Journal of Quantitative Economics, Vol. 9 No. (2), July 2011

ESTIMATING STRUCTURAL BREAKS ENDOGENOUSLY IN INDIA'S POST-INDEPENDENCE GROWTH PATH: AN EMPIRICAL CRITIQUE

RAVINDRA H DHOLAKIA[1]
AMEY A SAPRE[2]

Abstract

This paper attempts to address empirical and methodological issues with regard to endogenous estimation of break dates in India's GDP and sub-sector series and finds that detection of break dates is sensitive to base year changes, marginal extension of time series and alteration of the length of the partition. The study uses series of Indian GDP and sub-sectors at two different base years to evaluate its effect on variation in break dates. To take into account the effect of marginal increase of time series, break dates are estimated on time series from 1950-51 to 2003-04 and 2008-09. The study also raises the issue about selection of the length of partition, which can affect detection of break dates. These empirical limitations do not lead to any conclusive evidence of break dates and hence cannot help settle the debates over different growth and policy regimes of the Indian economy.

Keywords: Endogenous breaks, Time series, Structural breaks, Indian economy, growth path

JEL Classifications: C1, C22

1. Introduction

In this paper, we address empirical and methodological issues involved in estimation of structural breaks endogenously in the growth path of the independent India to further our understanding on distinct growth regimes. Several studies like Nagraj (1990, 1991), Ganesh (1992), Dholakia (1994), Panagaria (2004), Nagraj (2006), Nayyar (2006), Balakrishnan & Permeshwaran (2007, 2007a), Dholakia (2007) attempted to examine the question of structural breaks in the long-term trend growth of the Indian economy at an aggregate and sectoral level. Identification of structural breaks in the growth path (or for that matter in any time series) is critical

---

[1] Ravindra H Dholakia is Professor, Indian Institute of Management, Vastrapur, Ahmedabad-380015, Email: rdholkia@iimahd.ernet.in

[2] Teaching Assistant, Indian Institute of Management, Vastrapur, Ahmedabad – 380015, Email: ameysapre@iimahd.ernet.in

We thank Achim Zeileis for some clarifications and Ganesh Kumar N, for his suggestions on an earlier draft.

for analyzing the underlying changes and for evaluating the impact of shifts in policy regimes in the economy. Findings of the above-mentioned studies have not agreed on the precise break dates and hence there is a lack of consensus about the impact of the shifts in policy regime in the country. This is because identification of the turning points or the structural break dates poses several empirical and methodological challenges and by itself forms an interesting field of theoretical and applied work.[3]

Conventionally, structural break in a time series is identified using linear regression model with dummy variables for intercept and slope parameters to differentiate two distinct regimes. The break point is exogenously imposed at a date known *a priori* and the results are tested for statistical significance to establish the trend break. Chow test (1960) was another method to investigate the structural break in a time series. Boyce (1986) modified the conventional method by eliminating discontinuity between two linear segments and reduced the number of dummy variables. All these methods are easily extendable to consider multiple structural break points in a series, though all of those dates have to be exogenously decided. Subsequent developments have brought to fore endogenous methods of breakpoint identification and estimation such that, breaks could be identified without using any historic information or exogenous conditions. The earliest effort in this direction was in terms of using Quandt test (1958, 1960) to identify the break date by considering a series of alternative break dates. An important limitation of the Quandt test was that it was used for identifying only a single break date in a series at a time. Simultaneous multiple break dates were not found feasible to be estimated endogenously using the Quandt test.

The works of Bai (1997), Perron (1989), Bai & Perron (1998, 2003) (Bai – Perron methodology henceforth) and Perron & Zhu (2005) have pioneered the development of the endogenous method for multiple structural change models. Their method was superior and statistically sophisticated as compared to the exogenous method as it allowed simultaneous estimation of multiple break points. Following its development, it has been widely used on financial and macroeconomic time series for analysis of trend breaks. The work of Zeileis *et al* (2005) has made the endogenous break point estimation possible by providing the computational algorithm developed on the lines of this method. Despite the method's empirical acceptance, the subject matter of endogenous breaks has always been under extensive theoretical and empirical scrutiny. Studies of Ghosh (1999), Lee and Strazicich (2001), Harvey *et al* (2001), and Banejee (2005) have raised issues such as unit root and specifications of structural breaks, spurious rejections, and innovational outlier for precise estimation of endogenous break dates. Dholakia (2007) raised the issue of high sensitivity of the Bai-Perron method for estimation of endogenous break dates to: (a) marginal increase in number of data points in the series, and (b) change in the base year of the series done as a routine over time. Moreover, seasonal adjustment and change in the functional form of the time trend would certainly make a difference in the endogenous

[3] Bose and Chattopadhyay (2010) argued that simple demand and supply based Harrod-Domar growth models could generate growth path showing increasing observed growth rates over time, and that "a change in the observed rate of exponential growth does not necessarily signal a 'structural break'". Although it points to a theoretical possibility, the argument has some limitations: (a) it admits only monotonic behavior of growth, whereas the changes in observed growth rates are not always monotonic; (b) it takes the growth rates of components to be constant, which is inconsistent applying the same logic; and (c) it does not rule out possibility of genuine structural breaks. For these reasons, the present paper does not pursue their arguments further.

identification of exact break dates in a series. However, the pure empirical issues of marginal increase in data points and the change in the base year of the series require further consideration and investigation before concluding with the results of the endogenous method.

Present paper highlights some methodological and empirical limitations of the Bai-Perron method to estimate break dates in India's aggregate and sectoral income series endogenously and thereby contributes to the debate on Indian growth history and impact of shifts in policy regimes in the country. Balakrishnan and Parameswaran (2007, 2007a) argued that Bai-Perron method of identifying endogenous break dates being the state of the art technique should be considered the final word on distinct regimes and as a pre-requisite to understand and analyse the growth history of the country. Contrary to this claim, findings of the present paper show that Bai-Perron method has no finality about the break dates and that it cannot help settle the debate on impact of shifts in policy regimes, because it has several limitations. The paper is arranged as follows: section II briefly presents the theory, data-sources, and estimation procedure. Section III gives results of alternative break date estimation for various series pointing out the limitations of Bai-Perron method. Section IV discusses the findings about break dates endogenously determined in aggregate and sectoral incomes in India given the limitations of the Bai-Perron method, and section V gives concluding remarks.

2. Methodology and data

The methodology of the endogenous model following Perron (1989), Bai – Perron (1998, 2003), Perron & Zhu (2005) rests on a multiple regression model which estimates (m) parameters for (m+1) regimes. The break points say ($T_1 \ldots T_m$) are treated as unknown and the goal is to determine the location and number of breakpoints T_j for j = 1…..m. The estimation is based on the principle of ordinary least squares which gives the (m) parameters after minimizing the sum of squared residuals (RSS) over each partition or segment. The computational effort is to derive a triangular Residual Sum of Square (RSS) matrix, which gives the RSS for a segment starting at observation (*j*) and ending at *j'* with $j < j'$. This is achieved through a dynamic programming algorithm which estimates the breakpoints ($T_1 \ldots T_m$) as given by the outcome of the function ($T_1 \ldots T_m$) = arg min $S_T(T_{1 \ldots} T_m)$ where $S_T(T_{1 \ldots} T_m)$ is the RSS for a given (m) partition and that the minimization is done over all partitions.

Further, if the estimation allows for a change in all parameters, i.e. intercept and slope ($\beta_{1 \ldots}\ \beta_T$) the model is said to be a pure – structural break model. It may be noted that the estimation of breaks is not confined to use of a particular linear model. The models employed have differed considerably since Perron (1989), Banerjee (2005), BP(2007), essentially on account of the question under investigation and the nature of the time series. In the recent study, Balakrishnan and Parameswaran (2007) used this method and fitted an exponential trend growth model of the type $\ln Y_t = a + bt$ to time series of GDP and sub- sectors to estimate the breaks in growth rates over time. The present paper pursues the same question and re-estimates the breaks in trend growth by fitting the same model. The purpose in doing so is to highlight the performance of the method when the data series in question undergoes base year changes and is extended in time marginally. The estimated results are arguably comparable, as the choice of the functional form remains the same. The log – linearized model for estimating trend with (m) regimes can be specified as follows:

$\ln Y_t = ß_{0m+1} + ß_{1m+1} t + u_t$, where $t = T_m + 1, . . . T$ $[T_0 = 0$ and $T_{m+1} = T]$ Y_t takes the log values of GDP and other sub sector series in respective models, (t) is a time in years and (b's) are the regression coefficients. This model as in a pure structural change model allows a break(s) in the level (intercept) and in the slope coefficient. The estimation is thus to determine the number and location of the breakpoints T_j for j = 1 to m. In computing this, the parameter used is the length of the segment (h) which indicates the minimum number of observations in one segment on which the OLS is computed. This is alternatively expressed as a bandwidth parameter $0 < (\varepsilon) <1$ which gives (h) as a fraction of the number of observations. Thus if (ε) is 0.15, then for 59 observations, the integer value of (h) would be 9. This size of segment would then allow up to 6 breaks (or 7 regimes) in the series. Following the estimation of possible break dates, Bai and Perron (1998, 2003) and Wang (2006) have suggested the use of Bayesian Information Criterion (BIC) to identify the number of trend breaks in case of trending regressors. This is based on the proposition given by Bai (1997) wherein it is demonstrated that stationarity of regressors or disturbances is not required for estimation of break dates. Wang (2006) also shows that the BIC criteria can incorporate trending regressors and is demonstrated to be superior in selecting break dates under such a scheme. Break dates are thus given by the values for which the BIC is at minimum. In the said study the minimum length of the partition (h) is taken as (6). This might involve an element of judgment in selecting the length of the partition. However it may be argued that six years (and above) should serve as a sufficient time to analyze the trend behavior of the variable. The choice of smaller segments, though statistically valid up to h=3, might not adequately capture the variation and may not be plausible for analyzing long term structural shifts in the long term growth rate of the economy. Usually, medium to long-term growth rate implies a period of at least 5 to 6 years.

Zeileis et al.(2005) provide the Bai-Perron method in its operational form recognizing that detection of break dates is sensitive to the selection of the length of partition (referred as 'h' in the literature). A variation in this parameter causes alterations in the break dates and thus is left as a matter of judgment to the researcher to determine the optimal choice of the parameter. Present paper uses the computational algorithm developed by Zeileis et al. (2005), but iterates this process by taking values of partition (h) from 6 to 12 to take into account the variation in break dates as estimated by the model. For each value of the partition (h), the number of break date(s) corresponding to the minimum BIC is considered. Thus, different "optimal" trend break dates are obtained for different values of (h). However, it is not possible to find objectively the optimal value of (h) because BIC tends to fall as the value of (h) falls and so far, adjustments in BIC to make it comparable to varying number of (h) has not been worked out. It is, therefore, not possible to identify the break dates on purely endogenous and objective criteria.

The data used for this purpose are from the back series of national income aggregates made available from the Economic and Political Weekly Research Foundation (EPWRF, 2006) and the Economic Survey for various years. The series used are of national income and its sub sectors measured at 1993-94 prices and 1999-2000 prices for the period 1950-51 to 2008-09. The series with base year 1993-94 extends only up to 2003-04 while the one with base year 1999-00 is available until 2008-09.

3. Results of Alternative Break Dates

In order to verify the stability and hence reliability of the endogenously determined break dates given by the Bai-Perron method when (a) base year of the series changes, and (b) number of observations increase marginally, the Indian GDP at factor cost by sectors at 1993-94 prices and at 1999-00 prices were taken. The two series were taken from 1950-51 to 2003-04 for each sector to make them comparable. Break dates were identified for each series using the Bai-Perron method without deciding on any particular value of parameter (h). The results by sectors are reported in Table 1. Similarly, to obtain the effect of increasing the number of observations marginally on the endogenously determined break dates, the series with 1999-00 base was taken up to the year 2008-09 to get fresh break dates for each sector. The results are again reported in Table 1.

Table 1. Sensitivity of Bai-Perron Break Dates for Base Year and Number of Observations

Value Of h	*Base Year 1993-94 1950-51 to 2003-04*	*Base Year 1999-00 1950-51 to 2003-04*	*Base Year 1999-00 1950-51 to 2008-09*
I. GDP at Factor Cost:			
6	1964, 1971, 1978, 1994	1964, 1971, 1978, 1994	1964, 1971,1978, 1991, 2001
7	1964, 1971, 1978, 1994	1964, 1971, 1978, 1994	1964, 1971, 1978,1991, 2001
8	1978	1978	1978, 2000
9	1978	1978	1978, 1999
10	1978	1978	1978, 1998
11	1978	1978	1978, 1997
12	1978	1978	1978, 1996
II. Agriculture and Allied Sectors:			
6	1987	1987	1987
7	1987	1987	1987
8	1987	1987	1987
9	1987	1987	1987
10	1987	1987	1987
11	1987	1987	1987
12	1987	1987	1987
III. Industry:			
6	1957, 1964, 1973, 1979, 1990, 1996	1961, 1973, 1994	1961, 1973, 1994, 2001
7	1961, 1980, 1994	1961, 1973, 1994	1961, 1973, 1994, 2001
8	1961, 1980, 1994	1961, 1973, 1994	1965, 1979, 2000
9	1961, 1980, 1994	1961, 1973, 1994	1965, 1979
10	1961, 1980, 1993	1962, 1975, 1993	1965, 1979
11	1965, 1982	1961, 1980	1965, 1979
12	1965, 1982	1961, 1980	1965, 1979
IV. Mining and Quarrying:			
6	1959, 1969, 1980, 1987	1959, 1969, 1980, 1987	1959, 1969, 1980, 1987
7	1959, 1969, 1980, 1987	1959, 1969, 1980, 1987	1959, 1969, 1980, 1987
8	1959, 1969, 1980, 1988	1959, 1969, 1980, 1988	1959, 1969, 1979, 1987
9	1959, 1969, 1980, 1989	1959, 1969, 1979, 1988	1959, 1969, 1979, 1988
10	1959, 1969, 1979, 1989	1959, 1969, 1979, 1989	1959, 1969, 1979, 1991
11	1969, 1980, 1991	1969, 1987	1969, 1987

Value Of h	*Base Year 1993-94 1950-51 to 2003-04*	*Base Year 1999-00 1950-51 to 2003-04*	*Base Year 1999-00 1950-51 to 2008-09*
12	1969, 1987	1969, 1987	1969, 1987
V. Manufacturing:			
6	1965, 1979, 1990, 1996	1965, 1994	1965, 1994, 2001
7	1965, 1982, 1994	1965, 1994	1965, 1994, 2001
8	1965, 1982, 1994	1965, 1994	1965, 1979, 1990, 1998
9	1965, 1982, 1994	1965, 1994	1965, 1993
10	1965, 1982, 1993	1965, 1993	1965, 1993
11	1965, 1982	1965, 1979	1965, 1993
12	1965, 1982	1965, 1979	1965, 1993
VI. Services:			
6	1957, 1963, 1969, 1975, 1982, 1991	1957, 1963, 1972, 1978, 1984, 1991	1957, 1963, 1972,1978, 1984, 1991, 2002
7	1960, 1969, 1982, 1991	1956, 1963, 1972, 1983, 1991	1956, 1963, 1972, 1983, 1991, 2001
8	1960, 1969, 1982, 1991	1957, 1965, 1974, 1982, 1991	1957, 1965, 1974, 1982, 1991, 2000
9	1960, 1969, 1982, 1991	1962, 1972, 1982, 1991	1962, 1972, 1981, 1990, 1999
10	1959, 1969, 1981, 1991	1959, 1971, 1981, 1991	1962, 1981, 1997
11	1969, 1980, 1991	1962, 1980, 1991	1962, 1981, 1997
12	1969, 1983	1962, 1979, 1991	1962, 1980, 1996
VII. Construction:			
6	1968, 1974, 1981	1968, 1974, 1981	1968, 1974, 1981, 2000
7	1967, 1974, 1981	1967, 1974, 1981	1968, 1974, 1981, 2000
8	1969, 1981	1969, 1981	1969, 19881, 2000
9	1969, 1981	1969, 1981	1969,1981, 1998
10	1969, 1981	1969, 1981	1969, 1981, 1998
11	1969, 1981	1969, 1981	1969, 1981, 1997
12	1969, 1981	1969, 1981	1970, 1996
VIII. Trade and Transport:			
6	1955, 1964, 1971, 1978, 1993	1955, 1964, 1971, 1978, 1993	1955, 1964, 1971, 1978, 1994, 2001
7	1955, 1964, 1971, 1978, 1993	1955, 1964, 1971, 1978, 1993	1957, 1964, 1971, 1978, 1994, 2001
8	1962, 1974, 1993	1962, 1974, 1993	1962, 1974, 1991, 2000
9	1962, 1974, 1993	1962, 1974, 1993	1962, 1974, 1990, 1999
10	1962, 1974, 1993	1962, 1974, 1993	1962, 1974, 1993
11	1962, 1974, 1992	1962, 1974, 1991	1962, 1974, 1993
12	1962, 1974, 1991	1962, 1974, 1991	1962, 1974, 1993
IX. Finance and Banking:			
6	1965, 1973, 1979, 1988, 1997	1965, 1973, 1979, 1990, 1996	1965, 1973, 1979, 1988, 2002
7	1965, 1972, 1979, 1988, 1996	1965, 1972, 1979, 1988, 1996	1965, 1972, 1979, 1988, 2001
8	1966, 1979, 1992	1966, 1979, 1988	1966, 1979, 1988, 2002
9	1966, 1979, 1992	1966, 1979, 1988	1966, 1979, 1988, 1999
10	1966, 1979, 1992	1966, 1979, 1990	1966, 1979, 1993
11	1966, 1979, 1992	1966, 1979, 1990	1966, 1979, 1993
12	1966, 1979, 1991	1966, 1979, 1991	1966, 1979, 1993

Source: Our Calculations as described in the text.

Table 1 provides comprehensive evidence on the empirical limitations of the Bai-Perron method of identifying structural break dates endogenously using data on GDP at factor cost by industry of origin in India over the last six decades. It clearly shows that: (1) For a given time series, conclusions regarding the endogenously identified break dates would vary considerably as the value of length of partition (h) varies (different rows within each sector). (2) Given the value of parameter (h) and the number of observations in a series, the endogenously determined break dates would vary substantially as the base year for the series changes (columns 2 and 3). (3) Given the value (h) and the base year of the series, the break dates would vary as the number of observations increases even marginally (columns 3 and 4). Thus, one cannot claim any finality about the endogenously determined break dates obtained by using the Bai-Perron method. The method, in other words, does not help pronounce any final verdict on the debate about the turning points (and hence about impact of change in policy regimes) in the Indian growth history. This is because the change in base year and incremental data points are regular features of such statistics. The major limitation, however, is the arbitrariness involved in selecting the value of the length of the partition (h) to get the estimates of the break dates.

Table 2 provides the estimates of the minimum BIC for a given value of (h) for all the three time series considered in Table 1. It can be seen from Table 2 that, as the value of (h) falls from 12 to 6, the minimum BIC for a given series tends to fall in a step-wise manner. Table 1 and Table 2 together show that the value of minimum BIC for a series does not change with changes in (h) if (and only if) the identified break dates also do not change. However, barring a few exceptions, in most cases, the minimum BIC is substantially lower for h=6 and 7, as compared to higher values of (h). The subjective choice for (h) is, therefore, basically confined to those values of (h) for which the minimum BIC differs. For all these values, the endogenously determined break dates differ not only in number, but also in precise years.

Table 2. Minimum BIC Values as per the Size of Segment (h)

Value of (h)	*Base Year 1993-94 1950-51 to 2003-04*	*Base Year 1999-00 1950-51 to 2003-04*	*Base Year 1999-00 1950-51 to 2008-09*
I GDP at factor cost			
6	-242.07	-244.311	-264.858
7	-242.07	-244.311	-264.858
8	-108.528	-236.49	-226.238
9	-108.528	-236.49	-226.238
10	-108.528	-236.49	-226.238
11	-108.528	-236.49	-226.238
12	-108.528	-236.49	-226.238
II Agriculture and Allied sectors			
6	-153.306	-168.893	-190.113
7	-153.306	-168.893	-190.113
8	-153.306	-168.893	-190.113
9	-153.306	-168.893	-190.113
10	-153.306	-168.893	-190.113
11	-153.306	-168.893	-190.113
12	-153.306	-168.893	-190.113
III Industry			
6	-203.053	-207.75	-220.66

Value of (h)	*Base Year 1993-94 1950-51 to 2003-04*	*Base Year 1999-00 1950-51 to 2003-04*	*Base Year 1999-00 1950-51 to 2008-09*
7	-198.747	-207.75	-220.66
8	-198.747	-207.75	-213.241
9	-198.747	-207.75	-213.235
10	-191.986	-200.338	-213.235
11	-188.718	-194.359	-213.235
12	-188.718	-194.359	-213.235
IV Mining and Quarrying			
6	-185.145	-185.352	-203.774
7	-185.145	-185.352	-203.774
8	-181.643	-180.367	-198.104
9	-180.207	-177.882	-194.532
10	-179.379	-176.669	-193.792
11	-161.015	-160.121	-179.28
12	-160.507	-160.121	-179.28
V Manufacturing			
6	-194.892	-194.73	-206.67
7	-187.818	-194.73	-195.71
8	-187.818	-194.73	-196.17
9	-187.818	-194.73	-195.71
10	-180.434	-190.133	-195.71
11	-178.303	-180.63	-195.71
12	-178.303	-180.63	-195.71
VI Services			
6	-262.416	-266.402	-288.461
7	-256.969	-265.289	-285.988
8	-256.969	-262.198	-277.289
9	-256.969	-260.333	-262.045
10	-256.321	-259.511	-254.935
11	-251.199	-255.013	-254.935
12	-236.613	-252.944	-254.803
VII Construction			
6	-140.45	-135.821	-147.183
7	-139.318	-134.778	-145.995
8	-367	-133.69	-143.446
9	-367	-133.69	-141.791
10	-367	-133.69	-139.218
11	-367	-133.69	-136.808
12	-367	-133.69	-135
VIII Trade and transport			
6	-251.252	-251.993	-281.620
7	-250.705	-251.286	-280.732
8	-243.873	-230.382	-261.861
9	-243.873	-245.07	-259.295
10	-243.873	-245.07	-232.244
11	-240.697	-242.676	-232.244
12	-240.596	-242.676	-232.244
IX Finance and Banking			
6	-265.476	-277.852	-293.208

Value of (h)	*Base Year 1993-94 1950-51 to 2003-04*	*Base Year 1999-00 1950-51 to 2003-04*	*Base Year 1999-00 1950-51 to 2008-09*
7	-256.409	-268.351	-272.982
8	-250.126	-261.00	-262.819
9	-250.126	-260.58	-256.064
10	-250.126	-259.4	-244.134
11	-250.126	-259.4	-244.134
12	-244.397	-259.304	-244.134

Table 1 shows that adding a few more observations to a series largely affects more recent break dates. The early or distant break dates in most cases (though not in all cases) remain the same. This can be seen by comparing columns 3 and 4 for different sectors for different values of (h) in Table 1. The likely variation in break dates because of the change in the base year of the series appears to be an empirical problem with the Bai-Perron method of identifying break dates endogenously. Keeping in view these limitations, the following section examines the different growth rate regimes that the economy has observed over the past six decades. To differentiate these regimes the present paper considers two alternative lengths of partition as h=6 and h=12, since major policy and strategy changes are effected in the country with different five year plans. The selection of h=6 would allow for such frequent shifts(maximum of 10 shifts) if they have actually occurred and would also be consistent with the objective of identifying breaks endogenously to reflect on policy changes or growth regimes. The value of h=12 would allow maximum of five break dates or six distinct regimes, which are neither too few nor too many in a six decade growth history.

4. Break Dates in India's Growth Path

Tables 3 and 4 present the break dates, confidence intervals, growth regimes and their corresponding estimates of intercept and slope parameters and implied growth rates for all sectors and sub-sectors for all identified regimes. All calculations in Table 3 take the length of partition (h) as six for the reasons discussed above, while the calculations in Table 4 take the length of partition (h) as twice as much, i.e. 12.

Table 3. Break Dates (for h=6) and Growth Rates as per Regimes

Break Date	*Conf. Interval*		*Regime*	*Intercept*	*Coefficient*	*Gr. Rate %*
I. GDP at factor cost						
1964	1962	1965	1950 – 1964	12.269	0.0386	3.95
1971	1970	1972	1965 – 1971	12.130	0.0439	4.49
1978	1977	1979	1972 – 1978	11.994	0.0465	4.77
1990	1989	1991	1979 – 1990	11.752	0.0518	5.33
2001	2000	2002	1991 – 2001	11.390	0.0599	6.17
			2002 – 2008	10.110	0.0833	8.69
II Agriculture and Allied sectors						
1987	1986	1992	1950 – 1987	11.727	0.0222	2.25
			1988 – 2008	11.582	0.0280	2.84
III Industry						
1961	1960	1962	1950 – 1961	9.9919	0.0612	6.32
1973	1972	1974	1962 – 1973	10.330	0.0412	4.21
1994	1993	1995	1974 – 1994	9.9578	0.0553	5.69
2001	2000	2002	1995 – 2001	0.7662	0.0402	4.10
			2002 – 2008	8.9461	0.0748	7.77

Break Date	*Conf. Interval*		*Regime*	*Intercept*	*Coefficient*	*Gr. Rate %*
IV Mining and Quarrying						
1959	1958	1960	1950 – 1959	8.060	0.0398	4.07
1969	1968	1970	1960 – 1969	8.100	0.0490	5.03
1980	1979	1982	1970 – 1980	7.994	0.0467	4.78
1987	1985	1988	1981 – 1987	7.832	0.0556	5.72
			1988 – 2008	8.336	0.0460	4.72
V Manufacturing						
1965	1964	1966	1950 – 1965	9.795	0.0645	6.67
1994	1993	1995	1966 – 1994	9.958	0.0483	4.95
2001	2000	2002	1995 – 2001	10.542	0.0392	4.00
			2002 – 2008	8.365	0.0807	8.41
VI Services						
1957	1956	1958	1950 – 1957	11.182	0.0414	4.23
1963	1962	1964	1958 – 1963	11.040	0.0576	5.93
1972	1971	1973	1964 – 1972	11.310	0.0399	4.07
1978	1977	1979	1973 – 1978	10.913	0.0547	5.62
1984	1983	1985	1979 – 1984	10.945	0.0521	5.36
1991	1989	1992	1985 – 1991	10.522	0.0645	6.67
2002	2001	2003	1992 – 2002	10.056	0.0745	7.74
			2003 – 2008	8.6066	0.1014	10.67
VII Construction						
1968	1967	1969	1950 – 1968	9.051	0.0673	6.96
1974	1973	1975	1969 – 1974	10.64	-0.0133	-1.32
1981	1979	1982	1975 – 1981	9.453	0.0385	3.93
2000	1999	2001	1982 – 2000	8.905	0.0519	5.33
			2001 – 2008	5.516	0.1173	12.45
VIII Trade and Transport						
1955	1954	1957	1950 – 1955	10.080	0.0447	4.58
1964	1963	1965	1956 – 1964	9.981	0.0621	6.41
1971	1970	1972	1965 – 1971	10.255	0.0422	4.31
1978	1977	1979	1972 – 1978	9.744	0.0628	6.48
1994	1993	1995	1979 – 1994	9.878	0.0563	5.80
2001	2000	2002	1995 – 2001	9.070	0.0759	7.89
			2002 – 2008	7.246	0.1107	11.71
IX Finance and Banking						
1965	1964	1966	1950 – 1965	9.717	0.0307	3.12
1973	1968	1974	1966 – 1973	9.533	0.0405	4.13
1979	1978	1980	1974 – 1979	9.100	0.0562	5.79
1988	1987	1989	1980 – 1988	8.082	0.0868	9.08
2002	2001	2003	1989 – 2002	8.615	0.0743	7.72
			2003 – 2008	6.874	0.1059	11.17

Table 3 reveals that overall GDP in India shows as many as five breaks and hence six distinct growth regimes over the past six decades. Hardly any study on Indian economic development has found so many distinct break points and corresponding growth regimes. The table brings out that the economy continually moved to a higher growth trajectory from 3.9% up to the mid 1960s, to 4.5% and 4.8% up to the end of the 1970s, to 5.3% up to the end of 1980s, to

6.2% up to the end of 1990s, and to 8.6% until 2008-09. On the other hand, when h=12, the endogenously determined break dates are only two, viz. 1978 and 1996, implying only three distinct growth regimes (see, Table 4). These break dates broadly correspond respectively to the regimes of liberalization and globalization. However, 1978 is the only common break date identified with different values of (h). Relating such endogenously identified break dates with different policy regimes would be difficult and certainly not as 'objective' as it is argued to be.

Table 4. Break Dates (for h=12) and Growth Rates as per Regimes

Break date	*Conf. Interval*		*Gr. Regime*	*Intercept*	*Coefficient*	*Gr (%)*
I GDP at factor cost						
1978	1977	1979	1950 – 1978	12.2889	0.0356	3.63
1996	1995	1997	1979 – 1996	11.7475	0.0520	5.34
			1997 – 2008	10.9574	0.0684	7.08
II Agriculture and Allied						
1987	1986	1992	1950 – 1987	11.7278	0.0223	2.25
			1988 – 2008	11.5823	0.0280	2.84
III Industry						
1965	1964	1966	1950 – 1965	9.9724	0.0652	6.74
1979	1978	1980	1966 – 1979	10.2092	0.0468	4.79
			1980 – 2008	9.7818	0.0600	6.18
IV Mining and Quarrying						
1969	1968	1970	1950 – 1969	7.9959	0.0548	5.63
1987	1985	1988	1970 – 1987	7.6877	0.0591	6.09
			1988 – 2008	8.3370	0.0461	4.72
V Manufacturing						
1965	1964	1966	1950 – 1965	9.7954	0.0645	6.67
1993	1992	1994	1966 – 1993	9.9697	0.0479	4.90
			1994 – 2008	9.4600	0.0612	6.31
VI Services						
1962	1958	1963	1950 – 1962	11.1633	0.0461	4.72
1980	1979	1981	1963 – 1980	11.2871	0.0409	4.17
1996	1995	1997	1981 – 1996	10.6055	0.0624	6.43
			1997 – 2008	9.5043	0.0855	8.93
VII Construction						
1970	1969	1972	1950 – 1970	9.0647	0.0654	6.76
1996	1995	1997	1971 – 1996	9.3803	0.0403	4.11
			1997 – 2008	6.6746	0.0967	10.15
VIII Trade and Transport						
1962	1961	1963	1950 – 1962	10.0439	0.0556	5.72

Break date	*Conf. Interval*		*Gr. Regime*	*Intercept*	*Coefficient*	*Gr (%)*
1974	1973	1975	1963 – 1974	10.3147	0.0391	3.99
1993	1992	1994	1975 – 1993	9.9842	0.0536	5.50
			1994 – 2008	8.2325	0.0931	9.76
IX Finance and Banking						
1966	1964	1967	1950 – 1966	9.7192	0.0305	3.10
1979	1978	1980	1967 – 1979	9.4918	0.0422	4.31
1993	1992	1994	1980 – 1993	8.0618	0.0875	9.15
			1994 – 2008	8.3046	0.0806	8.40

Break dates in the other sectors and sub-sectors presented in Tables 3 and 4 are substantiating another point about endogenously distinguished growth regimes in an economy. The utility of such exercises is generally in terms of examining the impact of effective growth strategies in terms of sectoral priorities. In the growth history of an economy like India, it is always interesting and enlightening to know which sector turned first and which sectors followed. The agricultural and allied sectors show consistently only one break in 1987 (with different values of h) with an improvement in growth rate from 2.2% to 2.8%. This precedes only the fourth break date in total GDP which is 1990 (with h=6, see Table 3). Contrary to claims of agricultural sector undergoing a structural shift and improvement in growth rate because of green revolution during the late 1960s, the finding here does not indicate it as a major turning point of the agricultural sector. Thus, estimation of endogenous break dates does not support any hypothesis about agricultural sector playing a significant role in growth acceleration in the Indian economy. Manufacturing shows the first break in 1965 (irrespective of any value of h) with a deceleration in growth rate from 6.6% to 4.9% during 1965- 1994 combining the periods of license raj and initial liberalization. It further decelerates to 4% during the initial globalization regime of 1995-2001 and then registers a marked improvement to 8.4% during the substantial globalization regime of 2002-08 (when h=6). However, with h=12, the growth rate of manufacturing sector accelerates from 1994 and of the total GDP from 1996. This suggests that manufacturing took lead in the growth acceleration of the Indian economy since 1994. The same story does not emerge for h=6.

The overall services sector that includes, trade, transport, storage, hotels & restaurants, finance & banking, real estate and personal services shows seven breaks (when h=6) with the ones in 1957, 1972, 1984, 1991 and 2002 showing acceleration; and the ones in 1963 and 1978 showing deceleration. Thus, the service sector does not explain turning points in total GDP before 1990. The break date of 1984 in the service sector not only precedes the break date (1990) in the total GDP in the country, but also shows sustained accelerating growth in the subsequent 25 years. Thus, growth acceleration in India during the last two decades seems to be due to services sectors. Within services sector, trade & transport sub-sector has shown consistent acceleration since 1994; whereas finance & banking sub-sector has shown acceleration only since 2003, i.e. later than the acceleration in total GDP in 2001. Again this story is not clearly brought out when h=12. The service sector break dates are then 1962, 1980 and 1996, with the total GDP break dates at 1978 and 1996. Clearly, with h=12, service sector acceleration does not precede the total GDP acceleration. However, the acceleration in the sub-sector of transport and trade has preceded for both the break dates of 1978 and 1996 in the total GDP. Acceleration in the sub-sector of finance and banking has preceded the latest break date of 1996 in the GDP series. Thus, the sequencing of break dates by sectors that is critical in understanding and interpreting the growth history of an economy also does not remain unique and consistent if Bai-Perron method of endogenously determining the break dates is applied.

5. Conclusion

The purpose of the study was to evaluate the performance of the method of detecting multiple break dates in India's GDP and sub-sectors following Bai and Perron (1998, 2003) when the data series undergoes base year changes and is marginally extended in time. The study also addresses critical issues such as selection of the optimal length of a partition and its sensitivity to detection of break dates. We find through an iteration process of altering the length of the partition (h) and use of alternate base year series of GDP by sectors that the identified break dates do not coincide in several of the cases and vary considerably in both the number and years. This highlights a critical empirical limitation of the endogenous break detecting (Bai-Perron) method as the variation in break dates with change of series does not offer any conclusive evidence about break points in the series under investigation. Another limitation of the method is in determining the optimal length of the partition (h) which is sensitive to detection of break dates. The issues of identification of break dates remains important in understanding the shifts in growth paths and policy regimes in the economy. However, the empirical and methodological challenges have not led to any consensus on precise break dates and hence on impact of policy regimes. Findings in the present study using the Bai-Perron methodology of detecting endogenously multiple break dates simultaneously demonstrate inconclusiveness of the method in detecting break points objectively. Moreover, the sequencing of the break dates of sectors and sub-sectors in the economy to establish precedence (implying causation) is again not unique and objective to enable better understanding and interpretation of the growth history of the economy. The most attractive feature of the endogenous identification of break dates is its ability to establish sequence of the sectoral break dates and thereby reflect on the effective growth strategy followed in the economy. If the break dates are exogenous, the information content of the time series is not optimally utilized and it would give rise to controversies and debates over the impact of different policy regimes. Hope was that endogenous identification of break dates could resolve these issues. However, the present paper has shown that the empirical and methodological limitations have not made it possible to conclude on the finality of the endogenously detected break dates and hence on impact of different policy regimes in the economy.

Notes

1. The national income aggregates includes the following sectors: Agriculture & Allied includes forestry, logging and fishing; Industry includes manufacturing, mining & quarrying, construction and electricity, gas & water supply; Manufacturing includes, registered and un-registered manufacturing; Trade & Transport includes trade, hotels & restaurants, storage and communication; Finance & Banking includes insurance, real estate and business services; Services includes, trade, transport, hotels, storage, communication, finance, banking, real estate, personal and community services.

References

Bai, J & Pierre Perron (1998), "Estimating and Testing Linear Models with Multiple Structural Changes", *Econometrica*, Vol 66, No.1

Bai, J & Pierre Perron (2003), "Computation and Analysis of Multiple Structural Change Models", *Journal of Applied Econometrics, Vol. 18, No. 1*

Balakrishnan, P & M Permeshwaran (2007), "Understanding growth regimes in India: A pre-requisite", *Economic and Political Weekly,* July 14th, 2007

Balakrishnan, P & M Permeshwaran (2007a), "Understanding growth regimes in India: Further observations", *Economic and Political Weekly,* Nov 3rd, 2007

Banerjeea, Anindya & Giovanni Urga (2005), "Modeling structural breaks, long memory and stock market volatility: an overview", *Journal of Econometrics,* 129 – 1 – 34.

Bose, Amitava & Subhasankar Chattopadhyay (2010), "The Analytics of Changing Growth Rates", *Economic and Political Weekly,* July 10th, 2010

Boyce, J K (1986), "Kinked exponential models for growth rate estimation", *Oxford Bulletin of Economics and Statistics,* 48: 385-91

Chow, Gregory C (1960), "Tests of Equality Between Sets of Coefficients in Two Linear Regressions". *Econometrica* 28 (3): 591–605.

Dholakia, Ravindra H (1994), "Spatial Dimension of Acceleration of Economic Growth in India", *Economic and Political Weekly*, Vol 29, No 35

Dholakia, Ravindra H (2007), "Understanding growth regimes in India: Some observations", *Economic and Political Weekly,* August 25th, 2007

Dufour, Jean-Maria & Eric Ghysels (1996), "Editors' introduction Recent developments in the econometrics of structural change", *Journal of Econometrics,* 70 (1996)1-8

Economic and Political Weekly Research Foundation (2005), *National Accounts Statistics*, published by Economic and Political Weekly, Mumbai.

EPW Research Foundation (2002), *National Accounts Statistics of India 1950-51 to 2000-01*, EPW Research Foundation, Mumbai

Ganesh, Kumar N (1992), "Some Comments on the Debate on India's Economic Growth in the 1980s", *Indian Economic Journal*, Vol 39, No 4, pp 102-11.

Ghosh, Madhusudhan (1999), "Structural Break and Unit Root in Macroeconomic Time Series: Evidence from a Developing Economy", *Sankhya*, *The Indian Journal of Statistics, Series B, Vol. 61, No. 2*

Government of India (2009), *Economic Survey*, various editions

Nagaraj, R (2006), *Aspects of India's Economic Growth and Reforms*, Academic Foundation, New Delhi

Nagraj, R (1990), "Growth Rate of India s GDP, 1950-51 to 1987-88-Examination of Alternative Hypotheses", *Economic and Political Weekly,* Vol. 25, No. 26

Nagraj, R (1991), "Increase in India's growth rate: Discussion", *Economic and Political Weekly,* Vol. 27, No. 15

Nayyar, D (2006), "Economic Growth in India in Independent India: Lumbering Elephant or Running Tiger?", *Economic and Political Weekly,* April 15, 1451-58.

Newbold, Paul, David Harvey, Stephen Leybourne (2001), "Innovational outlier unit root tests with an endogenously determined break in level", *Oxford Bulletin Of Economics And Statistics,* 63, 5 (2001) 0305-9049

Panagariya, A (2004), "Growth and Reforms during 1980s and 1990s",*Economic and Political Weekly*, June 19: 2581-94

Quandt, R E (1958), "The Estimation of the parameters of a linear regression system obeying two separate regimes", *Journal of American Statistical Association*¸ 53 December, 873-80

Quandt, R E (1960), "Test of the hypothesis that a linear regression system obeys two separate regimes", *Journal of American Statistical Association*¸ 55 June, 324-30

Strazicich, Mark C & Junsoo Lee (2001), "Break point estimation and spurious rejections with endogenous unit root tests", *Oxford Bulletin Of Economics And Statistics*, 63, 5 (2001) 0305-9049

Wallack, J S (2003), "Structural Breaks in Indian Macroeconomic Data", *Economic and Political Weekly*, October 11: 4312-15

Wang, Z (2006), "The Joint Determination of the Number and the Type of Structural Changes", *Economic Letters*, 93: 222-27

Zeileis, A, F Leisch, K Hornik, C Kleiber (2005), "strucchange: An R Package for Structural Change in Linear Regression Models*", available from http://www.R-project.org/*

Zeileis, Achim & Christian Kleiber (2005), "Validating multiple structural change models – An extended case study", *Research Report Series, January 2005*

Zhu, X & Pierre Perron (2005), "Structural breaks with deterministic and stochastic trends", *Journal of Econometrics,* 129 (2005) 65 – 119

♦♦♦