EXPLORING THE CONVERGENCE PUZZLE IN INDIA

Combining neoclassical and endogenous models to understand growth experience of Indian states

Anshuman Kamila
Meeta Keswani Mehra

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Combining neoclassical and endogenous models to understand growth experience of Indian states

Anshuman Kamila and Meeta Keswani Mehra [1]

Abstract: The study of economic growth across countries is highly rewarding. Understanding the varied patterns of growth across countries is crucial because disparities in growth rates have, in due course of time, led to gaps in living standards and 'welfare'. The Economic Survey 2016-17 (2017) conducts an empirical exercise for the $\beta-$convergence for i) countries of the world; ii) provinces of China and iii) states of India. It depicts poorer countries are closing the per capita income gap with richer countries, the poorer Chinese provinces with the richer ones, but in India, the less developed states are not converging to their richer counterparts; instead they are, on average, going further from the richer states. Against the above backdrop, this study is an attempt to scrutinise existing literature on the subject of convergence and infer the gaps in literature pertaining to GSDP per capita growth experience of Indian states. Then, an attempt is made to test for applicability of neoclassical and endogenous growth models. Following this, is an inquiry into whether difference in growth of per capita GSDP across states is on account of difference in inputs in the production process or the difference in efficiency in utilising such inputs in the process of production. We discover that while neo-classical growth model broadly applies to Indian states, only 20% of variation in per capita GSDP across Indian states is explained by dispersion of values of rates of investment, population growth, depreciation and TFP growth − as opposed to nearly 60% dispersion of GDP across world economies being accounted for by such differences. In addition, 8 and 11 states show evidence for AK model and $R\&D$ model respectively. Finally, states that were initially 'rich' or 'poor' have shown similar growth rates for the past two decades, on account of similarity in investment in physical and human capital across these. Therefore, more progressive redistribution of physical and human capital is necessary for convergence in per capita GSDP levels.

[1] Anshuman Kamila is Officer Trainee(Probationer) in Indian Economic Service, Ministry of Finance, Government of India. Meeta Keswani Mehra is Professor of Economics, Centre for International Trade and Development, School of International Studies, Jawaharlal Nehru University, Delhi. The views expressed in the paper are those of authors and do not necessarily reflect the views of the institutions to which they belong. The authors are also thankful to participants of discussions of an earlier version of this paper at two forums, the Department of Economic and Policy Research (DEPR) Study Circle of Reserve Bank of India (Mumbai) on 25 September 2020 and seminar at Institute of Economic Growth (Delhi) on 28 January 2021, for their helpful comments and remarks which helped refine this work. Email: kamila.anshuman@gmail.com

1 Background

> *... real development cannot ultimately take place in one corner of India while the other is neglected.*
>
> ***Jawaharlal Nehru***, first Prime Minister of India

The study of economic growth across countries is highly rewarding. High economic growth is an avowed objective for economists and policymakers alike. Studying factors underlying economic growth, therefore, helps to set up conditions to induce high economic growth. Understanding the varied patterns of growth across countries is crucial because disparities in growth rates have, in due course of time, led to gaps in living standards and 'welfare'. A first generation of empirical growth analyses – by making claims about growth dynamics – have catalysed newer ways of studying cross-country growth experiences. The latter, in turn, are spawning fresh perspectives on growth with important implications for theory and policy. Investigating if less affluent countries of the world are converging with their richer counterparts in terms of income levels is in its own merit a question of paramount importance for investigating patterns of standards of living. Therefore, 'convergence' has become a nucleus around which dense development of growth literature has evolved. Further, since alternative growth theories have postulated different drivers of growth with varying policy implications, it is not surprising that this line of investigation of convergence has been pursued with much zeal. Apart from the universal importance of the inquiry, the insights are of greater significance for an economy like India's – where regionally balanced economic growth and development has been a primordial policy objective.

The Economic Survey 2016-17 (2017) conducts an empirical exercise for the $\beta-$convergence for i) countries of the world; ii) provinces of China and iii) states of India. [Hereinafter, we talk of $\beta-$convergence when a negative relation is obtained between growth rate of per capita income and the initial level of per capita income. That is, $\beta-$convergence is said to occur when less affluent economies tend to grow more rapidly vis-a-vis wealthy ones. Assuming diminishing returns, the marginal productivity of capital is higher in capital-poor country; therefore, if rich (capital-abundant) and poor (capital-scarce) economies have the same savings rates the latter will grow faster than the former. This yields a negative relation between initial income level and the growth rate exhibited later on; the ($\beta-$)coefficient on initial income level of income – when we regress growth rate against initial level of income – will be negative. Distinct from this, is the occurrence of $\sigma-$convergence which is said to occur when the dispersion of per capita income across units in a cross section tends to descend over time. It must be stated upfront, however, that $\beta-$convergence is *necessary* for $\sigma-$convergence: if richer units grow faster than the poorer units (i.e. an absence of $\beta-$convergence), *ipso facto* incomes of units grow farther apart from each other leading to absence of $\sigma-$convergence.] It depicts that in terms of convergence of GSDP-per-capita [per capita Gross State Domestic Product], states in India exhibit a stark unlikeness to the process of catching-up that is occurring globally and within China. Regressing growth of per capita Gross Domestic Product (GDP) on the log value of initial level of per capita income [per capita GDP (in Purchasing Power Parity [PPP] terms) for countries, per capita provincial domestic product for provinces of China and GSDP per capita for states of India], it is found that the association is strongly negative for the world and China, and positive for India. Poorer countries are closing the gap with richer countries, the poorer Chinese provinces with the richer ones, but in India, the less developed states are not converging to their richer counterparts; instead they are, on average, going further from the richer states. It asserts that while internationally, growth rates of per capita GDP diverged starting latest dating back to the 1820s with less affluent countries growing slower than richer ones – thus giving rise to the wide gulf between advanced and developing countries [Pritchett(1997)], from 1980 there has been a reversal of this long term trend – with poorer countries starting to catch up with richer ones [Roy et al.(2016)]. In opposition to this phenomenon, there is persistence of divergence within India at the sub-national level, or an aggravation of regional inequality (for the period 1984-2014). This phenomenon is specifically baffling since the forces promoting equity – migration of people and trade in goods – are stronger within India than they are across countries, and they are strengthening over time. Furthermore, public policy in India – operating through instruments such as Plan assistance, Centre-state transfers, Finance Commission-mandated devolution of resources, etc – has actively sought to promote equitable growth and to reduce inequality existing between states. Sala-i-Martin (1996) documents the efficacy of transfers of this broad genre in helping to reduce dispersion of per capita income across states of the U.S.A. Of course, since early 2000s, some less developed Indian states – for instance, Bihar, Madhya Pradesh and Chhattisgarh – had started posting incremental improvement to their performance (a process often termed *'frogleaping'*), such developments have neither been potent nor consistent enough to change the underlying picture of divergence or growing inequality. The primordial objective of ensuring more widespread and holistic growth – as evidenced from the quotation by the first Prime Minister of India alluded to in the beginning, to the thrust of the Eleventh and Twelfth Five Year Plans on *'faster and inclusive growth'*, to the emphasis on *'prosperity with equality'* in NITI Aayog's Fifteen Year Action Agenda – renders the study of non-/convergence of per capita incomes of Indian states an absolute imperative.

Against the above backdrop, this study is an attempt to scrutinise existing literature on the subject of convergence and infer the gaps in literature pertaining to GSDP per capita growth experience of Indian states. Then, an attempt is made to test for applicability of neoclassical and endogenous growth models. Following this, is an inquiry into whether difference in growth of per capita GSDP across states is on account of difference in inputs in the production process or the difference in efficiency in utilising such inputs in the process of production.

We discover that while neo-classical growth model broadly applies to Indian states, only 20% of variation in per capita GSDP across Indian states is explained by dispersion of values of rates of investment, population growth, depreciation and TFP growth – as opposed to nearly 60% dispersion of GDP across world economies being accounted for by such differences. Clearly, there is greater deal of heterogeneity in production function across Indian states than there exists among world's economies. However, level of human capital in impacting growth rate of an Indian state is concluded within the framework of human capital augmented neo-classical growth model. In addition, 8 and 11 states show evidence for AK model (where physical capital investment augments productivity of the entire capital stock of the economy) and $R\&D$ model (where human capital augmentation enhances productivity of the economy through processes of *innovation* and/or *imitation*) respectively. Finally, states that were initially 'rich' or 'poor' have shown similar growth rates for the past two decades, on account of similarity in investment in physical and human capital across these. Therefore, more progressive redistribution (*i.e.* comparatively more investment in 'poor' than in 'rich' states) of physical and human capital is necessary for convergence in per capita GSDP levels. At the same time, attracting more physical and human capital investment into states in a competitive federalism framework is essential to a more equitable growth experience across Indian states and Union Territories (UTs).

In what follows, the review of closely related literature on this subject is discussed.

2 Review of the Literature

A brief review of the vast literature on the topic of convergence may be categorised into three thematic sections:

1. Different growth models and what they imply for convergence;
2. Studies pertaining to economic units from around the globe; and
3. Exploration of the growth experience of Indian states.

2.1 *Different growth models and what they imply for convergence*

2.1.1 Neo-classical growth models

The growth rate of per capita level of output or income is found to be negatively associated with the initial level of output or income per person in neo-classical growth models for closed economies − for instance in Ramsey (1928), Solow (1956), Cass (1965) and Koopmans (1965). This leads to the inexorable conclusion that, given similarity among economies in preferences and technology, poor economies grow quicker than rich ones. We thereby have a pathway that leads to convergence in levels of per capita product and income.

The observable implication of a log linearised approximation to these models with Cobb-Douglas technology is captured in an expression for average or long run growth rate with β as the rate of convergence:

$$\frac{log[y(t)] - log[y(0)]}{t} = \alpha - \frac{1 - e^{-\beta t}}{t} log[y(0)] + u(t). \qquad (1)$$

The term $u(t)$ is an error term appended for regression analysis and the maintained assumption is that it is uncorrelated with appropriate explanatory variables on the RHS, *viz*. level of initial per capita output and other conditioning variables (like investment rate, population growth rate, etc.) when considered as part of the above equation. Thus, (1) postulates that the average growth rate depends negatively (given a positive β) on the initial condition − $log[y(0)]$ − among other things. A higher β implies greater responsiveness of the average growth rate to the gap between the initial condition and the steady state; in other words, higher β signifies accelerated transition to the steady state. The term α is a constant signifying the steady state level of output per unit of effective labour. [Appendix A motivates the equation (1) above.]

2.1.2 Endogenous framework: *'learning by doing'*

As opposed to the assumption in neo-classical growth models about the rate of labour augmenting technological progress being exogenously given (in the instant case it is x), there are good reasons to believe that this rate is determined endogenously within the model. Because financing of science, piling of human capital and other knowledge promoting exercises by profit seeking firms lead to industrial innovations, economic decisions are believed to determine technological change. The first approach in this direction was the *"learning by doing"* framework − wherein, technological progress is contingent upon production of capital in the aggregate, technological progress is seen as being incidental to the act of capital accumulation (instead of being an expected outcome of a deliberate process of investment in research and development (R&D)) and firms are all very small (whereby they can all be assumed to take the rate of technological progress as being given regardless of their own production of capital goods). So each firm optimizes profit by paying K and L their marginal products, bereft of any additional payment for their contribution to technological progress. The first model to be crafted using this logic was the famed AK model.

This AK model combines the perfect competition, substitutable factors and full employment of neoclassical models with the savings rate-dependent long run growth rate implication of a typical endogenous growth theory. The AK model builds from individual firms presumably deploying uniform level of capital stock, whereupon the aggregate production function can be shown with the overall capital stock in the economy having an exponent comprising two coefficients: one representing knowledge spillover and the other capturing decreasing returns to individual capital accumulation.

In the case where knowledge spillovers exactly offsets decreasing returns, we have a constant growth rate of aggregate output, $g = sA - \delta$. Assuming a constant rate of growth of population, the rate of growth of per capita output is also constant − independent of instant level of per capita output level but contingent on the economy's saving rate. Clearly, then, there is nothing intrinsic in this formulation of the AK model that leads to a scenario of faster growth for poor economies and slower growth for richer economies.

2.1.3 Endogenous framework: *technical change*

The origin of endogenous growth models based on technical change is traced by Romer (1994). Citing studies that fail to show convergence across countries and/or regions, he states that this non-occurrence of cross-country convergence inspired growth models that drop two fundamental assumptions of the neoclassical models: an exogenous technological change and universal availability of a common set of technological opportunities. The pioneering contribution by Romer (1990) is worthy of mention here. It starts with three premises that reflect contemporary reality:

1. Technological change − improvement in the design and/or blueprints for mixing raw materials − lies at the heart of economic growth. By providing incentive for continued capital accumulation, it accounts for much of the increase in output per hour worked observed over the years.

2. Technological change arises in large part because of intentional actions taken by people who respond to market incentives.

3. Technological change is non-rivalrous: i.e., its use by one does not diminish its availability for use by others. In other words, it is characterised by zero marginal cost in its use although its development involves incurring a fixed cost.

The main implication of the model so developed is that the rate of growth of Y ($g_Y = g_A = \delta H_A$) remains constant irrespective of the level of K; hence the absence of tendency for convergence across countries in this model. [In fact, because growth rate is positively related to level of human capital devoted to R&D sector, a rich country that typically enjoys a larger endowment of human capital in its R&D sector than a poorer counterpart grows faster; that is, a probable *divergence*.] This, notably, is in tune with the introductory remarks made in Romer (1994) about the absence of cross-country and cross-region convergence in data patterns.

Further, Aghion and Howitt (1992) develop a model of endogenous growth where the channel of growth is through industrial innovations which improve quality of products. In their model, rate of growth of an economy will depend on the rate of innovations in the research sector, which in turn is dictated by the characteristics of the economy such as endowment of skilled and specialised labour, rate of interest in the economy. Since these are not uniform across countries, there is no certainty of convergence of growth rates. Further, endowments of skilled and specialised labour are observed to be higher in more developed economies than in developing ones, whereas rate of interest in the economy varies inversely with the level of economic development of economies − making innovations quicker and growth faster in developed economies vis-a-vis developing ones. That is, a probable divergence.

2.1.4 Endogenous framework: *innovation and imitation*

Apart from models that motivate the idea of innovation as part of endogenous growth process (such as Aghion and Howitt (1992) above), there is also the process of growth being enabled through *imitation* of the technological frontier country (the country that is technologically the most advanced, usually assumed to be the USA in most empirical exercises). As postulated by Nelson and Phelps (1966), a larger stock of human capital confers on a country better ability to absorb new products and ideas discovered elsewhere.

As opposed to this consideration of imitation alone, Vandenbussche et al (2006) consider the dual causes of economic growth − imitation *and* innovation. They postulate that process of imitation and that of innovation require different kinds of human capital; whereas imitation relies heavily on unskilled human labour, innovation uses skilled labour more intensively.

Basu and Mehra (2014) characterise the process of *imitation* as well as *innovation* among laggard economies. They point out that even if laggard economies remain on imitation-only path, their convergence to 'advanced' economies is not an obvious outcome. They prove that an optimal combination of skilled and unskilled labour is necessary for ensuring convergence which can be realized through appropriate education policy initiatives, given that the world technology frontier is not growing at a faster rate. They further contradict the usual assumption of maintaining skilled and unskilled labour in water tight compartments. During the transition from imitation to innovation, the unskilled labour is also incentivised to shift to skilling for higher income as wage rates go up. They elaborate upon this by explicitly characterizing the cost of education of an individual and endogenously determining the composition of human capital in equilibrium in a laggard economy.

2.2 *Studies pertaining to economic units from around the globe*

Quoting a variety of empirical studies, Quah (1996) examines the significance of uniformity of β across cross sections and time periods. These include: 48 states of the U.S.A. for 1880-1990; 47 prefectures of Japan for 1955-1990; 90 regions of Europe for 1950-1990; 11 regions each of Germany and UK, 17 regions of Spain, 20 regions of Italy, 21 regions of France for 1955-1990 and 10 provinces of Canada for 1961-1991. The conclusion of occurrence of convergence at the rate of 2% per annum is reached with remarkable uniformity; but Quah ponders whether this empirical uniformity is related to convergence dynamics in economic growth. He postulates that the uniformity in β may simply be unit root regressions in disguise [that is, the β coefficient in equation (1) for different cross sections are uniform because of the asymptotic unit root in countries' evolution of y]. His assertion is buttressed by a Monte Carlo stimulation comprising moderately sized random walk samples (comparable to those used in β convergence analyses) yielding 2% convergence rates even while true convergence rate is 0. Therefore, he builds a case for doubting the credibility and interpretation of β convergence findings.

Durlauf (2000) also contains insights on the errors in approaching income distribution dynamics through the prism of β convergence analyses. Chiding the lack of attention to the implications of various growth theories for the specification of the empirical models used to compare growth theories, he critiques the use of linear regressions like (1) to settle the debate between neoclassical and endogenous growth theories, instead of direct testing of the competing models. He opines that for many endogenous growth theories, regressions of the nature of (1) are a classic case of model misspecification. That is, apart from regressions of the form of (1), a *separate* set of regression equations should be considered to evaluate the validity of endogenous growth theories − instead of inferring it from the former only.

Bernard and Durlauf (1996) sound yet another red herring regarding the interpretation of negative convergence coefficients. They show that the quotidian regression equation (such as (1)) used to estimate convergence coefficient for a cross section is in fact a misspecification of the law of motion for economies following endogenous growth theories. They go on to show that for a particular constellation of initial income distribution a negative convergence coefficient may be obtained for economies that are converging to respective steady states without necessarily coming close to one another − so, absolute convergence may be concluded from regression results whereas in reality it is only conditional convergence occurring.

In a seminal and much acclaimed work, Mankiw, Romer and Weil (1992) [oft referred to as MRW] estimate the following regression equation:

$$log[y(t)] = a + b.log(s) - c.log(n + \delta + x) + \epsilon(t), \qquad (2)$$

where s refers to the ratio of investment to GDP. The results are broadly supportive of the neoclassical growth model predictions and more importantly debunk the common claim that neoclassical models explain variation in labour productivity across countries largely by appealing to differences in technology. However, the results contradict the empirically observed value of share of capital in output, prompting an augmentation of the standard neoclassical model to include human capital. The log-linearisation of the same yields the following equation:

$$\begin{aligned} log[y(t)] - log[y(0)] = (1 - e^{-\beta t}).a.log(s) + (1 - e^{-\beta t}).b.log(s_h) \\ +(1 - e^{-\beta t}).c.log(n + \delta + x) - (1 - e^{-\beta t}).log[y(0)], \end{aligned} \tag{3}$$

where s_h measures the percentage of working age population in secondary school. A negative coefficient on $log[y(0)]$ is interpreted as saying that suppose countries were not to vary in their investment and population growth rates, there would be a discernible proneness for poor countries to grow more rapidly than rich ones. MRW therefore conclude that their probe into convergence, instead of pointing towards a failure of the neoclassical model, supports it instead. Conditioning for such variables that the neoclassical model postulates to determine the steady state [*viz.* rates of investment, population growth, technical growth and depreciation], there is perceptible convergence in income or output per capita. The coefficients on log of s_h and s in regressions of the above nature signify the manner in which the neo-classical prediction of convergence is affected by movements in these economic variables. Say, a positive coefficient on $log(s_h)$ would mean that if the percentage of working age population in secondary school remained the same across countries then with a negative coefficient on $log[y(0)]$ we would have unconditional convergence across countries but a richer country may still be seen to grow faster than a poorer counterpart if the percentage of working age population in secondary school in the richer country is higher than that in the poorer country.

In a pioneering initiative to ascertain whether empirical regularities accord well with insights from endogenous growth models, Barro (1991) investigated the role of human capital in determining growth experience in 98 countries for the period 1960 to 1985. He discovers that while the rate of growth of economies for the period bears no relation to their initial level of per capita income, after accounting for their human-capital (through primary and secondary enrolment rates) a statistically significant negative relation between the two is obtained. Therefore, unlike the prediction from neoclassical growth models where lower initial GDP per capita confers automatic advantage in terms of higher returns to capital investment (thus raising growth rates for poorer economies and leading to convergence of per capita GDP across economies), Barro's exposition shows the important role played by human capital in bringing about convergence. Thus, convergence in levels of per capita GDP − far from being a natural occurrence − is an outcome of human capital accumulation, a purely endogenous process. In a related exposition, he also discovers that for given value of initial per capita GDP greater human capital is associated with lower fertility and higher physical investment − lending support to the previously stated results.

2.3 *Exploration of the growth experience of Indian states*

The repertoire of literature on convergence of per capita incomes across Indian states does not conclusively point in one direction or the other; it is a mixed bag.

On the one hand there is an abundance of studies on the $\beta-$convergence of per capita GSDP of states of India in the pre-1990s. Absolute and conditional convergence for 1961 to 1991 was obtained by Cashin and Sahay (1996) by taking data pertaining to 20 states. Similarly, conditional convergence was discovered across 17 Indian states for 1960-1994 by Nagaraj et al. (1998), while observing that disparities are accounted for by differences in the structure of production, infrastructure endowments and state specific factors. Likewise, absolute convergence for the period 1973-2003 was claimed by Purfield (2006) who considered 14 states representing a wide per capita GSDP spectrum. At the opposite end, we have Ghosh et al (1998) who show absolute divergence for 26 states for the period 1960-61 to 1994-95; they also disregard the need for conditional convergence stating that "it is enough to look at the [above] regression as the states within a geopolitical boundary do share common characteristics. Interesting point is how *divergence* appears in such homogeneous environment". Seconding this finding, Rao et al. (1999) also report absolute divergence during 1965-1995 for 14 states of India.

For the more recent period also, a mixed record of findings is obtained. Ahluwalia (2000) posits that growth rates of the poorer states [notably the BIMARU states − an acronym for traditionally underdeveloped states of Bihar, Madhya Pradesh, Rajasthan and Uttar Pradesh] accelerated after 2000-01 and the process of "catch-up" was clearly visible; this bodes well for ultimate convergence of per capita GSDP across states. In a similar vein, Bhalla (2011) while investigating growth patterns of 21 states in India holds that the extent of acceleration in growth in the post-reform period is negatively correlated with the level of per capita GSDP, that is, the poorer states have actually experienced faster growth rates relative to the richer states. On the other hand, Subramanian et al (2012) explore two periods, 1993-2001 and 2001-2009, for 21 largest Indian states and find evidence of divergence. They use a combination of panel data convergence regression equations (such as [9]), plots of growth rates against initial levels of per capita GSDP and measures of $\sigma-$convergence in their study; they opine that despite the incidence of $frogleaping$ by a handful of states, the 'rich' states continue to post higher growth rates than their less affluent counterparts.

Mirroring the above theoretical position, the experienced reality of growth presents a mosaic of mixed findings. Several authors such as Quah (1996) discover the occurrence of catch up and a gradual movement towards convergence for several countries and regions; on the other hand, others like de la Fuente (1997) opine that save a few countries at the upper end of the per capita income scale, countries of the world have experienced increase in inequality. Furthermore, aspersions have been cast on the use of routine $\beta-$regressions (such as [9]) to check for tendency for convergence (or its absence thereof). Employing such regressions, however, the growth experience of Indian states has been seen to present contrary findings − with regard to tendency for convergence − for both pre and post reform periods.

2.4 *Gaps in literature*

In view of the foregoing survey of existing literature on general topic of convergence and with specific regard to evaluation of the growth experience of Indian states, the following gaps relevant to the instant study are encountered:

- An attempt to fit the neoclassical growth model to the growth experience of Indian states is lacking. The plethora of studies conducted with an aim to infer the occurrence or otherwise of $\beta-$convergence of Indian states is premised on the working of the neoclassical growth model, but no effort has been devoted to check whether this premise is a reasonable assumption to make. To be more specific, an attempt needs to be made to explain the wide disparity in levels of per capita GSDP across Indian states on the basis of the neoclassical growth model with a Cobb Douglas production function. No effort has been devoted to ascertain simple testable implications about the working of neoclassical growth model in the context of Indian states − a higher saving rate or lower population growth rate leads to a higher per capita GSDP. Further, the role of human capital as incorporated in neoclassical growth model also has not been empirically tested for Indian states.

- Whereas divergence across Indian states in terms of per capita GSDP has been obtained by several authors (e.g. Ghosh et al(1998), Rao et al (1999), Subramanian et al (2012)), an effort to fit the endogenous growth models to Indian states has not been made. As noted above, endogenous growth models in their basic conception do not provide mechanisms for poorer economic units to grow faster than richer counterparts and therefore offer the possibility of divergence. An endeavour to test the applicability of endogenous growth models is instructive in understanding the underlying reasons for the reported divergence, but has so far failed to garner academic attention.

- It has been appreciated that growth record is not a mere mechanical outcome of growth in inputs to production such as capital or human resource, but also contingent on how well such inputs are utilised in the production process. It is possible that despite experiencing similar quantitative growth in inputs that *'matter'* in growth of per capita income, states differ in their efficiency in transforming such inputs into output. While difference in technological coefficient (usually the multiplicative element in production function (A), in most growth models) is one way of looking at this, another approach is in exploring the difference across states in responsiveness to inputs such as per capita bank credit, literacy rate, per capita energy availability, etc. This has not been tested in any study so far.

This paper is an attempt to fill some of these gaps in terms of empirical analyses in the context of possibility of convergence of per capita GSDP across states in India. The subsequent section describes the extent of ground that the study intends to cover, viewed against the backdrop of the foregoing literature review.

3 Research Problem

3.1 *Objectives*

The intent of this study is to attain a clearer understanding of the growth experience of Indian states. To this end, the motive is to reconcile seemingly divergent findings across extant studies in literature and to explore hitherto uncharted territory. As an outcome of this endeavour, this research intends to fill gaps in literature pertaining to growth experience of Indian states, as highlighted above. The broad objectives are:

1. To fit the (baseline as well as human capital augmented) neoclassical growth model to the growth experience of Indian states and the observed diversity in their level of per capita incomes.

2. To test for evidence of endogenous growth models − the AK model and the R&D-led technological progress-based growth model − in growth record of Indian states.

3. To discover whether observable differences in growth record of per capita income are on account of quantifiable differences in inputs in the production process or on account of unobservable differences between states in their production efficiency.

4. To derive policy conclusions for achieving balanced, regionally inclusive economic growth in India, in light of the findings made.

3.2 *Research questions*

The research questions this effort attempts to find answers to are:

- Is neoclassical growth model based on a Cobb Douglas production function applicable in explaining growth experience of Indian states? Is a human capital augmented neo-classical growth model any better at doing so?

- Is growth record of per capita GSDP of Indian states consistent with implications of endogenous growth models such as the AK model and the R&D-led technological progress-based growth model?

- Is the dispersion in growth record of rich vs poor states more to do with difference in inputs in production process or with difference in responsiveness to such inputs?

3.3 *Hypotheses*

The apriori hypotheses that this study sets out to test are:

1. Conventional neoclassical growth model does not explain the dispersion in level of per capita GSDP across Indian states satisfactorily.

2. Human capital augmented neoclassical growth model does a better job than the baseline neoclassical growth model but falls short of adequately explaining dispersion in level of per capita GSDP across Indian states.

3. Growth record of per capita GSDP of Indian states is consistent with both the AK model and the R&D-led technological progress-based growth model.

4. Difference in growth record of (initially) rich *vs* poor states has more to do with difference in responsiveness (*or* realised efficacy) to growth promoting factors in the production process rather than the difference in quantity of growth promoting factors per se.

The next section details the methodology adopted to find answers to the research questions and to test the hypotheses as enumerated above.

4 Methodology

The first concern is to test for evidence of applicability of competing growth models in the growth experience of Indian states. To this end, we rely on existing literature to test this.

4.1 Neoclassical models of growth

As noted above, several studies have been conducted with a view to estimate the neo-classical $\beta-$convergence equation [9] for Indian states, yet no attempt has yet been made to fit the basic neo-classical model equation [27]. This exercise is imperative in order to infer whether or not the neo-classical growth model is applicable to Indian states, following which the $\beta-$convergence equation is meaningful. We start, therefore, with this basic estimation.

The seminal contribution of Mankiw, Romer and Weil (1992) [MRW] is profitably utilised here. They estimate the following equation:

$$log[y(t)] = a + b.log(s) + c.log(n + \delta + x) + \epsilon(t), \tag{A}$$

which in the context of Indian states would entail that $y(t)$ is per capita GSDP, s refers to the ratio of investment to GSDP, n is rate of growth of population (workforce), x is the rate of Total Factor Productivity (TFP) growth, δ is rate of depreciation of capital. The equation reflects the theoretical position that per capita income of an economic unit in a neo-classical growth model is positively related with the savings (or investment) rate and negatively with the sum of rates of depreciation and of growth of TFP and workforce. [See Appendix B for derivation of [A].]

However, admittedly, this is a situation when steady state has been reached by an economic unit or any disturbance from steady state(s) is entirely random. For economic units that are less likely to have attained their steady state, it is preferable to consider a regression equation that expressly captures out of steady state characteristics $-$ say, growth rates during transition to steady state. Because states in India may not have attained their equilibrium level of per capita incomes, we consider a derivative of equation (A), as estimated by MRW. In doing so, we also incorporate human capital in the exercise. This derivative of (A) which MRW estimate is as follows:

$$log[y(t)] - log[y(0)] = (1 - e^{-\beta t}).a.log(s) + (1 - e^{-\beta t}).b.log(s_h) + (1 - e^{-\beta t}).c.log(n + \delta + x) - (1 - e^{-\beta t}).log[y(0)], \quad (B)$$

where $y(0)$ is the initial level of per capita GSDP and s_h measures the percentage of working age population in secondary school (product of fraction of working age population of the state in the secondary school age bracket and the Gross Enrolment Rate(GER) of the state at secondary school level). The neo-classical model is deemed to hold good in explaining the growth experience if coefficients on s (and s_h) and on $n + \delta + x$ are of the opposite signs, significant and of the same absolute magnitude. A high R^2 in the above equations will definitively signal the applicability of neo-classical growth model(s).

4.1.1 Data

For regression (A), data on GSDP per capita is taken from various issues of RBI's *Handbook of Statistics on Indian States* annual publication for 30 states. Since GSDP have been measured across time using different bases (say, 1980-81, 1993-94, etc), data are brought to a common base of 2011-12 by method of splicing. Other relevant data are also taken from various sources: s is calculated by taking the ratio of sum of state government capital expenditure (from various issues of RBI's *Handbook of Statistics on Indian States*) and non-personal credit extended by scheduled commercial banks excluding amounts lent under *'Others'* that account for loans to governments (from various issues of RBI's *Basic Statistical Returns of Scheduled Commercial Banks (SCBs) in India*), to the relevant GSDP of the state in a given year; the underlying assumption is that non-personal credit by SCBs and state government capital expenditure go towards building up the capital stock in the economy. While capital investment may also occur on account of Foreign Direct Investment (FDI) inflows into the state/UT, we are unable to account for the amount of such annual investment due to lack of availability of consistent, workable figures on this for the time period we consider[2]. Next, n is calculated by converting decadal growth rates of population reported in RBI's *Handbook of Statistics on Indian States* to annual rates of growth. Following World Bank (2006, 2011), we use a uniform rate of depreciation of 5% per annum across states and years. [This estimate is fairly widely used in existing studies in the Indian context. The figure comes from the assumption of a service life of 20 years, which tries to reflect the mix of relatively long-lived structures and short-lived machinery and equipment in the aggregate capital stock and investment series. This choice of 20 years, in turn, is guided by a cross country study on capital estimates for 62 countries where a mean service life of 20 years for aggregate investment is used.] TFP growth rate is taken from the India KLEMS project at ICRIER in collaboration with the Reserve Bank of India, titled '*Estimates of Productivity Growth for Indian Economy*'. [Under the neoclassical assumption, technical progress is uniformly available to all economic units without any lag. Thus, the TFP estimates at the level of Indian economy are to be used for each state, under this assumption.] In order to derive the TFP growth rate for a given state in a given year, we use the weighted average of TFP growth rates across sectors of the economy, with weights being assigned on the basis of share of GSDP of the state in that year emanating from a given sector of the economy of that state. Estimates for TFP growth are calculated in the said study as per three specifications:

- A2: "based on number of persons employed and capital stock";
- B2: "based on labour input (combining persons employed and change in labour composition) and capital stock";

[2] No continuous data is consistently available for the entire duration of our study. The limited data available is in form of number of state-wise FDI proposals and/or amounts approved annually, which is usually not realised in the same year. Data on annually realised FDI inflows is available for only 2000-02.

- C2: "based on labour input and capital services (incorporating changes in the asset composition of capital stock)",

and for robustness of estimates, analyses are carried out for all these sets of estimates. On grounds of methodological considerations, the C2 measure of TFP growth is preferred over the others. In conventional estimates of productivity growth with 'capital stock' as the measure of capital deployed, output growth on account of changes in capital asset composition (say, increasing share of equipment vis-a-vis buildings − where both equipment and buildings are part of capital stock in the economy) is attributed to TFP growth. But, actually it should be ascribed to increase in capital productivity emanating from alteration in capital asset composition. Moving from 'capital stock' to 'capital services' incorporates these subtle adjustments that bring out more accurate TFP growth estimates. A similar argument holds for moving from 'number of persons employed' to 'labour input' as measure of labour deployed, wherein appropriate modification is made to capture changes in labour composition (say, increase in share of managers vis-a-vis skilled workhands − where both of them are part of persons employed). We source our TFP growth rate estimates from the above mentioned study.

For regression (B), following MRW (1992), s_h is taken as the product of secondary school enrolment ratio and the fraction of working age population in the relevant age group. Data on the secondary school enrolment ratio are sourced from *Statistics of School Education* for various years published by Ministry of Human Resource Development, Government of India. Fraction of working age population in the relevant age group is sourced from *Primary Census Abstract* for the relevant Census round. In some specifications where data on tertiary education are also included, the measures for tertiary education and secondary education are taken as number of tertiary education enrollment (from various issues of Ministry of Human Resource Development's *Selected Educational Statistics* and *All India Survey of Higher Education (AISHE)*) and number of secondary school education enrollment (from various issues of Ministry of Human Resource Development's *Selected Educational Statistics*) as a proportion of working age population (from *Primary Census Abstract* for the relevant Census rounds), respectively.

4.2 Endogenous growth models

Jones (1995) is a commendable effort in ascertaining the ability of endogenous growth models in explaining the growth experience of economic units. Beginning first with the simplest AK model [where as we saw earlier, the growth rate of output is $g = sA - \delta$, with s being the investment rate and A is the technological coefficient], it is clear that the dynamics of growth rates must be matched by the dynamics of investment rates: (no) increase in the investment rate will be matched by (no) increase in the growth rate. Thus, testing for working of the AK model for Indian states would entail checking whether investment rates and growth rates of output over time are simultaneously stationary. For this, we use alternative specifications (random walk with and without drift, random walk with deterministic trend) of three most commonly used stationarity tests − Augmented Dickey Fuller (ADF), Phillips Perron (PP) and Kwiatowski-Phillips-Schmidt-Shin (KPSS) tests. It is a simple way of gleaning whether there is evidence against the working of AK model of growth for Indian states. The focus is not on testing for 'convergence'.

After this, an attempt to find more conclusive evidence for the applicability of AK model is made. Jones(1995) estimated the following equation,

$$g_t = A.g_{t-1} + B.s_t + C.\Delta s_t + \epsilon_t, \tag{4}$$

where g_t is the growth rate of GSDP of a state in year t, s_t is the investment rate and Δs_t is the first difference of the investment rate, ϵ_t is the disturbance term. The validity of the AK model is examined by testing the null hypothesis of $B = 0$ against the alternative hypothesis of $B > 0$. The potential problem in including the autoregressive terms in equation [29] is biasing of estimates on account of disturbance term being serially correlated. To circumvent this, Li (2002) advocates the following alternative specification

$$g_t = \alpha + \overline{B}.s_t + \overline{C}.\Delta s_t + \epsilon_t, \tag{C'}$$

where α is a constant, $\overline{B}$ is long-run effect of the investment rate on the growth rate. Use of OLS to estimate [C'] may be problematic on account of the independent variable s_t and its lagged values being correlated with ϵ_t. [Say, cyclical fluctuations in the economy, which usually make both growth and investment rates deviate from their long-run values and introduce a correlation between the disturbance term and the current and lagged values of observed investment rate, may account for this.] To correct for this, Li estimates a co-integration regression. The rationale is as follows: suppose we consider a linear projection of ϵ_t on the current value of s_t and its lags, that is $\epsilon_t = P(L).s_{t+r} + v_t$, where $P(L)$ is a lag polynomial and v_t is the residual. By assumption, v_t is uncorrelated with s_t and its lags. There are non-zero coefficients in $P(L)$ because short run fluctuations in the economy affect its growth and investment rates and the correlation between s_t and ϵ_t is taken to be zero beyond r periods of lag. Whereas cyclical shocks may cause momentary gyrations in rates of growth and investment, they cannot influence the underlying parameters that determine the equilibrium relationship, i.e. no long-run relation holds between ϵ_t and s_t. Thus, $P(1) = 0$. Incorporating this restriction, we can rewrite the considered linear projection as $\epsilon_t = P(1).s_t + P'(L).\Delta s_{t+r} + v_t = \epsilon_t = P'(L).\Delta s_{t+r} + v_t$. We now rewrite [C'] as follows:

$$g_t = \alpha + \overline{B}.s_t + \overline{D}.\Delta s_{t+r} + v_t, \tag{C}$$

where $\overline{D} = \overline{C}$ for $r = 0$ and $\overline{D} = \overline{C} + P'(L)$ for $r \neq 0$. The above equation [C] is used to test for the AK model by testing the null hypothesis of $\overline{B} = 0$ against the alternative hypothesis of $\overline{B} > 0$. By design, v_t is uncorrelated with s_t and its Δ variations, and hence OLS estimates of $\overline{B}$ would be asymptotically efficient and consistent. *This equation is run for those states that show preliminary evidence for working of AK model through simultaneous stationarity or non−stationarity of g_t and s_t.* Since a *necessary* condition for working of AK model is the simultaneous stationarity or non−stationarity of g_t and s_t, we carry out *sufficiency* tests only for those states that fulfill the necessary criterion.

Moving to the endogenous R & D-led technological growth models, Jones contends that the implication of such models is encapsulated in $\dot{A}/A = \delta_A.L_A = \delta_A.f^*.L$, where A is the technology parameter, δ_A is a productivity parameter for the R & D sector, L_A is the labour engaged in R & D, L is the total labour force in the economy, f^* is the fraction of total labour force engaged in R & D. That is, the growth rate of knowledge − and by extension that of per capita output − is related to the labour engaged in R & D. Therefore, growth rate of per capita output should increase with numbers of persons engaged in R & D. It will suffice to look at the dynamics of growth rates of output (GSDP) and enrolment in higher education at the state level. For this, as before, we use alternative specifications (random walk with and without drift, random walk with deterministic trend) of the three most commonly used stationarity tests − Augmented Dickey Fuller (ADF), Phillips Perron (PP) and Kwiatowski-Phillips-Schmidt-Shin (KPSS) tests. The focus, again, is not on testing for 'convergence'.

We now venture to establish more definitive evidence of working of the R & D based model of growth. The approach is similar to the one adopted for AK model above, in that we regress the following equation for each state:

$$g_t = \beta + \tilde{B}.e_t + \tilde{D}.\Delta e_{t+r} + w_t, \tag{D}$$

where g_t is growth rate of GSDP in period t, e_t is higher education enrolment in the given state in period t, Δe_t is the change in higher education in the given state between period t and $t-1$. Here, w_t is the disturbance term which is, by design, uncorrelated with e_t and Δe_{t+r}; therefore estimate of $\tilde{B}$ is asymptotically efficient and consistent. Equation [D] is estimated for the applicability of the R & D based growth model by testing the null hypothesis of $\tilde{B} = 0$ against the alternative hypothesis of $\tilde{B} > 0$. *This equation is only run for those states that show preliminary evidence for working of R & D model through simultaneous stationarity or non-stationarity of g_t and e_t.* Since a *necessary* condition for working of the R & D based model of growth is the simultaneous stationarity or non−stationarity of g_t and e_t, we carry out *sufficiency* tests only for those states that fulfill the necessary criterion.

4.2.1 Data

From data discussed previously, growth rate of per capita GSDP can be obtained. Investment rate has also been discussed (as s) previously. Enrolment data on number of tertiary (higher) education enrollment are obtained from various issues of Ministry of Human Resource Development's *Selected Educational Statistics* and *All India Survey of Higher Education (AISHE).*

4.3 Quantitative vs qualitative components in growth

It is important to note that growth rates may be higher in one set of states (say, richer) vis-a-vis another set of states (say, poorer) on account of two distinct factors: (a) difference in the quantum of growth promoting factors available in each set, OR (b) difference in the efficiency with which such factors promote growth. In studying the difference in growth experience of two sets of states, it is worthwhile to decompose the observed difference in growth rates into two such components for better clarity in understanding the growth experience.

The handy tool for such an exercise is the Blinder-Oaxaca Decomposition (Oaxaca 1973, Blinder 1973) which decomposes the difference in an outcome variable Y (here, growth rate of per capita GSDP) for two groups A and B (here, 'rich' and 'poor' states) into difference in relevant characteristics (say, X) and difference in responsiveness to such characteristics (here, β). That is, the question is how much of the mean outcome difference $R = E(Y_A) - E(Y_B)$, where Y_l stands for the outcome variable for group 'l' where $l \in (A, B)$, $E(Y_l)$ denotes the expected value of the outcome variable for group 'l' is accounted for by group differences in the characteristics X.

Considering a linear model,

$$Y_l = X_l'\beta_l + \epsilon_l, E(\epsilon_l) = 0, \quad l \in (A, B), \tag{5}$$

where X is a vector containing characteristics and a constant, β contains the coefficients of responsiveness to characteristics, ϵ is the error term, the mean outcome difference can be expressed as the difference in the linear prediction at the group-specific means of the characteristics. That is,

$$R = E(Y_A) - E(Y_B) = E(X_A)'\beta_A - E(X_B)'\beta_B, \tag{6}$$

because $E(Y_l) = E(X_l'\beta_l + \epsilon_l) = E(X_l'\beta_l) + E(\epsilon_l) = E(X_l'\beta_l)$ where $E(\beta_l) = \beta_l, E(\epsilon_l) = 0$ by assumption.

Suppose, now, there was a set of coefficients of responsiveness that should be used to determine the contribution of the differences in the characteristics. Let the coefficients be β^*. This β^* is a counterfactual set of coefficients which is assumed to have been the true set of coefficients if there was no difference between groups A and B in responsiveness to characteristics X. This is purely a hypothetical construct, whereby the assumed value of β^* depends on the discretion of the researcher. Whereas Oaxaca (1973) used $\beta^* = \beta_A$ and $\beta^* = \beta_B$ consecutively to obtain a range of estimates of decomposition, subsequent researchers have innovated with several combinations for value of β^* − for example, they have taken β^* to be the β obtained from a pooled regression of Y on X for observations containing observations from both groups A and B; or they have taken a weighted average of β_A and β_B with relative shares of groups A and B in the population as weights to be β^*;

or any discretionary combination of β_A and β_B as β^*. The difference in outcomes, $R = E(Y_A) - E(Y_B)$ can then be written as

$$R = \underbrace{[E(X_A) - E(X_B)]'\beta^*}_{Qn} + \underbrace{E(X_A)'(\beta_A - \beta^*) + E(X_B)'(\beta^* - \beta_B)}_{Ql}. \qquad \text{(E)}$$

We therefore have a twofold decomposition of growth rates across two sets of states into $R = Qn + Ql$, where $Qn = [E(X_A) - E(X_B)]'\beta^*$ is that part of difference in growth rates attributed to group differences in the characteristics (the *quantity effect*) and $Ql = E(X_A)'(\beta_A - \beta^*) + E(X_B)'(\beta^* - \beta_B)$ is the portion arising on account of difference in responsiveness to characteristics (the *quality effect*). This helps us understand whether bridging the gap requires the easier task of eliminating difference in characteristics or that of working towards making responsiveness to characteristics more uniform across states. The relative magnitudes of 'quantity effect' and 'quality effect' guide us in this: when quantity effect explains more of the decomposition than does the quality effect the concern should be on eliminating difference in characteristics, else the focus should be on working towards making responsiveness to characteristics more uniform (Oaxaca 1973).

We carry out the above decomposition for two time periods − 1991-2001 and 2001-2011. Data are available for 32 states and UTs, albeit the final results may be available for a subset of these due to gaps in data.

4.3.1 Data

The characteristics X to be considered in the decomposition are inferred from extant literature that investigate the factors underlying growth performance (such as Ahluwalia (2000), Shand and Bhide (2000) and Krishna (2004)). Accordingly, data is taken for

- per capita credit extended by Scheduled Commercial Banks [from various issues of RBI's *Handbook of Statistics on Indian States*]
- Scheduled Commercial Bank branch density per km^2 area [calculated from various issues of RBI's *Handbook of Statistics on Indian States*]
- national highway (NH) density per km^2 area [calculated from various issues of RBI's *Handbook of Statistics on Indian States*]
- literacy rate [from various issues of RBI's *Handbook of Statistics on Indian States*]
- railway track density per km^2 area [calculated from various issues of RBI's *Handbook of Statistics on Indian States*]
- electricity availability per capita [from various issues of RBI's *Handbook of Statistics on Indian States*]
- public social expenditure per capita [calculated from various issues of RBI's *Handbook of Statistics on Indian States*]
- public capital expenditure per capita [calculated from various issues of RBI's *Handbook of Statistics on Indian States*]
- tele density per 1000 population [from Telecom Regulatory Authority of India].

5 Results and Inference

This section presents the estimation results for all the equations elaborated above based on data as discussed earlier.

5.1 Neoclassical model(s) of growth

To begin with, equation [A] is estimated, i.e.

$$log[y(t)] = a + b.log(s) + c.log(n + \delta + x) + \epsilon(t). \quad \text{(A)}$$

Data are taken for 23 years for the period 1993-94 to 2015-16 for 30 states and UTs of India. First of all, following MRW, we estimate pooled OLS estimates of the equation for all three measures of TFP growth with time and state fixed effects. This is given in Table 1.

Table 1: OLS for neoclassical growth model

Dependent variable: log(GSDP per capita)									
	1	2	3	4	5	6	7	8	9
	A2	A2	A2	B2	B2	B2	C2	C2	C2
log(s)	0.26*	0.33*	0.07	0.29*	0.33*	0.09*	0.33*	0.33*	0.15*
log(n+d+x)	-0.33*	-0.3*	-0.23	-0.54*	-0.52*	-0.41*	-0.56*	-0.51*	-0.51*
constant	11.69*	11.5*	10.88*	11.75*	11.43*	10.81*	11.73*	11.46*	10.98*
time f.e.	-	-	yes	-	-	yes	-	-	yes
state f.e.	-	yes	-	-	yes	-	-	yes	-
R-squared	0.15	0.81	0.29	0.16	0.82	0.31	0.19	0.82	0.33
N	635	635	635	632	632	632	631	631	631
									* p <0.05

Brief remarks about Table 1 are in order. Columns 1-3 use A2 estimates of TFP growth, 4-6 use B2 estimates and 7-9 use C2 estimates. [These different TFP estimates have already been defined and the methodology underlying their calculation has been distinguished earlier.] Columns 1, 4, 7 contain pooled OLS estimates of equation [A] without any fixed effects; columns 2, 5, 8 report such estimates with state fixed effects and columns 3, 6, 9 show pooled OLS estimates with time fixed effects.

Three insights support the Solow model for Indian states. One: the estimated coefficients on investment rate and sum of rates of population growth, depreciation and TFP growth are of expected signs and statistically significant [except in one case]. Two: the absolute magnitudes of the two coefficients are found to be *not* statistically different in the above specifications. Three: the R^2 is found to be fairly high and is always statistically significant.

The responsiveness to log(s) is found to be the highest at 0.33 when we consider the pooled OLS estimates with state fixed effects (our preferred specification − as will be clear shortly) and the coefficient estimates are identical and robust across the three measures of TFP growth. The lowest responsiveness is seen in the case of using B2 measure of TFP growth with time fixed effects; albeit statistically significant, it is about a fourth of the highest value of responsiveness as noted earlier. The absolute value of responsiveness to $\log(n + d + x)$ is seen to be the highest in case of C2 measure of TFP growth without any fixed effects; however, the estimated coefficient value is not significantly different when using B2 without any fixed effects, B2 with state fixed effects or C2 with state fixed effects. The least absolute value of the coefficient is estimated when using A2 measure of TFP growth with time fixed effects, albeit it is statistically insignificantly different from zero.

One aspect in which our estimates for states of India depart from MRW's findings for countries of the world is that whereas MRW (1992) found differences in investment rate and in sum of rates of population growth, depreciation and TFP growth to explain about 60% of variation in per capita GDP across countries, only 15-20% of such variation in GSDP across Indian states is explained by these characteristics [columns 1, 4, 7]. In other words, explaining variations in per capita output across Indian states requires greater reliance on variations in technologies than does explaining variations in per capita output across countries of the world. Taking state fixed effects to account for state-specific technologies raises the R^2 to about 80% [columns 2, 5, 8] which is ample evidence that the technological variation across Indian states is indeed larger than expected: Indian states are much less *homogeneous* than Ghosh et al (1998) assume them to be. The fact that time fixed effects impact R^2 less than state fixed effects in explaining variation of per capita GSDP across states [comparing R^2 in columns 3, 6, 9 with that in columns 2, 5, 8] is further evidence that modelling state-specific, time-invariant technologies better explains empirical observation than modelling time-specific, state-invariant technologies for Indian states. Given the finding above that production functions of states vary widely in India, capturing these production functions separately (through state fixed effects) is a better fit for empirical modelling than assuming a common production function for all states with uniform technological progress over time (through time fixed effects). In the former approach, across-state differences in production function are better captured − evidenced by a higher value of R^2 in case of pooled OLS with state fixed effects in comparison with time fixed effects.

We now present estimates of [A] taking cognisance of possible correlation of error terms across observations for the same state. The estimates based on A2 are given in Table 2, on B2 in Table 3 and on C2 in Table 4.

Table 2: Alternative specifications for Eqn [A] based on A2 TFP estimates

	Dependent variable: log(GSDP per capita)			
	Robust OLS	RE	FE	FE cross-section
log(s)	0.26***	0.32***	0.33***	0.33***
log(n+d+x)	-0.33***	-0.13**	-.12*	-0.12*
constant	11.39***	11.74***	11.74***	11.74***
N	635	635	635	635
		* p <0.05; ** p <0.01; *** p <0.001		

Table 3: Alternative specifications for Eqn [A] based on B2 TFP estimates

	Dependent variable: log(GSDP per capita)			
	Robust OLS	RE	FE	FE cross-section
log(s)	0.29***	0.33***	0.34***	0.34***
log(n+d+x)	-0.54***	0.0077	0.029	0.029
constant	11.75***	11.68***	11.68***	11.68***
N	632	632	632	632
		* p <0.05; ** p <0.01; *** p <0.001		

Table 4: Alternative specifications for Eqn [A] based on C2 TFP estimates

	Dependent variable: log(GSDP per capita)			
	Robust OLS	RE	FE	FE cross-section
log(s)	0.33***	0.34***	0.34***	0.34***
log(n+d+x)	-0.56***	-0.105	-0.087	-0.087
constant	11.73***	11.70***	11.70***	11.70***
N	631	631	631	631
		* p <0.05; ** p <0.01; *** p <0.001		

Here, the 'FE cross section' specification refers to the fixed effects results obtained after correcting for possible cross-sectional correlation. Some generic remarks may be made at the outset: for each of Tables 2 - 4,

1. Breusch Pagan LM test prefers Random Effects to pooled OLS estimates. [for 2: $\overline{\chi}^2 = 3996.00$, Prob > $\overline{\chi}^2 = 0.00$; for 3: $\overline{\chi}^2 = 3876.12$, Prob > $\overline{\chi}^2 = 0.00$; for 4: $\overline{\chi}^2 = 3736.21$, Prob > $\overline{\chi}^2 = 0.00$.] Therefore, we conclude that 'panel effect' is significant and error terms across observations from a given state are significantly correlated. This is in line with apriori expectations, given that we have already discovered the heterogeneity across Indian states in terms of production function. It is only natural that error terms from observations pertaining to any particular production function are correlated with one another.

2. Hausman test does *not* prefer Fixed Effects to Random Effects estimates. [for 2: $\chi^2 = 1.16$, Prob > $\chi^2 = 0.5597$; for 3: $\chi^2 = 3.60$, Prob > $\chi^2 = 0.1656$; for 4: $\chi^2 = 4.92$, Prob > $\chi^2 = 0.0854$.] It may be inferred that differences between states in terms of technology of production are not deterministic but random in nature, which points in the direction of spillovers of technical know-how between states.

3. Pesaran CD test shows that cross sectional correlation is significant. [for 2: Pesaran's test of cross sectional independence = 49.365, Prob = 0.00; for 3: Pesaran's test of cross sectional independence = 47.744, Prob = 0.00, for 4: Pesaran's test of cross sectional independence = 48.049, Prob = 0.00.] This leads us to deduce that there *are* spillovers of technological progress across states, which is not surprising given the physical, electronic and knowledge porosity of inter-state borders in India. For example, an industrial house may own establishments of production across multiple states, thereby causing diffusion of production technology across state borders; an engineering graduate who acquired technical skills and knowledge in one state may migrate to another for employment, causing technical know-how to disperse from the former to the latter state.

4. As mentioned before, C2 estimates are most preferred over A2 and B2.

We now proceed to discuss the estimates obtained and the inference that may be made from these. In Table 2, the usual sign of coefficients is obtained and they are found to be statistically significant across the various alternative specifications. The fact that the estimated coefficient on $log(s)$ is $\simeq$ 0.33 and on $log(n+d+x)$ is $\simeq$ -0.12 across the panel regressions attests to the robustness of these estimates. For Tables 3 and 4, whereas the coefficient on $log(s)$ is uniformly estimated to be $\simeq$ 0.34, panel regressions find the coefficient on $log(n+d+x)$ to be statistically insignificant. This is perhaps because of the following reason: panel regressions explicitly model variations of technologies across Indian states and this renders redundant the modelling based on yearly TFP growth rate captured in x [arguably, that is the chief component of interest in the term $log(n+d+x)$, since d is taken to be uniform across states and n remains static for the observation pertaining to each year of a decade]. The term $log(n+d+x)$, therefore, captures differential improvements across states in terms of shifts in their respective production functions over time; given that there are considerable spillovers across states − as deduced above − this term is not significantly capable of reflecting differences in production functions across states: thus the statistically insignificant coefficient. [It may be mentioned here that whereas state fixed effects capture technological variations as a *level* or *stock* variable, x captures the same as a $flow$ variable; we find that the former approach scores over the latter one.] The coefficient on $log(s)$ is seen to be robust across multiple specifications.

The inference to be drawn from the foregoing discussions is that there is overall support for the working of Solow model in Indian states − in that, investment rate positively influences per capita GSDP level but the expected negative coefficient on sum of rates of population growth, depreciation and TFP growth is not obtained when technology differentials across Indian states is explicitly modelled in a panel regression framework.

We now move on to ascertain certain facts about convergence of per capita GSDP across Indian states. For this, we rely on equation [B]:

$$log[y(t)] - log[y(0)] = (1 - e^{-\beta t}).a.log(s) + (1 - e^{-\beta t}).b.log(s_h) \\ +(1 - e^{-\beta t}).c.log(n + \delta + x) - (1 - e^{-\beta t}).log[y(0)]. \quad \text{(B)}$$

We consider growth rate over five-year time periods from 1993 through 2013 − 1993-98, 1998-2003, etc − a total of 4 periods. Investment rate is taken as described for [A]. Human capital variable, s_h, is taken as the product of secondary school enrolment rate and proportion of secondary school aged cohort in the working age population. Rates of population growth, depreciation and TFP growth [we consider the most preferred C2 estimates of TFP growth here] are as explained previously. The other variables in the regression are taken at their annual values for the year pertaining to the end of the respective five-year time period, in line with MRW (1992). We begin by first regressing the growth rate on the initial GSDP per capita to check for unconditional convergence. Results appear in Table 5.

Table 5: Testing for convergence using Eqn [B]

	Dependent variable: log(GSDP per capita_t) - log(GSDP per capita_0)		
	Robust OLS	RE	FE
GSDP per capita_0	0.0504	0.0504*	0.0799
constant	-0.3064	-0.3064	-0.6209
N	115	115	115

* p <0.05

Breusch Pagan LM test prefers random effects to pooled OLS estimates [$\overline{\chi}^2$ = 0.00, Prob > $\overline{\chi}^2$ = 1.00] and Hausman test decides in favour of random effects [χ^2 = 0.47, Prob > χ^2 = 0.49]. The growth rates are seen to be positively related to the initial starting point in a statistically significant manner, pointing to $\beta-$divergence of per capita GSDP across states in India. Given the wide differences between states in production function, a simple $\beta-$convergence regression equation of the nature of [9] − without controlling for other characteristics that distinguish different states, such as investment rates or enrolment rates − is likely to give erroneous results, as argued by Bernard and Durlauf (1996) and Durlauf (2000). Therefore, we go on to augment the regression equation with other controls and economic characteristics.

We now run the full specification of [B]. Results appear in Table 6.

Table 6: Full specification of Eqn [B]

	Dependent variable: log(GSDP per capita_t) - log(GSDP per capita_0)		
	Robust OLS	RE	FE
log(GSDP per capita_0)	0.001	-0.002	-0.024
log(s)	0.02	0.02	0.032
log(s_h)	0.122*	0.138**	0.258**
log(n+d+x)	0.0149	0.0088	-0.057
constant	-0.543	-0.605	-1.12
N	100	100	100

* p <0.05; ** p <0.01

Breusch Pagan LM test prefers random effects specification over OLS [$\overline{\chi}^2$ = 1.71, Prob > $\overline{\chi}^2$ = 0.095] and Hausman test decides in favour of random effects over fixed effects [χ^2 = 0.74, Prob > χ^2 = 0.95]. As opposed to the evidence for absolute $\beta-$ divergence earlier, there is no evidence for conditional $\beta-$ convergence or divergence in Table 6. This is in line with skepticism expressed by Durlauf (2000), whereby failure to account for difference in characteristics across states yields unreliable results regarding occurrence of convergence or otherwise, and Bernard and Durlauf (1996), whereby subjecting economies that exhibit endogenous growth properties to usual convergence regressions are unlikely to offer authentic results on the occurrence of convergence.

In other words, there are two possibilities: *either*

- neo-classical growth model is indeed a valid explanation for growth experience of Indian states but the difference between states require more detailed specification in regression models (for instance, including parameters on legal and/or institutional differences, governance efficiency, infrastructure stock, etc.) to capture the occurrence of conditional $\beta-$convergence, OR
- studying the growth experience of Indian states requires explicit modelling of regression equations for endogenous growth models.

Furthermore, the growth rate is found to be unrelated to the investment rate in the state but significantly positively related with the human capital variable [which captures investment of human capital in secondary education]; which points to the abiding and universal significance of human capital in driving growth across Indian states.

Let us now consider variables on tertiary or higher education within the framework of [B]. For this purpose, we define the relevant human capital investment in higher education variable to be the log of number of tertiary education enrolment as a proportion of working age population (*tert*). For uniformity of definition, we redefine the variable capturing human capital investment in secondary education as the log of number of secondary education enrolment as a proportion of working age population (*second*). Estimation results are reported in Table 7.

Table 7: Eqn [B] with secondary as well as tertiary education

	Dependent variable: log(GSDP per capita_t) - log(GSDP per capita_0)		
	Robust OLS	RE	FE
log(GSDP per capita_0)	0.006	0.005	-0.032
log(s)	0.024	0.028	0.048
second	0.645*	0.509	0.375
tert	2.902	3.274*	6.478**
log(n+d+x)	0.011	0.001	0.178**
constant	0.131	0.148	0.55
N	100	100	100

* p <0.1; ** p <0.05

As before, Breusch Pagan LM test prefers random effects specification over OLS [$\overline{\chi}^2 = 3.46$, Prob $> \overline{\chi}^2 = 0.0315$] and Hausman test indicates favouring random effects over fixed effects [$\chi^2 = 5.27$, Prob $> \chi^2 = 0.38$]. Whereas investment rate turns out to be insignificant in determining rate of growth $-$ as before, the role of human capital invested in secondary education turns insignificant now and that in tertiary education is found to be significant. This attests to the importance of higher education in influencing the growth rate of Indian states, vindicating the human capital augmented neoclassical model of growth.

To summarise the results obtained for the study of growth experience of Indian states within the framework of neo-classical growth model: we find that:

1. There is broad support for the working of the baseline neo-classical growth model, whereby per capita income levels are positively impacted by investment rate in a state, but wide heterogeneity is discovered across states in terms of production function. Whereas a negative coefficient is obtained on the sum of rates of depreciation, TFP growth and population growth, characterising differences in production function between states on the basis of fixed effects and accounting for cross-sectional dependence due to spillovers of technical know-how between states obliterates the negative coefficient. It may be inferred thereby that specifying differences in production function across states by means of fixed effects better accounts for the existing heterogeneity between states, than capturing such differences using differences in TFP growth rates.

2. There is absence of absolute $\beta-$convergence and there is evidence, instead, for divergence. However, accounting for differences across states – in terms of production function (through fixed effects), rates of investment in physical and human forms of capital, TFP growth rates etc – yields no systematic relationship between initial per capita income and subsequent growth rates for Indian states. This stresses the imperative of more detailed characterisation of differences between Indian states (to discover if indeed the neo-classical growth model is an apposite explanation of growth experience of Indian states) and of explicitly modelling the growth experience of Indian states in the framework of endogenous growth models. [We undertake the latter in the next section.]

3. Given the existing specification of neo-classical growth models in regression equations for Indian states, there is evidence for the importance of human capital – in particular the impact of tertiary education – in driving economic growth across Indian states. This may be seen as vindication of the human capital-augmented neo-classical growth model in the context of Indian states.

5.2 Endogenous growth models

To test for applicability of endogenous growth models – viz. *AK* and *R&D* models – to Indian states, we first check for simultaneous stationarity of growth rate of GSDP and investment rate and growth rate of GSDP and higher education enrolment respectively, *à la* Jones (1995). Using various specifications of the stationarity tests mentioned earlier, out of 29 states for which requisite data are available, we obtain the following. [Appendix C for details of stationarity tests.]

For *AK* model,

- 13 states show results contrary to expectations of *AK* model, i.e. here growth rate of GSDP and investment rate are not simultaneously stationary or non stationary.

- 16 states show results that are synchronous with expectations of *AK* model, i.e. here growth rate of GSDP and investment rate are simultaneously stationary or non stationary.

So, 16 states in India show preliminary evidence of physical capital investment exhibiting spillover on technological progress, thereby driving economic growth. The details are presented in Tables 8 – 9.

For *R&D* model, where we proxy the labour engaged in a state in R&D by means of enrolment in higher education in the state,

- 10 states show results contrary to expectations of *R&D* model, i.e. here growth rate of GSDP and higher education enrolment are not simultaneously stationary or non stationary.

- 19 states show results that are synchronous with expectations of *R&D* model, i.e. here growth rate of GSDP and higher education enrolment are simultaneously stationary or non stationary.

That is, 19 states show preliminary evidence for labour engaged in R&D contributing to technical progress in the state, thereby impacting economic growth. The details are presented in Tables 10 – 11.

Table 8: States where AK model seems to be operational

Growth rate and investment rate are both stationary	Growth rate and investment rate are both non stationary
	Arunachal Pradesh, Bihar, Delhi, Gujarat Haryana, Himachal Pradesh, Jammu and Kashmir, Karnataka, Kerala, Maharashtra, Meghalaya, Nagaland, Punjab, Tamil Nadu, Tripura, Uttar Pradesh

Table 9: States where AK model does not seem to be operational

Growth rate stationary, investment rate non stationary	Growth rate non stationary, investment rate stationary
Chhattisgarh, Goa, Jharkhand, Madhya Pradesh, Manipur, Odisha, Puducherry, Rajasthan, Sikkim, Uttarakhand	Andhra Pradesh, Assam, Chandigarh

Table 10: States where $R\&D$ model seems to be operational

Growth rate and higher education enrolment are both stationary	Growth rate and higher education enrolment are both non stationary
	Andhra Pradesh, Assam, Arunachal Pradesh, Bihar, Chandigarh, Delhi, Gujarat, Haryana, Himachal Pradesh, Jammu & Kashmir, Karnataka, Kerala, Maharashtra, Meghalaya, Nagaland, Punjab, Tamil Nadu, Tripura, Uttar Pradesh

Table 11: States where $R\&D$ model does not seem to be operational

Growth rate stationary, higher education enrolment non stationary	Growth rate non stationary, higher education enrolment stationary
Chhattisgarh, Goa, Jharkhand, Madhya Pradesh, Manipur, Odisha, Puducherry, Rajasthan, Sikkim, Uttarakhand	

In a bid to discover more conclusive evidence of working of AK model for those states that have indicated its applicability as above, we run the regression

$$g_t = \alpha + \overline{B}.s_t + \overline{D}.\Delta s_{t+r} + v_t, \tag{C}$$

where we consider $r = 1, -1$, following Li(2002). The basic object is to capture the presence (or otherwise) of a systematic relationship between investment and growth rates. The results are shown in Table 12.

Out of the several states for which growth rate of GSDP and investment rate were simultaneously non stationary, a systematic relation between these two variables, as suggested by AK model, exists for Haryana, Karnataka, Kerala, Maharashtra, Meghalaya, Punjab, Tamil Nadu and Uttar Pradesh: here, $\overline{B} > 0$ which was the test for categorically establishing working of the AK model, as elaborated previously.

No qualitative changes in these findings were observed if $r = 2, -2$ was considered in addition to the above specification. Li(2002) considers upto 4 lags. The absence of data for long enough time horizon impedes adding multiple lags to the model, for it comes at cost of degrees of freedom − which are already low in our case. The efficiency and consistency of coefficients in Li's regression are

Table 12: Equation C for states indicating working of AK model

	Dependent variable: g_t
State / UT ⇓	$\overline{B}$
Arunachal Pradesh	0.054
Bihar	0.271
Delhi	-0.004
Gujarat	0.257
Haryana	0.204**
Himachal Pradesh	0.074
Jammu and Kashmir	0.086
Karnataka	0.142**
Kerala	0.210*
Maharashtra	0.295*
Meghalaya	0.812*
Nagaland	0.217
Punjab	0.314*
Tamil Nadu	0.402*
Tripura	0.178
Uttar Pradesh	0.256**
	* p <0.05, ** p <0.10

founded on the maintained assumption that v_t is uncorrelated with s_t and Δs_{t+r}; the same is tested by taking correlations of the obtained residuals with the independent variables for each state. No significant value of correlation coefficient was obtained for any of the states considered above.

Some brief remarks are in order, attempting to explain the results obtained above. What we discover above is that out of all states and UTs in India, a handful show evidence that investment of physical capital leads to augmentation of productive ability − in the sense of upward shift in the production function(s). Several of these states are seen to be among those that showed greatest willingness to reform and attract investments [3]. Most of these are states that exhibited significant progress in reforming official procedures and protocols governing economic activity. Such reforms − by easing the burden of compliance and the process of engaging in economic activity − naturally lead to higher productive efficiency of enterprises. This is seen to have a salubrious impact on economy-wide productivity in the state. It is notable that most of these states have a substantial presence of manufacturing sector; manufacturing is capital intensive with substantial scope for spillovers across units of economic activity − which intuitively explains the above discovered technical spillover to the process of physical capital investment.

We now test for more conclusive evidence of working of $R\&D$ model. For those states in Table 10 that indicate working of the $R\&D$ model, we run regression of equation [D]

$$g_t = \beta + \tilde{B}.e_t + \tilde{D}.\Delta e_{t+r} + w_t, \tag{D}$$

where, as before, we consider $r = 1, -1$. The estimation results appear in Table 13.

Out of those states in Table 10 where growth rate and higher education enrolment are both non stationary, a systematic relation between these two variables, as suggested by $R\&D$ model, exists in Andhra Pradesh, Delhi, Gujarat, Haryana, Himachal Pradesh, Kerala, Maharashtra, Meghalaya, Punjab, Tamil Nadu: here, $\tilde{B} > 0$ which was the test for categorically establishing working of the $R\&D$ model, as elaborated previously.

As before, no qualitative changes in these findings were observed if $r = 2, -2$ was considered in addition to the above specification. Li(2002) considers upto 4 lags. The absence of data for long enough time horizon impedes adding multiple lags to the model, for it comes at cost of degrees of freedom which are already low in our case. Furthermore, the efficiency and consistency of coefficients

[3] See eodb.dipp.gov.in/, last seen 6 June 2019

Table 13: Equation D for states indicating working of *R&D* model

	Dependent variable g_t
State / UT ⇓	$\tilde{B}$
Andhra Pradesh	6.09E-8*
Assam	-8.82E-09
Arunachal Pradesh	1.37E-06
Bihar	1.47E-07
Chandigarh	1.72E-07
Delhi	4.99E-08**
Gujarat	2.41E-07**
Haryana	1.89E-07*
Himachal Pradesh	1.67E-07**
Jammu and Kashmir	1.42E-07**
Karnataka	3.84E-08
Kerala	1.59E-07*
Maharashtra	6.02E-08**
Meghalaya	1.76E-06*
Nagaland	1.25E-06
Punjab	1.58E-07*
Tamil Nadu	4.82E-08*
Tripura	1.19E-06
Uttar Pradesh	1.56E-08
	* p <0.05, ** p <0.10

in [D] are founded on the maintained assumption that w_t is uncorrelated with e_t and Δe_{t+r}; the same is tested by taking correlations of the obtained residuals with the independent variables for each state. No significant value of correlation coefficient was obtained for any of the states considered above.

The states that show positive evidence for working of *R&D* model are those where the human resource pool is seen to have an edge – terms of 'learning agility', 'adaptability', 'interpersonal skills', etc. – over their counterparts in other states. The *India Skills Report 2019* by *Wheebox* and *Confederation of Indian Industry* ranks most of these states to be the leading states in terms of the aforementioned skills among their human capital. Such states have shown evidence that as higher (or tertiary) education enrolment rises, human capital gets augmented which drives growth rate of per capita output [either through production of new knowledge that imparts enhanced technical productivity – *a la* Romer (1990) or through absorption of new products and ideas discovered elsewhere – *a la* Nelson and Phelps (1966)]. Thus, it is such positive characteristics among human capital which help in the working of the models motivated by Romer and Nelson and Phelps, thereby accounting for such states showing evidence for *R&D* model(s).

The key inference to be drawn from the foregoing analysis is that there seems to be irrefutable evidence about working of endogenous growth models such as the *AK* model as well as *R&D* model. As stated previously, these models do not encompass an instinctive tendency towards $\beta-$convergence; the possibility of absence of $\beta-$convergence or even occurrence of $\beta-$divergence is, therefore, very real in the context of Indian states.

5.3 Quantitative vs qualitative components in growth

We now take up the issue of decomposing growth experience into 'quantity effects' and 'quality effects', as explained previously. Adopting the Blinder-Oaxaca decomposition of the difference in growth of GSDP per capita of initially 'rich' and initially 'poor' states, we run the following regression:

$$R = \underbrace{[E(X_A) - E(X_B)]'\beta^*}_{QuantityEffect} + \underbrace{E(X_A)'(\beta_A - \beta^*) + E(X_B)'(\beta^* - \beta_B)}_{QualityEffect}, \tag{E}$$

for two time periods 1991-2001 and 2001-2011. The choice of β^* is taken as the coefficients from a pooled model over both groups as the reference coefficients. In other words, β^* is taken to be the β obtained from a pooled OLS regression of growth rate of per capita GSDP on relevant characteristics (enumerated earlier), with observations pertaining to both groups – initially 'rich' and initially 'poor' states of India. This estimation is automatically carried out as part of the pre-programmed `oaxaca` command in STATA. The decomposition for 1991-2001 appears in Table 14 and for 2001-2011 in Table 15.

Table 14: Blinder Oaxaca decomposition for 1991-2001

Blinder Oaxaca decomposition	Total no of states	22	
Period: 1991-2001	Rich in 1991	9	
Linear model	Poor in 1991	13	
	Coeff.	z	
Change in log GSDP per capita for poor states	2.084*	51.79	
Change in log GSDP per capita for rich states	1.94*	22.99	
Difference	0.143	1.54	% of total difference
Quantity effect	0.096	1.11	67
Quality effect	0.047	1	33
	* p <0.05		

Table 15: Blinder Oaxaca decomposition for 2001-2011

Blinder Oaxaca decomposition	Total no of states	29	
Period: 2001-2011	Rich in 2001	10	
Linear model	Poor in 2001	19	
	Coeff.	z	
Change in log GSDP per capita for poor states	0.815*	19.14	
Change in log GSDP per capita for rich states	0.959*	11.83	
Difference	0.144	1.58	% of total difference
Quantity effect	0.217*	2.03	150
Quality effect	-0.073	-0.69	-50
	* p <0.05		

It merits mention that division of the whole set of states for which data are available into 'rich' and 'poor' is based on taking an average of the GSDP per capita values of these states and classifying those with GSDP per capita above the average as 'rich' and the others as 'poor'. This follows from the approach taken in literature pursuing this strand of inquiry (for example Ledyaeva and Linden 2008). It may be noted that the 'Quality effect' in Table 15 is a negative quantity: it merely means that the aggregate value of the expression $E(X_A)'(\beta_A - \beta^*) + E(X_B)'(\beta^* - \beta_B)$ is negative, without any implication of material significance whatsoever. Having said so, we now make certain observations about the decomposition exercise:

1. Whereas, on an average, poor states have seen a greater rise in per capita GSDP than the rich in 1991-2001 [from Table 14, for the period 1991-2001, change in log of GSDP per capita for poor states is 2.084 whereas that for rich states is 1.94], the situation reversed in 2001-2011 wherein rich states experienced greater growth [from Table 15, for the period 2001-2011, change in log of GSDP per capita for poor states is 0.815 whereas that for rich states is 0.959]. However, in neither case is the difference between the magnitude of their average growth is statistically significant. Thus, states that were 'poor' or 'rich' to begin with have shown nearly

comparable changes in their levels of per capita GSDP. [Whereas Subramanian et al. (2012) found evidence for $\beta-$divergence across states of India for the periods 1993-2001 and 2001-2009 $-$ in that, 'rich' states grew faster than 'poor' states, averaging over the groups of 'rich' and 'poor' states respectively seems to obliterate the differences between the two groups. This is seen to be true for both the periods we consider, which are closely aligned to those considered by Subramanian et al. (2012).] That is, there seems to be no evidence of 'poor' states having grown faster than 'rich' states $-$ i.e., no evidence of $\beta-$convergence, concurring with results obtained in an earlier section.

2. In both periods, the quantity effect is greater than the quality effect [in second period, quantity effect is statistically significant also]. Thus, difference in growth experiences of rich and poor states is largely accounted for by difference in characteristics, rather than difference in responsiveness to characteristics. Therefore, states in India respond nearly in the same fashion to changes in characteristics $-$ which also hints at the absence of diminishing or increasing returns to inputs (*or* characteristics) in the growth process. Hence, bringing states up to a equitable distribution of per capita GSDP would require concerted redistribution of inputs (*or* characteristics).

3. Further analysis of components of the quantity effects reveals that in both time periods, the change in magnitude of physical capital (variables such as per capita credit extended by SCBs, per capita public capital expenditure, tele density) and of human capital (captured in literacy rate) account for the major part of the quantity effects. [Not shown in tables above.] This is in line with Ledyaeva and Linden (2008), where they find differences in amount of domestic physical investment to contribute to divergence between rich and poor regions of Russia, as well as insights gained above, whereby human capital was found to significantly impact growth rates for Indian states and UTs. Therefore, the major emphasis on redistribution of growth-impacting characteristics must be laid on equitable spreading of physical and human capital across Indian states.

6 Discussion

Some remarks about the methods applied and techniques used in the paper are in order. First, some concerns have been expressed about the use of stationarity tests (in the preliminary testing for endogenous models) in the context of small time duration. The bias of stationarity tests in small samples is indeed noted in literature, and it is advisable to exercise caution while drawing inferences based on that. But the apprehension is about spuriously accepting the presence of unit root where there may not be any at all. Furthermore, no firm conclusions of this discussion are drawn from mere unit root tests. In any case, since the time period under consideration can never be too large to eliminate the 'small sample bias' in stationarity tests and since we do not rely on unit root tests for firm findings, we do not get bogged down by this concern.

Second, some misgivings about the use of TFP growth rate and human capital variables in the same equation have been expressed; for fear of possible endogeneity in the measurement of the two. This is not notable since the TFP growth rate has been calculated independently and outside of the framework under discussion, and the human capital variables considered have not been considered in formulating the TFP growth figures. As such, TFP growth rate has been obtained as a residual after accounting for human capital (labour inputs and services, as considered in the $KLEMS$ framework), so there is no reasonable grounds to suspect the presence of endogeneity.

Third, in regressions that consider the human capital that is specific to an Indian state, some have advised to consider those components of human capital that are stationary instead of mobile (say, an original resident of Odisha attending technical college in Delhi should not be accounted in Delhi's human capital, since she is unlikely to stay on and augment the human capital stock of Delhi) in accounting for human capital of a state. While this argument has merit, the lack of such disaggregated data as to which components of human capital is mobile vs. which is stationary does not exist. In any case, the human capital regardless of its mobility while resident in a particular state contributes to the human capital stock of the state and should be accounted as such.

7 Conclusion

As the study noted at the outset, as against a policy focus on widespread and holistic growth across Indian states, what has been seen instead is the persistence of absence of $\beta-$convergence of GSDP per capita across Indian states (as noted in Economic Survey 2016-17). Investigating causes behind this was the principal objective of the instant study. To this end, an endeavour was made to apply different growth theories to data on per capita GSDP of Indian states to ascertain which growth theory best explains the evolution of per capita GSDP of Indian states.

First noteworthy fact that emerges elegantly is the broad applicability of the neoclassical Solow model of growth; this is evidenced in the positive relationship of investment rate and negative relationship of sum of rates of population growth, depreciation and TFP growth with per capita GSDP of a state or UT. In some specifications, the expected negative coefficient on sum of rates of population growth, depreciation and TFP growth is not obtained when technology differentials across Indian states is explicitly modelled in a panel regression framework. Whereas a negative coefficient is obtained on the sum of rates of depreciation, TFP growth and population growth, characterising differences in production function between states on the basis of fixed effects and accounting for cross-sectional dependence due to spillovers of technical know-how between states obliterates the negative coefficient. It may be inferred thereby that specifying differences in production function across states by means of fixed effects better accounts for the existing heterogeneity between states, than capturing such differences using differences in TFP growth rates. Surprisingly, however, whereas upto 60% dispersion of per capita GDP across countries of the world is explained by variation in investment rate and in sum of rates of population growth, depreciation and TFP growth, only a fifth of variation in per capita GSDP across Indian states is explained by such factors. While taking state fixed effects raises the R^2 to 0.80, taking year fixed effects raise R^2 to about 0.30. Modelling state invariant, time dependent technologies does worse than modelling time invariant, state dependent technologies in explaining variation of per capita GSDP across Indian states; clearly pointing to the heterogeneity of production technologies across Indian states [in the jargon of Cobb Douglas production function, the multiplicative technical coefficient varies across states of India]. Given the finding that production functions of states vary widely in India, capturing these production functions separately (through state fixed effects) is a better fit for empirical modelling than assuming a common production function for all states with uniform technological progress over time (through time fixed effects). In the former approach, across-state differences in production function are better captured − evidenced by a higher value of R^2 in case of pooled OLS with state fixed effects in comparison with time fixed effects.

It is no surprise, therefore, that evidence on β-convergence is discouraging. This is reconfirmed in the related regressions estimated herein to check for $\beta-$ convergence − both absolute as well as conditional − across Indian states. The foundation of such regressions is based on the assumption of a common production function across economies (here, states and UTs) whereby economies differ only in terms of investment rate or population growth rate (which induces differences in their steady state level of per capita output); controlling for such differences, economies starting from lower levels of per capita output grow faster than those starting from higher levels of per capita output. Because such an assumption is unreasonable to make in the context of Indian states and UTs − as we find that production functions of states and UTs vary very widely in India, a negative coefficient on the initial per capita level of output or income is unlikely to be obtained.

As stated previously, coefficients on indicators of human capital in β-convergence regressions signify the manner in which the neo-classical prediction of convergence is affected by movements in these economic variables. In a typical convergence regression equation (like [9]), a positive coefficient on human capital variables would mean that

1. if the percentage of working age population in secondary school remained the same across countries then with a negative coefficient on initial level of per capita output we would have unconditional convergence across countries; *but*

2. a richer country may still be seen to grow faster than a poorer counterpart if the percentage of working age population in secondary school in the richer country is higher than that in the poorer country.

In line with Barro (1991), we find that increases in human capital with initial per capita level of output held fixed are strongly positively related to subsequent growth − as encapsulated in significant and positive coefficient(s) on measures of human capital − in particular the measure of tertiary education − in β-convergence regressions. This points to the applicability of the human capital-augmented neo-classical growth model in the context of Indian states and UTs.

To conclude the findings in the neo-classical framework, the neoclassical growth model does a decent job in explaining disparity in per capita output levels across Indian states. But it does so only by appealing to differences in technologies across Indian states. Because of such inherent differences in production technologies, states in India are theoretically unlikely to exhibit the usual β-convergence phenomenon − and this has been borne out in empirical exercises too. The broad success of neo-classical growth model notwithstanding, the significance of human capital in dictating growth rates of per capita output for Indian states is seen to emerge with elegant inevitability − more so the human capital that is augmented through tertiary education. This calls for greater effort in improving human capital across Indian states for a more regionally balanced growth experience.

The absence of robust finding on β-convergence across economies of the world spurred the formulation of endogenous growth models, as noted earlier. It was in fitness of things, therefore, to check if endogenous growth models explain the growth experience of Indian states. The findings on this count are encouraging: 16 and 19 states and UTs out of a total sample of 29 show indicative evidence of working of AK and $R\&D$ model respectively and conclusive evidence is found for 8 and 11 states and UTs respectively.

In simpler words, 8 states in India show statistically significant evidence for working of the AK model whereby stockpiling of physical capital stock not only adds to productive capacity of the economy but works towards improving the productivity of the aggregate capital stock in the economy. Most of these exhibit significant progress in reforming official procedures and protocols governing economic activity. Such reforms lead to higher productive efficiency of enterprises by easing the burden of compliance and the process of engaging in economic activity − which is seen to have a salubrious impact on economy-wide productivity in the state. Similarly, 11 states in India show statistically significant evidence for working of the $R\&D$ model − a barebones description of the Nelson and Phelps (1966), Romer (1990) and Vandenbussche et. al. (2006). Such states have shown evidence that as higher (or tertiary) education enrolment rises, human capital gets augmented which drives growth rate of per capita output [either through production of new knowledge that imparts enhanced technical productivity − *a la* Romer (1990) or through absorption of new products and ideas discovered elsewhere − *a la* Nelson and Phelps (1966)]. These are states where human capital exhibits positively selected characteristics such as 'learning agility', 'adaptability', etc. − that are essential to the processes theorised in Romer (1990), Nelson and Phelps (1966) and Vandenbussche et. al. (2006). It is therefore no surprise that such states show evidence for working of $R\&D$ model(s).

Some states *viz.* Haryana, Kerala, Maharashtra, Meghalaya, Punjab and Tamil Nadu show evidence for working of both AK and $R\&D$ models. [By some accounts, these states have experienced the highest growth rates in recent past.[4]] With over a third of India's states showing evidence of working of at least one of the endogenous growth models that do not show tendency for β-convergence, it is therefore not surprising that there is absence of empirical evidence for β-convergence among Indian states. The upshot of findings on this count is that β-convergence of per capita output levels across Indian states is not guaranteed (which thereby rules out σ-convergence of per capita output levels [5]), thereby making pro-active policy initiative imperative in achieving the coveted equitable distribution of per capita incomes. A competitive attitude among states to enhance investment in physical capital and higher education enrolment therefore needs to be fostered − such that states keep up with each other in bringing about productivity gains through accumulation of physical and human forms of capital. A word of caution must be sounded here: merely the mechanical work of raising the stockpile of physical and human capital is unlikely to yield the coveted result of faster growth in the economy. It must be complemented and accompanied by reforms in regulation of economic activity (for *AK* model to work) and/or keen attention to developing market-oriented traits in human capital (for *R&D* model to work). Whereas the latter is more sophisticated and time-taking than the former, it is likely that states might settle for pursuing the *AK* model in their quest for faster growth. But, our insights from the human-capital neo-classical growth models persuade us to think of human and physical capital accumulation as being complements − and *not* substitutes.

The use of Blinder-Oaxaca decomposition in investigating growth experiences of rich *vs* poor states in India is a novel approach that seeks to unravel the causes behind any difference in such growth experiences over the past two decades. Taking a decade at a time, it is seen that 'rich' and 'poor' states have grown by roughly the same quantitative magnitude − that is, there has been no tendency towards $\beta-$ or $\sigma-$ convergence. Further, such similarity in growth experience is explained more by the quantifiable factors (i.e. *measurable* factors underlying growth performance) rather than *inexplicable* differences in responsiveness to such measurable factors. [Within the framework of the decomposition, the difference between groups of states in responsiveness to quantitative factors is deemed to be *unexplained*, albeit further research to explain the hitherto unexplained differences is a potentially fertile field of inquiry.] Finally, the substantial chunk of 'quantity effects' in explaining growth experiences is attributable to changes in magnitude of physical capital (variables such as per capita credit extended by SCBs, per capita public capital expenditure, tele density) and of human capital (captured in literacy rate).

It merits mention that whereas the baseline neo-classical model regression framework resorted to 'technological differences between states' to explain variation in per capita GSDP across states and UTs, the decomposition technique is able to explain the growth experience on basis of measurable, observable factors. Because the decomposition technique is not restricted by any growth model framework and considers an expansive list of factors underlying growth performance, the two results are not incongruous.

Such finding accords well with recent findings in Kwatra (2019) which discovers that share of largest state economies in the overall physical capital investment has plummeted while that of comparatively less affluent states has risen over the past 2 decades. Such inference is made by comparing projects under implementation in a group of states as a proportion of total projects under implementation across states of India; whereas their data are sourced from the Centre for Monitoring Indian Economy (CMIE), it is likely to correspond with the forms of physical capital considered in our study − which is an aggregate of private sector physical capital (captured in credit extended by SCBs), public capital expenditure and tele density. This churning in share of investments is driven by a fall in overall share of five most prominent state economies (*viz.* Maharashtra, Tamil Nadu, Gujarat, Uttar Pradesh and Karnataka) in investments and a concomitant rise in portion of investments accounted for by mid-sized state economies like Haryana, Andhra Pradesh, Telangana and Delhi. A multitude of reasons could account for the rise of these states − I.T. related infrastruc-

[4] See www.vccircle.com/policy-tracker-india-s-fastest-growing-states-are-not-what-you-might-think/ ; last accessed 18 April 2019

[5] It has been discussed earlier that β-convergence is necessary for σ-convergence to occur.

ture and construction boom in Andhra Pradesh and increasingly in Telangana too, improvement in infrastructure and economic conditions in Delhi which makes it a favourable investment destination (NCAER 2018), business processes reforms and spurt in construction activity in Haryana, etc.

For β-convergence and subsequently σ-convergence to take place, it is essential that less affluent states grow their per capita GSDP more rapidly than their more affluent counterparts. Findings above indicate that such outcome may be obtained by actively promoting convergence of physical capital and human capital investments across Indian states. Of course, pursuit of either is likely to crowd in the other by engendering conducive economic atmosphere for such investments. The jettisoning of the Planning Commission-directed and the Plan-based allocation of resources for investment in physical and human capital infrastructure has reduced the pre-eminent role of the Union government and spawned fertile grounds for cooperative and competitive federalism in realising such investments across Indian states. The findings of our study are likely to make states better aware of the salutary impact of physical and human capital investments in boosting standards of living and stimulate intensified efforts in this direction.

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9 Appendix A

Let us begin with the specification of the production function:

$$\overline{y} = f(\overline{k}) = \overline{k}^{\alpha}. \quad \text{(A1)}$$

Capital per effective labour input evolves as follows, since $f(\overline{k}) - \overline{c} = sf(\overline{k})$:

$$\dot{\overline{k}} = s\overline{k}^{\alpha} - (\delta + x + n)\overline{k}. \quad \text{(A2)}$$

Dividing throughout by $\overline{k}$,

$$\frac{\dot{\overline{k}}}{\overline{k}} = s\overline{k}^{\alpha-1} - (\delta + x + n). \quad \text{(A3)}$$

Now, taking taking *log* of (A1) and differentiating, we get:

$$\frac{\dot{\overline{y}}}{\overline{y}} = \alpha\frac{\dot{\overline{k}}}{\overline{k}}. \quad \text{(A4)}$$

Using (A3) in (A4) we get:

$$\begin{aligned} \frac{\dot{\overline{y}}}{\overline{y}} &= \alpha(s\overline{k}^{\alpha-1} - (\delta + x + n)) \\ &= \alpha(se^{log(\overline{k})(\alpha-1)} - (\delta + x + n)) \\ &= f(log(\overline{k})). \end{aligned} \quad \text{(A5)}$$

To linearise the above, we choose the steady state, $log(\overline{k}*)$. The linear approximation is as follows:

$$\frac{\dot{y}}{y} \simeq f(log(\overline{k}*)) + f'(log(\overline{k}*))[log(\overline{k}) - log(\overline{k*})], \quad \text{(A6)}$$

where the derivative of $f(log(\overline{k}))$ is $\alpha(\alpha-1)se^{log(\overline{k})(\alpha-1)}$. At the steady state, we can replace $se^{log(\overline{k})(\alpha-1)}$ with $(\delta+x+n)$ with reference to (A2). Also, let us consider the following log-linearisation of (A1):

$$log(\overline{y}) = \alpha log(\overline{k}), \tag{A7}$$

which when evaluated at the steady state and subtracting the same from the above yields:

$$log(\overline{y}) - log(\overline{y}*) = \alpha[log(\overline{k}) - log(\overline{k*})]. \tag{A8}$$

Using (A8) in (A6) we get:

$$\frac{\dot{\overline{y}}}{\overline{y}} = (\alpha - 1)(\delta + x + n)[log(\overline{y}) - log(\overline{y}*)] = \beta[log(\overline{y*}) - log(\overline{y})] \tag{A9}$$

where $\beta = (1-\alpha)(\delta+x+n)$. To solve the differential equation let's assume $x = log(\overline{y})$. We then have $\dot{x} = -\beta[x - x*]$. By rearrangement we obtain $\dot{x} + \beta x = \beta x*$. Multiplying both sides by $e^{\beta t}$ and integrating, this yields $e^{\beta t}x = e^{\beta t}x * +b$, where b is a constant of integration to be determined. Rearranging gives us $x = x * +e^{-\beta t}b$. To get the value of b, we use that $x(0) = x_0$. So we have $b = x_0 - x*$. Writing in terms of $log(\overline{y})$, we have:

$$log[\overline{y}(t)] = log[\overline{y}(0)].e^{-\beta t} + log[\overline{y*}].(1 - e^{-\beta t}), \tag{A10}$$

which forms the center piece of our analysis. Further, since $\overline{y}(t) = \frac{y(t)}{e^{xt}}$, consider:

$$\begin{aligned} log[\overline{y}(t)] = log[y(t)/e^{xt}] = log[y(t)] - xt &= log[\overline{y}(0)].e^{-\beta t} + log[\overline{y*}].(1 - e^{-\beta t}) \\ &= log[y(0)].e^{-\beta t} + log[\overline{y*}].(1 - e^{-\beta t}) \\ \Rightarrow log[y(t)] - log[y(0)] &= xt + log[\overline{y*}].(1 - e^{-\beta t}) - (1 - e^{-\beta t}).log[y(0)] \\ \Rightarrow \frac{log[y(t)] - log[y(0)]}{t} &= \alpha - \frac{1 - e^{-\beta t}}{t} log[y(0)] + u(t), \end{aligned} \tag{A11}$$

i.e. equation (1), where $\alpha = x + log[\overline{y*}].\frac{(1-e^{-\beta t})}{t}$.

10 Appendix B

This section seeks to establish the background for equation (A). Solow's model is a classic instance of neoclassical models of growth and here we operationalise Solow's model through a Cobb-Douglas production function. Herein, there are two inputs – capital and labour – that are paid their marginal products. The production function may be taken to be

$$Y(t) = K(t)^{\alpha}(A(t)L(t))^{1-\alpha}, \tag{B1}$$

where $0 < \alpha < 1$, $Y(t), K(t), L(t), A(t)$ are output, capital, labour and level of technology at time period t. L and A are assumed to grow at exogenously dictated rates n and x such that $L(t) = L(0)e^{nt}$ and $A(t) = A(0)e^{xt}$. The number of effective units of labour, $A(t)L(t)$, grows at rate $n + x$. It is assumed that a constant fraction of output, s, is invested in the economy.

Now, let us define $k = \frac{K}{AL}$ as capital stock per effective unit of labour and $y = \frac{Y}{AL}$ as level of output per effective unit of labour. If depreciation is assumed to occur at δ, the evolution of k is found to be

$$\begin{aligned} \dot{k(t)} &= sy(t) - (n + x + \delta)k(t) \\ &= sk(t)^{\alpha} - (n + x + \delta)k(t), \end{aligned} \tag{B2}$$

which may be equated to 0 to obtain steady state level of per capita capital stock as

$$k^* = [\frac{s}{n + x + \delta}]^{\frac{1}{1-\alpha}}. \tag{B3}$$

The corresponding level of per capita output in steady state is given by

$$y^* = [\frac{s}{n + x + \delta}]^{\frac{\alpha}{1-\alpha}}, \tag{B4}$$

which when log-linearised yields equation (A).

11 Appendix C

Table 16: Implication of stationarity tests for growth rate, investment rate, higher education enrolment figures

	Order of g	Order of s	Order of e	Favours *AK*	Favours *R&D*
Andhra Pradesh	1	0	1	no	yes
Arunchal Pradesh	1	1	1	yes	yes
Assam	1	0	1	no	yes
Bihar	1	1	1	yes	yes
Chandigarh	1	0	1	no	yes
Chhattisgarh	0	1	1	no	no
Delhi	1	1	1	yes	yes
Goa	0	1	1	no	no
Gujarat	1	1	1	yes	yes
Haryana	1	1	1	yes	yes
Himachal Pradesh	1	1	1	yes	yes
Jammu and Kashmir	1	1	1	yes	yes
Jharkhand	0	1	1	no	no
Karnataka	1	1	1	yes	yes
Kerala	1	1	1	yes	yes
Madhya Pradesh	0	1	1	no	no
Maharashtra	1	1	1	yes	yes
Manipur	0	1	1	no	no
Meghalaya	1	1	1	yes	yes
Nagaland	1	1	1	yes	yes
Odisha	0	1	1	no	no
Puducherry	0	1	1	no	no
Punjab	1	1	1	yes	yes
Rajasthan	0	1	1	no	no
Sikkim	0	1	1	no	no
Tamil Nadu	1	1	1	yes	yes
Tripura	1	1	1	yes	yes
Uttar Pradesh	1	1	1	yes	yes
Uttarakhand	0	1	1	no	no

Table 17: Stationarity tests for growth rate, investment rate, higher education enrolment figures

	GSDP growth rate (g)						investment rate (s)						higher education enrollment (e)					
	dfuller		pperron		kpss	order	dfuller		pperron		kpss	order	dfuller		pperron		kpss	order
	noconstant	drift	noconstant		notrend		noconstant	drift	noconstant		notrend		noconstant	drift	noconstant		notrend	
Andhra Pradesh	1	0	1	0	0	1	0	0	0	0	0	0	1	1	1	1	1	1
Arunchal Pradesh	1	0	1	0	0	1	1	1	1	0	1	1	1	1	1	1	1	1
Assam	1	0	1	0	1	1	0	0	0	0	0	0	1	0	1	0	0	1
Bihar	0	0	0	0	1	1	1	1	1	0	1	1	1	1	1	1	0	1
Chandigarh	1	0	1	0	1	1						0	1	1	1	0	1	1
Chhattisgarh	0	0	0	0	0	0	1	0	1	0	1	1	1	1	1	1	1	1
Delhi	1	0	1	0	0	1	1	0	1	0	1	1	1	0	1	0	1	1
Goa	0	0	0	0	0	0	1	0	1	0	1	1	1	1	1	1	1	1
Gujarat	0	0	1	0	0	1	1	0	1	0	1	1	1	1	1	1	1	1
Haryana	1	0	1	0	0	1	1	1	1	0	1	1	1	1	1	1	1	1
Himachal Pradesh	1	0	1	1	0	1	1	0	1	1	1	1	1	1	1	0	1	1
Jammu and Kashmir	1	0	1	0	0	1	1	1	1	0	1	1	1	1	1	1	1	1
Jharkhand	0	0	0	0	0	0	1	1	1	0	1	1	1	1	1	1	0	1
Karnataka	1	0	1	0	0	1	1	1	1	0	1	1	1	0	1	0	1	1
Kerala	1	0	1	1	0	1	1	1	1	0	1	1	1	1	1	0	1	1
Madhya Pradesh	0	0	0	0	0	0	1	1	1	0	1	1	1	1	1	0	1	1
Maharashtra	1	0	1	0	0	1	1	0	1	1	1	1	1	1	1	1	1	1
Manipur	0	0	0	0	0	0	1	1	1	1	1	1	1	0	1	0	0	1
Meghalaya	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1
Nagaland	1	0	1	0	0	1	1	0	1	0	1	1	1	1	1	1	1	1
Odisha	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	1	1
Puducherry	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
Punjab	1	0	1	1	0	1	1	0	1	0	1	1	1	1	1	0	1	1
Rajasthan	0	0	0	0	0	0	1	0	1	0	1	1	1	1	1	0	1	1
Sikkim	0	0	0	0	0	0	1	0	1	1	1	1	1	1	1	1	1	1
Tamil Nadu	1	0	1	0	0	1	1	0	1	1	1	1	1	1	1	0	1	1
Tripura	1	0	1	0	0	1	1	1	1	0	1	1	1	1	1	0	1	1
Uttar Pradesh	1	0	1	0	0	1	1	1	1	0	1	1	1	1	1	1	1	1
Uttarakhand	0	0	0	0	0	0	1	0	1	0	0	1	1	1	1	0	0	1

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INSTITUTE OF ECONOMIC GROWTH

University Enclave, University of Delhi
(North Campus) Delhi 110007, India
Tel: 27667288/365/424
Email: system@iegindia.org

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