Analysing economic growth and convergence has been scientifically one of the main issues confronting growth economics since long. Hence, it is not surprising that there are many growth and convergence models whose structures differ from simple to complex. A famous and simple model is the growth model of Solow (1956). This approach explains standards of living with only two or in the extended version three variables. Since [Mankiw Romer and Weil (1992)], published their seminar paper, growth models also get into the focus of econometrics. The authors provide empirical evidence on the neo-classical growth model of Solow (1956). Additionally, Mankiw Romer and Weil analysed the human capital extended version of the model and investigated the question of convergence. While finding the convergence, it has been generally thought of as evidence in support of the Solow-Cass-Koopmans model, absence of convergence has been regarded as supportive of endogenous growth theories. The controversy has given rise to the concept of “conditional convergence” meaning convergence after difference in the steady states across countries have been controlled for.

A common feature of existing empirical studies on this issue has been the assumption of identical aggregate production function for all the countries. Although it has been correctly felt that the production function may actually differ across countries, efforts

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to allow such differences have been limited by the fact that most of these studies have been conducted in the framework of single period cross-country regressions. In this framework, it is difficult to allow for such differences in the estimation of production. In the present study we have used three approaches to test convergence namely cross sectional approach, panel data approach and distributional approach. The first two approaches are used to test the β-convergence while as the third approach is used to test the σ-convergence. For testing the convergence across Indian states/union territories the data has been obtained from Central Statistical Organisation (CSO) on GSDP per capita on two different constant prices i.e. 1993-94 and 2004-05 prices and adjustment factor method is used to convert the data on same base year prices of 2004-05. The GSDP per capita data of 30 states/union territories has been taken account to test the convergence across states/union territories and rest of states/union territories has been dropped because the time series data was not available for them. In order to give due representation to various issues related to convergence the present chapter has been divided into two sections. Section I deals with different concepts, issue of convergence and approaches of convergence while section II deals with the empirical analysis of the convergence across Indian states/union territories and section III is devoted to test the convergence across three selected Northern states.

Section I

6.1 The issue of “Convergence” and its Empirical Search

In neoclassical growth models for closed economies, as presented by Ramsey (1928), Solow (1956), Cass (1965), and Koopmans (1965), the per capita growth rate tends to be inversely related to the starting level of output or income per person. In particular, if economies are similar in respect to preferences and technology, then poor economies grow faster than rich ones. Thus there is a force that promotes convergence in levels of per capita product and income across countries. Solow (1956) proposed one of the most popular economic growth models explaining standards of living by only two covariates. Although this simple model is about 60 years old, but it is still a basic reference in current literature. “The crucial assumption in the Solow model of diminishing marginal returns to capital leads to the growth process within an economy to eventually reach
the steady state where per capita output, capital stock and consumption grow at a common constant rate equalling the exogenously given rate of technological progress”. This led to the notion of convergence, which in turn can be understood in two different ways. The first is in terms of level of income. If countries are similar in terms of preferences and technology, then the steady state income levels for them will be the same, and with time they will all tend to reach that level of per capita income. The second is convergence in terms of growth rate determined by the exogenous rate of the technological progress, provided that technology is a public good to be equally shared. All countries will eventually attain the same steady state growth rate. The Cass-Koopmans version of the model, where the saving rate is dynamically optimized, also has these implications.2

It has now been quite some time that researchers have been using real data to test these hypotheses. Initially, much of this work was conducted on the basis of the data of the developed industrialised countries. Data availability had a significant role in this choice of sample and also an empirical estimation strategy. In one of the works on this topic, Baumol,3 for example, reported finding convergence among a group of countries included in Maddison’s4 sample. These countries tended to converge both to similar levels of per capita income and to similar rates of growth5. Several others provide economic extensions of the model and simultaneously its empirical validity is tested by econometric estimation (e.g. Mankiw et al., 1992; Barro, 1991; Barro & Sala-i-Martin, 2004).6

An important question in this regard is what should be the appropriate methodology for testing convergence. Since the notion of convergence pertains to the steady states of the economies, a test for convergence would require the assumption that the countries

2 ibid.
included in the sample are in their steady states. One way out around this problem, therefore, is to study the correlation between initial levels of income and subsequent growth rates. Because of diminishing marginal returns to capital, countries with low levels of capital stock will have higher marginal product of capital and hence, for similar saving rates, grow faster than those with already higher levels of per capita capital stock. Thus, a finding of negative correlation between initial levels of income and subsequent growth rates has become a popular criterion for judging whether or not convergence holds. It may be noted that this negative correlation has the scope of being interpreted as evidence of convergence in terms of both income level and growth rate. Poorer countries “catch up” (convergence in terms of income level) with the richer countries by initially growing faster, and then their growth rates slow down to the common rate of technological progress (resulting in convergence in growth rates).\(^7\)

As more wide-ranging data sets became available, empirical regularities of growth process over a wider cross section of countries started to draw the attention of researchers. Romer\(^8\) has been influential in drawing the attention of macroeconomists to the fact that over a large sample of countries, the correlation between initial income levels and subsequent growth rates is either zero or even positive. The evidence has also been interpreted as one of “persistence” of significant differences in income level and growth rates among countries.\(^9\) The rise of endogenous growth theories is known, has been, to a large extent, a response to these empirical findings.

A different response to the same facts has been the proposition of the concept of “conditional convergence.” Barro\(^10\) in his first empirical work on growth, showed that if differences in the initial level of human capital (along with some other pertinent variables) are controlled for, then the correlation between the initial level of income

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and subsequent growth rate turn out to be negative even in the wider sample of countries. This concept of conditional convergence found its more explicit formulation in Barro and Sala-i-Martin (1992) and Mankiw, Romer, and Weil (1992). Both these papers emphasized the fact that the neoclassical growth model (either Solow’s or its optimal saving version by Cass and Koopmans) did not imply that all countries would reach the same level of per capita income. Instead, what it implied is that countries would reach their respective steady states. Hence, in looking for convergence in a cross-country study, it is necessary to control for the differences in steady states of different countries.

The hypothesis that poor countries tend to grow faster than rich countries seems to be inconsistent with the cross-country evidence, which indicates that per capita growth rates have little correlation with the starting level of per capita product. By using the data from the Summers and Heston international comparison project, shows this type of relationship for 98 countries. The average growth rate of per capita real gross domestic product (GDP) from 1960 to 1985 (denoted GDP6085) is not significantly related to the 1960 value of real per capita GDP (GDP60); the correlation is 0.09. The finding accords with other models, such as Lucas and Rebelo that assume constant returns to a broad concept of reproducible capital, which includes human capital. In these models the growth rate of per capita product is independent of the starting level of per capita product.

Human capital plays a special role in a number of models of endogenous growth. In Romer, human capital is the key input to the research sector, which generates the new products or ideas that underlie technology progress. Thus countries with greater initial stocks of human capital experience a more rapid rate of introduction of new goods and

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15 ibid.
Convergence Analysis across Indian States

thereby tend to grow faster. In multi-country models of technological change, the spread of new ideas across countries (or firms or industries) is also important. As Nelson and Phelps\textsuperscript{16} suggested, a large stock of human capital makes it easier for a country to absorb the new products or ideas that have been discovered elsewhere. Therefore, a follower country with more human capital tends to grow faster because it catches up more rapidly to the technological leader.\textsuperscript{17}

Becker, et al\textsuperscript{18} assume that the rate of return of human capital increases over range, an effect that could arise because of the spill-over benefits from human capital that Lucas stresses. As an example, the return to some kinds of ability, such as talent in communications, is higher if other people are also more able. In this setting, an increasing in the quantity of human capital per person tend to lead to higher rates of investment in human and physical capital, and hence to higher per capita growth. A supporting force is that more human capital person reduces fertility rates, because human capital is more productive in producing goods and additional capital rather than more children.\textsuperscript{19}

During 80s and 90s, there has been a revival of interest on the forces that lead to economic convergence. This revival has been partly spurred by the renewed interest in the general topic of economic growth. A significant contribution to this revival has been the use of the convergence hypothesis as the main test to differentiate the two main current approaches to economic growth: the neoclassical model and the model of endogenous growth. Romer\textsuperscript{20} and Rebelo\textsuperscript{21} argued that the absence of convergence across economies throughout the world represented strong evidence against the neoclassical model and in favour of their theories of endogenous growth.

\textsuperscript{17} ibid.
\textsuperscript{19} ibid.
But there are reasons other than the testing of economic growth theories for empirical study of economic convergence. The economists are interested in knowing whether the distribution of income changes over time. For example, we are interested in whether, within a country, inter-regional differences in income levels tend to disappear or tend to increase over time. If they diminish, then we may be less worried about creating aid programmes (such as the Regional and Cohesion Fund Policies carried out by the Government of the European Community) than if these differences tend to perpetuate themselves. We are also interested in knowing whether the regions that are relatively poor now are the same as the ones that were relatively poor one hundred years ago. If the answer is yes (that is, if poverty tends to persist over time), then we may want to enact public aid programmes to allow the poor regions to escape this predicament. If the answer is no (that is, the economies that are relatively poor today are not likely to remain relatively poor in the future), then there may be no need to worry about the country-wide distribution of income.²²

The debate has in turn led to many different interpretations of convergence. In applying neo-classical growth theory (NCGT) to the study of cross-country growth regularities, researchers have, either explicitly or implicitly, added other assumptions (to the basic assumption of diminishing returns), and this has been the main reason for the emergence of different notions of convergence. The following, often encountered, dichotomies indicate some of the different ways in which convergence has been understood:

a) Convergence within an economy vs. convergence across economies;
b) Convergence in terms of growth rate vs. convergence in terms of income level;
c) β-convergence vs. σ-convergence;
d) Unconditional (absolute) convergence vs. conditional convergence;
e) Global convergence vs. local or club-convergence;
f) Income-convergence vs. TFP (total factor productivity)-convergence; and
g) Deterministic convergence vs. stochastic convergence.

It is not that all these different concepts of convergence were apparent from the very beginning. Research on convergence proceeded through several stages, and it is only with time that these different definitions emerged and gained currency. Convergence research has also witnessed the use of different methodologies, which may be classified broadly as follows:

a) Informal cross-section approach,
b) Formal cross-section approach,
c) Panel approach,
d) Time-series approach, and
e) Distribution approach.

There is some correspondence between the convergence definitions and the methodologies used. This correspondence is however not unique. For example, the informal and formal cross-section approaches, the panel approach, and the time-series approach (in part) have all studied β-convergence, either conditional or unconditional. These approaches have generally dealt with convergence across economies and in terms of per capita income level. In addition, the formal cross section approach and the panel approach have been used to study club-convergence and TFP-convergence. The cross-section approach has even been used to study σ-convergence. The time series approach has been used to investigate convergence both within an economy and across-economies. Finally, the distribution approach has gone beyond investigating just σ-convergence and has studied the entire shape of the distribution and intra-distribution dynamics.23 A useful way to start reviewing the convergence literature is therefore to provide a brief introduction to these different concepts of convergence.

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6.2 Different Concepts of Convergence

6.2.1 Convergence Within vs. Convergence Across

Robert Solow,\textsuperscript{24} in his exposition of growth theory, starts out by relating to six stylized facts about growth put forwarded by Kaldor.\textsuperscript{25} Coming to the fifth and sixth of these,\textsuperscript{26} Solow makes the following comment:

“The remaining ‘stylized facts’ are of a different kind, and will concern me less, because they relate more to comparisons between different economies than to the course of events within any one economy.”\textsuperscript{27}

It is somewhat ironic that one of the recent dissatisfactions with the Solow model concerns its alleged failure to explain between- or across-country variation in growth rate and income level. Historically, the main objective of the Solow model has been to show that once factor substitution is allowed, the economy could achieve stable dynamic equilibrium, instead of suffering from the inherent instability that characterized the previous Harrod–Domar growth model. In NCGT, no matter whether the economy starts off from a per capita capital stock that is lower or higher than the equilibrium capital level, the substitution possibility and diminishing returns force the economy to ‘converge’ to the equilibrium. Hence, this is a proposition of convergence, albeit within the economy. Paradoxically, the concept of convergence that arose and became associated with neo-classical growth theory (NCGT) refers to an across-economy process.

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\textsuperscript{26} The fifth of these stylized facts was that the growth rate of per capita output varied widely across countries, and the sixth was that economies with high share of profits in income had higher investment to output ratios.

6.2.2 Convergence in Terms of Growth Rate vs. Convergence in Terms of Income Level

The across-economy convergence may in turn be understood in two different ways, namely ‘convergence in terms of growth rate’ and ‘convergence in terms of income level.’ Both of these require extending the neo-classical growth theory (NCGT) conception of technology to the world level. The specification of technological progress in neo-classical growth theory (NCGT) is based on the following assumptions: (a) no resources are needed to generate technological innovation, (b) everybody benefits equally from it, and (c) nobody pays any compensation for benefiting from it. Extended to a global setting, these assumptions imply that all countries share in the technological progress equally, and hence they all can grow at the same rate in the steady state. This yields the hypothesis of convergence in terms of growth rate. To this researchers often added the assumption that all countries have identical aggregate production function. This implies that steady state income levels of all countries are also identical. This yields convergence in terms of income level.28

6.2.3 β-convergence vs. σ-convergence

Convergence in terms of both growth rate and income level requires what is called β-convergence. This follows from the assumption of diminishing returns, which imply higher marginal productivity of capital in a capital-poor country. With similar savings rates, poorer economies will therefore grow faster. If this scenario holds, there should be a negative correlation between the initial income level and the subsequent growth rate. This led to the popular methodology of investigating convergence, namely running what is now known as the growth-initial level regressions. The coefficient of the initial income variable in these regressions (say, β) is supposed to pick up the negative correlation. Convergence judged by the sign of β is known as the β-convergence.29

29 Note that negative can be interpreted as evidence of convergence in terms of both income level and growth rate.
However, such researchers as Quah,\(^{30}\) Friedman,\(^{31}\) and others have emphasized that convergence is a proposition regarding dispersion of the cross-sectional distribution of income (and growth rate), and a negative \(\beta\) from the growth-initial level regression does not necessarily imply a reduction in this dispersion.\(^{32}\) According to this view, instead of judging indirectly and perhaps erroneously through the sign of \(\beta\), convergence should be judged directly by looking at the dynamics of dispersion of income level and/or growth rate across countries. This gave rise to the concept of \(\sigma\)-convergence, where \(\sigma\) is the notation for standard deviation of the cross-sectional distribution of either income level or growth rate.

Despite the limitations above, researchers have continued to be interested in \(\beta\)-convergence, in part because it is a necessary, though not sufficient, condition of \(\sigma\)-convergence. The other reason is that methodologies associated with investigation of \(\beta\)-convergence also provide information regarding structural parameters of growth models, while research along the distribution approach usually do not provide such information.

### 6.2.4 Unconditional Convergence vs. Conditional Convergence

From a conceptual point of view, the most important distinction is probably between conditional and unconditional convergence. Proceeding from the Solow model and assuming a Cobb-Douglas production function of the type

\[
Y_t = K_t^\alpha (A_t L_t)^{1-\alpha}
\]

(1)

(where \(Y\), \(K\), \(L\), and \(A\) stand for output, capital, labor, and total factor productivity, respectively), the steady state level of per capita income, \(y^*\), is given by

\[
y^* = A_0 e^{\beta t} \left[ \frac{s}{n + g + \delta} \right]^{\alpha/(1-\alpha)}
\]

(2)


\(^{32}\) They point out that a negative can just be an example of the more general phenomenon of reversion to the mean, and, by reading convergence in it, growth researchers are falling into Galton fallacy.
where ‘s’ is the investment rate, g and n are the assumed exponential growth rates of \( A_t \) and \( L_t \), respectively.\(^{33}\) This shows clearly that the steady state income level of a country depends on the following six elements: \( A_0, s, g, n, \delta, \) and \( \alpha \), which may be combined in the vector \( \theta.\(^{34}\) Unconditional convergence implies that all elements of \( \theta \) are the same for the economies considered. In terms of the growth-initial level regression, this means that the sign of \( \beta \) should be negative even if no other variable is included on the right hand side. In contrast, the concept of conditional convergence emphasizes possible differences in the steady state and hence requires that appropriate variables be included on the right hand side of the growth-initial level regression in order to control for these differences. Which of the different elements of the vector \( \theta \) should be allowed to vary and which not, continues to be an important issue.\(^{35}\)

### 6.2.5 Conditional Convergence vs. Club Convergence

The concept of conditional convergence is also related with the notion of ‘club convergence.’ The latter term can be traced back to Baumol,\(^{36}\) but its more rigorous formulation owes to Durlauf and Johnson\(^{37}\) and Galor\(^{38}\). One property of the standard neo-classical growth theory (NCGT) is uniqueness of its equilibrium, and the usual notion of convergence assumes this uniqueness. In the case of unconditional convergence, there is only one equilibrium-level to which all economies approach. In the case of conditional convergence, equilibrium differs by the economy, and each particular economy approaches its own but unique equilibrium. In contrast, the idea of club-convergence is based on models that yield multiple equilibrium.\(^{39}\) Which of these different equilibrium an economy will reach depends on its initial position or some

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\(^{33}\) See for example Mankiw, Romer, and Weil (1992) or Barro and Sala-i-Martin (1995) for the derivation.

\(^{34}\) In the case of the Cass- Koopmans model, also has similar set of elements with s replaced by parameters for the rate of time preference and the elasticity of inter-temporal substitution in consumption.


\(^{39}\) For models with multiple equilibria, see, for example, Azariadis and Drazen (1990).
other attribute. A group of countries may approach a particular equilibrium if they share the initial location or attribute corresponding to that equilibrium. This produces club-convergence.

6.2.6 Income-convergence vs. TFP-convergence

Researchers have generally dealt with convergence in terms of per capita income, i.e., with income convergence. However, income convergence can be the joint outcome of the twin processes of capital deepening and technological catch-up. While most researchers have focused on parameters of the capital deepening process, other researchers, such as Dowrick and Nguyen,40 Dougherty and Jorgenson,41 Wolff,42 and Dollar and Wolff,43 have directed their attention to the process of technological catch-up. Since total factor productivity (TFP) is the closest measure of technology, these researchers have investigated whether countries have come closer in terms of TFP levels. This has given rise to the concept of TFP-convergence. Clearly, income convergence can get either accelerated or thwarted depending on whether initial TFP-differences narrow or widen over time.

6.2.7 Deterministic Convergence vs. Stochastic Convergence

Several researchers, such as Bernard and Durlauf44, Carlino and Mills,45 Evans,46 and Evans and Karras,47 Qi and Papell, and others have investigated convergence using time

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series econometric methods. As we shall see in more detail below, ‘within convergence’ is actually a time series concept. However, researchers have used time series analysis to examine ‘across convergence’ too. From this point of view, Two economies, i and j, are said to converge if their per capita outputs, $y_{i,t}$ and $y_{j,t}$ satisfy the following condition:

$$\lim_{k \to \infty} E \left( y_{i,t+k} - a \cdot y_{j,t+k} \mid I_t \right) = 0$$  \hspace{1cm} (3)$$

Where ‘$I_t$’ denotes the information set at time t. This definition of convergence is relatively unambiguous for a two-economy situation. This is not so when convergence is considered in a sample of more than two economies. Researchers differ on defining convergence in such multi-country situations. Some have taken deviations from a reference economy as the measure of convergence. In this treatment, $y_{i,t}$ in equation (3) is replaced by $y_{1,t}$, where 1 is the index for the reference country. Others have based their analysis of convergence on deviations from the sample average. In this treatment, $y_{i,t}$ is replaced by $\bar{y}_t$, the average for time t. This difference is not innocuous. The time series definitions of convergence can be related with the notions of conditional and unconditional convergence too. With $a = 1$, equation (3) represents a variant of unconditional convergence. On the other hand, if $a \neq 1$ then equation (3) may represent a variant of conditional convergence. Within this framework a distinction has also been made between ‘deterministic’ and ‘stochastic convergence.’ This distinction refers to whether ‘deterministic’ or ‘stochastic’ trend is allowed in testing for unit root in the deviation series.

From a chronological point of view, the study of convergence began with the notion of ‘absolute convergence’ and then moved to the concept of ‘conditional convergence.’ Both these concepts were initially studied using the notion of ‘$\beta$-convergence.’ The notion of $\sigma$-convergence arose later. Alongside emerged the concepts of ‘club-convergence,’ ‘TFP-convergence,’ and the time series notions of convergence. There was also a chronological progression from the ‘informal cross-section’ to ‘formal cross-section,’ and then on to ‘panel’ approach to convergence study. The ‘time-series’ and the ‘distribution’ approaches developed alongside.
Section II

6.3 An Analysis of Convergence in India

In this section an attempt has been made to test the convergence across Indian states/union territories. The objective here is to see whether there was any possibility of convergence or divergence across the states during the study period. There are different approaches and types of convergence as mentioned above. In present study only three approaches are used for convergence test such as: Cross Sectional Approach to Convergence, Panel Approach to Convergence and The Distribution Approach to Convergence. While the cross-section, panel, and time-series approaches have in one way or the other investigated $\beta$-convergence, the distribution approach focuses on $\sigma$-convergence and on changes in the cross-section income distribution as a whole.\(^{48}\) For testing the convergence the data on GSDP per capita has been obtained from CSO (Central Statistical Office). In this study the test of convergence is applied across the states in general and in particular to three selected northern states.

There are certain evidences of attempts made to analyse, empirically, convergence or divergence of income levels across Indian states. Cashin and Sahay (1996), Bajpai and Sachs (1996), Rao, Shand and Kalirajan (1999) and Singh and Srinivasan (2002) are such papers, which analyse the relationship between per capita income, lagged per capita income, and the convergence coefficient in a cross section regression framework.

First, Cashin and Sahay\(^{49}\) examine four sub-periods between 1961 and 1991, for a sample of 20 Indian states. Although they find evidence of unconditional and conditional convergence in all four sub-periods, their results are not statistically significant. They conclude that for the period as a whole, there is evidence of weak convergence. Second, analysing a sample of 19 Indian states for the period 1961-1993 (divided into three sub-periods), Bajpai and Sachs\(^{50}\) did not found statistically significant evidence of convergence.

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significant results of convergence for the period as a whole. It is only for the sub-period 1961-71 that they find evidence of convergence. Third, Rao et al.\textsuperscript{51} examine a sample of 14 major states over the period 1965-1994, divided into various sub-periods. Strikingly, they find evidence of absolute and conditional divergence in every sub-period they consider. This is in sharp contrast to the results of the other two studies. Fourth, in the most recent study on the literature on the subject, for a sample of 14 major Indian states for the period from 1990-91 to 1998-99, Singh and Srinivasan\textsuperscript{52} find weak evidence for both absolute and conditional convergence. Fifth Sachs, et al.\textsuperscript{53} analysed the differential economic performance of India’s 14 major states for the period covering 1980-98 and found that overall divergence during the study period, as well as during both the pre-reform and post-reform sub-periods from 1980-90 and 1992-98.

There is a rich literature using regional data to test whether growth in regions within India has converged or diverged over time. The hypothesis of convergence has been examined by several studies from different periods with each applying different approaches of convergence. Bajpai and Sachs\textsuperscript{54} made an attempt to examine the tendency towards convergence of income levels among the 19 states of India over the period 1961-71, 1972-82 and 1983-93. Rao, Shand and Kalirajan\textsuperscript{55} showed that the pattern of economic growth in India since mid-1960s did not confirm to the predictions of neo-classical growth theory. Per capita income across states over the last three and a half decade displayed divergence etc. and other studies which mainly used growth rate to test the convergence or cross sectional or panel data models restricted to some states.

The present study is different from previous studies in the sense that investigator has used three types of approaches to test the convergence namely cross-sectional approach, panel data approach and distributional approach and has also test the


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convergence for 30 states for whole period of 1993 to 2012 and also separately for two decades of 1993 to 2002 and 2003-2004, which is an addition to existing literature. The investigator has also tested the convergence among three sample states of northern India namely Jammu & Kashmir, Himachal Pradesh and Punjab which have some common and some diversified features and this also adds a valuable contribution to existing literature.

The unconditional cross-sectional convergence (β-convergence) has been tested across Indian states/union territories by using GSDP per capita. This analysis involves the imposition of certain restrictions in the fixed-effects specification. In particular, a common intercept is assumed by eliminating the state-fixed effects. The results are shown below.

Table: 6.1: Estimated Linear Regression of Growth Rates of per capita GSDPs of State on their respective Initial per capita GSDPs

<table>
<thead>
<tr>
<th>Variables</th>
<th>Equation</th>
<th>R²</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ln(GSDP)₀</td>
<td>0.086587</td>
<td>0.0211</td>
<td>20</td>
</tr>
<tr>
<td>Cons</td>
<td>0.065489</td>
<td>0.111386</td>
<td>0.443</td>
</tr>
</tbody>
</table>

Source: Author’s Computation based on CSO (Central Statistical Organisation) data
Relevant t-statistics are shown in parentheses below the parameter estimates

In above table β-convergence has been tested by using the cross sectional convergence method. The results do not support unconditional convergence (cross-sectional) in growth performance across all states as the coefficient of the log of initial per capita GSDP (estimated β equals 0.86) is positive. This implies unconditional divergence across states, i.e. the states are not converging to identical steady states. The results given above are not in line with neo-classical convergence model. The other studies also show the similar results [Dasgupta et al 2000; Ghosh et al 1998; Marjit and Mitra 1996; Raman 1996; Shaban 2002]. From these studies one can conclude that regional economies evolve in multiple ways. They can converge and diverge simultaneously at different regional scales. Due to this reason, the regional scale at which a study is undertaken becomes extremely important as it influences the results and conclusions.
So, it is evident that many of the studies found the Indian states are diverging from each other in terms of their growth performance from an identical steady states. The value of coefficient of determination ($R^2 = 0.0211$) is very low, which implies that there are some other important factors which explain the behaviour of per capita GSDP on growth rates across different Indian states.

In the following figure we plot the growth rate of the states for the period 1993-94 to 2012-13 against the log of per capita GSDP in 1993-94. If there is convergence in income levels, the relationship would have been downward sloping. But as figure below shows, the relationship between growth rate and initial level of per capita GSDP is upward sloping. This implies that the states with higher initial per capita GSDP on an average grow faster, suggesting that the inequality across states is increased and it is also important to clarify that although there is no sign of unconditional convergence (reducing dispersion of income), but still there might be conditional convergence. Conditional convergence can be consistent with divergence in PCIs over a certain period of time. It is possible that Indian states are converging to increasingly divergent steady states.56 The results of present analysis also coincide with the findings of that of Bakshi, S. et al (2015).

Now in next section the panel data model will be used for convergence test. A panel, or longitudinal data set, consist of a sequence of observations, repeated through time, on a set of statistical units (individuals, firms, countries, etc.). Panel data models have attracted the interest of many researcher in recent time. Baltagi, in the introduction of his seminar book on panel data, list some of the benefits and some limitation in using panel data (Hsiao, 1985, 1986; Klevmarken, 1989; Solon, 1989). Firstly, they allow controlling for individuals heterogeneity. Moreover, they are more informative with respect to time series or pure cross-sectional data, present more variability, less collinearity among the variables, more degrees of freedom and more efficiency. It should be emphasized that a panel data regression differs from a time series or cross-section regression in the sense that it consider both the temporal and the individuals’ dimension. Panel data offers two distinct advantages over pure cross-section or time

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First of all the units are observed through times and this fact simplifies the analysis of some economic problems that cannot be studied using purely cross sectional data. Furthermore, panel data allow the analysis of individual behaviour, controlling for individual heterogeneity.

On the other hand some problems arise using panel data. First of all design and data collection problems are more complicated than in the case of time series or cross-sectional data. Furthermore, measurement errors may arise producing distortions in the inferential procedures and in many cases, the time series dimension is too short. However, the main problem in using panel data is selectivity, arising in the various forms of self-selectivity, non-response, attrition and new entries.

While estimating the panel data model, two different interpretations may be given to the intercept coefficient, and, consequently, two different basic models may be distinguished. If the intercept coefficients are assumed to be fixed parameters to be estimated the model is termed fixed effect panel data model. Conversely, if the intercept coefficients are assumed to be random, the so-called random effect panel data model is generated. Generally speaking, fixed effect model is used when the regression analysis is limited to a precise set of individuals, firms or regions; random effect, instead, is an appropriate specification if we are drawing a certain number of individuals randomly from a large population of reference. For this reason, since in the present study the data set consists on the observation over 30 Indian states and union territories estimated in fixed parameters, so, it has been decided to use a fixed effect panel data model to check for convergence.

The panel data model in the present section is expressed by the following equation:


60 For more detail on the discussion regarding the use of this two models for panel data we suggest to see specialistic books on panel data (i.e. Baltagi 2001).
\[
\ln \left( \frac{y_{t+k,i} - y_{t,i}}{y_{t,i}} \right) = \alpha_i + \beta \ln y_{t,i} + \epsilon_{t,i}
\]

Where the dependent variable is the annual growth rate of per-capita GSDP, the regressor is represented by the (log) per-capita-GDP for region i at time t, and \( \alpha_i \) are interpreted as parameter to be estimated as in the fixed effect model specification. The estimated results of above panel data equation is presented in table 6.2.

**Table 6.2: Panel data fixed effect model β-convergence (income) for the period 1993 to 2012**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Equations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coef.</td>
</tr>
<tr>
<td>Log GSDP&lt;sub&gt;PC&lt;/sub&gt;</td>
<td>-0.7451771 (4.4)</td>
</tr>
<tr>
<td>Cons</td>
<td>5.162907 (2.95)</td>
</tr>
</tbody>
</table>

| No. of observations | 500 |
| No. of groups       | 30 (per group observation 20) |
| \( R^2 \)           | 0.0329 |
| Sigma_u             | 0.62858667 |
| Sigma_e             | 1.2403367 |
| Rho                 | 0.20434945 (fraction of variance due to \( \epsilon_{t,i} \)) |

Source: Author’s Computation based on CSO (Central Statistical Organisation) data
Relevant t-statistics are shown in parentheses below the parameter estimates.

Empirically, beta convergence can be estimated using cross-section, time series and panel data methods. The fixed panel data model helps one to estimate the steady state of every economy.\(^6\) In the above table the fixed effects panel data model has been employed to test the convergence/divergence in growth rates in terms of per capita GSDP across 30 Indian states for the period 1993-2012. Empirical evidence finds support for unconditional convergence (income convergence) in growth performance across all states as the coefficient of the log of the per capita of Gross State Domestic products (logGSDP<sub>PC</sub>) is negative (-0.74) and statistically significant. It is clear from the above results that across the states there is sign of convergence (income

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convergence) over the time, hence the Solow’s model of growth convergence is proved in this case. A study carried out on growth convergence among special category and non-special category states (Raju S.), using panel data model for the period of 2001-10, found that there is strong evidence of convergence among non-special category states and weak evidence of convergence among special category states, which support our results that the states/union territories of India are converging in terms of GSDP per capita over the reference period.

Table 6.3: Panel data fixed effect model β-convergence (income) for the period 1993 to 2002

<table>
<thead>
<tr>
<th>Variables</th>
<th>Equations</th>
<th>Coef.</th>
<th>Std. Err.</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log GSDP&lt;sub&gt;PC&lt;/sub&gt;</td>
<td></td>
<td>-4.210074 (-5.95)</td>
<td>.707457</td>
<td>0.000</td>
</tr>
<tr>
<td>Cons</td>
<td></td>
<td>40.06989 (5.62)</td>
<td>7.133674</td>
<td>0.000</td>
</tr>
<tr>
<td>No. of observations</td>
<td>300</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of group</td>
<td>30 (per group observation 10)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R²</td>
<td></td>
<td>0.1167</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sigma_u</td>
<td></td>
<td>1.8019314</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sigma_e</td>
<td></td>
<td>1.4887651</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rho</td>
<td></td>
<td>.59431301 (fraction of variance due to u_i)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Author’s Computation based on CSO (Central Statistical Organisation) data

Relevant t-statistics are shown in parentheses below the parameter estimates.

The estimated results for the period 1993 to 2002 are presented in above table. It evident from the estimated results that the coefficient of growth rate variable is negative (-4.21) and statistically significant, thus conforming the hypothesis of convergence among the Indian states for the reference period and the magnitude of convergence is higher at 4.21 percent as compared to that for the period 1993-2012 of 0.74 percent. From these results one can come to the conclusion that the reason for strong evidence of convergence across Indian states was the high degree of control exercised by the central government in many areas not leaving much greater scope for state level initiative and private investment.

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The table 6.4 presents the coefficient convergence for the period 2003-2012 across the Indian states.

**Table 6.4: Panel data fixed effect model β-convergence (income) for the period 2003 to 2012**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Equations</th>
<th>Coef.</th>
<th>Std. Err.</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log GSDP&lt;sub&gt;PC&lt;/sub&gt;</td>
<td></td>
<td>-0.1513085 (-0.65)</td>
<td>.2337002</td>
<td>0.518</td>
</tr>
<tr>
<td>Cons</td>
<td></td>
<td>-1.081872 (-0.44)</td>
<td>2.469238</td>
<td>0.662</td>
</tr>
<tr>
<td>No. of observations</td>
<td>300</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of group</td>
<td>30 (per group observation 10)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R&lt;sup&gt;2&lt;/sup&gt;</td>
<td></td>
<td>0.0016</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sigma_u</td>
<td></td>
<td>0.62462789</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sigma_e</td>
<td></td>
<td>0.80760803</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rho</td>
<td></td>
<td>0.37429343 (fraction of variance due to u&lt;sub&gt;i&lt;/sub&gt;)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Author’s Computation based on CSO (Central Statistical Organisation) data
Relevant t-statistics are shown in parentheses below the parameter estimates.

From the empirical estimates of convergence analysis for the period 2003-2012, it is evident that the coefficient of convergence is negative (-0.1513085) but not statistically significant, that is the evidence of convergence is the weakest for the 30 Indian states under study and the magnitude is also much lower as the coefficient of the log of per capita GSDP is the lowest at 0.1513085. We can conclude from the above analysis that during the period 2000 onwards the disparity has widened as compared to 1990s per capita GSDP. This situation can be attributed to reforms as the impact of reforms remained confined to already advanced states resulting in their further progress while as, other states have lagged behind. As concluded by Bhattacharya (2004), the disparity in terms of per capita GSDP growth across states in India during 2000s has increased as compared to 1990s. The problem is compounded by the negative relationship between population growth and income growth. Unfortunately, backward states with higher population growth are not able to attract investment –both public and private –due to a variety of reasons, like low income, poor infrastructure, poor

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governance, regional divide, political will, bureaucratic apathy, unskilled human resources, poor planning, political instability, etc.

Section III

It was all about the analysis of convergence across Indian states over three periods namely 1993-2012, 1993-2002 and 2003-2012. Now let us look into the convergence hypothesis across the sample north western states namely Punjab, Jammu & Kashmir and Himachal Pradesh. Here we have also estimated the coefficient of convergence for three time periods as mentioned above. The table 6.5 shows the estimation of convergence hypothesis for the three sample states.

Table 6.5: Panel data fixed effect model β-convergence (income) for three sample states for the period 1993 to 2012

<table>
<thead>
<tr>
<th>Variables</th>
<th>Equations</th>
<th>Coef.</th>
<th>Std. Err.</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log GSDP_{PC}</td>
<td></td>
<td>.066766</td>
<td>.5151999</td>
<td>.5151999</td>
</tr>
<tr>
<td>Cons</td>
<td></td>
<td>-3.849199</td>
<td>5.364631</td>
<td>0.476</td>
</tr>
<tr>
<td>No. of observations</td>
<td></td>
<td>300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of group</td>
<td></td>
<td>30 (per group observation 20)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R²</td>
<td></td>
<td>0.0003</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sigma_u</td>
<td></td>
<td>.37664676</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sigma_e</td>
<td></td>
<td>1.0035445</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rho</td>
<td></td>
<td>.12347013</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Author’s Computation based on CSO (Central Statistical Organisation) data
Relevant t-statistics are shown in parentheses below the parameter estimates.

By empirical, estimation of β-convergence for the period 1993-2012, the evidence was found against the unconditional convergence in growth performance across the three sample states as the coefficient of the log of per capita Gross State Domestic Products (logGSDP_{pc}) is positive, which means that over the period these three sample states have diverged in term of growth performance and the magnitude is much lower as the coefficient of the log of per capita GSDP is lowest at 0.66. The reason for this divergence are their divergent industrial base, agricultural structure, socio-political and
geographical characteristics. In case of Jammu & Kashmir political instability and lack of infrastructure is also a reason behind such a phenomena.

The convergence hypothesis for the period 1993-2002, by using fixed effects panel data model presented in table 6.6 has been estimated.

Table 6.6: Panel data fixed effect model β-convergence (income) for three sample states for the period 1993 to 2002.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Equations</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coef.</td>
<td>Std. Err.</td>
<td>P-value</td>
<td></td>
</tr>
<tr>
<td>Log GSDP&lt;sub&gt;PC&lt;/sub&gt;</td>
<td>-6.550869 (-2.75)</td>
<td>2.378126</td>
<td>0.011</td>
<td></td>
</tr>
<tr>
<td>Cons</td>
<td>63.4903 (2.62)</td>
<td>24.26337</td>
<td>0.015</td>
<td></td>
</tr>
<tr>
<td>No. of observations</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of group</td>
<td>3 (per group observation 10)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R&lt;sup&gt;2&lt;/sup&gt;</td>
<td>0.2259</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sigma_u</td>
<td>1.4484208</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sigma_e</td>
<td>1.2464224</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rho</td>
<td>.57453858 (fraction of variance due to u_i)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Author’s Computation based on CSO (Central Statistical Organisation) data
Relevant t-statistics are shown in parentheses below the parameter estimates.

While estimating the hypothesis of convergence for the sample states for the reference period, it was found that the coefficient of log of per capita GSDP is negative and statistically significant, which means that the sample states have converged in terms of their growth performance. The magnitude of convergence is much higher as the coefficient of log of per capita GSDP is at 6.55. The one of the main reason for the high convergence across sample states is the high degree of control exercised by the central government with regarding to initiative of private investment before reforms.

The table 6.7 presents the estimated convergence test for the sample states for the period 2003-2012.
Table 6.7: Panel data fixed effect model β-convergence (income) for three sample states for the period 2003 to 2012.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Equations</th>
<th>Coef.</th>
<th>Std. Err.</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log GSDP&lt;sub&gt;PC&lt;/sub&gt;</td>
<td>0.0334713 (0.13)</td>
<td>0.2531474</td>
<td>0.896</td>
<td></td>
</tr>
<tr>
<td>Cons</td>
<td>-3.320257 (-1.24)</td>
<td>2.687995</td>
<td>0.288</td>
<td></td>
</tr>
</tbody>
</table>

No. of observations: 30
No. of group: 3 (per group observation 10)
R<sup>2</sup>: 0.0007
Sigma_u: 0.25296891
Sigma_e: 0.2225536
Rho: 0.56370127 (fraction of variance due to u<sub>i</sub>)

Source: Author’s Computation based on CSO (Central Statistical Organisation) data
Relevant t-statistics are shown in parentheses below the parameter estimates.

The results of above table indicate that there is no sign of convergence across three sample states over the reference period as the coefficient of log of per capita GSDP is positive and statistically insignificant. Which implies that there is divergence across the sample states and the magnitude of coefficient of log of per capita GSDP is lowest at 0.33%. The reason for the divergence are their divergent industrial base, agricultural structure, socio-political and geographical characteristics. Through the process of circular cumulative causation based on external economies (size of markets and linkages between activities, labour market externalities, knowledge spill-overs, etc.) associated with leading regions leads to further larger disparity across states. We can conclude from the above analysis that during 2000s the disparity has widened as compared to 1990s. This is a matter of serious concern, with a scope for further research to find out the real sources of income and its distribution across these states, since 2000.

6.4 Sigma (σ) Convergence

Another important convergence concept is σ-convergence. The idea of this concept is that convergence is assumed if the dispersion measured by the standard deviation σ (or any of the measure of dispersion) of cross-economy per capita income declines over time. According to Barrow, Sala-I-Martin, Blanchard, & Hall (1991), if the researcher want to know “how the distribution of per capita income across economies has behaved
in the past or is likely to behave in the future”, the relevant metric that researchers should explore is sigma convergence. The concept of σ-convergence does not deal with the question to which steady-state the incomes convergence and thus, whether the average income rise or fall over time is not the subject matter of it. For analyzing σ-convergence the only important question is whether the cross-economy variance of log (yi,t) decreases over time and to see whether the incomes of various states at large come closer to each other or not? Sigma convergence concerns itself with the cross sectional dispersion of per capita income/product and is said to occur if the dispersion measured by the standard deviation of the logarithm of per capita income/product across states/regions declines over time. The coefficient of variation is an alternative indicator of measuring sigma convergence. As in the case of standard deviation, a declining value of the coefficient of variation over time would reflect convergence.64

In convergence literature, Friedman65 and Quah66 have argued that sigma convergence is the only valid measure of convergence because beta convergence test are subject to Galton’s fallacy67 of regression to mean. Barro and Sala-i-Martin68 tested for sigma convergence from 1880 to 1988 using state per capita income data. Their result supports sigma convergence for the U.S. economy throughout the study period except the 1920s and 1980s.

In the present study we have calculated coefficient of variation (CV) of per capita of GSDP at 2003-04 prices across states for each year. Then we have fitted a linear time trend over the series of coefficient of variation. The result is shown in table 6.8 given below.

67 The tendency to converge (β-convergence) disappears when the growth is plotted against the terminal year rather than the initial year, and the entries tend to diverge rather than converge. This phenomenon is referred as Galton’s fallacy or statistical (regression) fallacy.
Table 6.8: Estimated linear trend equation of per capita GSDP of States 1993-2012

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coef.</th>
<th>Std. Err.</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>0.211568</td>
<td>0.1101913</td>
<td>0.071</td>
</tr>
<tr>
<td></td>
<td>(1.92)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-370.235</td>
<td>220.659</td>
<td>0.111</td>
</tr>
<tr>
<td></td>
<td>(-1.68)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of observations</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R²</td>
<td>0.17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adj R²</td>
<td>0.1239</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Root MSE</td>
<td>2.8416</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Author’s Computation based on CSO (Central Statistical Organisation) data
Relevant t-statistics are shown in parentheses below the parameter estimates.

From the empirical analysis of the coefficient of variation with time, it was found that there is divergence across Indian states. The trend of the coefficient of variation is increasing with time and it has increased from 47.08 in 1993-94 to 54.34 in 2012-13 and the slope coefficient is positive but not significant and the R² is too low. It can be implied from the above results that the Indian states do not exhibit sigma convergence and the Indian states have diverged in terms of per capita GSDP during the reference period. The following figure makes the picture more clear.

Figure 6.2: Behaviour of Coefficient of Variation of per capita GSDP across States from 1993-94 to 2012-13
The plot of the coefficient of variation of per capita GSDP (2004-05 prices) for 30 states/union territories shows, that for the period 1993 to 2012, the value of coefficient of variation increased from 47.09 to 54.34. However, during 1993-2002, coefficient of variation increased to the highest value of 59.66 and in 2003 it decreased to 53.63. During 2003 to 2010 the value of coefficient of variation fluctuated between 52.26 to 55.08 and declined to 52.26 which implies the convergence in growth across states. However, the rise in the coefficient of variation after 2010, points to the emergence of divergence in growth across states. Thus the states shows a mixed process of convergence and divergence for the period 1993 to 2012, as the coefficient of variation tends to alternatively increase and decrease.

6.5 Conclusion

After explaining the various concepts and methods of estimating convergence, we just applied two methods of convergence testing namely cross sectional regression model and panel data regress model to estimate two types of convergence viz. sigma convergence and beta convergence. From the cross sectional estimation of convergence, we came to the conclusion that there is divergence across India states and the same result was found by estimating sigma convergence. While applying panel data regression model for the period 1993 to 2012, it was found that the results support for unconditional convergence (income convergence) in growth performance across all states as the coefficient of the log of the per capita of Gross State Domestic products (logGSDP_{pc}) is negative and statistically significant. Across the states there is sign of convergence (income convergence) over the time, hence support the Solow’s model of growth convergence. While dividing the whole study period into two sub-periods viz. 1993-2002 and 2003-2012, convergence hypothesis has been proved in both the cases. While estimating the convergence test across the three sample states, it is found that for whole period there were convergence and for sub-periods initially these states converged in terms of their growth performance and latter diverged in terms of their growth performance. The same result has been found when applying sigma convergence.
So for as above discussion is concerned it is clear that Indian states are converging to their steady states in terms of their per capita GSDP during the reference period 1993-94 to 2012-13 and this supports the Solow’s interpretation of growth of developing economies and substantiates the view point of some other researchers [for example Gosh (1998), Bhattacharya and Sakthivel (2004), Bakshi (2015). But while dividing the reference period of present study into two sub-periods i.e. 1993-94 to 2002-03 and 2003-04 to 2012-13, it is found that the former period shows convergence in terms of growth of per capita GSDP and later divergence. It is because of the reforms which created circular and cumulative causation, divergent industrial base, knowledge-spill-overs, geographical dualism, infrastructure gaps and persistence differences in a wide variety of development indices, like wage rates, per capita income, employment growth rates, level of unemployment, etc. due to which the development process has been uneven across states. As the already pointed out advanced states have tended to leapfrog and other states have lagged behind. The regional divergence between poor and advanced states has increased. The poorly states have not only performed poorly but their failure to stem population growth has left them in an even worse position.