CLAREMONT McKENNA COLLEGE

The Great Indian Growth Puzzle: What Caused a Spike in 2003?

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To my mother and father ...

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Abstract of the Thesis

The Great Indian Growth Puzzle: What Caused a Spike in 2003?

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This paper will employ unit root tests for finding structural breaks endogenously among India's key macroeconomic aggregate series, as well as their components and subcomponents. The same analysis will be repeated, wherever data are available, for states. The results from these unit root tests will then be used in regression models for national and state level data to understand the causes behind structural breaks. We find that breakpoints cluster around 1982 and 2003 for most series at the national and state level. The services component appears to be a promising candidate for explaining the 2003 structural break in some of the series.

SECTION 1

Introduction

> Nothing can stop an idea whose time has come
>
> ---
>
> Manmohan Singh quoting Victor Hugo to the Indian Parliament

The political economy of India has always attracted the interest of political scientists and economists. Since independence, India's economic performance and ability to alleviate widespread poverty have been watched carefully by domestic and foreign observers. The optimism present at the time of independence was not merely wishful thinking; it was accompanied by the rigor and elegance of the Mahalanobis-Feldman model and the administrative manpower of the Indian Administrative Service. Indian elites embraced the optimism, and its science, and helped establish institutions that would effectively close India's economy to the outside world; they willingly and enthusiastically hoped to create an economy where the government would control the commanding heights of the economy. The experiment seemed to have ended at some point in the late 1970s and early 1980s as scholars and policymakers increasingly acknowledged the urgent need for reform towards a fundamentally different political economy.

In 1991, then Finance Minister Manmohan Singh quoted Victor Hugo to the Indian Parliament, which found itself in the midst of a crisis of unprecedented proportions. As Finance Minister, with the support of then Prime Minister Narasimha Rao, Dr. Singh fundamentally changed the direction and structure of India's political economy by widening its economic sphere to include the world economy and the domestic private sector. The widespread liberalization and deregulation of industries had been, as Dr. Singh reminded his colleagues in parliament, an idea that had been in waiting for far too long. Among economists and technocrats, the reforms of 1991 were largely built from a longstanding consensus on India's urgent need for reforms (Mooij, 2005; Tendulkar and Bhavani, 2007).

The consensus seems to have wavered slightly since 2000. While the 1991 reforms are universally credited for their successful aversion of an impending crisis, there is greater disagreement about the effects of liberalization on economic growth (Krueger et al., 2002; Sachs et al., 2000). This disagreement partly arises from the peculiar nature of India's recent growth experience and overall macroeconomic history. Figure A.1 in Appendix A.1 outlines actual growth rates and their trend since 1950. A closer analysis of this series reveals puzzles in India's growth experience.

1.1 Puzzles in India's Growth Experience

By casual observation, growth in Figure A.1 seems to exhibit changes in the average growth rate at multiple points. Empirical analysis reveals these periods to be 1950-1982, 1983-2002, and 2003 onwards, which can be seen in Figure A.2. The average rate of growth from 1950-1982 of 4.63% increases to roughly 6.6% after 1982 and nearly 8.9% after 2003. What explains these spikes in the growth rate? Why did the rate of economic growth accelerate at these points? Why didn't growth accelerate substantially after the 1991 reforms? These questions forms the core of India's growth puzzle.

1.2 Explaining Structural Breaks

This paper will employ unit root tests for finding structural breaks endogenously among India's key macroeconomic aggregate series, as well as their components and subcomponents. The same analysis will be repeated, wherever data are available, for states as well. The results from these unit root tests will then be used in regression models for national and state level data. Section 2 reviews the relevant literature on India's growth puzzles. Section 3 and 4 outline this paper's data sources and methodology. Section 5 presents and analyzes empirical results, while Section 6 discusses the limitations in the data used and methods employed. It's advisable to read this paper in the stated order. However, if the reader is only interested in the segments on structural break tests or regression models, then he can follow the relevant subsections in all sections.

Notes

[1]The 'Father of India's Green Revolution' is said to be Norman Borlaug

SECTION 2

Literature Review

2.1 Overview

The serious and careful study of India's economic growth has expanded at a rate that is almost as impressive as India's economic expansion in recent decades. Greater interest in measuring and identifying the proximate and structural causes of growth is partly due to the widely acclaimed 'Indian growth miracle.' But a more important source of interest is the presence of explicit and implicit institutional reforms at various levels of government. Accompanying these broad-based structural reforms are softer fiscal and monetary policy changes during the same period as well. This combination makes India a particularly appealing and promising area of research.

As mentioned in the previous section, India's economic growth can be divided into three periods. The exact definition of each period depends on the econometric methods employed to determine structural breaks in the series. According to most of the literature – and according to the structural break analysis in this thesis – the three divisions are $1950 - 1982$, $1983 - 2003$, and $2004 - 2008$. [1] Therefore, the important breakpoints in the growth rate of India's output are 1982 and 2003. Most of the recent literature on economic growth in India and its determinants can be usefully organized into different hypotheses about the causes and origins of these breakpoints. The hypotheses themselves can be further divided into supply-side explanations and demand-side explanations. Before we examine these possibilities, it's important to note that most of these hypotheses are not mutually exclusive and should not be pegged against each other. While there are certain hypotheses that will be irreconcilable with either the data, or with other viewpoints, most of these hypotheses are the products of prolonged and highly acclaimed research by the finest scholars and policymakers who have chosen to study India. A more realistic view is that most of these hypotheses are likely to explain economic growth and its breakpoints to varying extents.

2.2 Supply-Side

Supply-side explanations in this context refer to hypotheses that attempt to explain economic growth with improvements in productivity, availability of capital, access to equipment goods etc. In this context, supply-side is used to refer to hypotheses that emphasize the role of economic reforms. These reform-based models discuss the importance of piecemeal reforms in the 1980s, systematic reforms in 1991, and industry-specific reforms from 1999-2003.

2.2.1 Reform-Based

Since 2000, there has been a healthy debate in the literature on the effect of the 1991 reforms. To opposing views have emerged. The first view is that systematic reforms in 1991 are largely responsible for high growth rates in the 1990s (Basu and Maertens, 2007; Bhalla, 2010; Lal, 2008; Panagariya, 2004a,b, 2008; Srinivasan, 2005; Virmani, 2004, 2006, 2009). According to this hypothesis, India's economic crisis in 1991 was averted by a radical plan for reform that involved substantial steps towards liberalization and deregulation. The second view is that growth during the last three decades was not caused by the 1991 reforms. Rather, the economy was already on a higher growth path that began in the 1980s (DeLong, 2001; Kohli, 2006; Rodrik and Subramanian, 2005a,b, 2007).

The primary argument made by the second viewpoint, henceforth referred to as Rodrik et al, is that average growth rates during the 1980s and 1990s were strikingly similar. Given the magnitude of the 1991 reforms, we should expect a substantial increase in the rate of economic expansion. The first viewpoint, henceforth referred to as Panagariya et al., counters by pointing to the unsustainable features of growth in the 1980s, as well as their contribution to the crisis in 1991. Specifically, they claim that growth during the 1980s was fueled by fiscal expansion, not productivity increases. The debate remains largely unresolved since the data do not conclusively provide evidence in favor of one view or another. Bhalla (2010) also correctly notes that neither hypothesis considered the slowdown in growth rates around 1997. Furthermore, he points out that average growth in the 1980s was also higher relative to the previous decade because of trends in the global economy.

A more recent debate concerns reforms undertaken by the National Democratic Alliance (NDA) government from 1999-2003. Unlike the previous debate between Panagariya et al. and Rodrik et al., this disagreement has remained relatively unacknowledged by the major participants. Panagariya (2008) argues that growth since 2003 is explained by substantial sectoral reforms that were undertaken by the government during the period. Others claim that there were no reforms during the same period, let alone significant or important reforms (Bhalla, 2010; Jalan, 2005, 2007).

2.3 Demand-Side

Demand-side explanations attempt to explain economic growth with changes in demographic factors, changes in fiscal deficit, & increases in public and private investment.

2.3.1 Demographic

The rapid growth of India's 'middle class' has often been attributed as a source of economic growth in the popular press. Most of the academic literature on this subject lists demographic trends as favorable factors, but few claim that demographic trends can explain India's growth puzzles (Acharya, 2007; Acharya and Mohan, 2010; Mohan, 2002).

2.3.2 Fiscal & Monetary Policy

Bhalla (2010) extensively details the role of the real interest rate and deficits in the growth slowdown after 1996-1997, and the subsequent spike in 2003. He admits that few commentators acknowledge a significant role for this hypothesis.

2.3.3 Investment-Driven

Bosworth et al. (2007)'s growth accounting exercise finds a role for investment. In particular, foreign direct investment is found to be an important determinant of growth. (Virmani, 2009) recognizes the importance of overall investment in the economy, but does not find evidence for investment explaining structural breaks in the growth rates.

2.3.4 Export-Driven

The role of exports in India's growth has been well documented in the academic literature and the popular press. Data series for exports exhibit a strong upward trend that is largely coincident with periods of high overall economic growth, but it's unclear if there is a causal effect (Aziz; Lal, 2008).

2.4 Structural Breaks

Few studies are exclusively focussed on the correct identification of breakpoints in India's economic growth. Most of the aforementioned studies base their analysis on assumptions about breakpoints; a few studies utilize econometric techniques to check their assumptions (Virmani, 2006). A small group of articles that appear mainly in the Indian journal, Economic &

Political Weekly, have conducted research on applying existing techniques for endogenously finding optimal breakpoints in Indian aggregate data (Ghatak, 1997; Hatekar and Dongre, 2005; Sinha and Tejani, 2004; Wallack, 2003). Most of these studies employ some variant of the basic Chow test. Only Balakrishnan (2007); Ghatak (1997) use unit root tests for finding structural breaks. Ghatak considers a much larger time series that includes pre-independence data. While this may serve as a useful econometric exercise is marking the optimal breakpoint in India's complete economic history, it does not contribute towards our understanding of recent economic growth. To this extent, pre-independence data are not relevant. The purpose of this exercise, and its relevance to the Indian growth puzzle, is in accurately locating growth spikes that caused a deviation from the low-growth decades since independence.

Structural break tests can potentially help us understand India's recent growth spikes. If used in conjunction with the the various hypotheses on the determinants of economic growth, they could help narrow our search for the factors that caused a growth spike in 2003. Furthermore, empirical analysis can also be taken one level deeper by examining state data. The presence of considerable divergence among Indian states suggests that some state-level factors may be significant.

Notes

[1]The third period ends in 2008 because most data series only stretch to 2008-2009.

SECTION 3

Data

The origin of nearly every data series in this study is the Central Statistical Organization, which is a part of the Ministry of Statistics and Programme (MOSPI) Implementation, and the Reserve Bank of India (RBI). The raw data series were obtained from a variety of channels that include the MOSPI website, the RBI Handbook of Statistics on the Indian Economy, the Database on the Indian Economy: RBI's Data Warehouse, and the Center for Monitoring the Indian Economy database products.[1] Additional sources include the Annual Survey of Industries database, India Public Finance Statistics and the Economic Survey of India reports, which are published by the Ministry of Finance, and the Planning Commission's Plan Statistics. Finally, data on monthly rainfall in India and its subdivisions were obtained from the online Data Archives of the Indian Institute of Tropical Meteorology, which is an autonomous body under the Ministry of Earth Sciences.

3.1 National-level data

National-level data for the following categories were collected. Unless stated otherwise, all series are denoted in Indian National Rupees crores[2]. Apart from rainfall and population, these economic series start in 1950-1951. The data were obtained in, or converted to, constant prices at 1999-2000 price levels.[3]

Each of these series were passed through the Hodrick-Prescott (HP) filter to decompose them into their cyclical and trend components. Growth rates for the smoothed and original series were then calculated by taking log differences.

Output Output measures include Gross Domestic Product (GDP), Net Domestic Product (NDP), both of which can be at factor costs or market prices. Since the components of output are only specified in gross terms at factor costs, the remaining measures of output have only been used as robustness checks where appropriate.

Components of Output The CSO divides output into three main components: Agriculture and Allied Products, Industry, and Services.[4] The precise definitions of these components have changed over the past few decades, however CSO manuals and notes indicate that the complete time series have been adjusted to create accurate estimates that combine the present methodology and the 'back-series.' The full list of current subdivisions of components can be found in Appendix A.3.

The shares of each component were calculated by the formula,

$$Share\ of\ Component = \frac{Component\ Output}{Total\ Output} \tag{3.1}$$

The contribution of each component towards growth was calculated as,

$$Growth\ share\ of\ Component = \frac{Growth\ Rate\ of\ Component \times Share\ of\ Component}{Growth\ Rate\ of\ Output} \tag{3.2}$$

Savings and Capital Formation Saving and capital formation data were obtained from the RBI online data warehouse.

Rainfall The Indian Institute of Tropical Meteorology has created and maintained monthly rainfall data since 1870. National rainfall data have already been calculated by taking a weighted average of rainfall across all regions, where the weights are determined by total crop area. The data were then annualized by taking an average of the months contained in the Indian financial calendar year, and then standardized to produce a series with mean of zero and standard deviation of one. Therefore, a value of zero in the index would represent average or normal rainfall in that particular year. It's important to note a severe limitation of this index. Since the index places equal weights on all months, it cannot identify and report a late monsoon. In other words, delayed and below average rainfall during the crucial months of June to September will not appear in the index if the subsequent months adequately compensate in rainfall. Agricultural output is likely to be as sensitive to delayed rainfall as it is to low rainfall. One possible remedy may require calculating the annual average as a weighted average, where months that fall during the monsoon season are weighted more than the rest of the year. However, the selection of these months will be somewhat arbitrary due to the presence of crop rotation and variation in the degree to which crops are dependent on the monsoon season. More importantly, the exact duration and importance of the monsoon season varies across India, which would force any weighted average to bias the index towards a certain set of states. Bhalla (2010) constructs his index exclusively from the monsoon season months of June to September. While this approach seems less preferable for the reasons stated above, it's important to note that the results do not vary significantly with the alternative index. It's possible that the results are more sensitive to rainfall for state-level analyses.

3.2 State-level data

For readers unfamiliar with Indian states, a summary table of key aggregate series from 2000 have been included in Appendix A.2.

In most series, data is available for 32 states. Due to insufficient data or large gaps in individual series, some states have been dropped during analysis. States that have been dropped in analysis include Daman & Diu, Andaman & Nicobar Islands, Lakshwadeep Islands, Arunachal Pradesh, Mizoram, and Nagaland.

Output Output measures in gross terms only date back to 1980 for most states. Net Domestic Product and Net Domestic Product per capita are available from 1970 for most states.

Components of Output The components of output, and their subdivisions, at the state-level are the same as the national level and can be found in Appendix A.3.

Savings and Capital Formation Savings and capital formation data is unavailable as a consistent and reliable series. Only a few states have collected data for these series, and their methodology is still at a nascent stage. The CSO website, which lists the status of state government statistical offices and their progress in various areas, speculates that a full and reliable series will not be available in the foreseeable future. One possible remedy to this situation is to use data from the CMIE CapEx database, which details project investment at the state level.

Rainfall The Indian Institute of Tropical Meteorology's rainfall data is divided into subdivisions that do not neatly correspond to state boundaries. Often states are omitted, grouped together, or divided. Larger states such as Maharashtra, Karnataka, and Uttar Pradesh are divided into two separate series. States that were grouped together were assigned the same rainfall data. Finally, states that were divided into sub-regions were averaged by their crop area. The rainfall index was calculated for states in the exact same way as the national rainfall index was calculated. As a result, it also suffers from the same limitations.

Notes

[1]CMIE products that were used include Industry Analysis Service, State Analysis Service, International Economics Statistics, and CapEx.

[2]One crore in the Indian number system equals ten million in the traditional numbering system

[3]All financial data in India are reported according to the Indian Financial Calendar, which runs from March 31 to April 1. Therefore, 1999-2000 refers to the financial year beginning on March 31 1999 and ending on April 31 2000. Annual figure will either be reported as 1999-2000 or with only the beginning period, i.e. 1999 in this case.

[4]With reference to components of output, agriculture will be used to refer to agriculture and allied services.

SECTION 4

Methodology

The methodology of this study can be organized into two categories: tests for endogenously identifying structural breaks in univariate time series and OLS techniques for explaining these structural breaks. The OLS models are further divided into time series models using national level, and panel regression models using state level data. The structure of these regression models is derived partly from the literature, and partly from the results of the structural break tests. This section will detail the methodology behind these structural break tests their influence on the regression models.

4.1 Structural Break Tests

Structural breaks in a series are usually defined in reference to the stability of parameters in a regression equation. The coefficients and t-statistics from standard OLS models are only unbiased and efficient if we believe the relationship between the explanatory and dependent variables to be constant across time. Accurate prediction or econometric inference requires stable parameters. In the presence of instability, regression models would force a linear relationship with constant parameters when the data are better fitted by multiple regression equations for each 'regime.' In the context of growth regressions, the determinants of economic growth must be estimated separately for each regime if parameters exhibit instability. In this study, structural break tests are used to identify the location and estimate the effect of breakpoints in aggregate data series. The purpose of this exercise is to correctly identify the point at which economic growth in India underwent a structural shift. This would help us in our attempts to identify the causes behind this shift.

The Chow test is an econometric technique that is often used to test the existence of an exogenously specified structural break. (Chow, 1960) developed a method to test if "subsets of coefficients in two regressions are equal." The Chow test statistic belongs to the F distribution and tells us if the constrained model is an improvement over the unconstrained models. Limitations of the Chow test have been discussed extensively (Hansen, 2001). The chief limitation for the purpose of this study is the exogenous specification of breakpoints. The Chow test requires us to know both the number of breakpoints and their exact location in the data series. More importantly, the Chow test is a multivariate test that only considers structural breaks in reference to a given regression equation. It does not naturally lend itself to univariate tests, although a regression equation with time as the only explanatory variable might produce similar results.

One-time shocks and their effects on a series are usually discussed as an instability that needs correcting to obtain accurate parameters. In this view, the position of structural breaks, or the level shift that occurs, are of little interest. For our purposes, this is not the case. Since we are interested in the breakpoints of economic growth, the univariate breakpoint test gives us useful information by itself; a formal model is not required. According to (Hansen, 2001), structural break tests have evolved in sophistication since the Chow test; they can now test for a break with unknown timing, estimate the timing of a break, and distinguish between a random walk and broken-time trend. (Perron, 2006) provides a comprehensive review of developments in this area.

The structural break tests employed in this study are based primarily on methods developed by (Clemente et al., 1998; Perron and Vogelsang, 1992; Zivot and Andrews, 1992), and they are best described as tests for a unit root with mean-shifts at unknown dates.[1] These tests serve our purpose well. We hope to find shocks in the growth rate of Indian output that persist and change mean of the original data series. It is important to not confuse this with a non-stationary process. One of the criticisms of traditional unit root tests such as the Augmented Dickey Fuller test, is that they are poor at distinguishing a stationary series around a structural break from a non-stationary series (Arranz and Escribano, 2006; Perron, 2006). The following subsection will state the formal model for these structural break tests.

4.1.1 Formal Methods

Structural break tests, in one form of another, are usually trying to estimate the effect, and identify the location, of an outlier in the series. (Box and Tiao, 1975; Chang et al., 1988) divided outliers into two categories: Additive Outliers (AO) and Innovational Outliers (IO). The structural break tests used in this study have followed this division as well. (Perron, 2006; Perron and Vogelsang, 1992) distinguish AO and IO models as follows: AO models specify an instantaneous or sudden change and IO models specify a gradual change in the mean of the series. In other words, AO models are more appropriate for testing structural changes where there is a one-time shock, which significantly affects the mean. IO models are more appropriate when a one-time shock persists dynamically through the remainder of the series (Perron, 1990). For these reasons, the IO model will be used to identify the date and estimate the effect of breakpoints in aggregate series. While the AO model may provide valuable insights into the structural changes of series such as exchange rates and real interest rates, the IO model is more useful if we are trying to identify a policy regime or productivity regime change that persists in its effects beyond the initial shock. For an example of a statistically significant IO breakpoint, see Figure 5.1.

The single break IO model uses the regression equation, unit root test, and critical values provided by (Perron and Vogelsang, 1992). It takes the form:[2]

$$y_t = \mu + \delta DU_t + \phi DT_{bt} + \alpha y_{t-1} + \sum_{i=1}^{k} \theta_i \Delta y_{t-i} + e_t \tag{4.1}$$

where DU_t is a dummy variable that equals 1 if $t > T_b$ (the breakpoint) and 0 otherwise; DT_{bt} is a pulse variable that equals 1 if $t = T_b + 1$ and 0 otherwise. Since the IO method models the effect of shocks gradually, it treats the shock similarly to any other shock in the model, i.e. as an autoregressive moving average. This functional form allows us to find the optimal breakpoint, $T_{b,t}$, and the appropriate lag order, k by testing the null hypothesis that the process has I(1) unit root, i.e. $\alpha = 1$.[3]

The double break IO model uses the regression equation, unit root test, and critical values provided by (Clemente et al., 1998). It takes the form:[4]

$$y_t = \mu + \delta_1 DU_{1t} + \delta_2 DU_{2t} + \phi_2 DT_{b1,t} + \phi_2 DT_{b2,t} + \alpha y_{t-1} + \sum_{i=1}^{k} \theta_i \Delta y_{t-i} + e_t \tag{4.2}$$

where DU_{1t} and DU_{2t} are dummy variables that equal 1 if $t > T_{mb}$ (their respective breakpoints) and 0 otherwise; $DT_{b1,t}$ and $DT_{b2,t}$ are pulse variables that equal 1 if $t = T_{mb}+1$ and 0 otherwise. Since the IO method models the effect of shocks gradually, it treats the shock similarly to any other shock in the model, i.e. as an autoregressive moving average. This functional form allows us to find the optimal breakpoints, $T_{b1,t}$ and $T_{b2,t}$, and the appropriate lag order, k by testing the null hypothesis that the process has I(1) unit root, i.e. $\alpha = 1$.[5]

The output from these IO models tells us the following: whether the process is non-stationary with structural breaks, when structural breaks occur and with what intensity, and whether they are statistically significant. The following section outlines how these results will be used in empirical analysis.

4.1.2 Use of Structural Break Tests

Structural break tests will be used to determine significant breakpoints in the growth rates of various measures of output and their components. These tests will be repeated for each component and subcomponent of output at the national and state level. The purpose of this exercise is to identify coincident structural breaks in various series. This may help us understand the proximate cause and longer term determinant of economic growth in India. In addition to identifying patterns in the univariate structural break tests, regression models at both state and national levels will be specified in a form that incorporates the breakpoints from our unit root tests. This will increase the overall accuracy and usefulness of the regression model since the breakpoints are endogenously obtained. The regression models will also supplement the breakpoint analysis by providing a multivariate test for structural break in each model.

There is no simple econometric test to choose between a two-break and one-break model. Practically, this is not a problem since the breakpoint from a one-break model is almost always reproduced in the two-break model. The selection of the model will have to be on a case-by-case basis by examining t-statistics for individual breakpoints and F-statistics for the entire model. For all cases, the two-break model was preferred to the one-break model for the reasons stated above.

4.2 Regression Models

All time series regression models in this study take the form,

$$y_t = \alpha + \overbrace{\underbrace{\sum_{i=1}^{m}\sum_{j=0}^{k}\beta_{ij}D_i x_{t-j}}_{m\ breaks;\ j\ lags}}^{Multiplicative\ Dummies} + \overbrace{\underbrace{\sum_{j=0}^{k}\phi_j x_{t-j}}_{j\ lags}}^{Ind.\ Variable} + \overbrace{\underbrace{\sum_{i=1}^{m}\theta_m D_m}_{m\ breakpoints}}^{Additive\ Dummies} + \overbrace{\underbrace{\sum_{j=0}^{k}\sum_{n=1}^{2}\gamma_{jn}{c_{t-j}}^{n}}_{j\ lags;\ n\ power}}^{Control\ Variable} + \overbrace{\underbrace{\sum_{j=1}^{k}\rho_j y_{t-j}}_{lag\ order\ j}}^{AR(k)\ Term} + \epsilon_t \tag{4.3}$$

The equivalent model for a panel specification includes the appropriate subscripts for panels along with a term denoting panel fixed effects. The number of lags for each regressor need not be the same. In this general model, the control variable has been squared since every regression model will use rainfall as a control variable. Rainfall should be specified in quadratic form since the sensitivity of output to rainfall is unlikely to be a linear relationship. Inflation was also used as a control variable but was not found to be significant in most specifications. While there is no ex-ante reason to suspect that substantial inflation has real effects on the Indian economy, the result may be a function of India's methodology of calculating inflation.

Despite the flexibility to include k lags, the optimal lag length in all models was found to be one through the AIC criterion. Similarly, the model allows for m breakpoints in the series, but the models in this study are limited to two breaks. This is partly due to the structural break test only allowing a maximum of two breaks. But it is also justifiable given the relatively short period of data being studied. Methods that allow for unlimited breaks would be more appropriate for a longer time series.

The model should be interpreted in the following way. ϕ_0 is the base level effect of x on y, i.e. an increase in x would cause a ϕ_0 change in y in the period before the first break. The β_{ij} terms represent the incremental jump in y after each structural break. The total effect can be calculated by adding the incremental effects of all previous periods and the base level effect of the first period. For example, $\beta_{1j} + \phi_0$ is the total effect of x on y in the period beginning after the first structural break. For all subsequent breaks the total effect for the period after the m^{th} break will be denoted by $\phi_0 + \sum_{i=1}^{m} \beta_{ij}$. The constant term and parameters on additive dummies should be interpreted in the following way. The benchmark growth rate in the first period is denoted by the constant term. The incremental jump in the benchmark growth rate after each structural break – and subject to the effects of the explanatory variables – is give by θ_m. Similar to the multiplicative dummies, the total effect, which in this case implies the benchmark average growth rate in the period after the m^{th} break, is given by $\alpha + \sum_{i}^{m} \theta_m$. The interpretation for these parameters does not change when lagged terms are involved.

Notice that the use of additive and multiplicative dummies follows the fundamental premise. and retains the intention, of (Chow, 1960) while preserving greater degrees of freedom (Gujarati, 1970). If the multiplicative and additive dummies are not significant, then that particular specification is better served by an unconstrained model. If this is the case, then the constant represents the average growth rate for the entire period and ϕ_0 is the slope.

4.2.1 Component Models

This variation of (4.3) will test for the existence of a multiplier effect among the components of output. For each of the three components of output – Agriculture, Industry, and Services – the model will test for the outsized effect of a component on its remaining counterparts. The multiplicative dummies will allow us to observe the relationship between a particular component and its counterparts after each structural break. This model requires us to remove component output from total output because we already know that each component will have a 1 : 1 effect. Any outsized effect may indicate a multiplier effect between the components. The basis of this model is (Virmani, 2009), where he divides the time series and his regression equations into three periods.

Model : Agriculture

Structural breaks in the growth rate of output are explained by the outsized effects of structural changes in agriculture output.

This seems like an unlikely hypothesis since the share of agriculture in output and its share, i.e. contribution, to output growth have decreased over time. More importantly, a sizable portion of India's agricultural sector is still used for subsistence and not commerce. It seems unlikely that agriculture can have an outsized effect through demand side or supply side channels on industrial output and services output. This model is tested with national and state data.

Model : Industry

Structural breaks in the growth rate of output are explained by the outsized effects of structural changes in industrial output.

While not as unlikely as the previous hypothesis, this hypothesis seems unlikely as well. The shares and growth shares of industry have not varied as much as agriculture and services. The channels through which industrial growth could have an outsized effect on non-industrial growth seem slightly more plausible. This model is tested with national and state data.

Model : Services

Structural breaks in the growth rate of output are explained by the outsized effects of structural changes in services output.

This final component model has stronger intuitive justifications than the previous two hypothesis. Both the shares of services in total output, and its growth share have increased over time. The demand-side and supply-side channels seem even more plausible than industry because of India's factor endowment, which could have a strong demand-side effect, and the potential for productivity gains from improvements in telecommunications and transport.

Recall that these hypotheses are testing for outsized effects. Even if we reject all three models, there is still a 1 : 1 effect by any of the three components.

4.2.2 Rainfall

These models also follow (Virmani, 2009). Virmani's stated purpose was to demonstrate a stable relationship between the effect of rainfall on the growth rate of output. The purpose of applying this model to (4.3) is to observe the effect of rainfall on growth rates during each period. (Virmani, 2004, 2006) extends his standard rainfall model to study the same effect, but with only one breakpoint in 1981. According to (Basu, 2008), the conventional wisdom in the literature is that rainfall would have a large impact on the overall growth rate from 1950-1980, i.e. when agriculture accounted for a large share in India's GDP. As mentioned earlier, (Bhalla, 2010) uses a similar model with a breakpoint in 1978.

Model : Rainfall

Structural breaks in the growth rate of output are explained by changes in how rainfall affects the economy

If (Virmani, 2004, 2006, 2009) is correct, then the effect of rainfall on the economy should not change, i.e. the multiplicative dummies should not be statistically significant.

4.2.3 Public Investment Models

The public investment model will attempt to explain structural breaks in a similar manner. Variations of this model have been employed extensively (Basu, 2004; Basu and Maertens, 2007; Bhalla, 2010; Virmani, 2004, 2009).

Model : Public Investment

Structural breaks in the growth rate of output are explained by changes in public investment during these periods.

The results from this regression would help us estimate the importance of investment by the Indian government in generating structural breaks.

Notes

[1]The statistical package (Baum, 2004) was used to perform these tests. It is based primarily on (Clemente et al., 1998), where the one-break forms of the test were devised from (Perron and Vogelsang, 1992; Zivot and Andrews, 1992).

[2]The exact specification is taken from (Baum, 2005) since the statistical package was built on this particular model:

[3]The optimal breakpoint is found by trying every feasible T_b to find the minimal t-ratio for the null hypothesis $\alpha = 1$. The optimal lag order is found with sequential F-tests.

[4]Same as single break IO model

[5]Same as the single break IO model, except all possible combinations of T_{b1} and T_{b2} are tried.

SECTION 5

Empirical Analysis

This section will present and discuss results from the structural break tests and regression models for national and state-level data.

5.1 Structural Breaks

Section 4.1.2 outlined the Innovational Outlier (IO) tests for one-break and two-break models. The tests specified by Clemente et al. (1998); Perron and Vogelsang (1992) are testing the hypothesis that the series is non-stationary with structural breaks. For our purposes in this section, only the location of the breakpoints, their coefficients, and t-statistics are of interest. The non-stationarity of any series has implications for inference and forecasting, but the location of breakpoints, their coefficients, and standard errors remain largely unchanged (Perron, 2006).

5.1.1 National

The literature widely cites two breakpoints in the growth rate of India's output. The first breakpoint is usually placed between 1978-1984 and the second breakpoint is placed between 2001-2004. Most studies find the breakpoints in 1982 and 2003. While few studies employ the Perron-Vogelsang (PV) or Clemente-Montanes-Reyes (CMR) tests, it's interesting to note that the unfiltered Gross Domestic Product at Factor Cost growth rates produce two optimal breakpoints in 1982 and 2003. Other measures of output and their filtered forms produced breakpoints in the ranges mentioned earlier.

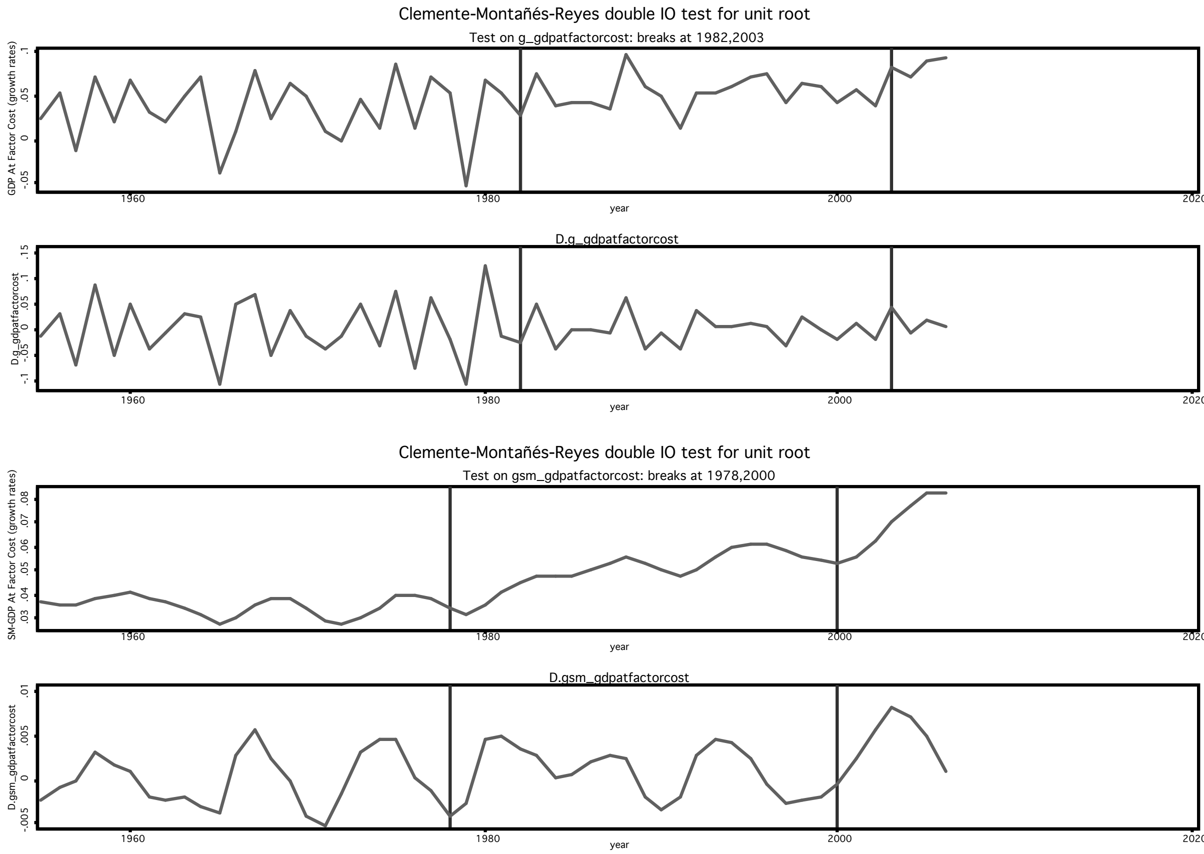

Figure 5.1: Optimal breakpoints for GDP at Factor Cost - Original and Smoothed

The unfiltered series clearly shows a shift in the mean after 1982. While the average growth before 1982 hit the new post-1982 mean of roughly 6%, it could not persist and its overall effect was balanced by downward troughs. The smoothed series show this trend more accurately. Remarkably, the data show a significant structural break around 2003, despite having only 6 observations after the break. Perhaps this is due to the persistence of growth during this period.

It's also important to note that the data do not show a breakpoint during the 1990s, especially around the reform year of 1991. Two different conclusions may be drawn from this fact. The first view is that the the reforms of 1991 did not induce a structural break immediately. This would suggest that the higher growth path of the economy began before the Narasimha Rao and Manmohan Singh reforms of 1991, which may be due to smaller steps towards reforms that were undertaken by Indira Gandhi and Rajiv Gandhi (Rodrik and Subramanian, 2005a, 2007). Kohli (2006) asserts that Indira Gandhi had a "change of heart" when she returned to office in 1980 and began to view the private sector more favorably. Her government removed implicit barriers to private investment and generally pursued policies that were more friendly towards economic growth.

The second view is that breakpoints in the raw output series do not account for high levels of external borrowing in the 1980s. According to this view, growth during the 1980s was unsustainable and caused a near-complete collapse in 1991, which required the subsequent reforms in 1991 (Panagariya, 2004a, 2008). Another way of stating this hypothesis is that the economy was 'overheated' in the 1980s. The excessive demand side pressures created an unstable boom period in the Indian economy that eventually crashed in the 1990-1991. Bhalla (2010) has also pointed out that the 'jump' in growth rate in the 1980s is also partly due to the prior decade being a slump for the world economy. He 'tests' the overheating hypothesis by comparing the HP filtered series of output growth with its original series. If there was overheating, the HP filtered series should be below the actual series in the 1980s, i.e. output was above potential. His analysis has been reproduced with our data in the figure below.

The comparison between actual growth rates and potential growth rates do not provide strong evidence for overheating. They do, however, show a definite correction towards the late 1980s and early 1990s. This would suggest some overheating in the 1980s may have occurred. Output does not stay above potential after 1989-1991. These facts suggests

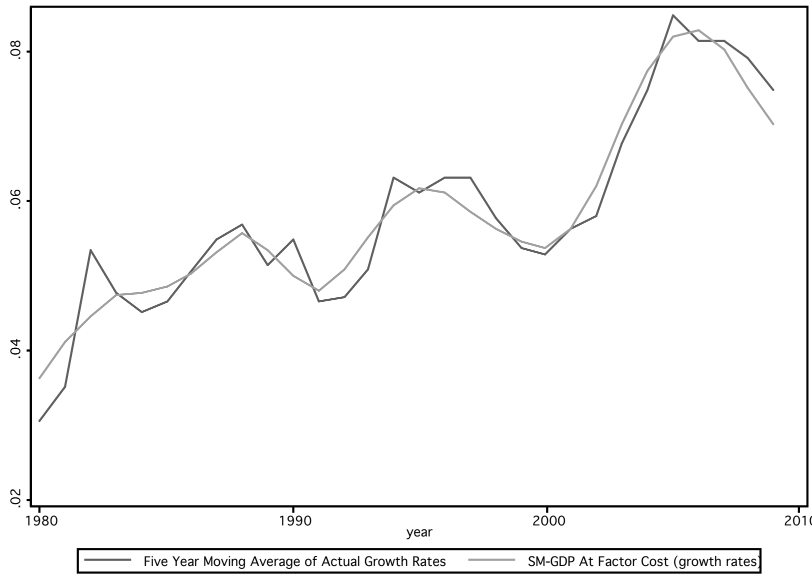

Figure 5.2: Was the economy overheated during the 1980s?

that some important change occurred around that period, which are not picked up by the structural break tests. If this analysis is correct, then we cannot conclude that the 1991 reforms are not a structural breakpoint.

We can now turn to the components of output to try and understand the factors behind these structural breaks.

By definition, the breakpoints of individual components will cluster around the breakpoint of their sum. This identity does not make this exercise trivial. It raises the possibility that a particular component is more important and has coincident breaks with the total series, while other components do not display significant and/or coincident breaks. From this perspective, the component services seems to match the first national breakpoint most closely for both the filtered and unfiltered series. Coincident second breakpoints include subcomponents of industry and services for the unfiltered series; for the filtered series, the services component seems to coincide the total series' breakpoint most closely.

Table 5.1: Optimal First Breakpoint - Components of GDP (unfiltered)

Component	Subcomponent	Breakpoint	T-Stat	P-Value	Coeff
Agriculture		1965**	2.037	0.049	0.056
	Agriculture	1965*	1.799	0.080	0.058
Industry		1994	(0.433)	0.667	(0.005)
	Manufacturing	1994	0.111	0.912	0.001
	Electricity, Gas, & Water Supp.	1962**	(2.131)	0.038	(0.021)
	Construction	1966**	(2.267)	0.028	(0.039)
	Mining & Quarrying	1978***	2.710	0.009	0.042
Services		1978**	2.239	0.029	0.010
	Trade, Hotels, Trnspr, Comm	1992***	3.475	0.001	0.028
	Finance, Ins, Real Est. etc.	1979***	4.406	0.000	0.060
	Comm/Social/Personal Serv.	1993***	3.264	0.002	0.032
Total		1982***	2.976	0.005	0.041

Table 5.2: Optimal Second Breakpoint - Components of GDP (unfiltered)

Component	Subcomponent	Breakpoint	T-Stat	P-Value	Coeff
Agriculture		1971	(1.090)	0.283	(0.028)
	Agriculture	1971	(0.628)	0.534	(0.020)
Industry		2004**	1.831	0.073	0.033
	Manufacturing	2004**	2.233	0.030	0.047
	Electricity, Gas, & Water Supp.	1994**	(2.008)	0.050	(0.018)
	Construction	2001***	3.029	0.004	0.074
	Mining & Quarrying	1989**	(2.544)	0.014	(0.041)
Services		1993***	2.833	0.007	0.017
	Trade, Hotels, Trnspr, Comm	2001	1.294	0.201	0.013
	Finance, Ins, Real Est. etc.	2004***	3.209	0.003	0.045
	Comm/Social/Personal Serv.	1998*	(1.983)	0.053	(0.021)
Total		2003***	3.626	0.001	0.063

Table 5.3: Optimal First Breakpoint - Components of GDP (filtered)

Component	Subcomponent	Breakpoint	T-Stat	P-Value	Coeff
Agriculture		1959***	(3.705)	0.001	(0.008)
	Agriculture	1958***	(3.080)	0.003	(0.006)
Industry		1968	(1.344)	0.190	(0.003)
	Manufacturing	1962**	(2.436)	0.019	(0.003)
	Electricity, Gas, & Water Supp.	1966***	(4.275)	0.000	(0.005)
	Construction	1965**	(2.500)	0.017	(0.005)
	Mining & Quarrying	1975**	2.543	0.015	0.003
Services		1978***	3.185	0.003	0.001
	Trade, Hotels, Trnspr, Comm	1989***	4.340	0.000	0.003
	Finance, Ins, Real Est. etc.	1978***	4.594	0.000	0.005
	Comm/Social/Personal Serv.	1979***	2.707	0.010	0.001
Total		1978***	4.404	0.000	0.003

Table 5.4: Optimal Second Breakpoint - Components of GDP (filtered)

Component	Subcomponent	Breakpoint	T-Stat	P-Value	Coeff
Agriculture		1964**	4.742	0.042	0.008
	Agriculture	1964*	3.843	0.062	0.005
Industry		1979	2.636	0.119	0.004
	Manufacturing	1990*	3.147	0.088	0.003
	Electricity, Gas, & Water Supp.	1993*	(3.113)	0.090	(0.002)
	Construction	1998*	3.765	0.064	0.008
	Mining & Quarrying	1994	(2.110)	0.169	(0.002)
Services		1999	2.346	0.144	0.002
	Trade, Hotels, Trnspr, Comm	1997	2.310	0.147	0.002
	Finance, Ins, Real Est. etc.	1999*	3.227	0.084	0.002
	Comm/Social/Personal Serv.	1990*	3.178	0.086	0.002
Total		2000*	3.838	0.062	0.004

Agriculture is not found to have a significant breakpoint that coincide with either of the two breakpoints. Furthermore, the location of the breakpoint around 1965, for both filtered and unfiltered series, probably reflects the massive structural change that agriculture underwent after the Green Revolution. In 1965, the government sought to modernize the agricultural sector by introducing high-yielding varieties of seeds and by encouraging the use of fertilizers and irrigation.[1] We can also treat this result as an informal verification of the CMR structural breaks model since agriculture should have a significant breakpoint after the Green Revolution. Due to the lack of any further reform in the agricultural sector, the model correctly fails to find any significant or large breakpoint after the agricultural reforms. The presence of negative coefficients can be attributed to periods of severe drought, which were common in the 1960s and emphasized the urgency of reform.

Breakpoints for industry and its subcomponents coincide with the second breakpoint, and not the first breakpoint. In particular, manufacturing seems to have a large and significant effect in the unfiltered series in 2004, and smaller effect in 1990 in the filtered series. The second breakpoint for construction coincides well for both the filtered and the unfiltered series. There are no immediate policy reforms or external regime changes that might explain increased construction activity after the breakpoint. Finally, mining & quarrying have breakpoints that are significant and coincide for the filtered and unfiltered series. In particular, the breakpoints near 1991 are noteworthy because the 1991 reforms and subsequent acts considerably liberalized the mining industry.

The services component provides breakpoints that match well for the national series, especially the first breakpoint. The subcomponents of services match the second breakpoint. This seems reasonable since the share of output that belongs to services has steadily risen since the 1980s. We can observe this feature of the Indian economy indirectly through the relatively larger coefficients on services and its subcomponents. The subcomponent, Finance, Insurance, Real Estate, and Business Services, seems to match all breakpoints extremely well. Perhaps this is due to its broad definition, but it suggests that intermediate services that affect the rest of the economy have an important role in determining growth. The coincidence of breakpoints in this subcomponent may also help us understand the role of economic reforms. This particular subcomponent is heavily regulated and requires significant government support through implicit channels such as common law institutions, as well as explicit liberalization and delicensing of these industries. One possible interpretation of this result is that structural breaks in economic growth are driven by structural breaks in services, which are primarily driven by structural changes in Finance, Insurance, Real Estate, and Business Services. An increase in output in these industries is also akin to the improvement of the underlying economic institutions that are meant to help economic expansion. Similarly, Trade, Hotels, Transportation, and Communication seems to have a statistically and economically significant first breakpoint around 1992 for both the filtered and unfiltered series.

According to this analysis, the services component of output seems to have caused the structural breaks in growth in 2003. This hardly seems surprising, given the extensive academic literature and media commentary on the importance and role of services in the Indian economy. Even without the use of structural break tests, we can observe the increasing importance of services in the Indian economy. Figure 5.3 compares the output of services, industry, and agriculture in levels. This fact is further strengthened when we consider the shares of each component to output and economic growth. Figure 5.4 indicates the changes in the shares and growth shares of smoothed component output since 1950. There is a clear trend visible; industry and services have steadily replaced agriculture. The growth shares of services have risen rapidly and have been higher than its share of output throughout most of the time series. By contrast, the growth share of agriculture has been considerably below its share of output, and the growth share of industry has mostly, but inconsistently, been above its share of output.

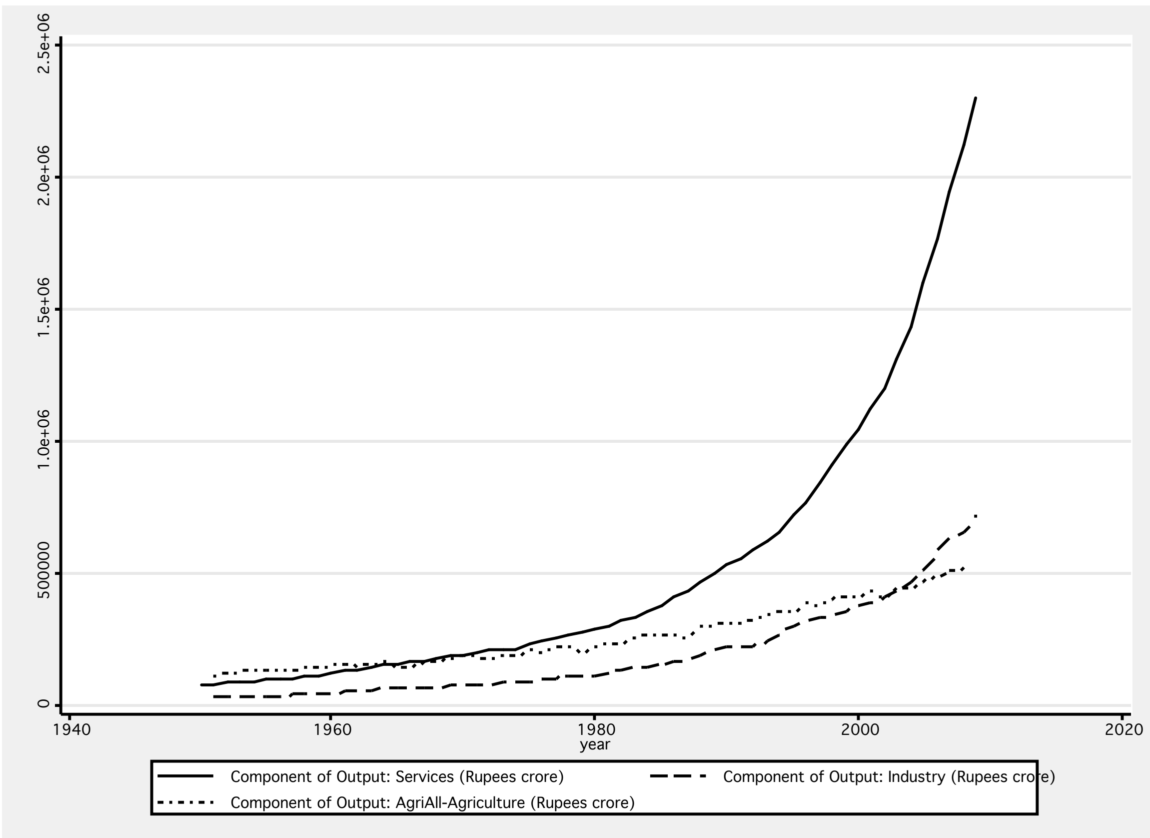

Figure 5.3: Components of Ouptut – Levels

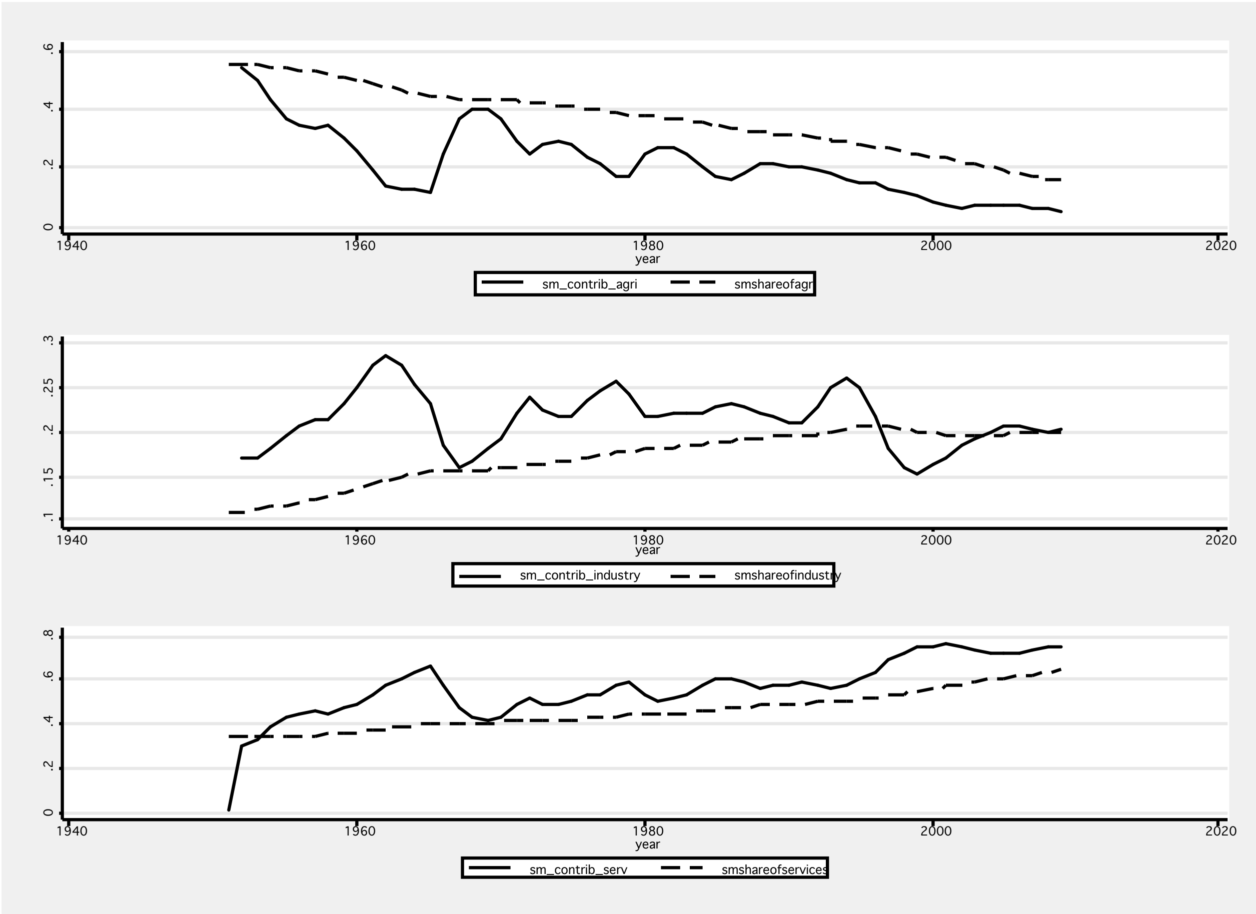

Figure 5.4: Shares and Growth Share of each component

5.1.2 State-Level

Breakpoint analysis at the state level has not been applied in the literature. This is probably due to a shorter times series and general data issues that arise when one deals with Indian state-level data. This subsection will consider the breakpoints in state output measures and breakpoints in components of output. The time series for the first set stretches back to 1970, while component-wise data is only available from 1980 onwards. Moreover, the 1970 series is only for Net Domestic Product and is thus not strictly comparable.

Figure 5.5 confirms the national breakpoints with a clear pattern of clustering around

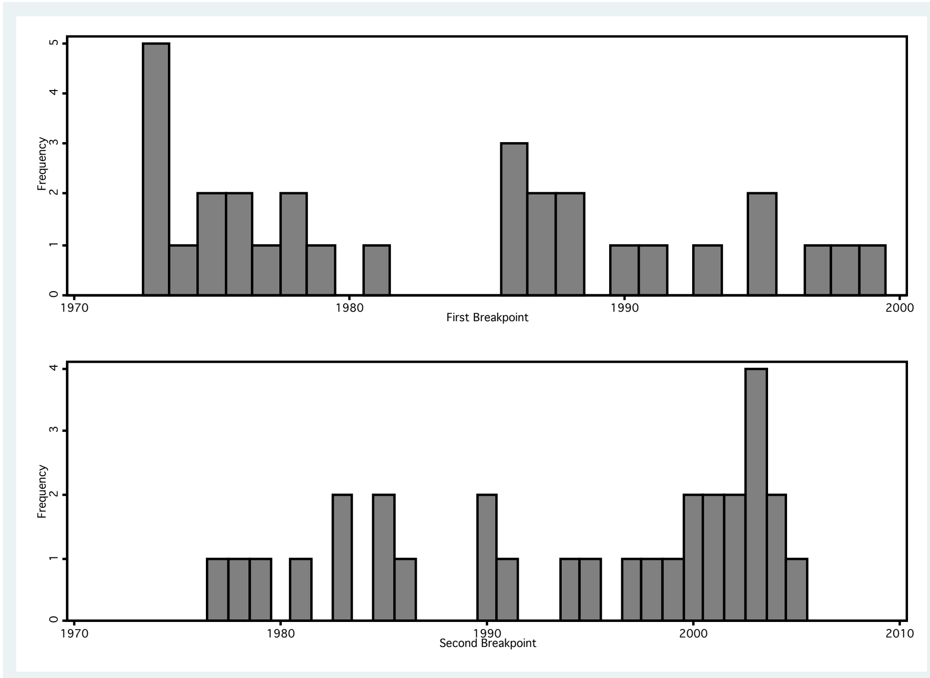

Figure 5.5: Distribution of the breakpoints among states - NDP

the first national breakpoint of 1982 and the second national breakpoint of 2003. This is a useful starting point for analysis because it confirms our structural break test for state level data by providing breakpoints that generally correspond to national breakpoints. However it tells us nothing about the nature of these individual observations and assigns equal importance to each one. Therefore, we must dig deeper and consider the statistical and economic significance of these breaks, and the states they occur in.

Table 5.5: State breakpoints using NDP

State	First Breakpoint	T-Stat	P-Value	Coeff	Second Breakpoint	T-Stat	P-Value	Coeff
Andaman & Nicobar Islands	1990***	3.575	0.002	0.140	1994***	(3.286)	0.004	(0.125)
Andhra Pradesh	1975	(0.710)	0.483	(0.022)	1985*	1.719	0.096	0.034
Arunachal Pradesh	1974*	1.875	0.070	0.069	1995*	(1.739)	0.092	(0.038)
Assam	1978				1983	0.521	0.610	0.017
Bihar	1991**	(2.519)	0.030	(0.081)	2004***	4.382	0.001	0.308
Chandigarh	1995	(1.447)	0.182	(0.029)	1998***	3.405	0.008	0.043
Chhattisgarh	1999	1.045	0.323	0.034	2002**	2.136	0.061	0.075
Delhi	1973*	1.749	0.090	0.049	2004**	2.515	0.017	0.062
Goa	1987	1.245	0.223	0.031	1997	(0.473)	0.639	(0.013)
Gujarat	1986	1.531	0.136	0.089	1990	(0.455)	0.653	(0.026)
Haryana	1973*	1.891	0.068	0.161	2005	(0.213)	0.832	(0.011)
Himachal Pradesh	1976	(0.792)	0.434	(0.019)	1983***	4.333	0.000	0.081
Jammu & Kashmir	1977	(0.990)	0.330	(0.011)	1986**	2.620	0.014	0.023
Jharkhand	1995	0.970	0.360	0.094	1999	(0.646)	0.537	(0.037)
Karnataka	1979	1.121	0.271	0.021	2003**	2.034	0.050	0.047
Kerala	1986***	5.271	0.000	0.067	2003***	3.420	0.002	0.056
Madhya Pradesh	1978**	1.995	0.055	0.051	2001	1.156	0.257	0.027
Maharashtra	1988	1.471	0.180	0.060	2003	1.141	0.287	0.042
Manipur	1975***	(3.007)	0.005	(0.073)	2001	1.566	0.127	0.030
Meghalaya	1987				1991	(0.430)	0.676	(0.007)
Orissa	1988	(0.352)	0.727	(0.009)	2002***	4.575	0.000	0.192
Puducherry	1993***	2.941	0.006	0.128	2000	(1.305)	0.202	(0.061)
Punjab	1973**	2.157	0.039	0.054	1977**	(2.328)	0.027	(0.030)
Rajasthan	1986***	3.062	0.005	0.156	1990	(1.520)	0.142	(0.073)
Sikkim	1997***	(5.701)	0.000	(0.033)	2000	7.505	0.000	0.043
Tamil Nadu	1973	1.279	0.210	0.047	1979	(0.349)	0.729	(0.007)
Tripura	1981	(1.291)	0.207	(0.045)	1985***	2.824	0.008	0.094
Uttar Pradesh	1973**	2.604	0.014	0.081	1978	(0.902)	0.374	(0.017)
Uttarakhand	1998***	9.595	0.000	0.083	2003	(0.366)	0.729	(0.004)
West Bengal	1976				1981	.		

Table 5.6: State breakpoints using NDP per capita

State	First Breakpoint	T-Stat	P-Value	Coeff	Second Breakpoint	T-Stat	P-Value	Coeff
Andaman & Nicobar Islands	1990***	4.019	0.001	0.150	1994***	(3.338)	0.003	(0.120)
Andhra Pradesh	1975	(0.760)	0.453	(0.024)	1985**	2.267	0.031	0.045
Arunachal Pradesh	1974				1995*	(1.815)	0.097	(0.080)
Assam	1978				1983	0.585	0.568	0.019
Bihar	1991	(0.523)	0.606	(0.011)	2004***	3.935	0.001	0.162
Chandigarh	1998*	1.940	0.084	0.047	2002***	(2.771)	0.022	(0.063)
Chhattisgarh	1999	1.120	0.292	0.037	2002*	1.985	0.078	0.070
Delhi	1983**	2.119	0.042	0.029	2004***	2.931	0.006	0.074
Goa	1987**	2.489	0.021	0.077	1997	(1.417)	0.170	(0.042)
Gujarat	1986	1.652	0.109	0.098	1990	(0.476)	0.638	(0.028)
Haryana	1973				2002***	3.860	0.001	0.104
Himachal Pradesh	1976	(0.765)	0.450	(0.019)	1983***	4.452	0.000	0.086
Jammu & Kashmir	1977	(1.054)	0.300	(0.013)	1986***	2.981	0.006	0.029
Jharkhand	1998**	(3.499)	0.013	(0.319)	2002***	3.789	0.009	0.409
Karnataka	1985***	5.049	0.001	0.133	2003	0.541	0.603	0.010
Kerala	1986***	5.977	0.000	0.093	2003***	4.331	0.000	0.074
Madhya Pradesh	1978*	2.005	0.054	0.052	2001	1.385	0.176	0.033
Maharashtra	1988	1.178	0.247	0.020	1999	0.923	0.363	0.017
Manipur	1975**	(2.729)	0.010	(0.066)	2001*	1.830	0.077	0.036
Meghalaya	1987				1991	(1.326)	0.217	(0.026)
Orissa	1976	1.343	0.189	0.050	2002***	4.654	0.000	0.169
Puducherry	1993***	3.384	0.002	0.153	2000*	(1.800)	0.082	(0.085)
Punjab	1973**	2.224	0.033	0.046	1977**	(2.081)	0.045	(0.028)
Rajasthan	1986**	2.855	0.017	0.223	1990	0.480	0.642	0.044
Sikkim	1997				2001***	11.204	0.002	0.144
Tamil Nadu	1973	1.381	0.177	0.052	1979	(0.099)	0.922	(0.002)
Tripura	1984**	2.639	0.022	0.058	1994***	3.100	0.009	0.107
Uttar Pradesh	1973**	2.531	0.016	0.077	1978	(0.765)	0.450	(0.014)
Uttarakhand	1998***	13.526	0.000	0.083	2003	(0.403)	0.704	(0.003)
West Bengal	1978				1992	0.865	0.404	0.015

The states with statistically significant breakpoints that coincide with the first national breakpoint are Kerala, Manipur, Puducherry, Punjab, Rajasthan, Uttar Pradesh, and Delhi. This group is largely similar for both the NDP and NDP per capita series. Similarly, the states with statistically significant breakpoints that coincide with the second national breakpoint are Bihar, Chandigarh, Chhattisgarh, Delhi, Karnataka, Kerala, Sikkim, and Orissa. The equivalent group for NDP per capita include all these states, and in addition, includes Haryana, Jharkhand, and Sikkim. It's interesting to note that Gujarat is missing from both groups; it does not have statistically significant breakpoints under NDP or NDP per capita series. Under NDP per capita, it has a breakpoint in 1986 that is almost significant at the 10% level. This result seems puzzling given the immense publicity and commentary surrounding Gujarat's economic performance. Another curious absentee from these groups is the state of Maharashtra, which houses India's financial capital, Mumbai. No breakpoint in either the NDP or NDP per capita series are statistically significant. Perhaps Gujarat and Maharashtra's strong and consistent economic performance 'excused' them from the structural changes that were occurring in weaker areas, i.e. the productivity gains from these structural changes were larger in slower states. If this explanation is correct, then it oddly suggests some degree of convergence.

On casual observation, more states seem to have significant structural breaks around 2003 than 1982. This may suggest that the 1982 growth spike was not led by state-specific changes and was more evenly spread; the 2003 growth spurt was caused by statistically and economically significant structural breaks in a few states. This divergence in growth must be compared with the reallocation in shares and growth shares of each component of national output. The movement from agriculture to industry and services is bound to benefit states with favorable factor endowments. We can observe this from the structural break tests, where the statistically significant states in 1982 are mostly different from their equivalent group in 2003. This suggests that most states only undergo a structural break once, i.e. the 'regime' that determines their growth path after a break displays strong signs of persistence, where a large external shock, such as a nation-wide structural break in 2003, has no effect. This further suggests a reallocation of resources across states, instead of structural changes from within to adapt to the services-based economy. In other words, the reallocation from agriculture to services and industry at the national level was carried out by reallocation across states, not by a reallocation among components within each state. In addition to the structural break tests, this is easily observed in the shares of each component for states. We find that the shares of each component in state output do not change substantially over time in most states. Growth shares of component, on the other hand, change substantially. Therefore, the only remaining channel for reallocation from agriculture to services and industry must be transfers across states, which results in divergent growth.

One possible 'test' for this narrative is to examine the components of output for states that exhibit statistically significant breakpoints around 2003. Similar to the interpretation for 5.1.1, components of output sum to the state's total output. We hope to find some pattern among the components, where a single component has statistically and economically significant coincident breaks, while the other components do not follow this trend. We should expect to some some combination of the services and industry components having breakpoints around 2003 in these states. For instance, the inclusion of city-states such as Chandigarh and Delhi suggests that services play a key role, since agriculture and industry are naturally limited in these states. Bihar, Jharkhand, and Orissa, on the other hand, are resource-rich states that emphasize industry over other components.

The group of states with statistically significant breakpoints around 2003 includes Bihar, Chattisgarh, Delhi, Karnataka, Kerala, Orissa, Sikkim, Chandigarh, Haryana, and Jharkhand.

Table 5.7: Component-wise breakpoints for selected states

State	Component	First Breakpoint	T-Stat	P-Value	Coeff	Second Breakpoint	T-Stat	P-Value	Coeff
Bihar	Agriculture	1985**	(2.275)	0.035	(0.178)	1991	1.403	0.178	0.061
Bihar	Industry	1996	0.473	0.641	0.018	2003***	4.401	0.000	0.229
Bihar	Services	1994**	2.803	0.019	0.033	2005***	6.044	0.000	0.150
Chandigarh	Agriculture	1997*	(1.972)	0.080	(0.246)	1999***	3.340	0.009	0.379
Chandigarh	Industry	1997*	(2.060)	0.069	(0.120)	2001**	3.202	0.011	0.206
Chandigarh	Services	2001	0.808	0.440	0.010	2005***	4.124	0.003	0.079
Chhattisgarh	Agriculture	1991***	(6.197)	0.000	(0.649)	1995***	5.855	0.000	0.565
Chhattisgarh	Industry	1988	(0.305)	0.763	(0.013)	2000*	1.738	0.098	0.069
Chhattisgarh	Services	1991				1995***	1599.391	0.000	0.747
Delhi	Agriculture	1997***	(38.101)	0.001	(0.528)	2001	(0.124)	0.913	(0.004)
Delhi	Industry	1989**	2.396	0.034	0.094	1997	1.748	0.106	0.049
Delhi	Services	1997**	(2.498)	0.021	(0.077)	2002***	3.607	0.002	0.146
Haryana	Agriculture	1983	(0.842)	0.410	(0.071)	1998	0.446	0.661	0.014
Haryana	Industry	1983***	3.539	0.002	0.195	2003	1.510	0.145	0.054
Haryana	Services	1988				1995**	2.837	0.030	0.048
Jhharkhand	Agriculture	2000**	(2.466)	0.022	(0.190)	2002**	2.473	0.022	0.198
Jhharkhand	Industry	1997*	(2.942)	0.099	(0.070)	2003	(0.182)	0.872	(0.004)
Jhharkhand	Services	1992**	2.791	0.011	0.026	2003	0.712	0.484	0.008
Karnataka	Agriculture	1986***	4.081	0.001	0.113	1995***	(3.725)	0.001	(0.078)
Karnataka	Industry	1985	1.681	0.109	0.044	2002**	2.637	0.016	0.063
Karnataka	Services	1993***	3.991	0.001	0.052	2004**	2.656	0.015	0.051
Kerala	Agriculture	1998***	(10.265)	0.002	(0.427)	2001***	8.400	0.004	0.466
Kerala	Industry	1985*	1.973	0.067	0.106	1998	(1.479)	0.160	(0.028)
Kerala	Services	1998	(1.519)	0.150	(0.021)	2004**	2.593	0.020	0.056
Orissa	Agriculture	1988				1999*	4.261	0.051	0.075
Orissa	Industry	1987	(0.810)	0.428	(0.027)	2002***	4.138	0.001	0.167
Orissa	Services	1982**	2.101	0.047	0.059	2002***	4.584	0.000	0.068
Sikkim	Agriculture	2000***	(3.547)	0.002	(0.280)	2002***	3.587	0.002	0.304
Sikkim	Industry	1993	(0.352)	0.728	(0.011)	2003	0.892	0.382	0.039
Sikkim	Services	1982	1.699	0.104	0.056	2001	1.423	0.170	0.022

Agriculture seems to have statistically and economically significant structural breaks for all states throughout the 1980s and 1990s. With the exception of Karnataka, these breaks have negative coefficients for all states with significant first breakpoints in agriculture. In some cases, such as Delhi, Chandigarh, Kerala, Chhattisgarh, and Sikkim, the negative coefficient is large. In the case of city-states such as Delhi and Chandigarh, large coefficients are probably explained by small agricultural sectors. Small changes in the output of these components would produce large swings in their growth rate. The breaks may be associated with bad monsoons during the given period, or large movements in labor and capital from agriculture towards other components. It must also be noted that state-level data for components only begins around 1980 for most states. As a result, the known mean-shifting outlier that is associated with the Green Revolution of 1965 will not appear in the data. It's likely that a full time series that begins in 1950 for state-level data will not produce these breakpoints. More generally, we should only 'look' for state component breakpoints that cluster around 2003, since the first breakpoint in 1982 probably occurs too early in state series. From this perspective, states with agricultural breakpoints around 2003 include Chandigarh, Chhattisgarh, Jharkhand, Karnataka, Kerala, Orissa, and Sikkim. Once again, results from Chandigarh and Delhi should be treated with caution. It's interesting to note that all states, excep Sikkim, with statistical significant agriculture breakpoints have at least one more significant breakpoint in a different component. This suggests that agriculture may have either been the originator or the receiver of an outsized effect from a structural break in other components.

Industry has fewer significant structural breakpoints in the first breakpoint series. Haryana and Delhi both experience statistically and economically significant breakpoints in the 1980s, but none afterwards. This suggests that Delhi and Haryana, among other states, may have benefitted from the government's 'piecemeal' approach to reform. Unsystematic reforms are likely to affect the industrial sector more than services since the latter requires wide-spread changes in the political and regulatory environment. The services component depends on the enforcement of private contracts, the stability of the policy environment, and the promotion of competition between private entities. More importantly, services are more dependent on Foreign Direct Investment (FDI) since technology transfers such as equipment, brand names, and professional management occur when foreign multinationals operate in developing countries. Since Indian industry is not producing 'cutting edge' products, technology transfers are less important. Therefore, piecemeal reforms in the 1980s would flow largely to industry, while systematic reforms in 1991 would flow more naturally towards services. This does not mean that industry did not, or should not be expected to, benefit from systematic reform. Indeed, the data show significant breakpoints in the industry component around 2003.

This trend is verified among most states, where structural breakpoints for the services component occur around the 1990s and around 2003. Several states such as Bihar, Delhi, Karnataka, and Orissa exhibit two structural breaks in services; the first occurs in the early 1990s and the second in the early 2000s. Perhaps services underwent two structural breaks. The first break occurred after the systemic reforms of 1991 and the second in 2003. The 2003 break may have been due to reforms undertaken by the government from 1999-2003. It's also possible that demand-side factors stimulated the growth in services around 2003. Regardless of which hypothesis is correct, the pattern among states clearly shows a trend towards two structural breakpoints in services (Fig 5.6)

The statistically and economically significant breaks among the key states seem to occur in industry and services. Within each group, industry seems to have breakpoints in the 1980s and, to a lesser extent, in the 2000s. Services has breakpoints throughout the 1990s and, to a greater extent, the 2000s. This difference is probably attributable to the nature of these components and their varying sensitivity to piecemeal and systematic reform. The cross sectional variation across states is probably attributable to their factor endowments in each component.

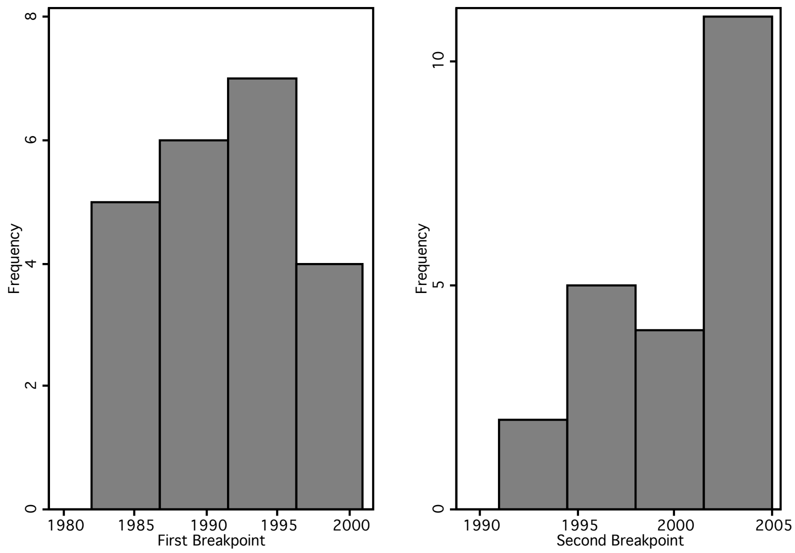

Figure 5.6: State-wise distribution of structural breaks in services

5.2 Regression Models

The regression models specified in 4.2 will be tested using national time series data and panel state data. The original intention was to test time series state-models with state-specific breakpoints as well, but unfortunately most states lacked sufficient degrees of freedom.

The results have been provided in Appendix B. All variables are in growth rates, except for rainfall, which is an index, and additive time dummy variables.

5.2.1 Components Model

This model seeks to identify outsized effects in a component of output on the remaining two components. These results should be viewed in conjunction with the structural break tests from the previous section. None of the three models suggest that multiplier effects among the components help explain structural breaks.

Model : Agriculture

Structural breaks in the growth rate of output are explained by the outsized effects of structural changes in agriculture output.

Results from this model suggest that the relationship between the outsized effects of agricultural output on non-agricultural output does not change significantly after structural breaks. The aggregate series of non agricultural output is itself only significant after the first break, i.e. after controlling for the effects of agricultural output. The smoothed data suggest a weakly significant relationship between the lagged effect of the growth rates of smoothed agricultural output on the growth rates of smoothed non agricultural output. However, the smoothed data series also has a highly significant lagged dependent variable with a coefficient of nearly one. In the smoothed regression, the explanatory variables – additive and multiplicative dummies – are not jointly significant. From this analysis, we can conclude that outsized agricultural effects on non agricultural output do not explain structural breaks in the growth rate of output.

At the state level, our panel model shows the same results, except the base level effect, i.e. the effect of agriculture on non agricultural output, is significant with a large positive coefficient of 0.23. However the lack of significance on the multiplicative dummies suggests that this parameter represents the stable relationship between the outsized effects of agriculture on non agricultural output throughout the time series. Among the component models, this model is perhaps the weakest. The specification does not account for the relationship between rainfall and agricultural output. However, removing rainfall from the regression does not change the results for state level data. The coefficient is still 0.23 and the variable remains significant at the 1 % level. The national time series model remains unchanged as well.

Model : Industry

Structural breaks in the growth rate of output are explained by the outsized effects of structural changes in industrial output.

Results from this model suggest that the outsized effects of industrial output on non industrial output are constant over time in the unfiltered series. The stable multiplier is estimated at 0.33 and is significant and the 10% level. In the filtered series, the data show a significant effect for the multiplicative dummies after allowing for a single lag. The contemporaneous effect in the first period is 0.33, while the lagged effect in the first period is -0.3123. The contemporaneous incremental jumps are not significant, but after allowing for lagged effects, the multiplicative dummies are significant. The coefficient on the change after the first break is 0.29 and is significant at 10%, while the second break is associated with a fall of 0.52 percentage points in the growth rate of non industrial output after 2003. According to this analysis, we find a weak and unstable relationship between industry and its outsized effect on non industrial output.

The state-level panel model shows a significant and economically sizable base level effect. Apart from the multiplicative dummy on lagged industrial output, none of the other explanatory variables are significant. Unlike the national series, non industrial output demonstrates significant breaks in the benchmark average growth rate after controlling for the outsized effect of industrial output. The breaks themselves are not economically significant since they only add roughly 0.04 percentage points to the benchmark growth rate. Thus, the state level data reaches the same conclusion as national level data that changes in the relationship between the outsized effects of industrial output on non industrial output do not help explain structural breaks.

Model : Services

Structural breaks in the growth rate of output are explained by the outsized effects of structural changes in services output.

The services model performs poorly as well; it indicates no structural change in the relationship between services and its outsized effects on non service output. These results are consistent in both filtered and unfiltered series. Despite the constant relationship, it's important to note that the stable outsized effect is statistically and economically significant. A percentage point increase in the growth rate of services increases the growth rate of non service output by 1.12 percentage points. This astonishingly large multiplier reveals, once again, the crucial role of services in the economy. The smoothed series only report a coefficient of 0.6, however this result is still relatively large. The panel model produces the same results and has a statistically and economically significant coefficient of 1.05. If this multiplier has been accurately estimated, then it suggests that the beneficial spillover effects from growth in services output are responsible for growth in industry and agriculture. The channel for this effect could be higher aggregate demand or increases in productivity since growth in most services can be considered as an improvement in technology or institutions as well.

5.2.2 Rainfall Model

This model seeks to understand the effect rainfall has on growth in output and how that relationship changes after each structural break. As mentioned earlier, one of the hypotheses explaining the relatively high growth rates of the 1980s in the absence of systematic reforms is more favorable monsoon seasons, especially relative to the previous two decades. The rainfall model allows to formally test whether structural breaks in this relationship exist.

Model : Rainfall

Structural breaks in the growth rate of output are explained by changes in how rainfall affects the economy

As argued by Virmani (2006), the relationship between rainfall and output growth is essentially stable across the entire time series. The effects are coincident, i.e. lagged values are not significant. Across the four measures of output, a one standard deviation increase in rainfall increases output by a stable effect of 0.015 to 0.016 percentage points, but at a decreasing rate, which is also a stable effect, at -0.008. These results seem intuitive since better than average rainfall will help agricultural productivity, but too much rainfall will harm agricultural productivity. The lack of structural breaks in this model may seem puzzling, given the Indian economy's steady reallocation from agriculture to industry and services. While this objection is valid, the net effect of rainfall on output is also a function of agricultural technology, i.e. irrigation facilities, crop rotation, and the use of fertilizers. It's plausible that changes in these factors have increased agricultural productivity, which has subsequently, led to larger changes in output from smaller changes in rainfall. Any diminishing effect that may arise from a farmer's ability to 'hedge' against rainfall are likely to be small since Indian agriculture is still largely dependent on a good monsoon season. These two opposing forces would generate a stable relationship between rainfall and its effect on the growth rate of output, which increases at a decreasing rate.

Results from the HP filtered series for this model must be treated cautiously since it's unclear if the filter has already factored out 'rainfall shocks' from the series.

The state-level panel model produces strikingly different results. The relationship between rainfall and growth is no longer stable, i.e. structural breaks are partly explained by changes in the relationship between rainfall and output. According to this view, rainfall is decreasing in its effect after each structural break. The findings are robust across different measures of output.

5.2.3 Public Investment

These models are only tested for national time series data due to issues with the state-level series. The purpose of these models is to understand the importance of investment and its effect on output growth after each structural break. We first test the model for public investment and then for total investment.

Model : Public Investment

Structural breaks in the growth rate of output are explained by changes in public investment during these periods.

The results demonstrate a stable relationship between the lagged growth rate of public investment and the growth rate of output. The statistically significant relationship is not present in the smoothed series. The unfiltered series show that a percentage point increase in public investment causes a decrease in the growth rate of output by 0.082 percentage points after a lag of one period. The fact that this relationship is stable also demonstrates that, according to the model, public investment was not associated with structural breaks in output growth.

Notes

[1]The 'Father of India's Green Revolution' is said to be Norman Borlaug

SECTION 6

Robustness & Limitations

This section will discuss the robustness of empirical results from the previous section and limitations of the methods employed in this paper. There are no explicit tests for robustness that check for violations of standard ordinary least squares assumptions. This is partly due to the fact that all data series except rainfall are used as growth rates. More importantly, the structural break tests employed in this paper are already testing for the stationarity of the series in the presence of structural breaks.

6.1 Data

Data related issues in this particular study, and on any empirical analysis of India generally, are tremendous. Their presentation and structure place some limitations on any conclusions that are drawn from this analysis. Most of these issues have been adequately dealt with, however issues related to state-level data are especially relevant. Overall, the data issues discussed in this section do not invalidate or diminish the results from this study. Nor do they limit the potential for future research in this area as government and non-government entities are making a concerted effort at improving data collection methods and increasing data availability for national and state-level series. One instance of this trend is the availability and general reliability of data in user-friendly and downloadable formats from the Reserve Bank of India online data warehouse. The Ministry of Statistics and Programme Implementation has also made improvements by regularly updating its newly launched website with CSO and ASI data. Finally, state governments have become increasingly proactive in uploading detailed, state-specific data series through the relevant state ministry or governing body. Among all these groups, there is a commitment to not only improve current and future data collection and processing, but to also recreate past data and provide a complete time series. These 'back-series' have been immensely useful in this study. All of these trends are promising and will diminish the importance of any data related issues in research on India.

6.1.1 General Data Issues

The CSO has presided over multiple changes in methodology since 1950. Each change in methodology is accompanied by a comprehensive and lengthy CSO report on the exact modifications and a comparison of the old and the new series. Most of these changes correspond at the state-level as well. The key points in methodology changes are 1980, 1993, 1999, 2003, and minor changes afterwards as well. For most of the key aggregate series, such as output and components of output, the CSO/RBI have created a complete time series at constant prices that adjusts for all methodology changes. However, for many other data series, the CSO would divide the complete time series by methodology, while providing overlapping years. For instance, the savings and capital formation series were provided in two methodological divisions: 1980 series and prices, and 1999 series and prices. The two series would overlap for at least one year, which would allow us to calculate 'exchange rates' from the 1980 series to the 1999 series. This approach affords the CSO some flexibility in uploading the full time series without making adjustments that are presumably difficult to reconcile. They allow researchers to adjust at their own discretion. For some data series, the data included all 4 methodologies. While the overlapping years made the process simple, there are probably 'errors' in the dataset. The 'exchange rate' between two different methodologies would invariably combine actual changes in measurement with changes in the base year for calculating inflation. The implications of this bias in the data are discussed in following sections.

Bosworth et al. (2007) discuss the inaccuracy of Indian data series in the presence of a large unorganized private sector that operates outside standard reporting programs, and their reliance on quinquennial surveys of households and small enterprises. They show how the outdated distinction between the organized and unorganized sectors of the economy leads to the actual output measures only capturing a portion of India's actual economic activity. Most of the inaccuracies and biases in data collection and measurement seem to be associated with survey and employment data. Aggregate measures of output and their components are fairly precise.

6.1.2 State-Level Series

The limitations discussed in the previous subsection concerning changes in methodology are especially pertinent to state-level data. The CSO has only created back-series that make the relevant adjustments for changes in measurement for Net Domestic Product and Net Domestic Product per capita. The structural breakpoints have been calculated from this single and complete time series that begins in 1970. For all other series, the CSO has provided a disclaimer that researchers must be aware that cross-state comparisons are not recommended due to differences in measurements across states.

The remaining measures of output and its components have been compiled by combining data series from three different methodologies. The data at the state level for subcomponents of output underwent substantial changes in methodology. For instance, several subcomponent data series are missing from earlier periods. As a result, state subcomponents have not been used in either structural break analysis or regression models. The CSO has partially corrected the situation by gradually updating the back series, or at least limiting the number of methodologies in the full time series from three to two.

Theoretically, it should be possible to gain an approximation of the raw price-level change and methodology change between two series by consulting the relevant CSO report. Some series would have no measurement change, but would still show a difference, which is due to shifting the base year. We can take this as the true 'exchange rate' and ensure that we are not confusing constant prices with methodology changes. However, one can reasonably expect that over time, the CSO will make series-wise adjustments to eventually create a full time series data.

At each stage of this study, the results from state-series have been compared with national series, which are available as a time series in one methodology. The similarity between these two series in various break tests and regressions models suggests that the bias in our state data is not substantial, i.e. our results are not greatly distorted.

6.1.3 Rainfall

Section 3 discussed the construction of the rainfall index. Unlike the index suggested by Bhalla (2010), our rainfall index does not emphasize or limit itself to the monsoon season, which Bhalla defines as June to September. There is some loss in precision from both methods. An extensive knowledge of agriculture and India's monsoon is required to find the rainfall index that captures intra-year and inter-year variations best. Bhalla's method does not have a substantial agricultural or meteorological basis. With the absence of such expertise or consensus, an average of all months in the calendar was found preferable for this study.

Despite this relevant discussion of rainfall indices, it must be noted that our results do not differ considerably from Bhalla (2010); Virmani (2009). Thus the results are not very sensitive to the composition of the rainfall index. For state level data, the rainfall index may perform less optimally, since intra-year distributions may matter more for individual states.

6.2 Filtering Techniques

The correct use of the Hodrick Prescott Filter requires the appropriate smoothing parameter to be applied. As mentioned earlier, Ravn and Uhlig (2002) recommend 1600 for quarterly data and 6.25 for annual data. Other studies that use the HP filter have not specified their smoothing parameter, but most seem to have used 6.25 since their trended series are similar to this study's trended series. The HP filter was not applied to any state-level data since most of the series had fewer than 27 observations. Virmani (2009) reached the same conclusion after applying the HP filter to the national series, which begins in 1950. Even if the HP filtered was applied to state-level data, the changes in methodology would further complicate our interpretation of the trended series.

More generally, the HP filter has been shown to incorrectly identify or find trends when there are none. Schlicht (2008) uses times series with known structural breakpoints to show the the misidentification of trends by the HP filter.

Finally, (Aguiar and Gopinath, 2007) show that trend extraction is complicated and may lead to erroneous results when applied to developing countries because of frequent shocks to the trend itself.

6.3 Structural Breaks Tests

The use of the CMR and PV tests for unit root with single/double mean shifts has been justified in section 4. The methodological changes in the data may lead to a bias towards identifying structural breaks at points where a new measurement regime is introduced. The structural break tests are trying to find a shift in the mean after an outlier in the series. Any methodology change could potentially create an artificial mean shift. The coincidence of methodological changes and structural breakpoints may suggest that this bias exists and has distorted the data. However, the methodological changes have been diluted substantially by converting all previous measurement regimes through the calculated 'exchange rate.' This procedure limits the size of any potential mean shift. It's possible that the AO model may be more prone to incorrectly identifying a methodological change as a structural break. This is because the AO model looks for a single outlier and not a persistent effect. Methodological changes are more likely to produce a single outlier over a persistent mean shift after we have manually made the appropriate adjustments. Since this study only uses the IO model, we may have considerably reduced the potential for any distortion of this nature. Furthermore, the use of growth rates instead of levels reduces this distortion as well.

Finally, structural break test results are consistent for national and state-level series. This means that our test identifies the same breakpoints with data that only contain a single methodology and data that contain multiple methodologies.

The empirical analysis of this study did not discuss the stationarity of series from the structural break tests. This is partly because the non-stationarity has no practical implications for the purpose of this study. The presence of unit root after accounting for structural breaks would pose severe restrictions on forecasting, but the position of breakpoints is not substantially biased. In our empirical analysis, data series on output and its components were stationary, while very few subcomponents were non-stationary.

6.4 Regression Models

As mentioned in the earlier section, the regression models used in this study force a linear relationship with only a single lag. While the single lag is justifiable by the AIC criterion, which recommended an optimal lag order of one for all series, the linear relationship may be inappropriate for certain relationships. In particular, the components model is probably better served by a more complicated model since the channels through which components of output may have multiplier effects on each other are numerous and are unlikely to be coincident. However, this type of model will have to deal with a potential endogeneity problem, where a virtuous feedback loop between two or more components will require techniques such as 2SLS.

The time series models for state-level data would have been useful in understanding structural breaks. Unlike the panel model, the time series models were designed to use state-specific breakpoints to understand the stability of key relationships. Due to insufficient degrees of freedom, this model was dropped from the analysis.

SECTION 7

Conclusion

The purpose of this paper was to find and analyze structural breaks in the growth rates of key national and state series by using unit root tests. These structural break test results were then used to specify breakpoints in regression models that were informed by the secondary literature. The combination of these two methods allowed us to study structural breaks in a univariate and multivariate manner. The inclusion of state level data added another useful dimension to this study as we could dissect the widely cited aggregate national relationships and breakpoints into their state level equivalents.

Structural breakpoint analysis found statistically significant breaks in the growth rate of Indian Gross Domestic Product at Factor Costs occur in 1982 and 2003. Among the components of output, services seem to have statistically and economically significant breakpoints that coincide with the first aggregate breakpoint. Within services, the subcomponent "Finance, Insurance, Real Estate, and Business Services" coincides almost perfectly with both national breakpoints. The component 'Industry' does not have a statistically significant breakpoint that coincides with the first aggregate breakpoint, however its second breakpoint is in 2004. Its subcomponent "Manufacturing" coincides more than other subcomponents. Similar patterns emerge for breakpoints at the state level. The component-wise study of breakpoints for selected states reveals a clustering of Industry breakpoints throughout the 1980s and 1990s, and a similar clustering for Services in the 2000s. It's suggested that this pattern is a function of the piecemeal reforms of the 1980s, which benefit Industry more, and the systemic reforms of the 1990s, which favor services. The same analysis also shows the presence of two structural breaks in services among the key states; the first is around 1990 and the second is around 2003. Regression models show stable relationships between components of output and their outsized effects, rainfall, and public investment. The stability in these parameters suggest that structural breaks must be explained from other sources. Our structural break tests suggest useful starting points for analysis.

While the Indian growth puzzle remains unsolved, it does not seem unsolvable after we decompose it into components and subcomponents of output and growth at the state level. The structural break tests provide only weak evidence regarding the 1991 reforms. The ultimate cause of the 2003 growth spike is still a mystery. However, our structural break tests have suggested that growth in Finance, Insurance, Real Estate, and Business Services are relevant. These industries may be the beneficiaries of growth as demand for their services increases with rising profits; or they produce a supply-side effect by improving the quality of underlying institutions, which would improve productivity.

Further study should rationalize the estimation of structural breaks by using techniques that endogenously 'give' us the breakpoint. Structural breakpoint analysis should also be expanded to more subcomponents of output, as well as other industry-specific series. The model specified in 4.3 is not specific to the explanatory variables used in this paper; it can be expanded to other determinants as well.

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APPENDIX A

Tables and Figures Describing the Data

A.1 India's growth experience

A.1.1 Growth trend since 1950

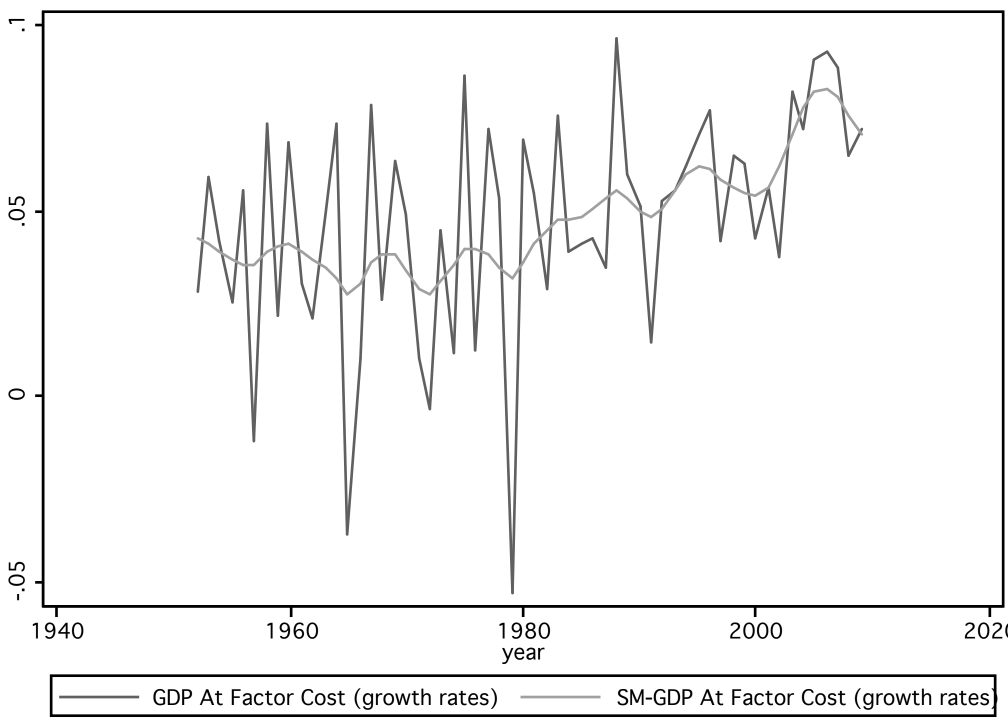

Figure A.1: Economic growth in India since 1950

A.1.2 Average growth in three periods

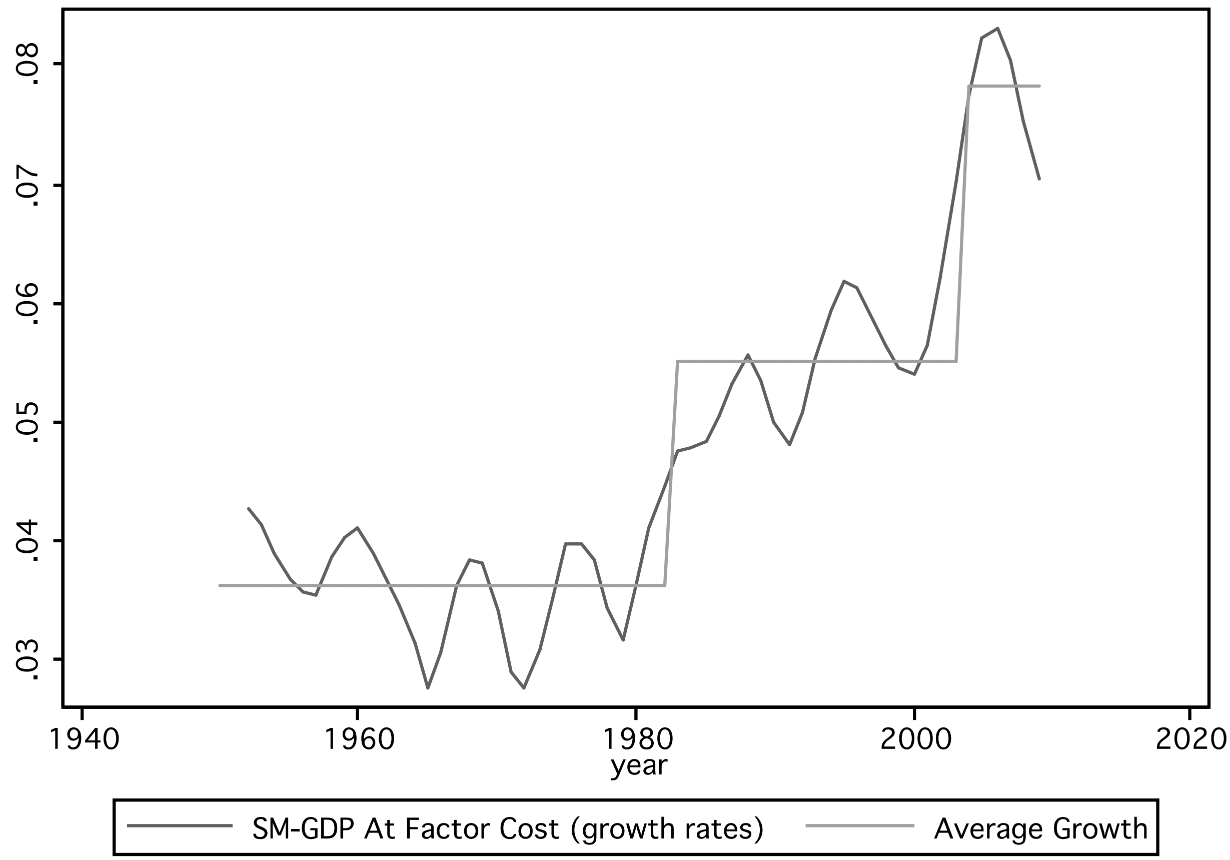

Figure A.2: Average Growth in three periods

A.2 Summary statistics for states

Table A.1: Summary statistics for states

State	GDP	GDPCapita	Population	ShareofIndustry	ShareofServices	ShareofAgri
Andaman & Nicobar Islands	936.85	26465	354	0.116198	0.557763	0.326039
Andhra Pradesh	139312	18320	76045	0.226146	0.472279	0.301575
Arunachal Pradesh	1725.86	15819	1085	0.356909	0.0004	0.642691
Assam	35715	13545	26368	0.180023	0.481165	0.338813
Bihar	58222.6	7111	81873	0.106933	0.505016	0.388051
Chhattisgarh	25840.4	12483	20700	0.377667	0.423526	0.198807
Delhi	57604.7	42220	13584	0.193354	0.793211	0.013436
Goa	6093.05	44934	1356	0.419768	0.47016	0.110071
Gujarat	104494	20827	50172	0.402798	0.447327	0.149875
Haryana	55565.3	26562	20919	0.279364	0.417048	0.303589
Himachal Pradesh	15004.2	24690	6077	0.365902	0.386173	0.247924
Jammu & Kashmir	16213	16145	10042	0.232948	0.466065	0.300987
Jharkhand	30941.1	11581	26717	0.405671	0.418811	0.175518
Karnataka	102687	19551	52521	0.2416	0.47586	0.282539
Kerala	71608.9	22549	31699	0.210081	0.569961	0.219958
Madhya Pradesh	74581.6	12459	59864	0.25786	0.506461	0.235679
Maharashtra	242615	25228	96168	0.275733	0.571266	0.153001
Meghalaya	3773.37	16442	2295	0.509788	0.000479	0.489733
Mizoram	1627.18	18508	8792	0.165218	0.635861	0.198921
Nagaland	3267.04	16806	1944	0.131504	0.553859	0.314636
Orissa	42272.7	11543	36622	0.245044	0.46699	0.287965
Punjab	69803.1	28714	24310	0.231347	0.402384	0.36627
Rajasthan	81059.6	14504	55889	0.277859	0.43792	0.284222
Sikkim	963.88	18118	532	0.231834	0.55178	0.216386
Tamil Nadu	142065	22846	62183	0.304547	0.528309	0.167144
Uttar Pradesh	178997	10874	165	0.226979	0.434116	0.338905
Uttarakhand	14141	16783	8426	0.2249	0.499603	0.275497
West Bengal	140574	17607	79840	0.181553	0.528195	0.290252

A.3 Components of Output

The components of output, as currently calculated by the CSO, for both national and state series are as follows:

1. Agriculture & Allied Activities (Primary)
    - Agriculture
    - Forestry & Logging
    - Fishing
2. Industry (Secondary)
    - Mining & Quarrying
    - Manufacturing
    - Electricity, Gas, & Water Supply
    - Construction
3. Services (Tertiary)
    - Transport, Storage, & Communication
        - Railways
        - Transport by other means
        - Storage
        - Communication
    - Trade, Hotels, & Restaurants
        - Trade
        - Hotels & Restaurants

- Financing, Insurance, Real Estate & Business Services
  - Banking & Insurance
  - Real Estate, Ownership of Dwellling
- Community, Social, & Personal Services
  - Public Administration & Defense
  - Other Services

APPENDIX B

Tables and Figures from Empirical Analysis

In all the following tables, D1 refers the first dummy variables. D2 refers to the second dummy variable. 'L' is used to denote a lagged effect, and sm indicates filtered/smoothed series.

Table B.1: Component Model-Agriculture: National Series (Full)

	(1) g_NagGDP b	(2) g_sm_NagGDP b
g_agralliedactivites	0.1280	
L.g_agralliedactivites	0.0298	
D1g_agralliedactivites	-0.0978	
D2g_agralliedactivites	0.7288	
D1Lg_agralliedactivites	-0.0020	
D2Lg_agralliedactivites	0.3606	
D1	0.0144*	0.0155**
D2	-0.0209	-0.0013
c_annualaverage	0.0017	0.0005
L.c_annualaverage	0.0011	0.0004
csq_annualaverage	-0.0006	0.0001
L.csq_annualaverage	-0.0014	0.0001
L.g_NagGDP	0.2747	
gsm_agralliedactivites		0.2490
L.gsm_agralliedactivites		-0.0392
D1gsm_agralliedactivites		0.0205
D2gsm_agralliedactivites		1.0750
D1Lgsm_agralliedactivites		-0.5148*
D2Lgsm_agralliedactivites		-1.0267
L.g_sm_NagGDP		0.9410***
_cons	0.0338***	-0.0019
N	56.0000	56.0000
r2	0.6152	0.9715

Table B.2: Component Model-Industry: National Series (Full)

	(1) g_NinGDP b	(2) g_sm_NinGDP b
g_industry	0.3355*	
L.g_industry	-0.1946	
D1g_industry	-0.2350	
D2g_industry	0.0208	
D1Lg_industry	0.1871	
D2Lg_industry	-0.0333	
D1	0.0266	-0.0073
D2	0.0300	0.0070
c_annualaverage	0.0122***	-0.0008*
L.c_annualaverage	-0.0052	-0.0013***
csq_annualaverage	-0.0073***	-0.0001
L.csq_annualaverage	-0.0049*	0.0004
L.g_NinGDP	-0.4097**	
gsm_industry		0.3290***
L.gsm_industry		-0.3123***
D1gsm_industry		-0.1626
D2gsm_industry		0.3898
D1Lgsm_industry		0.2973*
D2Lgsm_industry		-0.5232**
L.g_sm_NinGDP		1.0004***
_cons	0.0548***	-0.0009
N	56.0000	56.0000
r2	0.7418	0.9868

Table B.3: Component Model-Services: National Series (Full)

	(1) g_NsGDP b	(2) g_sm_NsGDP b
g_services	1.1226*	
L.g_services	-0.6236	
D1g_services	-1.2761	
D2g_services	1.1488	
D1Lg_services	0.6333	
D2Lg_services	0.6539	
D1	0.0431	0.0087
D2	-0.1593	-0.0241
c_annualaverage	0.0175***	-0.0010*
L.c_annualaverage	-0.0095	-0.0021***
csq_annualaverage	-0.0083*	-0.0001
L.csq_annualaverage	0.0001	0.0006
L.g_NsGDP	-0.1363	
gsm_services		0.6268**
L.gsm_services		-0.5357*
D1gsm_services		-0.2361
D2gsm_services		0.4668
D1Lgsm_services		0.0884
D2Lgsm_services		-0.1415
L.g_sm_NsGDP		0.8802***
_cons	0.0210	-0.0015
N	56.0000	56.0000
r2	0.6610	0.9336

Table B.4: Rainfall Model (Original)- National Series

	(1)	(2)	(3)	(4)	(5)	(6)
	g_gdpatfactorcost	g_gdpatfcpercap	g_gdpatmarketprices	g_gdpatmppercap	g_GDP	g_GDPcapita
	b	b	b	b	b	b
c_annualaverage	0.0155***	0.0161***	0.0153***	0.0159***	0.1597*	0.1755*
L.c_annualaverage	-0.0030	-0.0028	-0.0015	-0.0013	0.0508	0.0482
csq_annualaverage	-0.0077**	-0.0078**	-0.0077**	-0.0078**	0.0665	0.0756
L.csq_annualaverage	-0.0048	-0.0047	-0.0055*	-0.0055*	0.0751*	0.0749*
D1c_annualaverage	-0.0057	-0.0068	-0.0071	-0.0081	-0.1422*	-0.1582*
D1Lc_annualaverage	-0.0006	-0.0009	-0.0028	-0.0031	-0.0567	-0.0551
D2c_annualaverage	-0.0209	-0.0187	-0.0262	-0.0242	-0.0194**	-0.0199**
D2Lc_annualaverage	-0.0750	-0.0718	-0.1079	-0.1050	0.0065	0.0070
D1csq_annualaverage	0.0016	0.0023	0.0013	0.0021	-0.0712	-0.0804
D1Lcsq_annualaverage	0.0041	0.0049	0.0040	0.0048	-0.0745*	-0.0743*
D2csq_annualaverage	-0.1783	-0.1739	-0.2268	-0.2232	0.0125**	0.0139**
D2Lcsq_annualaverage	-0.1640	-0.1612	-0.2290	-0.2270	0.0142**	0.0161**
L.g_gdpatfactorcost	-0.3270*					
D1	0.0154	0.0157	0.0123	0.0127		
D2	0.1416	0.1461	0.1763	0.1811		
L.g_gdpatfcpercap		-0.3129*				
L.g_gdpatmarketprices			-0.2790			
L.g_gdpatmppercap				-0.2673		
L.g_GDP					-0.3179***	
L.g_GDPcapita						-0.2971***
_cons	0.0634***	0.0349***	0.0640***	0.0365***	0.0760***	0.0495***
N	56.0000	56.0000	56.0000	56.0000	568.0000	568.0000
r2	0.6839	0.6902	0.6684	0.6772	0.2332	0.2279

Table B.5: Rainfall Model (Smoothed)- National Series

	(1) gsm_gdpatfactorcost b	(2) gsm_gdpatfcpercap b	(3) gsm_gdpatmarketprices b	(4) gsm_gdpatmppercap b	(5) gsm_GDP b	(6) gsm_GDPcapita b
c_annualaverage	-0.0004	-0.0004	-0.0001	-0.0002	0.0143*	0.0111
L.c_annualaverage	-0.0012*	-0.0013*	-0.0009	-0.0010	-0.0033	-0.0028
csq_annualaverage	-0.0002	-0.0003	-0.0004	-0.0004	0.0086*	0.0067
L.csq_annualaverage	0.0003	0.0003	0.0002	0.0001	-0.0017	-0.0016
D1c_annualaverage	-0.0003	-0.0002	-0.0005	-0.0004	-0.0147*	-0.0116
D1Lc_annualaverage	-0.0004	-0.0003	-0.0005	-0.0004	0.0016	0.0010
D2c_annualaverage	-0.0104*	-0.0102	-0.0106	-0.0104	-0.0011	-0.0012
D2Lc_annualaverage	-0.0178	-0.0171	-0.0180	-0.0169	0.0008	0.0007
D1csq_annualaverage	0.0007	0.0008	0.0008	0.0009	-0.0086*	-0.0067
D1Lcsq_annualaverage	0.0009	0.0010	0.0011	0.0012	0.0020	0.0019
D2csq_annualaverage	-0.0358	-0.0342	-0.0355	-0.0330	0.0006	0.0007
D2Lcsq_annualaverage	-0.0283	-0.0269	-0.0286	-0.0264	0.0001	0.0003
L.gsm_gdpatfactorcost	0.9893***					
D1	-0.0005	-0.0009	0.0003	-0.0004		
D2	0.0238	0.0226	0.0248	0.0229		
L.gsm_gdpatfcpercap		1.0191***				
L.gsm_gdpatmarketprices			0.9222***			
L.gsm_gdpatmppercap				0.9712***		
L.gsm_GDP					0.9202***	
L.gsm_GDPcapita						0.9375***
_cons	0.0004	-0.0001	0.0032	0.0009	0.0055***	0.0037***
N	56.0000	56.0000	56.0000	56.0000	568.0000	568.0000
r2	0.9742	0.9797	0.9655	0.9730	0.8687	0.8897

Table B.6: Investment Model-Public: National Series (Full)

	(1) g_gdpatfactorcost b	(2) gsm_gdpatfactorcost b	(3) g_gdpatfcpercap b	(4) gsm_gdpatfcpercap b
g_cfpublicsector	-0.0170		-0.0169	
L.g_cfpublicsector	-0.0824**		-0.0821**	
D1g_cfpublicsector	0.0378		0.0325	
D1Lg_cfpublicsector	0.0923		0.0915	
D2g_cfpublicsector	0.1049		0.1229	
D2Lg_cfpublicsector	0.0554		0.0719	
L.g_gdpatfactorcost	-0.2489			
c_annualaverage	0.0145***	-0.0004	0.0147***	-0.0004
L.c_annualaverage	-0.0030	-0.0012**	-0.0037	-0.0013**
csq_annualaverage	-0.0066**	-0.0002	-0.0067**	-0.0002
L.csq_annualaverage	-0.0043	0.0003	-0.0039	0.0003
gsm_cfpublicsector		0.0032		0.0079
L.gsm_cfpublicsector		-0.0044		-0.0072
D1gsm_cfpublicsector		0.0510		0.0498
D1Lgsm_cfpublicsector		-0.0191		-0.0191
D2gsm_cfpublicsector		0.1623		0.1541
D2Lgsm_cfpublicsector		-0.1789*		-0.1708
L.gsm_gdpatfactorcost		0.9844***		
L.g_gdpatfcpercap			-0.1975	
L.gsm_gdpatfcpercap				1.0024***
_cons	0.0716***	0.0006	0.0442***	-0.0000
N	56.0000	56.0000	56.0000	56.0000
r2	0.6565	0.9735	0.6442	0.9792