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An investigation into the convergence of economic growth among Indian States and the path ahead

Jitendra Kumar Sinha*
Jitendra Kumar Sinha, Bihar Government, Patna, India

Abstract. This study offers a comprehensive examination of economic growth and convergence in the Indian States and Union Territories (U.T.) over the period from 1991 to 2020. It investigates absolute, sigma, and conditional convergence within this diverse set of states and utilizes the augmented Solow and extended Solow models to explore conditional convergence dynamics. The empirical findings reveal several significant insights. First, there is no substantial negative correlation between the initial per capita GDP ratio and the average annual growth rate, indicating the absence of absolute convergence across the Indian States and U.T. economies during the study period. These results align with those obtained from sigma convergence analysis, reinforcing the absence of widespread convergence. However, conditional convergence is observed, as evidenced by the rate of conditional convergence (coefficient of initial GDP per capita) estimated at 0.038 among the Indian States and U.T. The presence of conditional convergence implies that while initial conditions matter, other factors, including physical and human capital, population growth, and additional variables, significantly contribute to the growth and convergence of Indian regions. The study concludes that policies aimed at promoting economic growth in the Indian States should prioritize the expansion of the labor force, investments in physical and human capital, and prudent government consumption. Furthermore, fostering an environment that encourages access to new technologies and ideas, maintaining sound macroeconomic management, and increasing investments in human capital formation are essential for sustained growth. Effective resource allocation through prudent budgetary policies and heightened investments in the health sector are recommended. Incentives to reduce fertility rates and adept monetary policy management are also identified as crucial elements for ensuring stability and sustainable growth. In summary, this research underscores the importance of adopting a holistic approach to foster economic growth and convergence in the Indian States. The suggested policy measures create a conducive environment for sustained development and prosperity in this diverse and dynamic region.

Keywords: Absolute convergence, sigma convergence, conditional convergence, augmented solow model, extended solow model

1. Introduction

Convergence in growth economics embodies the idea that developing economies tend to grow at a faster pace in comparison to their developed counterparts, ultimately narrowing the per capita income disparities across various economies. This concept is grounded in the neoclassical perspective, which posits diminishing returns to capital. According to this assumption, developing economies, with lower capital-labor ratios, should experience higher marginal returns on investment in contrast to wealthier economies with higher capital-labor ratios. Consequently, all economies should, over time, converge towards a common steady-state income level, assuming uniform growth rates in savings, population, and technology across regions. This form of convergence is termed absolute or unconditional β convergence. Empirical confirmation of absolute convergence typically emerges as a statistically significant negative relationship between income growth and the initial level of per capita income. Another measure, Sigma (σ) convergence, focuses on the dispersion of per capita incomes across economies over time. A diminished degree of income dispersion lends credence to the hypothesis of unconditional convergence.

*Corresponding author: E-mail: jksinha2007@rediffmail.com.

However, the neoclassical prediction of eradicating the development gap between poorer and richer economies over time finds limited empirical substantiation, except in the case of select economies that have made remarkable strides toward attaining the standards of industrialized economies. Sabbaghpoor-Fard, Mina [1] underscores the importance of the economic growth and convergence debate, primarily due to the wide gap that persists between rich and poor economies. Notably, this gap is consistently widening for some impoverished economies, challenging the neoclassical growth theory and raising questions about Robert Solow's [2] growth model. Two principal concerns are the assumption of diminishing returns to capital and the exogenous nature of technology. Technology is treated as a public good accessible equally to all economies. The assumption of diminishing returns to capital implies that every economy will converge to a common steady state, irrespective of its initial income level. Once this steady state is achieved, growth becomes solely reliant on the advancement of technology, considered exogenous in the model. However, Romer [3,4] contends that the Neoclassical Growth Model (NCGM) fails to explain the long-term growth trajectory, particularly when examining a broader spectrum of economies with inherent disparities, where each entity has distinct steady-state income levels influenced by factors like savings and population growth rates. This concept of conditional convergence suggests that richer economies may indeed grow faster than poorer economies, leading to disparities in per capita income. It is important to note that unconditional convergence holds true among economies sharing common characteristics such as savings preferences, population growth rates, and production functions, as substantiated by empirical findings.

The absence of robust empirical evidence supporting the unconditional convergence tenet of neoclassical growth theory, as exemplified in the Solow-Swan model [5], sparked a substantial debate among economists in the 1980s, prompting a re-evaluation of economic growth and convergence. This paved the way for the advent of endogenous growth theory, which strives to offer a satisfactory rationale for the divergences between affluent and disadvantaged economies globally. Endogenous growth models challenge the notion of diminishing returns to capital and propose constant or even increasing returns while integrating human capital into the production function to counteract diminishing returns. Moreover, these models posit that technological progress hinges on the portion of income allocated to research and development (R&D) activities, education, and skill enhancement, rendering growth endogenous. This provides a plausible explanation for the expanding development gap between rich and poor economies, suggesting the possibility of divergence instead of convergence.

This study pursues two primary objectives: i) to ascertain whether different growth theories are mutually exclusive, thereby evaluating the validity of the convergence hypothesis in the context of the Indian States; and ii) to scrutinize the impact of variables such as the government's role, globalization, and the formation of both physical and human capital on growth performance. This investigation assumes paramount significance due to the Indian States' protracted exposure to planning models since gaining independence seventy-five years ago. After decades of operation within a centrally planned closed economic system, these states have transitioned through various phases of the market economy. Consequently, this study contributes to the existing body of literature on growth and convergence by concentrating on the Indian States, as no prior endeavors have been undertaken to investigate these facets in this particular context.

The structure of this paper presented in eight Sections unfolds as follows:

Section 1: The introduction provides the thematic background;
Section 2: The literature review delivers an encompassing survey of both theoretical and empirical studies about growth and convergence;
Section 3 The sections on the Indian States furnish historical and economic performance.
Section 4: Furnishes data sources concerning the broader categories of the Indian States.
Section 5: Mention the relevance and implication of various types of convergence.
Section 6: This section encapsulates the estimation and empirical findings of augmented Solow and extended Solow models in the Indian States.
Section 7: Derive policy implications.
Section 8: Discuss conclusions, and indicates further research potential.

2. Exploring economic growth and convergence: A literature review

This literature review delves into the ongoing debate among economists concerning disparities in economic growth rates across economies. It traces the historical perspectives on economic growth, commencing with

classical economists like Adam Smith and David Ricardo. The review subsequently examines the evolution of economic growth theories, encompassing the contributions of Harrod, Solow, and the endogenous growth model. It also explores empirical studies on convergence, with a focus on various regions and countries, and assesses the factors influencing convergence rates. The review concludes by underscoring the significance of investment, human capital, technological progress, and other determinants in comprehending long-term economic growth and convergence.

2.1. Historical perspectives on economic growth

The review initiates by delving into the viewpoints of classical economists, prominently Smith [6] and Ricardo [7]. Smith accentuated the impact of capital accumulation on labor productivity and underscored the division of labor as a pivotal determinant of growth. In contrast, Ricardo foresaw a stationary state owing to diminishing returns in agriculture, a view supported by Karl Marx's theory [8] of the long-term decline of capitalist economies.

2.2. Evolution of economic growth theories

Subsequently, the review traces the evolution of economic growth theories, commencing with Harrod's [9] dynamic theory. This theory concentrated on steady-state growth, the role of capital accumulation, and the challenges related to steady-state economic growth. The model delineates the pace at which investment should grow to sustain steady growth. Here, the rate of capital accumulation assumes a crucial role in determining economic growth. Nevertheless, the assumption of fixed K/L and K/Y, wherein L and K must grow at the same rate to maintain equilibrium, resulted in instability due to the rigid technical coefficient assumption in the Harrod model. This instability would steer the economy toward persistent depression or prolonged inflation [10]. Subsequently, Solow's neoclassical growth model [2] was introduced, which brought flexibility to factor prices and factors of production substitutability. This model predicted convergence, with poorer countries outpacing wealthier ones due to diminishing returns to capital. Consequently, the notion of convergence in the per capita income of countries across the world [8]. In this model, the economy experiences growth for a certain period but not indefinitely. Over time, growth decelerates as the country approaches a steady state, eventually ceasing altogether at the steady state [11]. However, in a broader sample of countries displaying significant heterogeneity, each country possesses distinct steady-state income levels, precluding convergence.

2.3. Endogenous growth model

The endogenous growth model relaxes the assumption of diminishing returns to capital, redefining capital by including human capital and R&D expenditure. This augmented capital exhibits either constant or increasing returns [3]. In the absence of diminishing returns to capital, investment assumes a pivotal role in determining long-term economic growth. With constant or increasing returns, per capita income across countries does not converge. Barro [12] scrutinized U.S. states' data from 1960 to 85, revealing compelling evidence of poorer states growing faster than their wealthier counterparts, illustrating unconditional convergence. However, no such convergence emerged when comparing U.S. states with a cross-country sample of 98 nations from 1960 to 1985. Nevertheless, upon controlling additional regressors such as school enrolment, government consumption, variations in steady-state value, and technology, the estimated outcomes align with convergence, akin to that observed in U.S. states, substantiating conditional convergence. Dobson and Ramlogan [13] explored convergence in Latin America from 1960 to 1990, indicating evidence of absolute convergence during this period. Yet, sigma convergence was not observed across the entire sample. Further evidence of conditional convergence surfaced, albeit at a slower rate compared to many developed nations. Development programs implemented by poorer countries, along with external financial support, fostered convergence among less affluent nations. Urmas and Vahter [14] investigated economic convergence in transition economies from 1995 to 2004, revealing both absolute and sigma convergence during the specified period.

2.4. Empirical studies on convergence

The review then delves into empirical studies encompassing various regions and countries. It explores research on convergence in U.S. states, Latin America, transition economies, ASEAN countries, Africa, OIC countries, and German states following reunification. These studies furnish evidence of both absolute and conditional convergence, with several factors impacting the speed and extent of convergence. Menbere [15] assessed the extent to which Central and Eastern Euro-

pean transition economies reduced per capita disparities with European Union members during the 1990s. The author employed diverse regression tests to analyze the empirical results. The initial cross-sectional regression, covering the period 1990–2000, revealed no significant convergence in GDP per capita among the transition economies of Central and Eastern Europe and the EU15. However, after controlling various macroeconomic variables such as human capital, physical capital, and initial capital levels, evidence of conditional convergence emerged between transition economies and the EU15, aligning with the augmented Solow model's predictions. Furthermore, the regression results suggested that nations exhibiting strong macroeconomic indicators, FDI, financial development, and robust structural adjustment generally experienced superior economic growth compared to those lacking these indicators. Ghosh [16] explored regional disparities in agricultural development across 15 states in India during 1960–2002. The author assessed α and β Convergence (Absolute and Conditional) in land productivity and per capita agricultural output across states, particularly after the adoption of new HYV technology and extensive economic reforms. The findings revealed no significant convergence in land productivity and per capita agricultural output after the initiation of economic reforms in the 1990s. Sigma convergence indicated a reduction in land productivity variation but an increase in per capita output variation after the introduction of HYV technology. Nonetheless, the author identified conditional convergence as positively influenced by physical capital, human capital, and infrastructure. Ismail [17] investigated growth and convergence in ASEAN countries using a dynamic, heterogeneous group approach, namely Pool Mean Group Estimation, from 1960 to 2004, unveiling evidence of both absolute and conditional convergence within the ASEAN countries during this period. The pace of convergence ranged from 1.6% to 16.6% per annum, with the formation of ASEAN positively correlated with growth. Djennas and Ferouani [18] conducted a cross-country analysis in Africa, employing a decomposition approach to assess absolute convergence, sigma convergence, and conditional convergence of GDP growth and its dynamics. The analysis incorporated data from 52 African countries spanning the period 1980 to 2011. Except for a few cases, most nations displayed weak evidence of absolute convergence, sigma convergence, and conditional convergence in Africa. Unal [19] identified evidence of conditional convergence among 31 OIC countries from 1980 to 2009. Although the coefficient of absolute convergence was negative, it proved statistically insignificant. The inclusion of human capital explained a 50 percent cross-country variation in per capita income, while the introduction of additional variables explained 70 percent of the overall variation. The computed coefficient of conditional convergence was 1.3 percent per annum, suggesting it would take OIC economies approximately 55 years to reach half of the steady state. Gömleksiz et al. [20] examined GDP per capita income growth and convergence between German states following reunification. Employing the neoclassical growth model in a panel approach, the authors found evidence of moderate convergence when incorporating technological progress and financial development into the model. The explanatory variable coefficients for economic growth were statistically significant, with variable marginal impacts contingent on economic prosperity. Net migration negatively impacted the economic growth of poorer economies but positively affected advanced economies. Michal et al. [21] scrutinized economic convergence in the Czech Republic and Slovakia from 1998 to 2016, focusing on Gross National Income (GNI) per capita growth. The analysis indicated significant convergence between the Czech Republic and Slovakia and the E.U. average during the period spanning 2003 to 2008. Various policy and economic variables, including FDI, industrial legacies, and labor market reforms, influenced the rate of convergence. Additionally, the global financial crisis adversely affected the rate of convergence in the Czech Republic and Slovakia.

In conclusion, this review underscores the importance of investment, human capital, technological progress, and other determinants in comprehending long-term economic growth and convergence. It emphasizes the need for further research to explore the intricacies of convergence dynamics in diverse economies.

3. Economic perspective of the Indian States

India's states have experienced divergent economic growth trajectories, leading to the emergence of two distinct groups: high-income and low-income clubs. The high-income club encompasses economically prosperous states like Gujarat, Maharashtra, Punjab, Haryana, Tamil Nadu, and Karnataka. These states each exhibit unique drivers of economic growth. For instance, Gujarat and Maharashtra stand as industrial powerhouses, while Punjab and Haryana serve as the country's primary agricultural regions, contributing significantly to India's rice and wheat production. Tamil Nadu thrives

on manufacturing, and Karnataka has cultivated a self-sustaining growth engine with a focus on finance and international information technology consulting.

In contrast, the low-income club comprises struggling states, including Uttar Pradesh, Rajasthan, Madhya Pradesh, Bihar, Jharkhand, and Odisha. Despite some engagement in agricultural activities, these states grapple with immense challenges such as natural calamities and make minimal contributions to the national GDP. Lacking a robust growth engine, they struggle to connect with and benefit from the economic spillover effects generated by high-income states. This imbalance carries worrisome implications for India's overall economic growth and regional development [22, 23,24,25,26].

While India has witnessed notably high GDP growth rates in recent years, this growth appears primarily driven by select sectors of the economy and confined to a handful of states. The growth hubs in India remain disjointed, both geographically and in terms of their specific engines of growth. Consequently, employment opportunities are highly concentrated in certain states, leaving pockets of poverty in economically disadvantaged regions. This pattern of uneven economic growth threatens to exacerbate regional poverty and disparities.

One might ponder the reasons behind the disparities in economic growth across different states. Some scholars argue that government policies play a pivotal role in influencing the returns on factors like capital accumulation. Studies by King [27], Levine and Renelt [28], and Young [29] have shed light on the connection between stable macroeconomic policies, economic growth, and the positive impact of open trade regimes. These findings underscore the critical significance of sound policy frameworks and trade openness in nurturing robust and inclusive economic growth.

For a more in-depth exploration of this topic, readers can delve into these references, which provide a deeper understanding of the interplay between government policies, macroeconomic stability, trade openness, and economic growth, shedding light on the complexities of regional economic disparities in India.

4. Data source

The variables employed in our model have been meticulously curated from diverse sources, each contributing unique insights into the economic landscape. A comprehensive description of these variables and their respective data sources are presented in Table 1, as follows:

India, comprising 28 states and 9 union territories, presented a comprehensive dataset. However, for the years spanning from 1991 to 2020, the availability of comparable data was limited to 26 states/union territories, which are enumerated as follows:

1. Andhra Pradesh; 2. Maharashtra; 3. Arunachal Pradesh; 4. Manipur; 5. Assam; 6. Bihar; 7' Nagaland; 8. Meghalaya; 9. Delhi; 10. Odisha; 11. Goa; 12. Pondicherry; 13. Gujarat; 14. Punjab; 15. Haryana; 16. Rajasthan; 17. Himachal Pradesh; 18. Sikkim; 19. Jammu & Kashmir; 20. Tamil Nadu; 21. Karnataka; 22. Tripura; 23. Kerala; 24. Uttar Pradesh; 25. Madhya Pradesh; 26. West Bengal

Notably, the states/union territories that could not be included in this dataset encompass:

1. Puducherry; 2. Lakshadweep; 3. Ladakh; 4. Dadra and Nagar Haveli; 5. Chandigarh; 6. Andaman & Nicobar Islands; 7. Uttarakhand; 8. Telangana; 9. Mizoram; 10. Jharkhand; 11. Chhattisgarh

This selection was determined by the availability and comparability of data, ensuring the reliability and coherence of our analysis.

5. Convergence: Relevance and implications

The concept of convergence in economics, often referred to as the catch-up effect, centres on the idea that economies with lower per capita incomes will experience faster growth rates than their wealthier counterparts. This hypothesis finds its roots in the Solow-Swan growth model, which posits that economic growth is primarily driven by the accumulation of physical capital until an optimal level of capital per worker, known as the "steady state," is reached. At this point, economic indicators such as output, consumption, and capital remain constant. This model predicts accelerated growth when the level of physical capital per capita is low, commonly termed "catch-up" growth. Consequently, it is anticipated that all economies will eventually converge in terms of per capita income.

Developing economies hold the potential for outpacing developed ones in growth because the diminishing returns, especially concerning capital, are less pronounced in capital-scarce economies. Additionally, less affluent economies can adopt and adapt production methods, technologies, and institutional frameworks from more developed counterparts.

In economic growth literature, the term "convergence" can take on two distinct meanings. "Sigma-

Table 1
Description of variables and data sources

Serial	Variables	Indicators	Sources
1.	Economic growth	GDP per capita annual growth	Ministry of Statistics and Programme Implementation (MoSPI), Government of India (GoI)
2.	The initial level of income	Lag of GDP per capita	Ministry of Statistics and Programme Implementation (MoSPI), Government of India (GoI)
3.	Population	Population annual growth rate	Registrar General of India (RGI)
4.	Physical capital	Capital formation	Ministry of Statistics and Programme Implementation (MoSPI), Government of India (GoI) & the concerned Department of Economic Statistics (DES)
5.	Human capital	Percentage of GDP spent on health & education	Government of India (GoI) & the concerned State Government
6.	Health	Life expectancy	Registrar General of India (RGI)
7.	Government consumption	Government consumption as a percentage of GDP	Government of India (GoI) & the concerned State Government

convergence" refers to a reduction in the disparity of income levels among different economies, while "beta-convergence" occurs when poorer economies grow at faster rates than wealthier ones. "Conditional beta-convergence" is observed when economies experience "beta-convergence" while holding other variables, such as investment and population growth rates, constant. In contrast, "unconditional beta-convergence" or "absolute beta-convergence" exists when an economy's growth rate declines as it approaches its steady state.

Historically, there has been a transition from the Great Divergence, which peaked before World War I and continued until the early 1970s, to the Great Convergence, where most Third World countries achieved notably higher economic growth rates than many First World countries. However, the presence of prerequisites, often referred to as "Social Capabilities," is crucial for realizing catch-up growth. These capabilities include the ability to absorb new technology, attract capital, and participate in global markets.

The theory assumes that technology is accessible to developing nations attempting to catch up, and the availability of affordable capital is essential for catch-up growth. However, capital scarcity in developing countries can hinder this process, as it can lead to a cycle of low efficiency, where the most advanced technology remains out of reach.

Professor Jeffrey Sachs points out that convergence isn't universal due to the closed economic policies of some developing countries. In a study between 1970 and 1989, Sachs and Andrew Warner discovered that open-economy developing countries experienced higher growth rates compared to closed-economy developing countries.

The "Lucas paradox" raised by Robert Lucas questions why capital does not flow from developed to developing countries despite lower capital levels in the latter. Despite this, there are numerous examples of countries that have indeed converged with developed nations. Japan, Mexico, and the East Asian Tigers – Singapore, Hong Kong, South Korea, and Taiwan – all rapidly converged with developed economies, validating the catch-up theory.

However, some economists argue that endogenous factors, particularly government policies, play a more significant role in economic growth than exogenous factors. For instance, governments can compensate for missing prerequisites to stimulate catch-up growth. Economic historians Kenneth Sokoloff and Stanley Engerman propose that factor endowments, such as soil and climate, have a substantial impact on structural inequality and institutional development in certain countries. These differences can explain why some countries have not converged, particularly when land suitability for specific crops affects the distribution of wealth, political power, and access to public education.

In conclusion, the notion of convergence in economics represents a dynamic process where economies, particularly developing ones, have the potential to catch up with developed counterparts. However, the extent of this convergence is influenced by various economic, social, and political factors, and the journey towards convergence is far from uniform across all nations.

6. Estimating convergence in Indian States

6.1. Absolute convergence

The hypothesis of absolute convergence posits that, over time, the Gross Domestic Product (GDP) per worker (or per capita) in different economies will gravitate towards a common growth trajectory. In simpler terms, this theory suggests that all economies will even-

Table 2
Absolute convergence in Indian states based on cross-sectional regression analysis dependent variable: GDP per capita growth rate

Variable	Coefficient interval	Standard error	t-value	95% confidence interval
$\alpha 1$	−0.2817	1.5687	−0.21	−3.7723 to 3.2788
$\alpha 0$	5.7565	4.8991	1.18	−5.2108 to 16.7486

Source: Author's processing

Table 3
Sigma convergence with Newey-West standard errors: Indian States

Dependent variables: Standard Deviation of GDP per capita				
Variables	Coefficient	Standard error (Newey-West)	t-value	95% confidence interval
γ_1	-0.0029^{***}	0.0113	2.70	−0.0059 to −0.0053
γ_0	-5.1913^{**}	2.2641	−2.30	−9.8997 to −4.8283

***,**indicates significance at the 1% and 5% levels of significance, respectively. γ_0 is the intercept and γ_1 is the time coefficient. Source: Author's processing.

tually reach the same level of income per worker. This convergence process is typically evaluated using cross-sectional regression analysis and is estimated through the following equation:

$$GR = \alpha_0 + \alpha_1 \log y_{i0} + \varepsilon_{it} \quad (1)$$

Where:

- *GR*: the growth rate of an economy.
- $\log y_{i0}$: the initial level of income.
- ε_{it}: the error term.
- α_0 and α_1: the coefficients of the regression Eq. (1).

To determine whether absolute convergence is taking place, it is essential for the coefficient $\alpha 1$, associated with the initial level of income, to display a significantly negative value. To investigate the presence of absolute convergence, an empirical analysis was conducted using Ordinary Least Squares (OLS) econometric techniques, and the results are presented in Table 2.

The regression results, based on data spanning from 1991 to 2020 for the Indian States, reveal that the coefficient linked to the initial level of GDP per capita is indeed negative. However, it lacks statistical significance. Consequently, we can infer the absence of absolute convergence. This implies that Indian states do not seem to be converging towards the same steady-state income level. This lack of convergence can be attributed to differences in investment rates, population growth rates, and levels of technology among these states. Therefore, it is not a reasonable expectation that the poorer states will eventually reach a uniform steady-state economic target.

6.2. Sigma convergence

The concept of sigma convergence relates to the cross-sectional dispersion of income. There is sigma convergence if income dispersion, measured by the standard deviation of the logarithm of GDP per head across a specific group of countries, declines over time. Grier and Grier [30] and Streissler [31] utilized linear regression analysis to investigate sigma convergence, focusing on cross-sectional variances of economies. Building upon their methodology, the assessment of sigma convergence involves examining a linear trend equation, which can be expressed as follows:

$$\sigma_t^s = \gamma_0 + \gamma_{1t} + u_t \quad (2)$$

In the context of studying sigma convergence, dispersion is measured using the standard deviation of the logarithm of income, denoted as σ^s. γ_0 and γ_1 are the two constants and u_t is the error term of Eq. (2).

The presence of sigma convergence is indicated by a negative coefficient γ_1. The outcomes of the analysis on sigma convergence for Indian States are presented in Table 3, with t-statistics calculated using the Newey-West (HAC) consistent standard errors (The Newey-West [32] variance estimator is an extension that produces consistent estimates when there is autocorrelation in addition to possible heteroskedasticity. The Newey-West variance estimator handles autocorrelation up to and including a lag of m, where m is specified by stipulating the lag () option).

The table reveals that the time series coefficient of the standard deviation is positive and statistically significant. Consequently, **no evidence of sigma convergence is observed**. Therefore, the disparity in GDP per capita income among the Indian states has increased over the analyzed period, suggesting a widening gap.

6.3. Conditional β convergence

Considering the diverse geographic, demographic, and socio-economic characteristics of the Indian states,

the notion of absolute convergence becomes implausible. The cross-sectional analysis of the states rejects the presence of absolute convergence.

6.3.1. Models for conditional convergence

Barro and Salal-i-Martin [33] introduced the concept of conditional convergence within the framework of the neoclassical growth model (NSGM) to account for variations in steady-state incomes among economies. By incorporating these steady-state income differences, the notion of conditional convergence emerged in the literature on economic growth, which refers to the negative relationship between the growth rate and the initial level of income, taking into account the disparities in steady-state incomes across countries [34]. Consequently, differences in GDP per capita among economies can be attributed to various underlying factors, such as population, capital stock, human capital formation, exports, government consumption, inflation, and other relevant parameters that shape a country's GDP.

Bassanini, Scarpetta and Hemmings [35] presented the following dynamic growth model equation of conditional Convergence:

$$\begin{aligned}\Delta logy_{it} &= \beta_{0i} - \phi_i logy_{i,t-1} + \beta_{1,i} logsk_{i,t} \\ &\quad - \beta_{1,i} logn_{i,t} + \beta_{m+1,i} t + \Delta logsk_{i,t} \\ &\quad + \alpha_{2,i} \Delta logn_{i,t} + \epsilon_{i,t} \qquad (3)\end{aligned}$$

In the context of studying conditional convergence, where y_{t-1} represents the lagged dependent variable, ϕ denotes the convergence parameter, sk represents the investment share in GDP, n denotes population growth, and t represents the time trend. Additionally, α captures short-term dynamics, while ϵ represents the country/region-specific error term.

Barro [36] introduced a comprehensive framework for studying conditional convergence, often referred to as the "extended version of the Solow growth model." In this extended version, Barro incorporated additional macroeconomic, socio-economic, and demographic indicators that influence economic growth. The Extended Barro equation is derived by augmenting the equation with various additional variables. To estimate the extended Solow equation, variables such as GDP per capita growth rate, gross capital formation, human capital, population growth rate (adjusted for depreciation), life expectancy, and government consumption are considered crucial determinants of economic growth. By including these additional regressors, the extended Solow growth model provides a more comprehensive understanding of the factors influencing the convergence of economies.

$$\begin{aligned}logy_t - logy_0 &= v_i - \beta_1 logy_0 + \beta_2 logs_k \\ &\quad + \beta_3 logh_k - \beta_4 log(n + \delta + g) \\ &\quad + \beta_5 logG_C + \beta_6 logLE + \theta_t \qquad (4)\end{aligned}$$

In the equation, additional variables are introduced: *In* represents the rate of inflation, *GC* denotes government consumption as a percentage of GDP, and *LE* denotes life expectancy at birth. The previously defined terms remain the same.

The ratio of exports to GDP serves as an indicator of an economy's openness, as highlighted by Pereira and Xu [37]. An increase in exports leads to economies of scale and enhanced productivity [38]. Empirical evidence supports the existence of a long-run relationship between exports and GDP growth, indicating that exports drive economic expansion [39].

Government consumption has a dual impact on economic growth. On one hand, taxes reduce the marginal product of capital, exerting a negative influence. On the other hand, government services and spending contribute positively to the marginal product. Initially, the positive effect dominates at lower levels of public spending, resulting in increased growth rates. However, beyond a certain threshold, the negative impact dominates [40]. Connolly and Cheng [41] and Grier and Tullock [42] find a statistically significant negative relationship between the GDP growth rate and the growth rate of government consumption.

The impact of money on economic growth is determined by the effect of inflation on the steady-state equilibrium level of output. This impact can be neutral, positive (known as Tobin's effect), or negative (referred to as anti-Tobin's effect). Sidrauski [43] finds a neutral impact of money, while Tobin [44] considers it a substitute for capital, thus having a positive impact on economic growth. Stockman, on the other hand, views money as complementary to capital, resulting in a negative impact on economic growth.

Regarding life expectancy, its impact on economic growth is complex. Cervellati and Sunde [45] suggest that lower mortality increases resource productivity but may decrease per capita output. Lorentzen, McMillan, and Wacziarg [46] find a strong and positive relationship between GDP growth and life expectancy, indicating a beneficial effect on economic growth.

6.4. Estimation of conditional convergence: Method and challenges

Barro and Sala-i-Martin [33] and Mankin et al. [47] employed a cross-sectional approach to analyze the con-

vergence hypothesis. However, cross-sectional estimation overlooks time series variations and fails to explain heterogeneity among different cross-sectional units. To address these limitations, panel data estimation is utilized, which allows the incorporation of data for multiple cross-sections over a specific period. In essence, panel data analysis combines both cross-sectional and time series dimensions, offering several advantages over time series and cross-sectional analyses. It provides greater variability, reduced collinearity among variables, increased degrees of freedom, and enhanced efficiency [48]. Furthermore, panel data enables a better assessment of the impact of economic, political, institutional, and social policies and programs, as it observes the same cross-sectional units across different periods [49].

Various methods can be employed for panel data estimation. The pooling method (PM) assumes homogeneity among countries and estimates a common constant for all countries. The fixed effect (F.E.) method allows for different dummies or indicators for each country, thereby providing a distinct constant for each country. On the other hand, the random effect (RE) method assumes that each country exhibits variations in its error term. The fixed effect estimator remains consistent even when the estimator is correlated with individual effects. The growth regression, i.e., the equation of convergence in the dynamic panel takes the form as follows:

$$y_{it} = \alpha_1 y_{t-1} + \Sigma \eta_1 x_{it} + \delta_t + \mu_t + u_{it} \qquad (5)$$

where y_{t-1} is a lag of per capita GDP, the dependent variable, and the second term of Eq. (5) represents the sum of regressors. The third and fourth terms of Eq. (5) are the time effect and state-specific effect respectively, and the last term is the error term.

However, Panel data estimation also faces several challenges, including serial correlation, correlated individual effects, inaccurate standard errors, and endogeneity issues. The dynamic nature of panel data introduces a correlation between the error terms and the lagged dependent variable, y_{t-1}, leading to bias and underestimation of the convergence coefficient. Consequently, the random effect regression is unsuitable for estimation as it assumes an exogeneity of variables, implying no correlation between the error term and the regressors. To address these problems, Arellano and Bond [50] developed the first-differenced generalized method of moments (GMM). This approach utilizes lagged levels of variables as instruments, assuming specific moment conditions and the absence of serial correlation in the error term before differencing the regression equation. However, the first-differenced GMM method has limitations, particularly in cases where time series exhibit persistence, as the lagged values of variables used as instruments become weak when differencing is applied, leading to correlation with the error term [1]. To overcome the drawbacks of the first-differenced GMM, Blundell and Bond [51] introduced the dynamic system generalized method of moments (sysGMM). This approach estimates a system of equations in both levels and first differences, with the first differences serving as instruments. As a result, the sys-GMM method mitigates the problems of omitted variable bias and endogeneity.

In the dynamic system GMM, the Sargen test is employed to examine the correlation between the error term and instruments. The null hypothesis states that the instruments are valid and not correlated with the error term. If the null hypothesis is rejected, it indicates that the instruments are not valid. Additionally, the AR (1) and AR (2) tests are used to assess residual serial correlation. The null hypothesis suggests that the test should reject the presence of first-order serial correlation while not rejecting second-order serial correlation [52].

6.4.1. Results and discussions

To present the results of the regression analysis on the conditional convergence of Indian states/UT using the Augmented Solow Model and Extended Solow Model, we can organize the findings systematically as follows.

In Table 4 [Testing Conditional Convergence of India 26 States/UT (1991–2020)], we present the results of two models: the Augmented Solow Model and the Extended Solow Model. The models are used to assess the conditional convergence of Indian states/UT based on various economic variables.

7. Results

1. According to the Augmented Solow Model, the coefficient of the log of initial GDP per capita (-0.0378) is significantly and negatively related to the real GDP per capita growth of Indian states/UT. This implies conditional convergence, where poorer states experience faster economic growth compared to wealthier ones.
2. Physical capital ($\ln(s_k)$) has a positive and significant influence on economic growth in Indian states (0.021, significant at the 10% level).
3. Human capital ($\ln(h_k)$) is significantly conducive to economic growth at the 1% level, with an elasticity coefficient of 0.22.

Table 4
Testing conditional convergence of Indian 26 states/UT (1991–2020)

Variable	Augmented solow model	Extended solow model
$\pounds$Ln(y_{it-1})	0.4181***(0.0257)	0.5636***(0.0041)
Ln(y_{it-1})	−0.0378***(0.0356)	−0.4337***(0.0014)
Ln (s_k)	0.0217*(0.0068)	0.0435***(0.0009)
Ln (h_k)	0.2266***(0.0266)	0.0241***(0.0009)
Ln($n+\delta$)	0.0825*(0.0483)	0.2238***(0.0029)
Ln(Gc)	–	−0.0649***(0.0008)
Ln(LE)	–	1.0384***(0.0163)
AR(1) p-value	0.0921	0.0701
AR(2) p-value	0.2261	0.1201
Sorgan test p-value	0.5030	0.3240

*, ***shows significance level at 10% and 1% respectively. Source: Own processing. $y_{i,t-1}$ is lag of GDP per capita, s_k is physical capital, h_k is the human capital. $n+\sigma$ is population growth plus 0.5% depreciation. G_c is the government consumption as a percentage of GDP, and LE is the life expectancy at birth. AR (1) is significant hence the rejection of first-order correlation, but AR (2) is insignificant. The Sargan test is insignificant and confirms instruments are valid. Variables: $\pounds$Ln(y_{it-1}): The log of the lagged GDP per capita. Ln(y_{it-1}): The log of the initial GDP per capita. Ln(s_k): The log of physical capital. Ln(h_k): The log of human capital. Ln($n+\delta$): The log of population growth plus depreciation. Ln(Gc): The log of government consumption as a percentage of GDP. Ln(LE): The log of life expectancy at birth. AR(1) p-value: p-value for first-order autocorrelation. AR(2) p-value: p-value for second-order autocorrelation. Sorgan test p-value: p-value for instrument validity.

4. Population growth (ln($n+\delta$)) is positively and significantly associated with economic growth in Indian states/UT, suggesting the need for policies to address fertility rates.
5. In the Extended Solow Model, which includes government consumption and life expectancy, the coefficient of the initial GDP per capita demonstrates a significant negative relationship, indicating conditional convergence. This model provides a better explanation of economic growth, and the coefficients differ from those in the Augmented Solow Model.
6. Life expectancy (ln(LE)) has the greatest positive and significant effect on economic growth, highlighting the importance of health in determining growth rates.
7. The government consumption ratio (ln(Gc)) is found to be negatively and significantly related to economic growth in Indian states/UT, aligning with the negative impact of government spending on economic growth observed in developing countries.
8. The first-order autocorrelation (AR(1)) is significant, indicating first-order correlation, while the second-order autocorrelation (AR(2)) is insignificant.
9. The Sargan test confirms the validity of the instruments.

These results suggest that conditional convergence exists in Indian states/UT, with lower-income states experiencing faster economic growth. The inclusion of additional variables in the Extended Solow Model enhances our understanding of economic growth in the region, and the effects of various macroeconomic variables vary.

These findings have important implications for policymakers in India, as they highlight the significance of factors like human capital, health, and government spending in driving economic growth and the need for measures to control population growth.

8. Policy implications

The study's findings have several important policy implications:

i.) Economic growth is positively influenced by factors such as labor force expansion, investment in physical and human capital, and prudent government consumption. Prioritizing spending on health and education is crucial for fostering growth.

ii.) Open economies benefit from accessing new technologies, ideas, and specialization in production processes, contributing to faster economic growth.

iii.) Higher government saving rates lead to higher investment levels and faster growth, indicating sound macroeconomic management.
iv.) Government spending on education and health positively impacts per capita income growth, necessitating increased investments in human capital formation.
v.) Government consumption as a percentage of GDP should be managed prudently to efficiently allocate resources.
vi.) Life expectancy positively affects economic growth, underscoring the importance of budgetary resource allocation to the health sector.
vii.) Population growth contributes positively to economic growth, highlighting the need for policies to incentivize reduced fertility rates and harness the demographic dividend.
viii.) Effective monetary policy management remains crucial for stability and growth.

9. Conclusions

In this section, we summarize the key findings and conclusions of the study:

- The study examined economic growth and convergence in 26 Indian states/UT over a 30-year period from 1991 to 2020.
- Absolute β convergence, indicating a negative correlation between the initial per capita GDP ratio and average annual growth rate, was not observed in the Indian states' economies during the study period.
- Sigma convergence analysis yielded results consistent with those of the absolute convergence model.
- The Augmented Solow Model and the Extended Solow Model were employed to account for heterogeneity among the Indian states.
- The Augmented Solow Model revealed a conditional β-convergence rate of 0.037, highlighting the role of initial GDP per capita, physical and human capital, and population growth in state growth.
- In the Extended Solow Model, the coefficient of initial GDP per capita was 0.43, emphasizing the contributions of various factors, including physical and human capital, population growth, and additional variables, to state growth and convergence.

For future research in the field of economic growth and convergence, the following suggestions can enhance the robustness of results:

1. Extend the time series and incorporate additional determinants of economic growth, using techniques such as Mean Group Estimators (MGE) or Pooled Mean Group Estimators (PMGE) for more reliable results.
2. Explore the convergence hypothesis by examining multiple independent variables, including labor productivity and institutional factors, to gain a more comprehensive understanding of convergence dynamics.
3. Classify states based on their distance from the national per capita income and test the convergence hypothesis with additional explanatory variables.
4. Consider including all states/UT in the study to assess convergence patterns more comprehensively and enhance the generalizability of findings.

These suggestions provide avenues for future research to deepen our understanding of economic growth and convergence dynamics, leading to more nuanced insights into the determinants and patterns of economic development in the Indian context.

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