently increased in the agricultural and allied sector, but declined in the services sectors. For the industrial sector, although the CV has slightly increased from 21.73 per cent in 1990-91 to 22.63 per cent in 2006-07, it shows a downward trend during the entire period – from 34.99 per cent in 1970-71 to 22.63 per cent in 2006-07. These findings may be construed to be an indication of the structural convergence across states during the period under consideration.

Despite the declining share of the agricultural sector in GDP, the importance of this sector can hardly be over emphasised in view of the observation that, apart from the fact that this sector still absorbs around 60 per cent of the workforce, overall growth in GDP is dependent on the growth of GDP originating from agriculture (GDPA). The correlation coefficient between the annual growth rates of GDP and GDPA during 1960/61–2006/07 turns out to be 0.834, implying that year-to-year fluctuations in the growth rates of GDP are highly correlated with those of GDPA. The correlation coefficient between the two variables for different sub-periods, however, indicates that the dependence of GDP growth rates on GDPA has declined with time – from 0.938 during 1960/61–1990/91 to 0.593 during 1991/92–2006/07.

IV.1.2 *Growth Performance in Agriculture*

Table 2 presents the annual growth rates of gross domestic product originating form agriculture (GDPA) and net state domestic product originating from agriculture (NSDPA) at constant (1993-94) prices. The growth rate of GDPA has declined from 3.13 per cent in the pre-reform period (1970/71–1990/91) to 2.76 per cent in the post-reform period (1991/92–2006/07). Better growth performance in agriculture during the pre-reform period was achieved due to high growth in the 1980s; the growth rate of GDPA during the 1980s (4.71 per cent) was substantially higher than that in the 1970s (1.39 per cent). The growth performance of Indian agriculture has worsened during the post-reform period.

TABLE 2. ANNUAL GROWTH RATE OF NET STATE DOMESTIC PRODUCT FROM AGRICULTURE (NSDPA)

(*per cent*)

State (1)	1970/71-1979/80 (2)	1980/81-1990/91 (3)	1970/71-1990/91 (Pre-reforms) (4)	1991/92-2006/07 (Post-reforms) (5)
Andhra Pradesh	1.54	2.78	2.39	2.78
Assam	2.00	2.28	2.40	1.06
Bihar	0.71	2.64	2.28	2.02
Gujarat	3.30	-0.54	2.95	3.89
Haryana	2.43	4.23	3.80	2.03
Karnataka	2.66	2.47	2.99	1.48
Kerala	-1.20	2.81	1.53	-0.90
Madhya Pradesh	-1.79	3.59	2.63	1.06
Maharashtra	6.47	3.78	3.81	1.85
Orissa	1.07	0.99	1.68	0.77
Punjab	3.95	5.03	4.29	2.25
Rajasthan	1.41	4.22	3.49	2.43
Tamil Nadu	0.95	3.44	1.05	0.23
Uttar Pradesh	1.31	2.89	3.32	2.42
West Bengal	2.63	5.60	3.94	2.93
India*	1.39	4.71	3.13	2.76
CV (per cent)	108.7	49.5	33.8	67.6

Sources: Estimated from data reported in EPW Research Foundation (2003), Government of India (2008a) and Reserve Bank of India (2007).

Note: *For India, the growth rate is of gross domestic product from agriculture (GDPA).

The selected states experienced similar trend in the agricultural growth performance. All the states except two (Andhra Pradesh and Gujarat) experienced deceleration in the growth rate of NSDPA during the post-reform period relative to the pre-reform one. Moreover, a comparison of the growth rates of NSDPA during the 1970s and 1980s reveals that the growth rate accelerated significantly during the 1980s in all the states except Gujarat, Karnataka, Maharashtra and Orissa. The improved growth performance in the 1980s contributed to the higher agricultural growth rates in the states during the pre-reform period relative to the post-reform one.

The slowing down of agricultural growth rates at the national and state levels has been associated with large and widening inter-state differences in agricultural growth performance during the post-reform period. The growth rate of NSDPA varies from 1.05 per cent in Tamil Nadu to 4.29 per cent in Punjab during the pre-reform period; it varies from –0.90 per cent in Kerala to 3.89 per cent in Gujarat during the post-reform period. The inter-state variation in agricultural growth rate has increased remarkably during the post-reform period, as the CV of growth rates across states has increased from 33.8 per cent during the pre-reform period to 67.6 per cent in the post-reform period.

The economic reforms and the liberalisation of the economy and its integration with the world economy were expected to end discrimination against agriculture and help accelerating its growth through enhanced incentives for production and export. Contrary to the expectations, the post-reform period experienced a significant deceleration in the growth rate of agricultural output. Bhalla (2007) argues that the slowing down of agricultural growth during the post-reform period has been due to, among other things, significant reduction in public investment in critical areas of agricultural growth, viz., irrigation and drainage, rural road, soil conservation, water management system, and research and technology.

The slowdown in agriculture has often been attributed by some researchers to economic reform programmes in the 1990s, apparently because of the coincidence of the period of slowdown with the economic policy regime that has undergone reform since 1991. Balakrishnan *et al.* (2008) find this view limited, and argue that some structural factors on the supply side of Indian agriculture are more important and deserve greater attention in explaining slowdown of growth in agriculture over the past one and a half decades. They argue that "to focus *a priori* and exclusively on the reforms as the likely root cause of agricultural slowing may be misleading. However, ... the reforms as implemented since 1991 – or some associated policy changes – may not have been altogether benign towards agriculture" (Balakrishnan *et al*., 2008, p.6).

Balakrishnan *et al.* (2008) explain the observed slowdown in agriculture in terms of some price and non-price factors. While they do not find evidence to consider relative price movement over the last 15 years as central to understanding the slowdown of agricultural growth since 1991, the non-price factors, which are likely to be responsible for slowdown in agriculture, are: (i) stagnation of public investment for about a quarter of a century, (ii) slowing down of the rate of expansion of irrigation since 1991, (iii) smaller farm size making it more difficult to adopt new technology and more efficient form of production organisation, (iv) downscaling of production due to farm fragmentation, (v) environmental stress, (vi) slower growth in public expenditure in real terms on research and extension since 1990 which was historically low as a share of agricultural output, and (vii) declining efficiency of public investment.

IV.2 *Critical Turning Points in Agriculture*

This section attempts to identify the significant structural breaks in the agricultural sector of the selected states. For this purpose, using the ADF test for a unit root, it first evaluates the univariate time-series properties of NSDPA, with the assumption that there is no structural break in the data. It then applies the Z-A's method of unit-root test, and estimates endogenously the critical turning points in agriculture. It also applies the tests to GDPA in order to compare the state-level results with those at the all India level.

IV.2.1 *Univariate Time Series Properties*

Using the ADF test for a unit root, we examine if the variables are more adequately represented by a DS rather than a TS process, and if the random shocks have permanent effect on the long-run level, and fluctuations are highly persistent.

We examine the nature of trend (deterministic or stochastic) and the relative importance of individual shocks in the time series. This is performed by testing the presence of a unit root in the univariate time series representation of the variables. A test for the null hypothesis of DS against the alternative of TS is performed by estimating the ADF type regression (equation 1) by the OLS method.

The results of the unit root test based on the ADF method are reported in Table 3. All the variables (viz., NSDPA and GDPA) are expressed in natural logarithm. The optimal number of augmenting lag is selected by the Akaike Information Criterion (AIC). It can be seen that when the ADF test is applied, the null hypothesis of a unit root with a drift and a trend cannot be rejected for NSDPA and GDPA. This implies that these variables are better represented by a DS rather than a TS process. These results appear to be consistent with the random walk hypothesis, implying that random shocks have permanent effects on the long-run level, and fluctuations are highly persistent. Based on these results, one may be tempted to conclude that the variables are better characterised as non-stationary stochastic processes rather than stationary fluctuations around a deterministic trend.

TABLE 3. THE ADF TEST FOR STATIONARITY IN NSDPA AND GDPA

State (1)	ADF (τ_τ) (2)
Andhra Pradesh	-3.103 (3)
Assam	-2.529 (2)
Bihar	-2.389 (3)
Gujarat	-2.801 (5)
Haryana	-2.526 (2)
Karnataka	-2.797 (3)
Kerala	-2.014 (2)
Madhya Pradesh	-2.921 (2)
Maharashtra	-2.979 (2)
Orissa	-3.135 (3)
Punjab	-0.748 (4)
Rajasthan	-2.226 (5)
Tamil Nadu	-2.476 (2)
Uttar Pradesh	-3.161 (5)
West Bengal	-2.802 (2)
India (GDPA)	-3.106 (2)

Notes: Figures in parentheses are the optimal number of augmenting lags selected by the Akaike Information Criterion (AIC). None of the test statistics is statistically significant. For Haryana and Punjab, number of observation (T) = 42 (1965/66-2006/07); For Assam, T = 39 (1968/69-2006/07); For India and all other states, T = 47 (1960/61-2006/07). For T = 50, 1 per cent and 5 per cent critical values for τ_τ are –4.15 and –3.50 respectively.

However, we shall see that the conclusion is premature, as it turns out to be erroneous when appropriate structural breaks are incorporated in the trend functions. Balke and Fombay (1991) and Perron (1989), among others, argue that random shocks are infrequent, and most macroeconomic time series are trend-stationary if appropriate structural changes are allowed for in the trend functions. In such a condition, if the outlying events are separated from the noise functions and modelled as interventions in the deterministic part of the time series, then the variables may turn out to be trend-stationary instead of difference-stationary. Hence, before drawing any conclusion about the univariate time-series properties of the variables, it is necessary to conduct unit-root test after accounting for appropriate structural break in their trend functions.

IV.2.2 *Endogenously Estimated Breakpoints*

The above results about the time series properties of the variables are based on the implicit assumption that the long span of time series data used in the analysis did not involve any structural break in the trend functions. The assumption, however, does not appear to be plausible in view of the fact that the data span over a period of forty seven years and include some major events such as drought, devastating flood, technological change, extension of new technology to several crops and regions, changes in government policies, economic reforms, which could conceivably cause structural break in the data.

A visual inspection of the time plots of the logarithm of GDPA and NSDPA clearly revealed that the trend functions involve sudden changes in the intercept and/or slope at several time points (figures are not reported to save space). In view of possible structural break in the data, it seems necessary to examine if the movements in the series have been generated by *big shocks* or by accumulation of frequent shocks each of which has permanent effect. We need to examine the validity of the unit-root hypothesis against the alternative hypothesis of flexible trend stationarity after allowing for appropriate structural break in the trend functions.

One way to perform this is to undertake a test for the unit-root hypothesis after allowing for structural break, exogenously determined on the basis of prior information about some important historical events, or on the basis of visual inspection of the time plots of the variables. This may be performed by using the Perron’s (1989) method, which allows test for a unit root, treating structural break in an exogenous manner, selected on the basis of prior knowledge about some important events. The null hypothesis of a unit root is tested against the alternative hypothesis of deterministic trend with a one-time exogenous break in the level and/or slope.

However, Banerjee *et al*., (1992) and Christiano (1992) pointed out that the choice of breakpoints based on prior observation of the data involves the problems of data-mining and pre-testing bias. It has, therefore, been argued that the date of structural break should not be treated as known *a priori*, but should instead be estimated from the underlying data generating process (DGP) of the series. Naturally, inference about the unit-root hypothesis drawn from the results obtained by using the Perron’s (1989) method can be misleading, since the choice of the breakpoints is based on visual inspection of the data and prior knowledge about particular economic events. Apart from pre-testing bias, these results are likely to involve errors due to the likelihood of selecting the change date at sub-optimal point. Since Indian agriculture in the post-Independence period is characterised by the presence of *several* shocks, we do not know exactly when the optimal date of change occurred. In such circumstances, the structural breakpoint should be determined endogenously, and the correct procedure for testing for a unit root should estimate the breakpoints objectively. To achieve this, we have undertaken a test for the unit-root hypothesis after allowing for structural break, endogenously determined from the data. This is performed by using the Z-A's method (outlined in Section III) in which the point of structural break is estimated rather than treated as known *a priori*.

All the three models (equations 6, 7, 8) were estimated for GDPA and NSDPA. However, assessing the significance of the test statistics for $\rho^i = 1$ (i = a, b, c) and also of the coefficients of the structural break dummies, Model C (equation 8) was found to be most appropriate for the variables. This model offers additional benefits, as the estimates of this model enable us to examine whether the trend functions of agricultural output have undergone structural breaks in the level as well as growth rate. Table 4 presents the results of the unit-root test based on Model C of the Z-A's method. We have estimated by the OLS method T-2 (T=number of observations) regressions using the model with the break fraction $\lambda = T_B/T$, ranging from j=2/T to j=(T-1)/T. Estimating the model for the variables, and treating the break fraction as the outcome of the estimation procedure defined in (9), we have assessed the significance of the unit-root null hypothesis. Based on the significance of the test statistics for $\rho^c = 1$, we have reported two most significant breakpoints for the variables. The t-statistics for $\rho^c = 1$, reported in the table corresponding to the most significant structural break (Rank I) for each variable, are the minimum values over all T-2 regressions. The next minimum values of the t-statistics correspond to the second most significant structural break (Rank II) for each variable. The estimated breakpoints $\hat{T}_\beta (= \hat{\lambda}_T)$ are the years corresponding to these minimum values of $t_{\hat{\rho}i}(\lambda)$. The significance of $t_{\hat{\rho}i}\left(\hat{\lambda}^i \inf\right)$ is assessed by using the asymptotic estimated-breakpoint critical values reported by Z-A (1992, Table 4, p.257).

The estimates of Model C show that the breakpoints in most of the states do not coincide with the breakpoints in Indian agriculture as a whole. Table 5 summarises the breakpoints and the nature of shifts in the level and growth rates of agricultural output. Tables 4 and 5 reveal that Indian agriculture experienced significant upward shift in the level and growth rate of GDPA in 1967-68 presumably due to introduction of the HYV-technology in the mid-1960s. However, although the level of GDPA shifted upward in 1988-89, its growth rate started slowing down since then, as the slope of the trend function has declined. Thus, the positive effects of HYV-technology that ushered in an era of green revolution in Indian agriculture could not be sustained in the late 1980s.

TABLE 4. THE Z-A'S TEST FOR A UNIT ROOT AND ENDOGENOUS STRUCTURAL BREAK IN NSDPA AND GDPA

Estimated Equation (Model C): $y_t = \mu^c + \beta^c t + \theta^c DU_t(\hat{\lambda}) + \gamma^c DT_t^*(\hat{\lambda}) + \rho^c y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + e_t$

State (1)	$\hat{T}_B$ (2)	Rank (3)	$\hat{\mu}^c$ (4)	$\hat{\beta}^c$ (5)	$\hat{\theta}^c$ (6)	$\hat{\gamma}^c$ (7)	$\hat{\rho}^c$ (8)	$s^2(\hat{e})$ (9)
Andhra Pradesh	1970/71	I	13.78	-0.008	0.075	0.033	-0.006	0.007
			(6.58)*	(-0.72)	(1.78)**	(2.89)*	(-6.58)*	
	1988/89	II	12.69	0.018	0.078	0.005	0.065	0.008
			(6.06)*	(4.85)*	(1.64)***	(1.54)***	(-6.07)*	
Assam	1989/90	I	11.03	0.021	0.084	-0.01	0.117	0.002
			(5.46)*	(4.91)*	(2.78)*	(-3.40)*	(-5.48)**	
	1998/99	II	10.81	0.022	-0.069	-0.009	0.134	0.002
			(5.28)*	(5.18)*	(-2.07)**	(-1.68)**	(-5.28)**	
Bihar	1983/84	I	15.16	0.016	0.166	-0.009	-0.13	0.013
			(7.14)*	(3.56)*	(2.28)**	(-1.76)**	(-7.16)*	
	1967/68	II	13.27	-0.059	0.232	0.073	0.028	0.014
			(6.62)*	(-2.12)**	(2.49)*	(2.58)*	(-6.67)*	
Gujarat	2000/01	I	14.06	0.031	-0.60	0.138	-0.076	0.054
			(6.84)*	(5.30)*	(-2.65)*	(2.98)*	(-6.86)*	
	1975/76	II	12.75	-0.001	0.297	0.024	0.035	0.061
			(6.21)*	(-0.01)	(1.92)**	(1.68)**	(-6.18)*	
Haryana	1988/89	I	11.54	0.032	0.153	-0.014	0.079	0.006
			(6.68)*	(5.19)*	(3.06)*	(-2.87)*	(-6.67)*	
	1994/95	II	12.03	0.038	-0.018	-0.017	0.037	0.007
			(6.21)*	(5.68)*	(-1.51)***	(-2.34)**	(-6.21)*	
Karnataka	1998/99	I	10.63	0.026	0.168	-0.041	0.178	0.007
			(5.53)*	(5.32)*	(2.32)**	(-3.22)*	(-5.57)*	
	1991/92	II	8.90	0.019	0.142	-0.012	0.313	0.008
			(4.96)*	(4.40)*	(2.45)*	(-2.19)**	(-4.98)***	
Kerala	1990/91	I	5.22	0.006	0.142	-0.010	0.588	0.005
			(3.55)*	(2.77)*	(2.56)*	(-2.47)*	(-3.55)	
	2000/01	II	3.62	0.006	-0.221	0.029	0.713	0.004
			(2.98)*	(2.98)*	(-3.89)*	(2.37)**	(-2.99)	
Madhya Pradesh	1993/94	I	11.72	0.022	0.218	-0.021	0.106	0.020
			(5.97)*	(5.06)*	(2.18)**	(-2.06)**	(-6.00)*	
	1966/67	II	11.90	-0.072	0.241	0.094	0.116	0.019
			(5.92)*	(-2.13)**	(2.19)**	(2.71)*	(-5.93)*	
Maharashtra	1992/93	I	8.23	0.017	0.203	-0.015	0.383	0.012
			(4.99)*	(4.37)*	(2.73)*	(-2.13)**	(-5.02)***	
	1973/74	II	8.62	-0.007	0.23	0.025	0.363	0.011
			(4.97)*	(-0.82)	(3.20)*	(2.47)*	(-5.02)***	
Orissa	1969/70	I	12.86	0.104	0.109	-0.095	-0.057	0.013
			(6.95)*	(4.33)*	(1.78)**	(-4.10)*	(-6.91)*	
	1990/91	II	8.64	0.022	-0.222	-0.012	0.312	0.016
			(5.47)*	(4.08)*	(-2.69)*	(-1.55)***	(-5.42)**	
Punjab	1989/90	I	9.09	0.028	0.086	-0.012	0.294	0.001
			(5.45)*	(5.12)*	(3.37)*	(-4.19)*	(-5.43)**	
	1997/98	II	8.44	0.027	-0.056	-0.009	0.344	0.001
			(4.76)*	(4.59)*	(-2.08)**	(-1.91)**	(4.85)***	
Rajasthan	1970/71	I	14.35	-0.007	0.355	0.047	-0.125	0.027
			(7.52)*	(-0.34)	(2.92)*	(2.13)**	(-7.55)*	
	1988/89	II	13.04	0.038	0.210	-0.013	-0.035	0.029
			(6.97)*	(5.28)*	(2.01)**	(-1.56)***	(-6.95)*	

(Contd.),

TABLE 4 (CONCLD.)

State (1)	$\hat{T}_B$ (2)	Rank (3)	$\hat{\mu}^c$ (4)	$\hat{\beta}^c$ (5)	$\hat{\theta}^c$ (6)	$\hat{\gamma}^c$ (7)	$\hat{\rho}^c$ (8)	$s^2(\hat{e})$ (9)
Tamil Nadu	1991/92	I	10.31	0.006	0.278	-0.005	0.232	0.011
			(5.14)*	(2.56)*	(3.31)*	(-1.81)**	(-5.15)**	
	1983/84	II	7.99	-0.001	0.113	0.012	0.407	0.012
			(4.32)*	(-0.002)	(1.76)**	(2.01)**	(-4.83)***	
Uttar Pradesh	1981/82	I	16.59	0.022	0.179	0.008	-0.187	0.005
			(7.51)*	(5.90)*	(3.50)*	(2.04)**	(-7.81)*	
	1995/96	II	11.94	0.023	0.073	-0.008	0.141	0.007
			(5.98)*	(5.61)*	(1.76)**	(-1.71)**	(-6.01)*	
West Bengal	1983/84	I	9.14	0.018	0.153	0.005	0.30	0.005
			(5.28)*	(4.55)*	(3.49)*	(1.41)***	(-5.30)**	
	1991/92	II	6.84	0.019	0.079	-0.005	0.472	0.006
			(4.13)*	(4.17)*	(1.59)***	(-1.72)**	(-4.86)***	
India (GDPA)	1988/89	I	9.84	0.024	0.100	-0.001	0.033	0.049
			(6.85)*	(6.56)*	(3.13)*	(-1.53)***	(-6.86)*	
	1967/68	II	9.95	-0.010	0.068	0.037	0.033	0.050
			(6.41)*	(-0.83)	(1.69)**	(2.91)*	(-6.40)*	

Notes: Figures in parentheses below the estimated parameters other than ρ^c are the t-statistics for the null hypothesis that the parameters are equal to zero. Figures in parentheses below ρ^c are the t-statistics for $\rho^c = 1$. *, ** and *** denote significance at 1 per cent, 5 per cent and 10 per cent levels, respectively. While the significance of $\rho^c = 1$ is assessed by using the asymptotic estimated-breakpoint critical values reported in Zivot and Andrews (1992, Table 4, p.257), the significance of the other parameters is evaluated by Student's t-statistics.

The evidence of a downward shift in the growth rate of GDPA in 1988-89 may be interpreted to indicate that the agricultural slowdown process, which is usually believed to have taken place since the early-1990s, might have actually started since 1988-89. The slowing down of growth since this year has often been explained in terms of environmental degradation (Ghosh, 2008) and fall in public sector capital formation in agriculture since the early-1980s which became sharper in the late-1980s (Bhalla, 2007). This 'increasing neglect' of agriculture in terms of investments since the early-1980s is presumed to have affected agricultural growth in due course. Some of the factors, identified by Balakrishnan *et al.* (2008) as important for the slowdown in agriculture since 1991, might have started working before the early1990s.

The nature and timing of structural shifts identified in the present study are at variance with those in B-P (2007a), Dholakia (1994), Dholakia and Dholakia (1993) [henceforth, D-D (1993)], Ghosh (2002, 2008), and Kumar (1992). While Kumar (1992) observed 1980-81 as the most significant breakpoint for the primary sector, Dholakia (1994) found it to be 1979-80. D-D (1993) identified 1966-67 and 1980-81 as two breakpoints in Indian agriculture. While the initial phase of the green revolution (1966/67–1980/81) experienced a higher growth rate relative to the pre-green revolution phase (1950/51–1966/67), the more recent phase of modernisation (1980/81–1988/89) experienced a significantly higher growth rate, and marked a clear departure from the past trend in terms of the growth of total factor inputs (TFI) and total factor productivity (TFP). More recently, B-P (2007a) observed only a

TABLE 5. NATURE AND TIMING OF STRUCTURAL BREAK IN AGRICULTURE

State (1)	Breakpoints (2)	Shift in level (3)	Shift in slope (Growth) (4)	Net effect (5)
Andhra Pradesh	1970-71	Upward	Upward	P
	1988-89	Upward	Upward	P
Assam	1989-90	Upward	Downward	NL
	1998-99	Downward	Downward	N
Bihar	1983-84	Upward	Downward	NL
	1967-68	Upward	Upward	P
Gujarat	2000-01	Downward	Upward	PL
	1975-76	Upward	Upward	P
Haryana	1988-89	Upward	Downward	NL
	1994-95	Downward	Downward	N
Karnataka	1998-99	Upward	Downward	NL
	1991-92	Upward	Downward	NL
Kerala	1990-91	Upward	Downward	NL
	2000-01	Downward	Upward	PL
Madhya Pradesh	1993-94	Upward	Downward	NL
	1966-67	Downward	Upward	PL
Maharashtra	1992-93	Upward	Downward	NL
	1973-74	Upward	Upward	P
Orissa	1969-70	Upward	Downward	NL
	1990-91	Downward	Downward	N
Punjab	1989-90	Upward	Downward	NL
	1997-98	Downward	Downward	N
Rajasthan	1970-71	Upward	Upward	P
	1988-89	Upward	Downward	NL
Tamil Nadu	1991-92	Upward	Downward	NL
	1983-84	Upward	Upward	P
Uttar Pradesh	1981-82	Upward	Upward	P
	1995-96	Upward	Downward	NL
West Bengal	1983-84	Upward	Upward	P
	1991-92	Upward	Downward	NL
India	1988-89	Upward	Downward	NL
	1967-68	Upward	Upward	P

Notes: The breakpoints are estimated using the Z-A's method (see Table 4).

P: Net effect positive; PL: Net effect positive with a lag after the break; N: Net effect negative; NL: Net effect negative with a lag after the break.

single upward shift in the growth rate of GDPA in 1964-65. Based on this finding, they argue, "the acceleration of agricultural growth may not be entirely due to the miracle seeds with which the green revolution tends to be identified" (B-P, 2007a, p.2918). However, Ghosh (2002, 2008) reported that while the level of agricultural output declined significantly at the end of 1964-65 due to severe drought, it increased after 1987-88.

The observed variations in the estimates regarding the nature and timing of structural breaks in agriculture across studies may be explained in terms of their differences in methodology, sample size, and base year of the time series (Dholakia, 2007; Balakrishnan and Parameswaran, 2007b). Table 6 summarises these variations across studies. The sample period and the methodology by which the breakpoints were estimated in Kumar (1992) and Dholakia (1994) exclude the possibility of structural breaks in 1967-68 and 1988-89, identified in the present study. Kumar

(1992) confined his search for break in the slope of the trend function by limiting the switching process within the period from 1974-75 to 1984-85. Dholakia (1994) applied similar methodology. However, the present study applies an advanced econometric method, and allows for the possibility of structural break during the entire period of analysis by extending its search for break at all observation points except the first and the last ones. Our estimates of breakpoints in 1967-68 and 1988-89 broadly corroborate the first breakpoint of 1966-67 but not the second one of 1980-81 reported by D-D (1993), who applied a different methodology to a different data set. Our estimates also differ from those of B-P (2007a) possibly due to differences in methodology, sample size and base year. It is particularly odd to observe [as B-P (2007a) did] growth acceleration in 1964-65 immediately after which India experienced two consecutive years of unprecedented drought, which adversely affected agricultural production. The contradictions between the estimates of the present study with those of Ghosh (2002) may be explained in the following way. The upward shift in the level and growth rate of GDPA in 1967-68, and an upward shift in the level of GDPA in 1988-89 followed by deceleration of growth in the subsequent period could not be identified in Ghosh (2002), possibly due to the reason that he estimated a level-shift model (Model A of Z-A) rather than a level-cum-growth-shift one (Model C of Z-A) with different sample size and base year of the time series.

TABLE 6. DIFFERENCES IN THE PRESENT AND PAST STUDIES

Study (1)	Estimated Breakpoints in Indian Agriculture (2)	Methodology (3)	Sample Size (4)	Base Year (5)
Present study	1967-68 1988-89	Model C of Zivot and Andrews (1992); Allowed for shift in level and slope of the trend function.	1960-61 to 2006-07	1993-94
Balakrishnan and Parameswaran (2007a)	1964-65	Bai and Perron (1998, 2003); Allowed for shift in level and slope of the trend function.	1950-51 to 2003-04	1993-94
Ghosh (2002, 2008)	1964-65 1987-88	Model A of Zivot and Andrews (1992); Allowed for shift in level but not in slope of the trend function.	1950-51 to 1999-2000	1980-81
Dholakia (1994)	1979-80	Switching regression; Allowed for shift in slope but not in level of the trend function.	1960-61 to 1989-90	1980-81
Dholakia and Dholakia (1993)	1966-67 1980-81	Neo-classical growth accounting framework; Kinked time trend with a slope dummy.	1950-51 to 1988-89	1980-81
Kumar (1992)	1980-81	Switching regression; Allowed for shift in slope but not in level of the trend function.	1950-51 to 1989-90	1980-81

IV.2.3 *Inter-State Variations*

The experiences of the states regarding the nature and timing of structural break are found to be at variance with those observed at the all India level. Tables 4 and 5 clearly reveal large inter-state differences in the nature and timing of structural breaks in the level and growth rate of agricultural output. Presumably due to introduction of the HYV-technology, the level and growth rate of agricultural output in Andhra Pradesh experienced an upward shift in 1970-71. The state's agricultural output underwent another significant upward shift in its level and growth rate in 1988-89. Assam experienced an upward shift in the level of agricultural output followed by a downward shift in its growth rate in 1989-90. The level and growth rate of agricultural output declined significantly in 1998-99. Bihar appears to have undergone structural break in agriculture in 1967-68, as the level and growth rate of its agricultural output increased in that year. However, the growth rate started slowing down since 1983-84, even though the level increased in that year.

The positive effect of new agricultural technology was felt in Gujarat in 1975-76, as the level and growth rate of agricultural output increased significantly. The state experienced another upward shift in the growth rate of agricultural output in 2000-01, after a fall in its level. Haryana and Punjab, whose agriculture underwent remarkable transformation immediately after the introduction of HYV-technology in the mid-1960s, started experiencing deceleration in agricultural growth rate since the late-1980s and again in the mid-1990s. In Haryana, although the level of agricultural output increased, its growth rate decelerated in 1988-89; the level and growth rate of agricultural output underwent a downward shift again in 1994-95. Similarly, the growth rate of Punjab's agricultural output started decelerating since 1989-90 after an upward shift in its level. However, its level and growth rate declined in 1997-98. The impact of the green revolution technology, which contributed significantly to agricultural production in Haryana and Punjab immediately after its introduction during the mid-1960s, could not be seen in the trend functions due to the reason that the data used for these two states cover the period 1965/66–2006/07.

The growth rate of agricultural output in Karnataka appears to have slowed down during the post-reform period. Although the level of agricultural output increased in 1991-92 and again in 1998-99, its growth rate started slowing down since those years. Similarly, agricultural output in Kerala started decelerating since 1990-91, after an upward shift in its level. However, its agricultural growth rate accelerated in 2000-01 following a downward shift in its level. The experiences of Madhya Pradesh, Maharashtra and Rajasthan appear to be more or less same. While Madhya Pradesh experienced the benefits of HYV-technology since 1966-67 as the level and growth rate of its agricultural output shifted upward, Maharashtra's agricultural output underwent significant upward shift in its level and growth rate in 1973-74. Similarly, in Rajasthan, agricultural growth rate accelerated since 1970-71, after a significant upward shift in its level. The growth rate of agricultural output in these three states started slowing down since the late-1980s (Rajasthan) and early-1990s (Madhya Pradesh and Maharashtra) following an upward shift in the level.

The experiences of Tamil Nadu, Uttar Pradesh and West Bengal regarding the nature and timing of structural breaks are also more or less same. The level of agricultural output in these states shifted upward and the growth rate accelerated in the early-1980s. However, the growth rate started slowing down since 1991-92 (Tamil Nadu and West Bengal) and 1995-96 (Uttar Pradesh), after an upward shift in the level. In Orissa, the growth rate of agricultural output decelerated since 1969-70 following an upward shift in the level. The level of agricultural output, however, declined and the growth rate started slowing down again in 1990-91.

It seems difficult to estimate the quantitative magnitude of net change of the shifts in level as well as slope. However, some qualitative observations regarding the net change can be made, considering four possible combinations of shifts in level and slope, and comparing the trend level of output obtainable after the shift (post-shift trend) with the trend level of output that would have been obtainable without the shift (pre-shift trend).

(i) *Upward shifts in both level and slope*: The net effect on the trend level of output would be undoubtedly positive, and the positive gap between the post-shift and the pre-shift trend levels of output would be increasing over time after the break. This situation is represented by P.

(ii) *Downward shift in level but upward shift in slope*: The immediate net effect would be negative, as the difference between the post-shift and the pre-shift trend levels of output would be negative. However, the gap between the two would be narrowed down, and the net effect would turn out to be positive and increasing over time after some years following the break. Thus, the net effect of the shift would be positive after a lag. This situation is indicated by PL.

(iii) *Upward shift in level but downward shift in slope*: The immediate net effect would be positive, since the post-shift trend level of output would be higher than the pre-shift one. However, the gap between the two would come down and the net effect would turn out be negative after some years of the break. Thus, the net effect of the shift would be negative after a lag (indicated by NL).

(iv) *Downward shift in level and slope*: The net change would be undoubtedly negative as the difference between the post-shift and the pre-shift trend levels of output would be negative, and the negative gap between the two would be increasing over time after the break. This situation is represented by N.

It follows that acceleration in growth rate after break is crucial for obtaining a positive net effect with or without a lag. We have classified the states according to their experience of structural shifts with positive or negative net effect on agricultural output with or without a lag after the break. Table 5 shows that while the structural break in 1967-68 yielded positive net effect on agriculture output at the all-India level since the time of break, the same in 1988-89 generated negative net effect with a lag after the break. The state-level results reveal that, of 30 structural breaks (two each for the states), while 12 generated positive net effect with or without a lag, the remaining 18 produced negative net effect with or without a lag. Of these 18 breaks, 12 took place in or after 1990-91. While both the shifts yielded positive net effect with or without a lag in Andhra Pradesh and Gujarat, they generated negative net effect with or without a lag in Assam, Haryana, Karnataka, Orissa and Punjab. Again, while one of the shifts produced positive net effect with or without a lag, the other generated negative net effect with or without a lag in Bihar, Kerala, Madhya Pradesh, Maharashtra, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal.

Three important observations emerge from the experiences of the states: (i) Whenever the agricultural sector experienced the benefits of HYV-technology, the result was felt in an upward shift in the level and an accelerated growth rate of agricultural output in most cases; eight states (Andhra Pradesh, Bihar, Gujarat, Maharashtra, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal) have had this experience; Madhya Pradesh experienced an accelerated growth after a fall in level, and Orissa experienced an upward shift in level followed by a deceleration in growth; (ii) During the post-reform period, the growth rate of agricultural output decelerated in all the states except Andhra Pradesh and Gujarat; of the 18 structural shifts that produced negative net effect with or without a lag, 12 took place in or after 1990-91; (iii) The nature and timing of structural break in agriculture vary across states, and in many states, these are different from those observed at the all India level.

V

SUMMARY AND CONCLUSIONS

We have estimated the critical turning points, and evaluated the growth performance of agriculture in fifteen major Indian states during 1960/61–2006/07. At the all India level, the growth rate of GDPA declined substantially during the post-reform period relative to the pre-reform one. Better growth performance in agriculture during the pre-reform period was achieved mainly during the 1980s. The states experienced similar trend in agricultural growth performance. All the states except Andhra Pradesh and Gujarat experienced deceleration in the growth rate of NSDPA during the post-reform period relative to the pre-reform one. The slowing down of agricultural growth rates has been associated with large and widening inter-state differences in growth performance.

The results further reveal that Indian agriculture experienced significant upward shift in the level and growth rate of GDPA in 1967-68 presumably due to the introduction of HYV-technology in the mid-1960s. However, although the level of GDPA shifted upward in 1988-89, its growth rate started slowing down since then. Thus, the positive effects of HYV-technology that ushered in an era of green revolution in Indian agriculture could not be sustained in the late-1980s. The experiences of the states regarding the nature and timing of structural break are found to be at variance with those at the all India level. Moreover, there are inter-state differences in the nature and timing of shift in the trend functions of agricultural output. The experiences of the states reveal that whenever the agricultural sector experienced the benefits of HYV-technology, the result was felt in an upward shift in the level and an accelerated growth rate of agricultural output in most cases. However, growth rate decelerated in all the states except Andhra Pradesh and Gujarat during the post-reform period. The results have important policy implications for augmenting agricultural output. The findings about the nature and timing of structural breaks in agricultural output offer insights for understanding the growth process in agriculture. The state-level results help in understanding the spatial characteristics of growth acceleration/deceleration in agriculture during different phases. These are particularly useful in exploring the factors behind the slowdown process in the 1990s and suggesting appropriate measures for reversing it.

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