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EFFECT OF CLIMATE CHANGE ON ECONOMIC GROWTH OF INDIAN STATES

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Asia is one of the top most vulnerable regions to climate change on the planet and India being an Asian country is home to an extraordinary variety of climatic regions. With India being the second most populated country in the world, this phenomenon presents serious concerns for policymakers in the region given the increasing intensity of hotter temperatures every year. The present study analyses the impact of climate change on economic growth of 13 major states of India over a period of 23 years from 1980-81 to 2002-03 by incorporating temperature and precipitation as proxies for climate change.

1. INTRODUCTION

Climate conditions play a very important role in functioning of the agricultural systems in India. Indian states have gone through major climate shocks like temperature and rainfall largely different from normal levels and these have impacted agricultural, manufacturing and other sectors' productivity. Researchers at IITM, Pune have told that "the annual mean, maximum and minimum temperatures over India showed a significant increasing trend of 0.6 degrees Celsius, 1.0 degrees C and 0.18 degrees C per 100 years, in analysis of data from 1901 to 2010." But when they analysed the period 1981 to 2010

– they concluded that the largest rise was in the minimum temperature that means weather has become hotter. Similarly India faces a major risk of drought for crop yield in the future as told my researchers. This risk in India is majorly because of irregular and varied monsoon rains, depleted groundwater, and the burden of food demand from a huge population of 1.252 billion. Similarly for 1951-2011, statistical analyses of precipitation, researchers have shown "statistically significant decreases in peak-season precipitation over the core monsoon region have co-occurred with statistically significant increases in daily-scale precipitation variability."

The impacts of temperature change on people are not evenly distributed. The poorest states of India are more affected by fluctuations in temperature than richer states. In poor states, a high proportion of the population is affected by sectors like agriculture where climate has an important contribution and there is very limited scope to develop and implement mitigation strategies. The rich states are expected to bear no significant impact of temperature change on economic growth because of their ability to develop and adopt better technologies and strategies.

In this paper, we check for the effects of climate change on **Economic Growth i.e Per Capita GDP Growth Rate**. We checked for which sector of economy if most affected by temperature change, i.e. impact of climate change on the main sectors of economy such as **Agriculture, Manufacturing and Services.**

Also, we construct past mean temperature deviations and annual precipitation data for each state and year in India from 1980 to 2003. The main strategy uses year-to-year deviations in temperature from mean temperature of each state and annual precipitation within states to estimate the impact of year to year fluctuations in temperature andprecipitation on per capita economic growth.

The rest of the paper is as follows: First section gives a brief introduction of past trends in climate, section II describes a review of the literature and presents earlier work done in the same area and what results they have obtained. In section III, the sources of the data and a brief analysis of the data have been presented. Section IV includes the detailed methodology that we will adopt for the analysis. Section V is devoted to a description of the estimation results and insights drawn and section VI concludes our analysis in which some policy implications are also presented.

2. LITERATURE REVIEW

To Climate Change is of utmost importance for the World Economy. However, there's presence of basic and fundamental challenges in terms of complexity, i.e. the procedure through which climate change may affect economic outcomes, both upwards and downwards, in studying and analysing the economic effects of climate change.

The paper by **Melissa Dell, Benjamin F. Jones** and **Benjamin A. Olken** titled, "**Climate Change and Economic Growth: Evidence from the Last Half Century**", identifies different mechanisms one at a time and studies the effects of temperature and precipitation data for the world and each of the countries from 1950 to 2003 and then compares it with historical growth data. They also study the already present relationship between climate fluctuations and economic growth. Their results suggest that there are substantial effects of climate change, but only in poor countries. In poor countries, a one degree Celsius rise in temperature in a given year reduces economic growth by 1.1 percentage points on average. They also say that climate change probably affects the rate of economic growth rather than just the level of output. Larger estimates are produced using the analysis from the overall change in climate from 1970 to 2000, suggesting that in the medium term, adaptation may not be able to reverse these effects. It is also found that high temperatures in poor countries not only reduce agricultural output, but also decrease industrial output and aggregate investment and leads to an increase in political instability. They conclude by saying that income gaps between rich and poor countries might widen substantially, with poor countries dragged towards greater poverty, other things equal. While going through the paper titled, "**Cross-Country Variability in Impact of Climate Change on Total Factor Productivity**" authored by **Surender Kumar** and **Madhu Khanna**, we read about the effects of climate change induced changes in precipitation and temperature on economic output which had been done by estimating country specific measures of Total Factor Productivity (TFP) using a one-step stochastic frontier approach with panel data for 121 countries for the period 1960- 2010. Stochastic production frontier specifies maximal output as a function of factor inputs plus a random (normal) error, and then actual output equals maximal output minus a one-sided error term whose distribution depends on temperature. The one- sided error term is termed as a measure of production inefficiency or the opposite of TFP. They examine both short run as well as long run effects of changes in temperature on TFP growth and uncertainty. They find that an increase in temperature by one degree Celsius reduces average TFP while increases the uncertainty of TFP levels; these effects are larger for poor countries relative to rich countries. The marginal effects of an increase in temperature differ widely across countries. At the margin they find that a one degree Celsius increase in temperature is beneficial for countries located in cold or very cold temperature zones but it is harmful for countries located in hot or very hot temperature zones. They also find that the adverse effects of climate change are largely due to changes in temperature and that the effect of changesin precipitation on TFP is not statistically significant for both rich and poor countries.

In the paper by **Minsoo Lee, Mai Lin Villaruel**and **Raymond Gaspar**, titled "**Effects of Temperature Shocks on Economic Growth and Welfare in Asia**", they have used the Burke, Hsiang and Miguel framework to study the effects of temperature and precipitation fluctuations on economic growth. Their results suggest that compared to BAU (Business as usual) scenario, the economic productivity of developing Asia would be 10% lower by 2100. Their predictions suggest that large, globally affecting macroeconomic impacts, moving beyond the agricultural sector could be the results of the 21st century warming. The average global per capita income is estimated to decrease by 4.4% by 2100. Also, average developing Asia per capita income is estimated to reduce by 10% by 2100 due to the projected higher temperature. They conclude by saying that there will be differential impacts on developing Asian sub regions based on differences in average temperature.

Qing Pei, David D Zhang, Guodong Li, Philippe Foretand **Harry F Lee** authored the paper titled, "**Temperature and Precipitation effects on agrarian economy in late imperial China**", where they analyse the climate change-economy relationship of late imperial China to that of early modern Europe. However, their study does not refute any existing theories on agrarian China within differentiated spatial and temporal genres. They find that vulnerabilities of one country or region may differ from the vulnerabilities of another country or region. They also say that the vulnerabilities are aggravated by increasing population size as they hamper the economic growth potential. They conclude by saying that for late imperial China and other similar countries, the burden on the society will be increased by a large population size and so will the vulnerabilities of that economy to climate change due to the fact that socioeconomic vulnerabilities also need to be taken into account.

Another paper by **AyodeleOdusola**and **BabatundeAbidoye** titled "**Effects of Temperature and Rainfall Shocks on Economic Growth in Africa**", examines the impact of temperature and rainfall volatility on economic growth in 46 African countries by employing the Bayesian hierarchical modelling approach which allowed to estimate both country level and Africa-wide impact of climate change and extreme events on economic growth in Africa. The vulnerability of the African economy and key sectors driving economic performance to climate change is substantial. The impact of changes in temperature and rainfall on Africa's economy is considerably large. A one degree Celsius increase in temperature leads to 1.58 percentage points decline in economic growth while an unexpected one degree standard deviation from the average shock tends to generate 3.22 percentage points decline in GDP. On the other hand, a one percent change (rise/fall) in rainfall leads to 6.7 percent (increase/decrease) in economic growth. The authors finally conclude by saying that these developments make proactive management of climate change adaptation and the impact of climate change imperative in Africa.

3. DATA

Our data is a Panel Data consisting of 13 different states of India i.e. West Bengal, Assam, Karnataka, Tamil Nadu, Uttar Pradesh, Bihar, Haryana, Kerala, Andhra Pradesh, Arunachal Pradesh, Himachal Pradesh, Jammu and Kashmir and Gujarat, that have been picked up to cover the whole north, south, west and east India. These states are studied for 23 years i.e. from 1980-81 to 2002-03. The variables are: Population of states, State Gross Domestic Product (SGDP) that has been further classified into 3 components i.e. State Agricultural GDP, State Manufacturing GDP and State Services GDP. To study the effect of climate change on growth of economic output, the main two factors considered are the Mean temperature and Total precipitation of different states in each year. Apart from these, the other main factors that affect economic output are Population and Human Capital that is the pool of skilled individuals. A proxy for human capital that is the literacy rate of each state has been used.

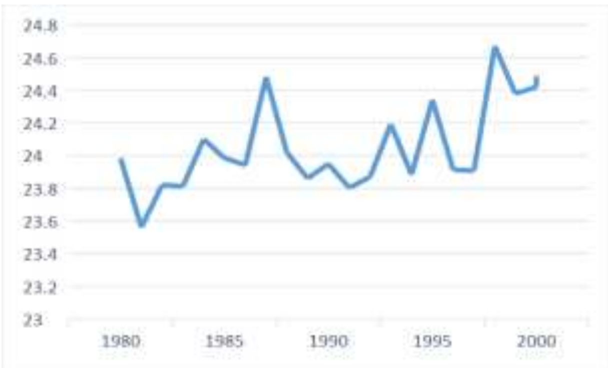
A brief description and details of the data used in this study are presented in the following table.

DATA	DATA SOURCE	COMMENT
Total State GDP	State Statistics,Niti Aayog	Total State Domestic Product atConstant Prices
Agricultural (Ag)	State Statistics,Niti Aayog	Agricultural State DomesticProduct
Manufacturing (Mn)	State Statistics,Niti Aayog	Manufacturing State DomesticProduct (Registered + Unregistered)
Services (Sr)	State Statistics,Niti Aayog	Services State Domestic Product(Transport, Storage& Communication + Banking & Insurance + Real Estate & business services)
Temperature	Meteorological Data,India Water Portal	Mean temperature for the year iscalculated by using the monthly data.
Precipitation	Meteorological Data,India Water Portal	Annual precipitation is calculated by using the monthlydata.
State Population	Census Data of India,State Statistics, Niti Aayog	Population of each year is calculated by using the base year population and increasing itby the compound growth rate ofpopulation of that state.
Human Capital	State Statistics, Niti Aayog	Proxy for human capital is Literacy rate
Labour Shares ineach sector	Census Data of India	Labor share in Agriculture,Manufacturing, Services

4. DESCRIPTIVE STATISTICS

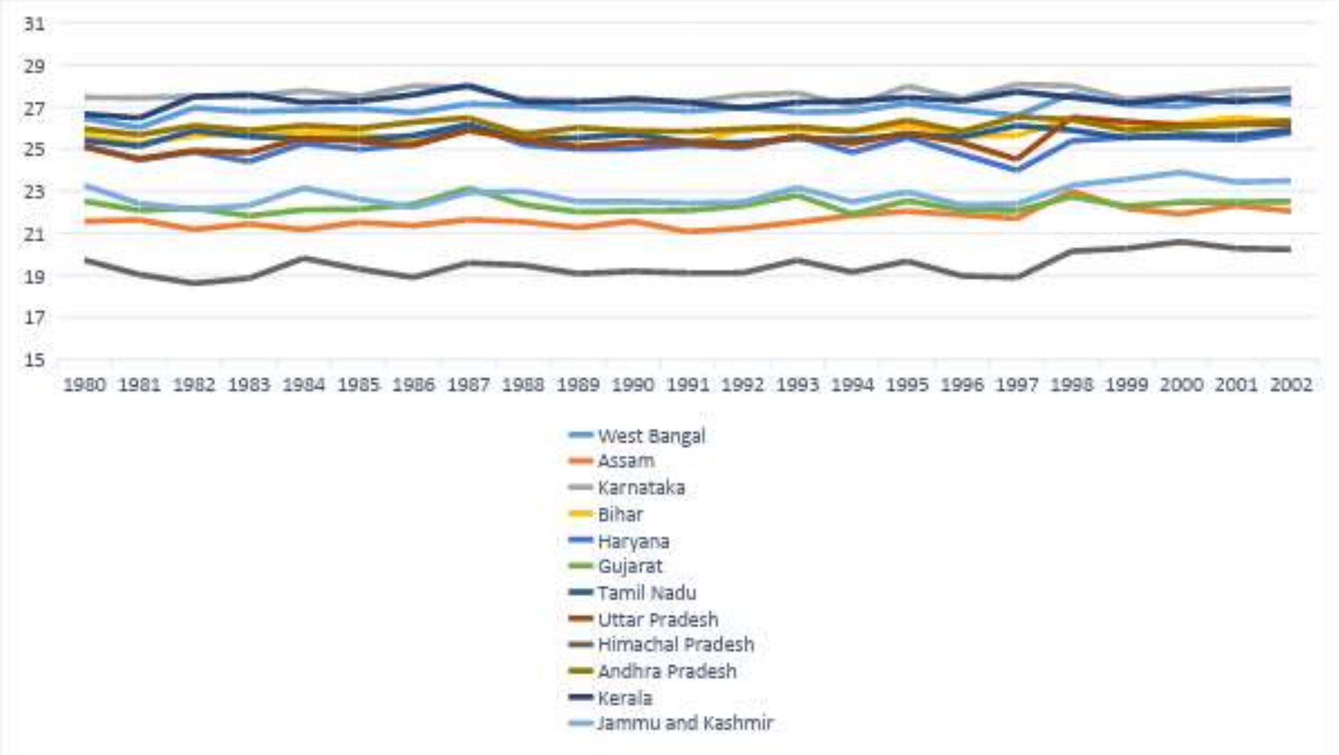
Figures 1 to 13 (Appendix) showcase the trend of mean annual temperature of the 13 chosen states that clearly depict that India was not left behind from the extreme-weather events that plagued the world. All the graphs show rising temperatures from 1980 to 2003 but there is a sudden increase in the mean annual temperature in the year following 1997. A large number of extreme climatic changes with immense amount of impacts on humans happened to occur in the same period and most of them were explained as the probable effects of the uncommonly strong El Niño of 1997-98 and the global greenhouse warming. El Nino is recurring, one-two punch to the global climate system that is driven by distinctive warming and later, cooling of surface waters in the tropical Pacific Ocean. The aforementioned years and the occurrence of the El Niño in the same are clearly depicted in all the graphs with a sudden and steep increase in mean annual temperature in all the selected states. The record-breaking and long-lasting El Niño of 1997-1998 began in April of the first year and continued until May of the next year. It almost certainly contributed in projecting 1998 as the world's warmest year on record.

Figure 1: Mean Annual Temperature of India



As it is evident from figure 1, there is a clear increase in the mean annual temperature, ranging from 23.982 degree Celsius to 24.488 degree Celsius from 1980 to 2003 which suggests that the states have become warmer by more than 0.5 degree Celsius.

Figure 15: Mean Annual Temperature



COMPARISON

Figure 15 compares the Mean Annual Temperature of the 13 states over the stipulated time frame. All the states clearly show increasing trends in the temperature, thus indicating the occurrence of gradual global warming and its repercussions. Karnataka and Kerala are shown to be the hottest states while Himachal Pradesh boasts of its cold temperature. But nevertheless, the temperatures of all the states have more or less similar within state variability which indicates that the effect of global warming and other climatic conditions have had similar effects of mostly all the states that have been selected for our study.

Figures 16 to 28 (Appendix) has proved that annual precipitation has shown an increase or decrease with well-marked differences at local, regional, and continental scales. Data depicts a decrease in the pre-monsoon rainfall over central India. Significant decreasing trend in monsoon rainfall have been found for Gujarat, Uttar Pradesh and Kerala; and an increasing trend in the Konkan region. The analysis indicates that there is a long-term fluctuation in rainfall of period 22 years—possibly linked to the double sunspot cycle that occurred during the same phase.

The graphs showcasing the annual rainfall of the selected states reveal that in 1981- 2011, the intensity of rainfall during wet spells was considerably higher than that in 1950-1980. Also, in 1981-2011, the frequency of dry spells became 27% more. Thus, we can say that there has been an increase in the intensity of wet spells and in the frequency of dry spells.

The graph shows a slow increase in the amount of total precipitation over the years. The annual rainfall has increased by about 600 cm. The increase in precipitation is well documented and is consistent with most climate models, which predict that global warming will come along with increased precipitation on average.

Figure 2: Total Annual Rainfall (India)

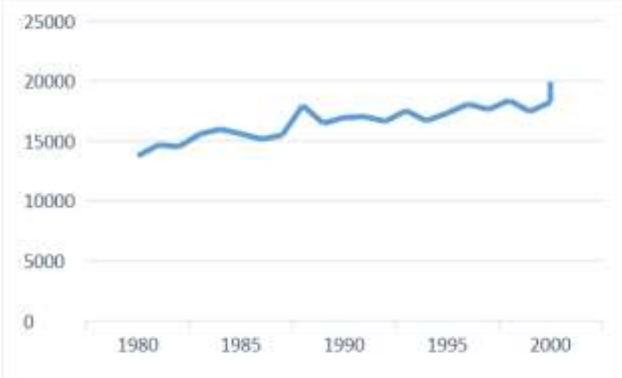


Figure 3: Annual Rainfall Comparison

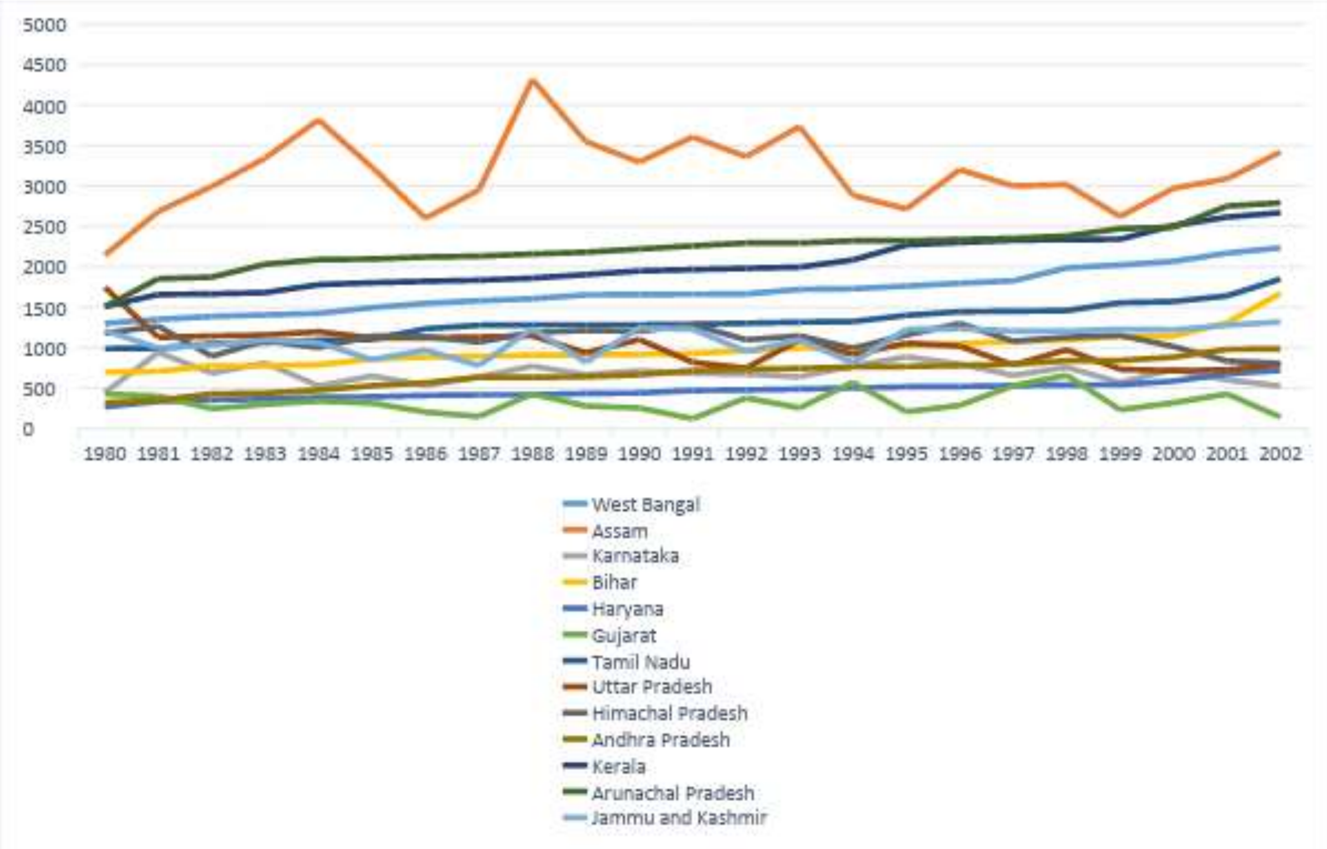


Figure 3 compares the Total Annual Rainfall of each year from 1980 to 2003 for the 13 states. While the state of Assam boasts of the highest rainfall (in mm), the state of Gujarat records the lowest during the same time frame. This is in consistent with the rainfall trend in the respective states. The within state variation is quite visible. This also is in line with the numerous recent floods that have occurred. The states of Arunachal Pradesh and West Bengal show smooth upward trend in rainfall while most other states have varying amounts over this span of 20 years.

5. METHODOLOGY

THEORETICAL MODEL

Dell, Jones and Olken (2008) incorporated the climatic variables in the production function of their model, which was used as the baseline for the present study. The model provided the theoretical basis for incorporating climate change into growth equations and the guidelines for decomposition of the impacts of changes in weather on economic growth.

Consider the production function.

$$Y_{it} = e^{\alpha T_{it}} A_{it} L_{it} K_{it} \tag{1}$$

Where Y is GDP, L is labour force, A is technology and can be referred to as labour productivity, T is the impacts of climate and K is human capital.

$$\frac{\Delta A_{it}}{A_{it}} = g_i + \beta T_{it} \tag{2}$$

Where g_i is the growth rate of GDP.

The direct effects of climate variation on GDP growth rate are captured by Equation (1), such as impacts on labour productivity. Equation (2) captures the indirect (dynamic) effect of climate change, such as the impact of climate on variables that indirectly influence GDP growth. Notably, equation (1) directly relates climate change to GDP whereas in equation (2), climate changes affect labour productivity, which will, in turn, affect GDP growth.

After taking logs of equation (1) and differencing with respect to time, the following equation can be derived.

$$g_{it} = g_i + (\alpha + \beta)T_{it} - \alpha T_{it-1} \tag{3}$$

The above equation separately examines the direct and indirect impact of climate change on growth. Where git is the growth rate of per capita output, direct effects of climate variation on GDP per capita growth are captured by α and indirect effects are indicated by β. gi reveals the fixed effects.

EMPIRICAL MODEL

In the light of the theoretical model, the following super reduced form equation of economic growth will be estimated. The equation is an empirical specification of the equation (3) of the preceding section.

$$\mathbf{g_{it} = a_0 + a_1\, Tmp_{it} + a_2\, Pr_{it} + a_3\, Hc_{it} + E_{it}} \qquad \textbf{(A)}$$

Where subscripts 'i' and 't' are for states and years respectively and g_{it} = growth rate of per-capita output
Tmp_{it} = deviations from mean temperature Pr_{it} = annual rainfall
Hc_{it} = human capital E_{it} = error term

In order to see the differential impacts of climate change on sectors of the economy, the model is also tested on the main sectors of total output, such as primary sector (agriculture), secondary sector (manufacturing) and tertiary sector (services). The model that is estimated in this regard is the following:

$$\begin{aligned} \mathbf{Ag_{it}} &= \mathbf{a_0 + a_1\, Tmp_{it} + a_2\, Pr_{it} + a_3\, Hc_{it} + \epsilon_{it}} \\ \mathbf{Mn_{it}} &= \mathbf{a_0 + a_1\, Tmp_{it} + a_2\, Pr_{it} + a_3\, Hc_{it} + \mu_{it}} \qquad \textbf{(B)} \\ \mathbf{Sr_{it}} &= \mathbf{a_0 + a_1\, Tmp_{it} + a_2\, Pr_{it} + a_3\, Hc_{it} + \Theta_{it}} \end{aligned}$$

Here,
Ag_{it} = growth rate of agricultural per-capita output Mn_{it} = growth rate of manufacturing per-capita output Sr_{it} = growth rate of services per-capita output
ϵ_{it} , μ_{it} , Θ_{it} = respective error terms

Note: Each sector's per capita output has been calculated by dividing the total output of that sector by the labour force of that sector. Labour force for each sector is estimated by using labour shares in each sector from the census data.

In the estimation process, our focus will be on the Null Hypothesis that climate change does not affect growth:

H_0: a_1=0 and a_2=0

Three different specifications are tested:
Specification 1: **deviations** from mean temperature
Specification 2: **only positive deviations** (all negative deviations replaced by 0)Specification 3: **only negative deviations** (all positive deviations replaced by 0)

The last two specifications have been selected to analyse how the upward and the downward fluctuations from average temperatures affect economic growth. Mainly, the upward deviations are expected to be significantly affecting growth because hotter weather reduces labour productivity and also leads to crop failure. Generally, downward fluctuations that lead to colder weather do not concern us much.
The random effect model and fixed effect model technique were considered to estimate the models. The Hausman test of endogeneity was used to select the suitable technique.

H_0: Difference in coefficients is not systematicH_A: Difference in coefficients is systematic

If the p value obtained is less than 0.05, then the null hypothesis is rejected which means difference in coefficients is systematic or not random and hence a fixed effects model is preferred. Models A and B are estimated using Panel data of 13 states for 23 years.

The effects of climate change will not be uniformly distributed across the globe and there are likely to be winners and losers as the planet warms. So an analysis of the differential impact of climate change on the rich vs. the poor states of India has also been done. The states having poverty rates greater than 30% are considered to be poor. Note that here only one specification has been attempted that is the effect on total GDP growth rate including both positive and negative temperature deviations. The following separate regressions were used to estimate the results:

$$\mathbf{Richg_{it} = a_0 + a_1\, Tmp_{it} + a_2\, Pr_{it} + a_3\, Hc_{it} + {}_3{}_{it}}$$
$$\mathbf{Poorg_{it} = a_0 + a_1\, Tmp_{it} + a_2\, Pr_{it} + a_3\, Hc_{it} + £_{it}} \qquad \textbf{(C)}$$

Where
$Richg_{it}$ = growth rate of per-capita output of Rich states$Poorg_{it}$ = growth rate of per-capita output of Poor states
The selection of an indicator of climate change is a critical issue. In this regard, pollution emission levels and concentration levels, global average temperature, sea- level increase and occurrence, magnitude or frequency of abnormal changes in climate are the most commonly used indicators. But here temperature and precipitation has been selected as an indicator of the climate change for two reasons. First, data was available on monthly basis for these two indicators. The second reason is that changes in mean temperature have a direct relationship with other factors like pollution etc.

6. ESTIMATION RESULTS

Before estimating the empirical model, the Hausman test was used to select the appropriate estimation methodology, which would be either a fixed effect model or a random effect model. The significant Chi-square test statistics suggest that the use of a fixed effect model would be appropriate instead of using the random effect model in all three specifications.

TABLE 1. Hausman Test Results

SPECIFICATION	CHI-SQ. STATISTIC	P VALUE
Specification 1	913.95	0.000
Specification 2	428.33	0.000
Specification 3	426.13	0.000

The results of estimation of our main equation by using the fixed effect model (fixed period) are summarized in table 2.

TABLE 2. Single Equation Estimation Results (Fixed Effect Model)

VARIABLE	SPECIFICATION 1	SPECIFICATION 2	SPECIFICATION 3
Tmp Dev	-0.176840***	-0.218166***	-0.32193***
Pr	0.000188**	0.000208**	0.000207**
Hc	0.012924***	0.011663***	0.01199***
Constant	-0.851391***	-0.76037***	-0.89247***

*NOTE: *** denotes significance at 1%, ** at 5% and * at 10%. Specification 1 includes both positiveand negative deviations of temperature. Specifications 2 and 3 include only the positive and the negative deviations of temperature respectively.*

The per capita GDP growth rate of states is found as the combined result of different climate-related factors and human capital. The results show that the proxy for human knowledge has a significant and positive impact on per capita Economic Growth. This isas expected with the theory that human development leads to increase in economic growth.

On comparing different specifications we can see that magnitude of coefficient on temperature deviations is highest under specification 3 which is quite surprising because it's the positive deviations or hotter conditions that affect growth more adversely. An increase in temperature will negatively affect economic growth. Magnitude for precipitation is similar across specifications and significant at 5 %. An increase in precipitation has a positive impact while. A 1^{o} Celsius increase in temperature deviation leads to fall in growth by 0.17% on an average and an increase in precipitation by 100 mm leads to an increase in growth by 0.018% on average. We can decompose the effect of temperature on economic growth in two possible ways:

1 .Output effect: Influencing the level of output, by affecting agricultural yields, or

2. Productivity effect: Affecting an economy's ability to grow, by affecting institutions that influence productivity growth.

So there is evidence that deviations in climatic variables from normal have adverse effects on Per Capita Economic Growth.

The results of estimating the reduced model of various sectors of Per Capita EconomicGrowth are shown in Table 3:

Table3. Economic Sector Wise Estimation Results

VARIABLES	SPECIFICATION 1	SPECIFICATION 2	SPECIFICATION 3
	AGRICULTURAL	SECTOR	
Tmp	-0.2611573***	-0.325493***	-0.471031***
Pr	0.000292*	0.000321**	0.000320**
Hc	.01823***	0.016414***	0.016812***
Constant	-1.2407***	-1.1071***	-1.2989***
	MANUFACTURE	SECTOR	
Tmp	-0.200248***	-0.24805**	-0.36321***
Pr	0.000223	0.0002457*	0.000244*
Hc	0.016574***	0.015161***	0.015508***
Constant	-1.09178***	-0.98896***	-1.13755***
	SERVICES	SECTOR	
Tmp	-0.084610*	-0.064083	-.207698**
Pr	0.000102	0.000121	.000102
Hc	0.005852***	0.004695**	.005962***
Constant	-0.385857***	-0.332842**	-.436083***

*NOTE: *** denotes significance at 1%, ** at 5% and * at 10%. Specification 1 includes both positive and negative deviations of temperature. Specifications 2 and 3 include only the positive andthe negative deviations of temperature respectively.*

As indicated by the negative regression coefficients, the per capita economic growth falls under higher temperature but the impacts are not highly significant for all sectors. They reveal that impacts of temperature change on different sectors are not evenly distributed. Agricultural sector is the most affected by temperature variation where a 1^{o}Celsius increase leads to fall in per capita agricultural growth by about 0.26%. Results also show that temperature has a significant impact on manufacturing sector, which may be due to two effects.

- First due to demand spill over effect i.e. agricultural demand falls due to poor performance of agriculture.
- Second is productivity effect which states that labour productivity may fall under hotterweather.

Higher temperature does not have a significant impact on service sector. This can be verified on comparing specifications as temperature under specification 3 is significant and cease to be significant under specification 2.

Like temperature, precipitation variation also impacts agricultural sector the most. A 100 mm increase in precipitation leads to increase in per capita growth by about 0.02% in agriculture sector. This is because water is one of the main inputs in agriculture and India being a developing country where main occupation is agriculture; it is highly dependent on rainfall for irrigation. In the manufacturing and services sectors, precipitation has an insignificant or very small impact on economic growth.

The results also show that Human capital increases agriculture, manufacturing and services (all sectors) which are consistent with economic theory that productivity of output depends on specialized work force and multi skilled humans which worked for thesuccess.

TABLE 4. Estimation results of impact on Rich vs. Poor States GDP Growth

VARIABLE	RICH STATES	POOR STATES
Tmp	0.02440	-0.15634***
Pr	0.00052***	5.20e-06
Hc	0.00836***	0.01311***
Constant	-0.91948***	-0.51923**

*Note: *** denotes significance at 1%, ** at 5% and * at 10%.*

Above table shows negative effect of temperature deviations but only in poorer states. In poor states, we see that a 1^{o}C rise in temperature deviation in a given year reduces per capita economic growth in that year by about 0.16%. Similar analysis on richer states shows no significant impact. Coefficient of annual precipitation is insignificant for poor states while in richer states, there is very negligible effect of rainfall on growth which shows richer states are better able to utilize the effects of rainfall. Human capital as expected positively affects growth in both types of states.

Poor people face the highest brunt of climate change. This is supported by the fact that agriculture is mainly rain-fed for poor states in India. Small farmers are highly vulnerable to climatic change as their options for diversifying their resources and income sources are limited.

While agricultural output effects are present, we also find adverse effects of hot years on industrial output and aggregate investment. Further, higher temperatures lead to political instability in poor states, maybe because of more anger in people due to poor performance.

7. CONCLUSION AND POLICY IMPLICATIONS

The present study has carried out panel data research on the relationship between changes in weather patterns (an indicator of climate change) and economic output for the Indian economy. The results show that temperature and precipitation have signi- ficant impact on per capita GDP growth as well as with the productivity in agriculture, manufacturing and services sectors. However, the severity of these negative effects is higher in the agriculture sector as compared to the manufacturing and services sectors.

The study reveals that economic growth of Indian states will be adversely impacted if the climate conditions are not controlled or mitigated. Hence, there is a need for a policy regarding the adoption of mitigation strategies to control climate change. The reduction in economic growth will also result in increasing poverty. Although the poor states may contribute the least to causing climate change, they are the worst victim of climatechange due to their main occupation being agriculture and they don't have the monetary and other resources required to adopt preventive or mitigation measures. Therefore, control of climate change is crucial for poverty alleviation and better development ofthe country.

The estimates given here are primarily short run fluctuations in temperature and it alone cannot provide precise predictions about the estimated impact of future climate change. However it still provides a basis for policy implications and which group will face the brunt of climate change the most. So government policies need to be targeted more towards the protection of those groups.

8. APPENDIXTEMPERATURE

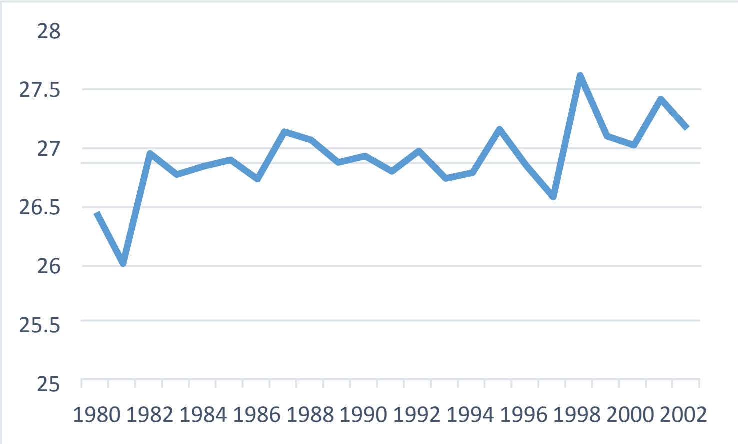


Fig. 1: **Mean Annual Temperature of West Bengal**

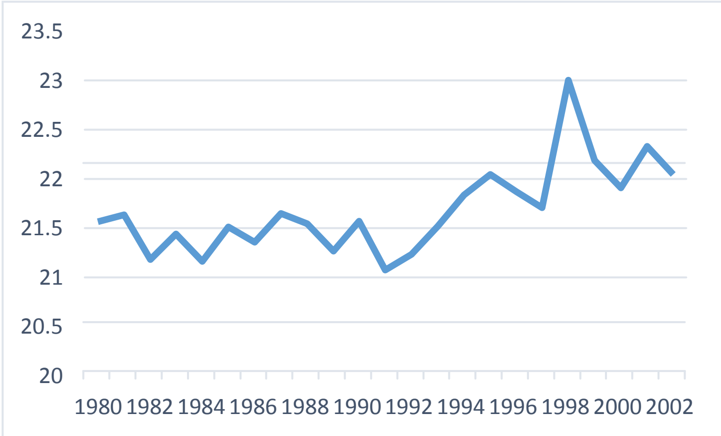


Fig. 2: Mean Annual Temperature of Assam

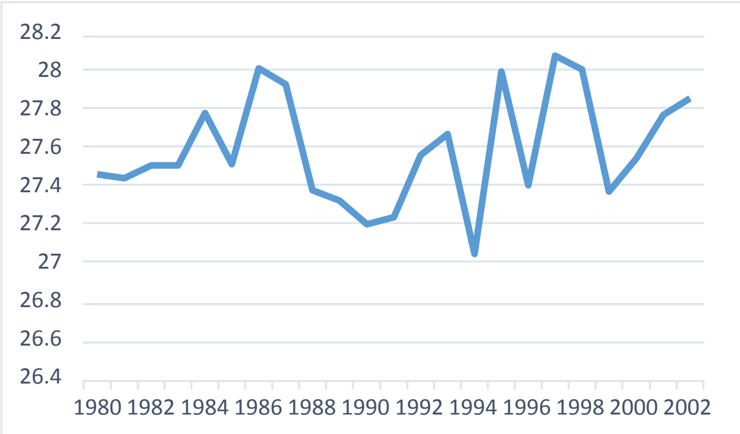


Fig. 3: Mean Annual Temperature of Karnataka

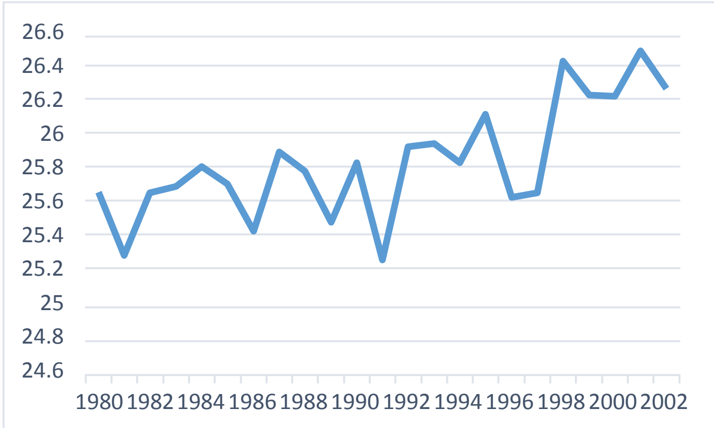


Fig. 4: Mean Annual Temperature of Bihar

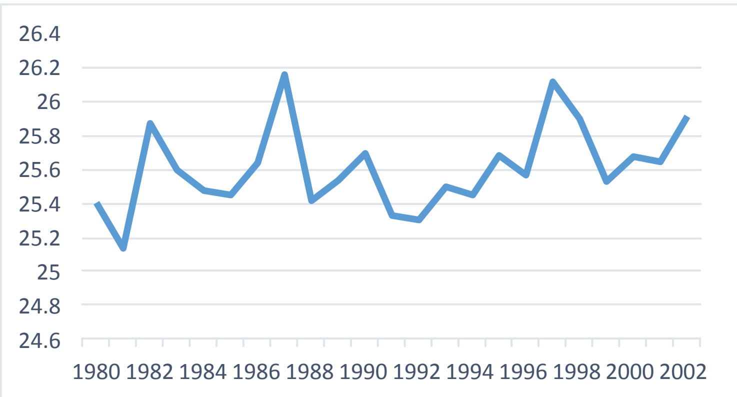


Fig. 5: Mean Annual Temperature of Haryana

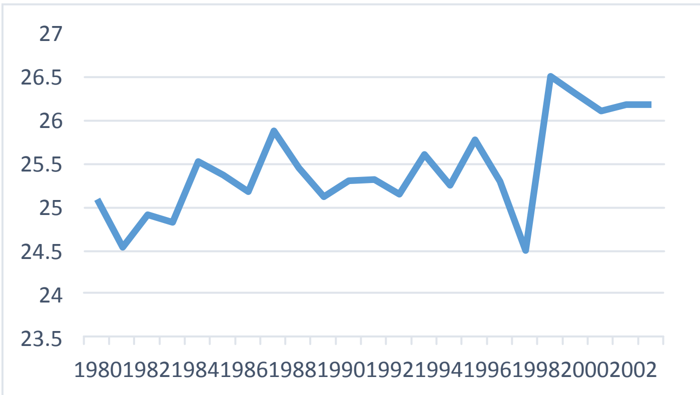


Fig. 6: Mean Annual Temperature of Gujarat

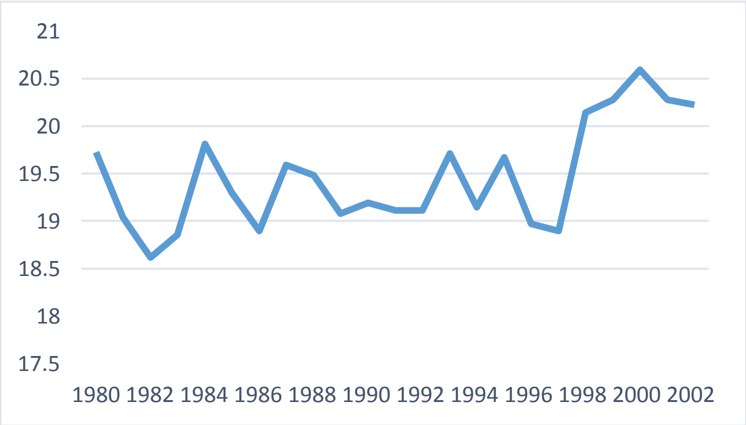


Fig. 7: Mean Annual Temperature of Tamil Nadu

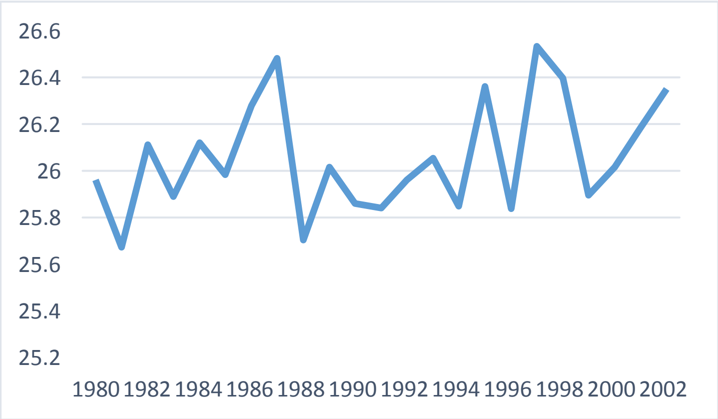


Fig 8: Mean Annual Temperature of Uttar

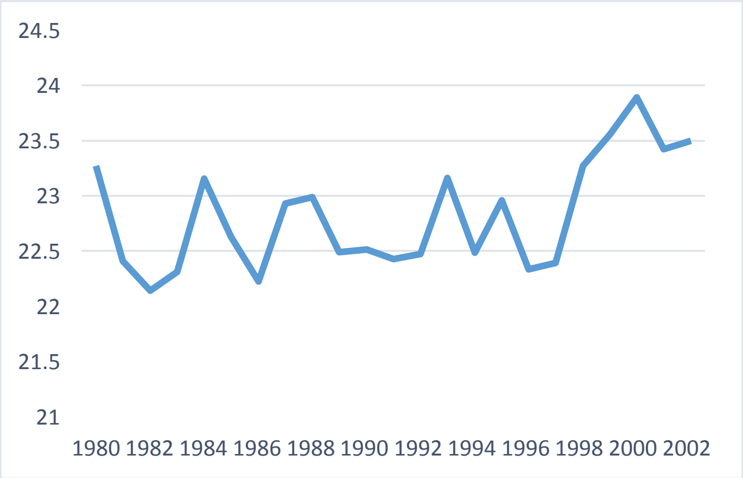


Fig. 9: Mean Annual Temperature of Himachal Pradesh

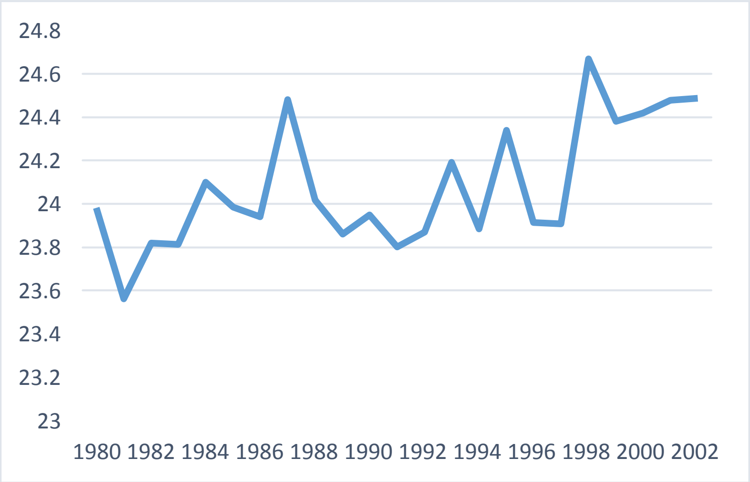
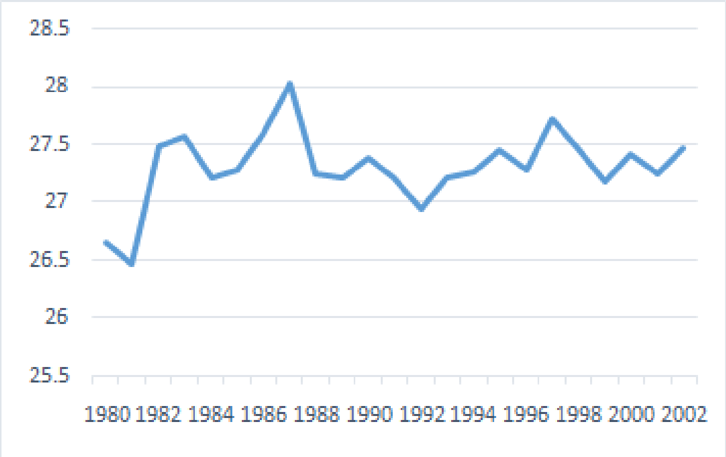


Fig. 10: Mean Annual Temperature of A.P.



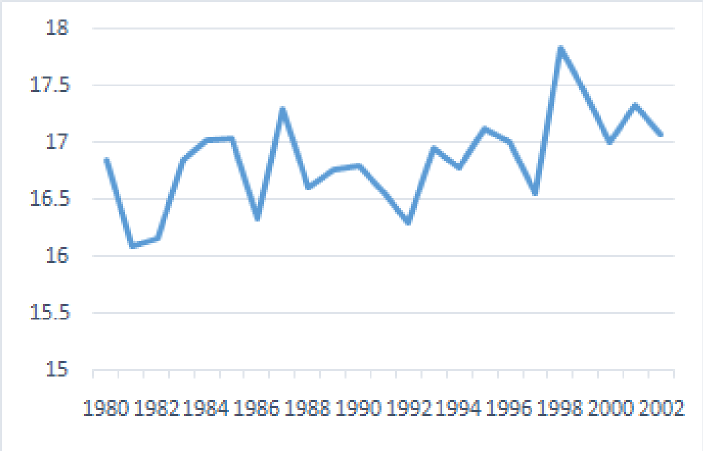


Fig. 11: Mean Annual Temperature of Kerala

Fig. 12: Mean Annual Temperature of Arunachal Pradesh

RAINFALL

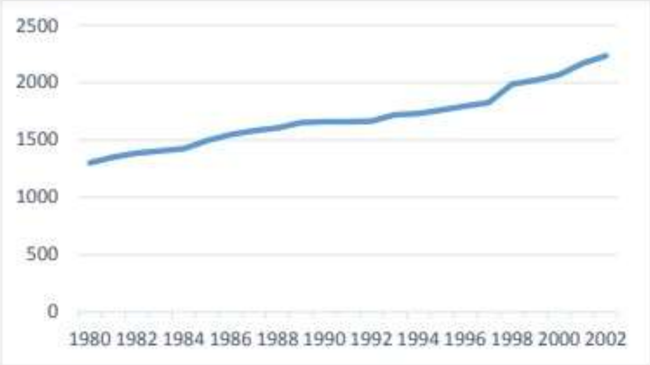


Fig. 16: Annual Rainfall of West Bengal

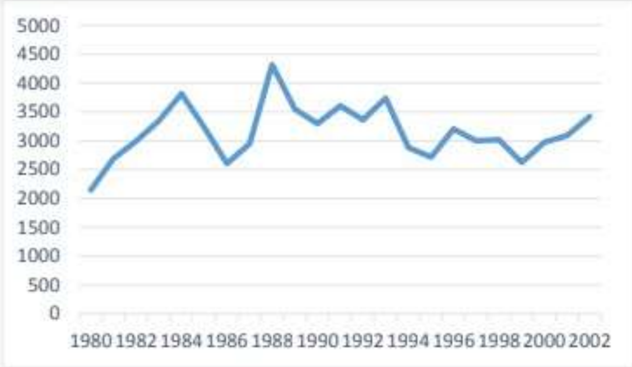


Fig. 17: Annual Rainfall of Assam

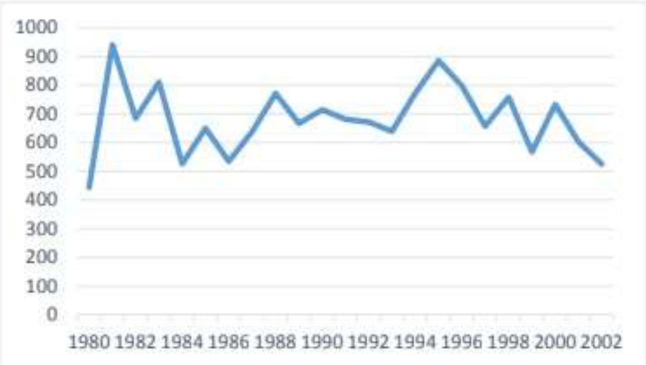


Fig. 18: Annual Rainfall of Karnataka

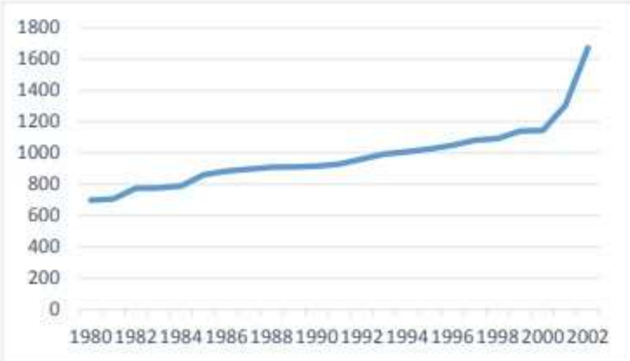


Fig. 19: Annual Rainfall of Bihar

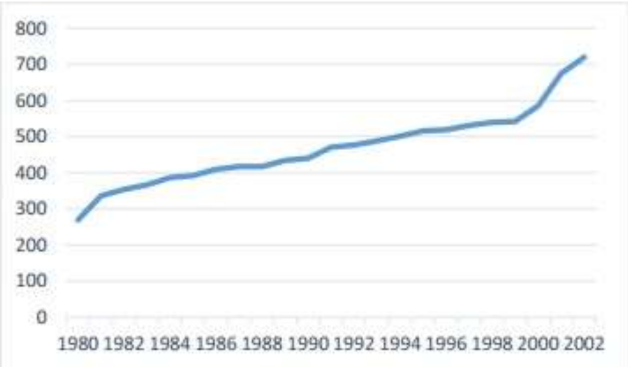


Fig. 20: Annual Rainfall of Haryana

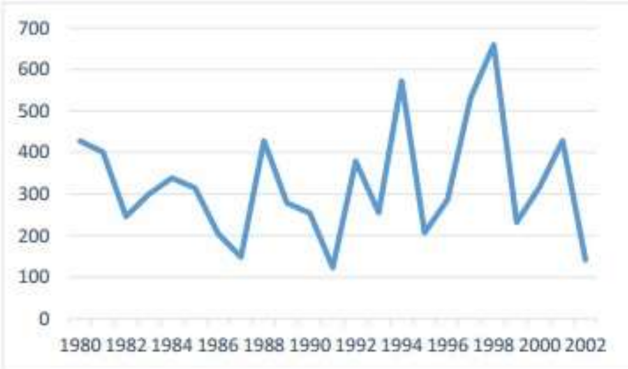


Fig. 21: Annual Rainfall of Gujarat

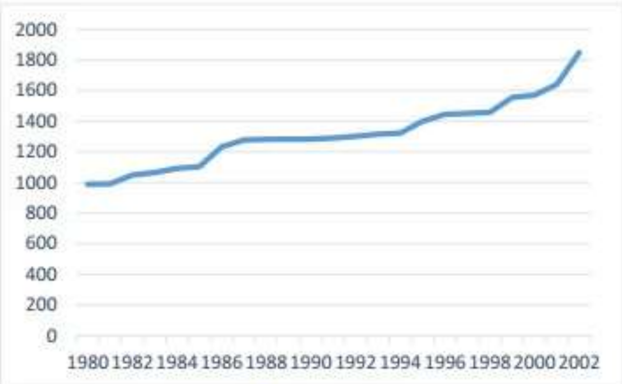


Fig. 22: Annual Rainfall of Tamil Nadu

Fig. 23: Annual Rainfall of Uttar Pradesh

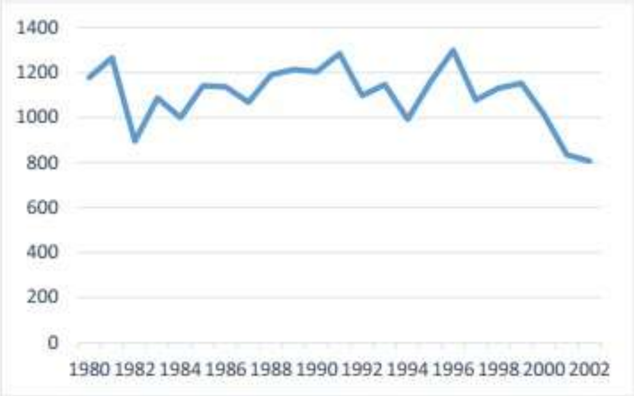


Fig. 24: Annual Rainfall of Himachal Pradesh

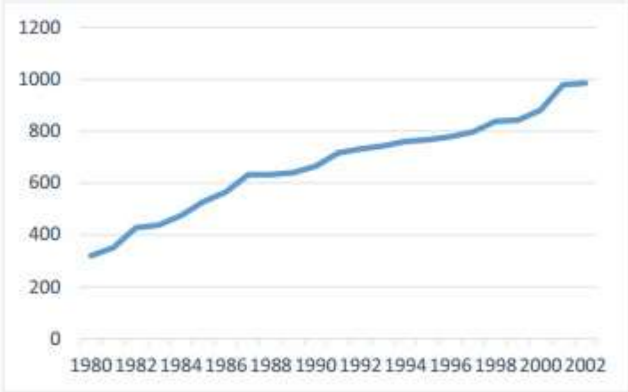


Fig. 25: Annual Rainfall of Andhra Pradesh

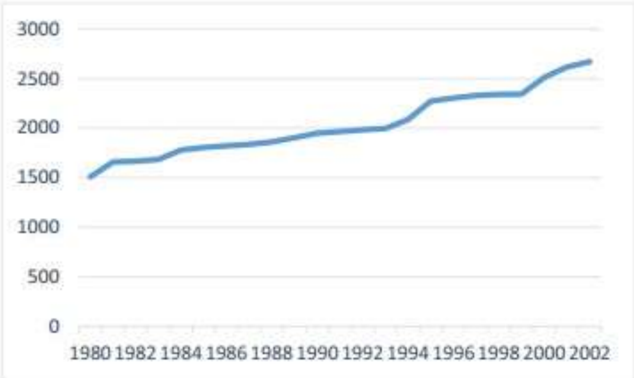


Fig 26: Annual Rainfall of Kerala

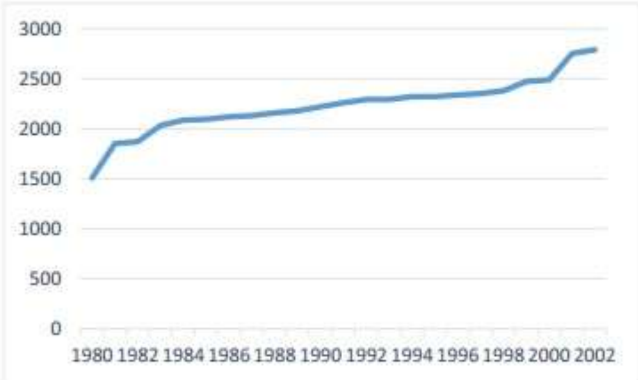


Fig. 27: Annual Rainfall of Arunachal Pradesh

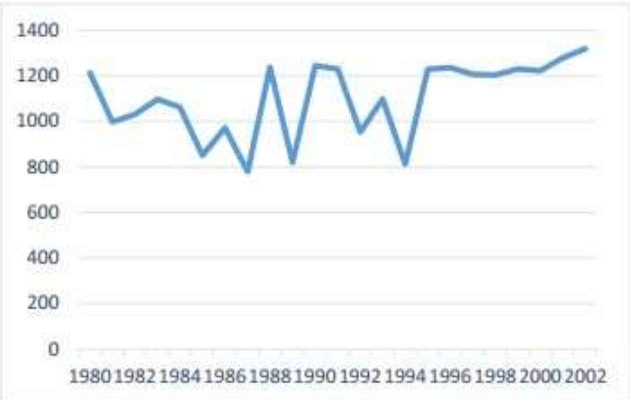


Fig. 28: Annual Rainfall of Jammu and Kashmir

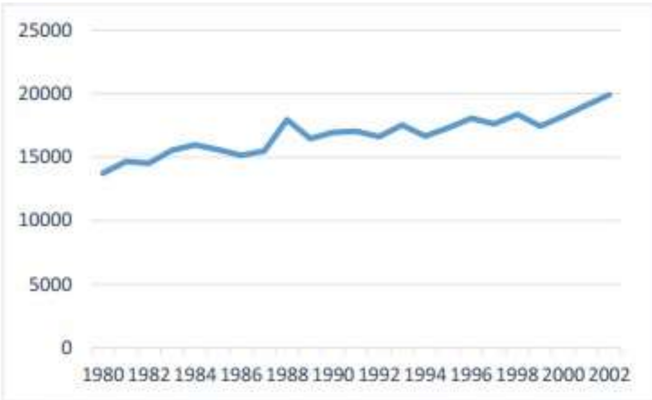


Fig. 29: Total Annual Rainfall (India)

STATA RESULTS

General Growth Effect, Specification 1, 2 And 3 (Table 2)

```
Fixed-effects (within) regression               Number of obs     =        299
Group variable: StateCodes                      Number of groups  =         13

R-sq:                                           Obs per group:
     within  = 0.1497                                         min =         23
     between = 0.0088                                         avg =       23.0
     overall = 0.0334                                         max =         23

                                                F(3,283)          =      16.61
corr(u_i, Xb)  = -0.8850                        Prob > F          =     0.0000

------------------------------------------------------------------------------
 TotalGrowth |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    Rainfall |   .0001889   .0000731     2.59   0.010     .0000451    .0003327
    mTempDev |  -.1768406   .0372051    -4.75   0.000    -.2500745   -.1036067
Literacyrate |   .0129244   .0024377     5.30   0.000     .0081262    .0177227
       _cons |  -.8513919   .1588879    -5.36   0.000    -1.164144   -.5386398
-------------+----------------------------------------------------------------
     sigma_u |  .25196363
     sigma_e |  .30677504
         rho |  .40283656   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0: F(12, 283) = 2.26                     Prob > F = 0.0097
```

```
Fixed-effects (within) regression               Number of obs     =        299
Group variable: StateCodes                      Number of groups  =         13

R-sq:                                           Obs per group:
     within  = 0.1215                                         min =         23
     between = 0.0021                                         avg =       23.0
     overall = 0.0220                                         max =         23

                                                F(3,283)          =      13.05
corr(u_i, Xb)  = -0.9046                        Prob > F          =     0.0000

------------------------------------------------------------------------------
 TotalGrowth |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    Rainfall |   .0002086   .0000741     2.81   0.005     .0000627    .0003544
     mpveDev |  -.2181665   .0609859    -3.58   0.000    -.3382101    -.098123
Literacyrate |   .0116639   .0024519     4.76   0.000     .0068375    .0164903
       _cons |   -.760379   .1592514    -4.77   0.000    -1.073847   -.4469114
-------------+----------------------------------------------------------------
     sigma_u |  .25559653
     sigma_e |  .31181289
         rho |  .40188759   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0: F(12, 283) = 2.06                     Prob > F = 0.0195
```

```
Fixed-effects (within) regression               Number of obs      =       299
Group variable: StateCodes                      Number of groups   =        13

R-sq:                                           Obs per group:
     within  = 0.1468                                         min =         23
     between = 0.0003                                         avg =       23.0
     overall = 0.0309                                         max =         23

                                                F(3,283)           =     16.23
corr(u_i, Xb)  = -0.8855                        Prob > F           =    0.0000

------------------------------------------------------------------------------
 TotalGrowth |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    Rainfall |   .0002074   .0000725     2.86   0.005     .0000646    .0003501
     mnveDev |  -.3219363   .0693577    -4.64   0.000    -.4584587   -.1854139
Literacyrate |   .0119949   .0023815     5.04   0.000     .0073072    .0166826
       _cons |  -.8924799   .1612255    -5.54   0.000    -1.209833   -.5751266
-------------+----------------------------------------------------------------
     sigma_u |  .25196965
     sigma_e |  .30730191
         rho |  .40202275   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0: F(12, 283) = 2.17                     Prob > F = 0.0132
```

Agricultural Growth Effect, Specification 1, 2 And 3 (Table 3)

```
Fixed-effects (within) regression               Number of obs      =       299
Group variable: StateCodes                      Number of groups   =        13

R-sq:                                           Obs per group:
     within  = 0.1362                                         min =         23
     between = 0.0017                                         avg =       23.0
     overall = 0.0289                                         max =         23

                                                F(3,283)           =     14.87
corr(u_i, Xb)  = -0.8866                        Prob > F           =    0.0000

------------------------------------------------------------------------------
  GrowthAgri |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    Rainfall |   .0002928    .000113     2.59   0.010     .0000704    .0005153
    mTempDev |  -.2611573   .0575475    -4.54   0.000    -.3744328   -.1478818
Literacyrate |   .0182307   .0037705     4.84   0.000     .0108089    .0256525
       _cons |   -1.24073    .245762    -5.05   0.000    -1.724484    -.756977
-------------+----------------------------------------------------------------
     sigma_u |  .37349735
     sigma_e |  .47450834
         rho |  .38255051   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0: F(12, 283) = 2.07                     Prob > F = 0.0189
```

```
Fixed-effects (within) regression               Number of obs      =       299
Group variable: StateCodes                      Number of groups   =        13

R-sq:                                           Obs per group:
     within  = 0.1108                                         min =        23
     between = 0.0003                                         avg =      23.0
     overall = 0.0192                                         max =        23

                                                F(3,283)           =     11.76
corr(u_i, Xb)  = -0.9062                        Prob > F           =    0.0000

------------------------------------------------------------------------------
  GrowthAgri |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    Rainfall |    .000321   .0001144     2.81   0.005     .0000958    .0005463
     mpveDev |  -.3254932   .0941568    -3.46   0.001    -.5108298   -.1401567
Literacyrate |   .0164146   .0037856     4.34   0.000     .0089631     .023866
       _cons |    -1.1071     .24587    -4.50   0.000    -1.591066   -.6231339
-------------+----------------------------------------------------------------
     sigma_u |  .37901958
     sigma_e |  .48141137
         rho |  .38266106   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0: F(12, 283) = 1.90                     Prob > F = 0.0343
```

```
Fixed-effects (within) regression               Number of obs      =       299
Group variable: StateCodes                      Number of groups   =        13

R-sq:                                           Obs per group:
     within  = 0.1323                                         min =        23
     between = 0.0006                                         avg =      23.0
     overall = 0.0263                                         max =        23

                                                F(3,283)           =     14.39
corr(u_i, Xb)  = -0.8884                        Prob > F           =    0.0000

------------------------------------------------------------------------------
  GrowthAgri |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    Rainfall |   .0003208   .0001122     2.86   0.005     .0000999    .0005417
     mnveDev |  -.4710316   .1073323    -4.39   0.000    -.6823024   -.2597607
Literacyrate |   .0168124   .0036854     4.56   0.000     .0095581    .0240668
       _cons |  -1.298902   .2494993    -5.21   0.000    -1.790012   -.8077917
-------------+----------------------------------------------------------------
     sigma_u |  .37430119
     sigma_e |  .47555527
         rho |  .38252498   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0: F(12, 283) = 2.01                     Prob > F = 0.0234
```

Manufacturing Growth Effect, Specification 1, 2 And 3 (Table 3)

```
Fixed-effects (within) regression               Number of obs     =        299
Group variable: StateCodes                      Number of groups  =         13

R-sq:                                           Obs per group:
     within  = 0.1019                                         min =         23
     between = 0.0388                                         avg =       23.0
     overall = 0.0268                                         max =         23

                                                F(3,283)          =      10.71
corr(u_i, Xb)  = -0.8768                        Prob > F          =     0.0000

------------------------------------------------------------------------------
  GrowthManu |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    Rainfall |   .0002237   .0001101     2.03   0.043     7.02e-06    .0004404
    mTempDev |  -.2002489   .0560611    -3.57   0.000    -.3105986   -.0898992
Literacyrate |   .0165749   .0036731     4.51   0.000     .0093448     .023805
       _cons |  -1.091787   .2394143    -4.56   0.000    -1.563045   -.6205279
-------------+----------------------------------------------------------------
     sigma_u |  .30729341
     sigma_e |  .46225238
         rho |  .30648246   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0: F(12, 283) = 1.79                     Prob > F = 0.0494
```

```
Fixed-effects (within) regression               Number of obs     =        299
Group variable: StateCodes                      Number of groups  =         13

R-sq:                                           Obs per group:
     within  = 0.0853                                         min =         23
     between = 0.0339                                         avg =       23.0
     overall = 0.0198                                         max =         23

                                                F(3,283)          =       8.80
corr(u_i, Xb)  = -0.8928                        Prob > F          =     0.0000

------------------------------------------------------------------------------
  GrowthManu |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    Rainfall |   .0002457   .0001109     2.22   0.027     .0000275    .0004639
     mpveDev |   -.248052   .0912414    -2.72   0.007    -.4276499   -.0684541
Literacyrate |   .0151614   .0036684     4.13   0.000     .0079406    .0223821
       _cons |   -.988963   .2382571    -4.15   0.000    -1.457944   -.5199821
-------------+----------------------------------------------------------------
     sigma_u |  .31007978
     sigma_e |  .46650531
         rho |  .30642644   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0: F(12, 283) = 1.65                     Prob > F = 0.0766
```

Fixed-effects (within) regression		Number of obs =	299
Group variable: StateCodes		Number of groups =	13
R-sq:		Obs per group:	
within = 0.0999		min =	23
between = 0.0247		avg =	23.0
overall = 0.0249		max =	23
		F(3,283) =	10.47
corr(u_i, Xb) = -0.8767		Prob > F =	0.0000

GrowthManu	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Rainfall	.0002448	.0001092	2.24	0.026	.0000299	.0004597
mnveDev	-.3632102	.1044476	-3.48	0.001	-.5688029	-.1576175
Literacyrate	.0155085	.0035864	4.32	0.000	.0084491	.0225679
_cons	-1.13755	.2427937	-4.69	0.000	-1.615461	-.6596392
sigma_u	.30688279					
sigma_e	.46277404					
rho	.30543557	(fraction of variance due to u_i)				

F test that all u_i=0: F(12, 283) = 1.75 Prob > F = 0.0555

Services Growth Effect, Specification 1, 2 And 3 (Table 3)

Fixed-effects (within) regression		Number of obs =	299
Group variable: StateCodes		Number of groups =	13
R-sq:		Obs per group:	
within = 0.0666		min =	23
between = 0.0445		avg =	23.0
overall = 0.0187		max =	23
		F(3,283) =	6.73
corr(u_i, Xb) = -0.8705		Prob > F =	0.0002

GrowthServ	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
mTempDev	-.0846108	.0280737	-3.01	0.003	-.1398706	-.029351
Rainfall	.0001023	.0000551	1.86	0.065	-6.20e-06	.0002108
Literacyrate	.0058521	.0018394	3.18	0.002	.0022315	.0094727
_cons	-.3858579	.1198914	-3.22	0.001	-.62185	-.1498657
sigma_u	.12233191					
sigma_e	.23148203					
rho	.21831232	(fraction of variance due to u_i)				

F test that all u_i=0: F(12, 283) = 1.01 Prob > F = 0.4367

```
Fixed-effects (within) regression               Number of obs     =        299
Group variable: StateCodes                      Number of groups  =         13

R-sq:                                           Obs per group:
     within  = 0.0433                                         min =         23
     between = 0.0180                                         avg =       23.0
     overall = 0.0082                                         max =         23

                                                F(3,283)          =       4.27
corr(u_i, Xb)  = -0.9071                        Prob > F          =     0.0057

------------------------------------------------------------------------------
  GrowthServ |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    Rainfall |   .0001215   .0000557     2.18   0.030     .0000118    .0002311
     mpveDev |  -.0640835   .0458372    -1.40   0.163    -.1543086    .0261417
Literacyrate |   .0046953   .0018429     2.55   0.011     .0010678    .0083228
       _cons |  -.3328422   .1196939    -2.78   0.006    -.5684456   -.0972388
-------------+----------------------------------------------------------------
     sigma_u |  .12753946
     sigma_e |   .2343597
         rho |  .22848904   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0: F(12, 283) = 0.93                     Prob > F = 0.5135
```

```
Fixed-effects (within) regression               Number of obs     =        299
Group variable: StateCodes                      Number of groups  =         13

R-sq:                                           Obs per group:
     within  = 0.0888                                         min =         23
     between = 0.0410                                         avg =       23.0
     overall = 0.0288                                         max =         23

                                                F(3,283)          =       9.19
corr(u_i, Xb)  = -0.8402                        Prob > F          =     0.0000

------------------------------------------------------------------------------
  GrowthServ |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    Rainfall |   .0001021    .000054     1.89   0.059    -4.09e-06    .0002084
     mnveDev |  -.2076983   .0516211    -4.02   0.000    -.3093084   -.1060882
Literacyrate |   .0059622   .0017725     3.36   0.001     .0024732    .0094512
       _cons |  -.4360831   .1199959    -3.63   0.000     -.672281   -.1998853
-------------+----------------------------------------------------------------
     sigma_u |  .12134575
     sigma_e |  .22871687
         rho |  .21965432   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0: F(12, 283) = 1.08                     Prob > F = 0.3753
```

Growth Effect for Rich States, Specification 1 (Table 4)

```
Fixed-effects (within) regression               Number of obs      =       207
Group variable: StateCodes                      Number of groups   =         9

R-sq:                                           Obs per group:
     within  = 0.1343                                         min =         23
     between = 0.1721                                         avg =       23.0
     overall = 0.0119                                         max =         23

                                                F(3,195)           =     10.08
corr(u_i, Xb)  = -0.9456                        Prob > F           =    0.0000

------------------------------------------------------------------------------
 TotalGrowth |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     TempDev |   .0244054   .0705505     0.35   0.730    -.1147345    .1635454
    Rainfall |   .0005263    .000117     4.50   0.000     .0002956    .0007571
Literacyrate |   .0083684   .0032201     2.60   0.010     .0020177    .0147191
       _cons |  -.9194899   .2151853    -4.27   0.000    -1.343879   -.4951006
-------------+----------------------------------------------------------------
     sigma_u |  .40191299
     sigma_e |  .33702492
         rho |  .58714066   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0: F(8, 195) = 3.40                      Prob > F = 0.0011
```

Growth Effect for Poor States, Specification 1 (Table 4)

```
Fixed-effects (within) regression               Number of obs      =        92
Group variable: StateCodes                      Number of groups   =         4

R-sq:                                           Obs per group:
     within  = 0.1381                                         min =         23
     between = 0.6996                                         avg =       23.0
     overall = 0.0993                                         max =         23

                                                F(3,85)            =      4.54
corr(u_i, Xb)  = -0.6287                        Prob > F           =    0.0053

------------------------------------------------------------------------------
 TotalGrowth |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    mTempDev |  -.1563427   .0509748    -3.07   0.003    -.2576943   -.0549912
    Rainfall |   5.20e-06   .0000781     0.07   0.947    -.0001501    .0001605
Literacyrate |   .0131106   .0039282     3.34   0.001     .0053003    .0209208
       _cons |  -.5192331   .2284861    -2.27   0.026    -.9735248   -.0649415
-------------+----------------------------------------------------------------
     sigma_u |  .07538758
     sigma_e |   .2412042
         rho |  .08899221   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0: F(3, 85) = 0.58                       Prob > F = 0.6304
```