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TESTING THE CONVERGENCE HYPOTHESIS IN SOLOW GROWTH MODEL: A STATISTICAL EVIDENCE FROM SAARC ECONOMIES

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ABSTRACT

The literature reveals three concepts of convergence, namely Absolute/Unconditional Beta (β) convergence, Sigma (σ) convergence, and Conditional Beta (β) convergence. Annual data of real GDP per capita over the period 1972-2012 of six SAARC countries has been utilized to test the convergence hypotheses. OLS estimates from the cross-sectional data revealed that there is no evidence of sigma (σ) convergence. A panel data approach has also been applied to test the convergence of real GDP per capita among six SAARC countries. Empirical results from both Levin, Lin, and Chu and the Hadri z-stat showed no evidence of convergence among the SAARC countries. Thus, the results of our study are not consistent with the basic growth model of Solow-Swan (1956) which posits the existence of conditional convergence of income among developed and developing economies.

Keywords: Beta convergence; Sigma convergence; Solow; SAARC
JEL Code: O47, F43

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I. Introduction

Convergence hypothesis states how the poor economies will catch-up to richer ones in terms of per capita income through the channel of technology transfers in liberal trade regimes. The convergence hypothesis crucially depends upon assumptions of perfect competition, technological change, no externalities, and exogeneity of technology. Violation of any of the assumptions leads to non-prevalence of the convergence evidence, hence results in divergence. The economies having a low level of initial capital stock bear the ability to grow faster than the economies having more initial capital stock due to the law of diminishing marginal productivity of capital. The convergence can be classified as, Absolute Beta (β) Convergence; Sigma (σ) Convergence, and Conditional Beta (β) Convergence. Absolute Beta (β) convergence states how the poor economies of the world are growing faster in terms of real GDP per capita than the richer economies. Sigma (σ) convergence explains that the economies of the world are converging in a sense that the dispersion of their real GDP per capita is diminishing over time. Conditional Beta (β) convergence is that all the variables, such as saving rate, population growth rate, and technological improvement are growing at the constant rate towards the steady-state level (Sala-i-Martin, 1993).

Any country having initially low per capita income should have some social capabilities to absorb new technology, capital stock, and access to the global market to catch-up on the income levels of developed economies. The logic behind the fact is that return on capital embodied a negative relationship with the stock of capital. Similarly, the countries having a smaller capital stock are more likely to attract investment which in turn earns higher marginal returns. The prevalence of higher marginal productivity of capital in poor economies set the stage to catch-up the income levels of richer economies. Technology absorption by developing countries induce the production of skilled labor, efficient utilization of capital, and improved educational abilities, which in turn generate additional capital stock, higher saving rates, and investment, hence they grow faster than the richer ones. Romer (1996) briefly explained the three main causes of the technological catching-up process. Firstly, the countries converge to their balanced growth path as predicted by the neoclassical growth models (Solow & Swan, 1956). The poor countries will grow faster than the rich ones in terms of real GDP per capita and hence will catch-up to the richer ones. Secondly, due to the law of diminishing marginal returns to capital, the return on capital is higher in poor economies due to low capital stock and is low in rich economies due to the abundance of capital stock. Lastly, lags in the diffusion of knowledge, technology absorbing capacity, and social capabilities arise from the differences in the initial level of real income. These all types of differences are withdrawn when all the poor economies achieve access to the cutting-edge technology and at that point (convergence level) both economies, the rich and the poor will be growing at the same rate.

The concept of conditional convergence holds in the neoclassical growth model of Solow & Swan (1956), in which saving rate, technological progress, and population growth rate are fixed throughout the analysis. Secondly, the concept of unconditional and/or absolute β-convergence is applicable only for the developed countries, OECD economies, Japanese prefectures, and European economies mean all the regions grow in absolute terms and without imposing any conditions (Sala-i-Martin, 1996). Similarly, Barro and Sala-i-Martin (1992) also found that absolute β-convergence holds only in the case of OECD and the United States, but not for the poor economies. Moreover, the σ-convergence holds only for the case of East Asian economies, Taiwan; Singapore; Hong Kong, and South Korea. Neo-classical growth economists argue in favor of conditional convergence originated by the Solow-Swan model (1956), however, endogenous growth theorists support the unconditional convergence. Based on the absence of consensus on the prevalence of convergence hypothesis across different blocs (See, Solow-Swan model, 1956; Barro and Sala-i-Martin, 1992; Sala-i-Martin, 1996), the present study is aimed at examining all of the convergence hypotheses for the panel of SAARC countries by utilizing the data of real GDP per capita for (1972-2012).

II. AN OVERVIEW OF SAARC ECONOMIES

South Asian Association for Regional Cooperation (SAARC) consists of eight countries namely, Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka. The SAARC is aimed at promoting regional and economic integration. The organization also encourages joint work and a spirit of friendship. SAARC economies are experiencing enormous differences in terms of the size of the economy, population growth rates, and their respective economic development. These economies also embodied diversity in the arrangement of political, economic, and social characteristics for which huge difficulties and challenges arise in the formation of SAARC. Table-1 presents key performance indicators of the SARRC economies, like GDP growth rate, population growth rate, investment, gross domestic saving, and Trade. All the variables incorporated in the study show that each country bears different rates of growth due to differences in population growth rate, domestic saving rate, investment, and trade openness. The analysis explains that Sri Lanka is on top of all the SAARC economies due to high GDP growth, low population growth, and high saving and investment rate.

Table-1
Key Performance Indicators of SAARC Economies

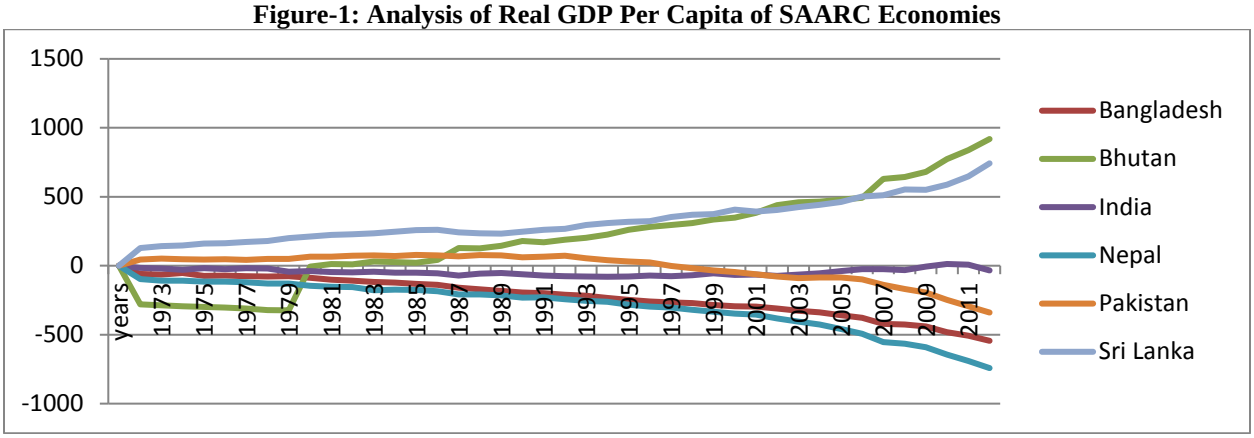
Country	Variables	2012-2013
Afghanistan	GDP Growth Rate	6.96%
	Population Growth Rate	2.45%
	Gross Capital Formation (GCF)*	16.55%
	Saving*	-11.02%
Bangladesh	GDP Growth Rate	6.32%
	Population Growth Rate	1.19%
	GCF*	25.83%
	Saving*	15.12%
	Trade Openness*	0.56
Bhutan	GDP Growth Rate	9.44%
	Population Growth Rate	1.68%
	GCF*	40 %
	Saving*	41.76%
	Trade Openness	0.78
India	GDP Growth Rate	3.24%
	Population Growth Rate	1.26 %
	GCF	33.48 %
	Saving*	27.91 %
	Trade Openness*	0.55
Maldives	GDP Growth Rate	3.42%
	Population Growth Rate	1.94%
	GCF*	30.59%
	Saving*	8.74%
Nepal	GDP Growth Rate	3.9%
	Population Growth Rate	1.15%
	GCF*	21.55%
	Saving*	8.62%
	Trade Openness*	0.47
Pakistan	GDP Growth Rate	2.96%
	Population Growth Rate	1.73%
	GCF*	15.21%
	Saving*	8%
	Trade Openness*	0.34
Sri Lanka	GDP Growth Rate	8.25%
	Population Growth Rate	1.04%
	GCF*	26.06%
	Saving*	15.39%
	Trade Openness*	0.66

* Percentage of GDP

Except for Pakistan and India, all the SAARC economies have a small area of land of its total territorial size. Nepal and Bhutan are encircled by land but are also in the essential need of Indian cooperation to keep in touch with the rest of the world. However, the Maldives and Sri Lanka are well-endowed with islands and India by its size of the land and territorial area occupies nearly about 90% of the region, and 70% of the land since it hugs all the SAARC economies in terms of the oceanic boundary. Indian GDP also accounts for 77% of the respected region GDP and 80% share in the manufactured industry/value-added goods which shows a huge volume of imports and exports. Figure-1 shows the trend of real GDP per capita of the selected six SAARC economies over different periods. The mean value of real GDP per capita for each year is used to observe the dispersion of each country from it. The dispersion of real GDP per capita among the SAARC economies has been increasing since year 1970s. Thus, the dispersion of real GDP per capita is high in the latest years, compared with the initial periods. The dispersion shows

no evidence on Absolute/Unconditional Beta β-convergence and Sigma σ-convergence and hence implies divergent SAARC economies.

Figure-1: Analysis of Real GDP Per Capita of SAARC Economies



III. REVIEW OF LITERATURE

Growth facts of differences among different countries and income convergence between poor and rich economies have attained a great deal of attention for decades. A wide range of literature provides the studies examining the convergence among different countries in terms of geography, composition, and size (Chowdhury, 2004; Evans and Kim, 2005; Ali, 2011; yanthakumaran and Lee, 2013; Ali, 2015; Ali 2018). Many economists suggested that the country which has initially low per capita income should have some 'Social Capabilities' to absorb new technology, capital stock, and access to the global market for catching-up. The logic behind the fact is that return on capital embodied a negative relationship with the stock of capital. Similarly, the countries having a smaller capital stock attracts more investment which in turn earns higher marginal returns. The marginal product of capital is higher in poor economies than the richer ones which give high marginal returns and hence lead towards the catching-up process. Chawdhury (2004) examined the convergence issue of per capita GDP for the sample of the South Asian Association for Regional Cooperation (SAARC) countries throughout 1960-2000, using the World Bank's World Tables data source. Applying the OLS method, the result shows no evidence of absolute β-convergence and σ-convergence; implies the increasing dispersion in real income levels for the selected sample. However, weak evidence regarding the conditional β-convergence occurs only from 1980 to 1982 and 1990-1994. Postiglione et al. (2013) found the conditional β-convergence and absolute β-convergence for the sample of 26 MENA economies over the period 1950-2007. The empirical result strongly rejected the absolute β-convergence hypothesis, as it failed for the sample of countries under analysis. However, the evidence supports conditional β-convergence for the sampled countries. However, Tosun (2012) found strong evidence of convergence at the aggregate level. Measurement categories applied to the data set show a significant degree of convergence for Croatia and FYR Macedonia, but not for Moldova, among countries taken in the sample.

Payne (2012) contributed to the convergence process of per capita energy use for the sample of 25 OECD economies over the period 1960-2010. Applying LM-unit root jointly with structural breaks contributed a lot in conditional convergence and hence energy intensity decreases, and efficiency increases in the industrialized economies. Empirical results suggest that log of per capita energy use is stationary relative to the average of OECD economies, which implies strong convergence.

Nguyen-Van et al. (2010) showed that non-linearity and heterogeneous growth, imply no convergence for low and high-income regions except for medium-income regions. Likewise, Cunado (2010) found that strong evidence convergence of Nigeria towards Africa exists; also with the consent of structural breaks significant evidence of catching-up, in terms of relative incomes, is found for Indonesia and Angola. Fung et al. (2010) found evidence on the convergence hypothesis of TFP among banks, mainly for the case of Hong Kong. The initially smaller banks will catch-up to initially larger ones in terms of rapid growth with the condition to decline in the gains from scale economies and hence the difference lies in the initial size of the institutes/ banks. The empirical findings didn't support absolute β-convergence, as the less productive bank is not growing faster than the highly productive one. The result supports conditional β-convergence, as each bank is converging toward its own steady-state TFP path. Manca (2010) analyzed the process of technology catch-up for developed and developing economies based on cross-

section analysis and incorporating quality institutes. Empirical evidence shows that economies endowed with the quality institutes are growing faster in terms of technology catch-up, but the same is not true for economies lacking minimum quality institute requirements. Enforcement of property rights leads to the high cost of technology imitation which lowers growth rate and technology catch-up rate. Trade openness, on the other hand, an important determinant for innovation, leads to technology catch-up in the open economies due to the adoption of new and high technology e.g. China and India. Salvatore (2009) analyzed the data set of 19 industrialized (OECD) countries over the period 1970-2006, applying both time-series and cross-sectional tests for convergence. The empirical results provide significant evidence of convergence regarding environmental quality and individual preferences. Empirical evidence of double convergence hypothesis (DCH) fits for the individual countries but not for all economy's, also the idea of diminishing returns to capital, in terms of marginal benefit, is applied which indicates diminishing, implies strong evidence of convergence. Gianfranco et al. (2009) conducted an empirical investigation of growth models for productivity's convergence dynamics over the sample period 1991-2004. The empirical result explains that the growth model with spatial externalities represents the best candidate for the European region's growth patterns. The relative location effect is highly significant and increases regional spatial dependence of output per worker but decreases the speed of convergence. Holding fixed the geographical distances, regions with the same institutional framework tends to converge with greater speed.

Lee (2009) studied the convergence of long-run manufacturing productivity using samples of 25 OECD countries for 1975-2004, also comparison of trade and foreign trade investment (FDI) was made in the analysis. Applying panel unit-root technique for the relationship between trade, FDI, manufacturing products, and the long-run convergence, evidence shows long-run productivity convergence for both, trade-related and FDI related. Empirics also indicate that grouping leads to more significant evidence for trade patterns, which dominates FDI patterns, in terms of speed of convergence. Overall analysis proved that trade is more important than FDI and the low convergence of FDI and trade exist in services sectors for long-run productivity. Skidmore et al. (2008) used a macroeconomic model consistent with its growth literature for the best convergence in government spending, over the period 1990-2000. Theoretical and empirical evidence suggests that competition at the regional level leads to the convergence of per capita output for factors of production. The empirical finding shows strong evidence for the convergence of government spending at the local level. Huang (2005) used pooled data averaged for the 1960s, 1970s, and 1980s for the analysis of 86 countries, including 258 observations. Applying the regression tree and flexible non-linear approaches result explains the strong evidence of cross-country growth regression convergence but not for multiple steady states.

Arielle Beyaert (2003) analyzed the convergence of 14 countries of the European Union using panel data tests of convergence of per capita GDP expressed in 1995 constant and international prices, over the period 1970-2000. Empirical results using bootstrap technology proposed by Evans and Karras (1996) show no evidence of convergence for the selected sample. However, the empirics show only a little evidence of conditional convergence and implies the reduction I regional inequalities for the sub-sample of 1970-1986 but vanished after 1987. Miller et al. (2001) studied the convergence of total factor productivity and real GDP per capita for the pooled data analysis. The study opted sample of developed and developing countries. The Result support both the absolute and conditional convergence for total factor productivity. However, the findings indicate only conditional convergence to real per capita GDP. Finally, the absolute β-convergence exists only for developed countries but not for mixed economies as the conditional convergence requires.

Eatzaz et al. (2000) used the panel data of 54 countries classified on the basis income level for the sample period 1961-1992. The estimated value of β found from non-linear least squares shows the existence of no strong β and σ-convergence, because of the rise in dispersion in income level. They used time-series analysis for average ranks and cross-section for the relative analysis which shows no strong evidence of convergence hypothesis for poor and lower-middle countries. But in the case of East Asian countries strong evidence of convergence hypothesis holds. On the other hand, Klomp et al. (1997) argued on the test of the convergence hypothesis for the Solow growth model that how the variance of productivities across different economies diminishes over time. The results for the sample period (1960-1985) show no evidence regarding the convergence hypothesis, but for the sub-sample (1961-1972) shows strong evidence of convergence.

Sala-i-Martin (1996) made a contribution to convergence analysis of the world economies for the period of 1960-1990, by applying the absolute and conditional β-convergence, and σ-convergence. The empirical result shows no σ-convergence and absolute β-convergence. However, strong evidence of conditional β-convergence holds by taking the saving rate, population growth rate, and technology as constant. Moreover, in the case of OECD and European

economies strong evidence of absolute and conditional β-convergence, and σ-convergence holds. Quah (1996) made a critical analysis of the earlier key findings related to convergence including important policy implications. The empirical evidence indicates that there is increasing dispersion among different income groups, such as the poor become poorer, richer become richer, and so on. Similarly, Sala-i-Martin (1996) has extended the evidence of convergence and regional growth across the US, Japan prefectures, and five European regions. The estimated speed of convergence is 2% per annum means half of the distance to steady sate path would be covered in 35 years, implies very slow due to the inverse relationship of technology adoption and its cost of imitation. Bernard et al. (1995) applied cross-section and time-series data sets for different types of economies for the analysis of the convergence hypothesis. The cross-section test shows a negative correlation between initial per capita income and growth rate, which implies strong convergence. But in the case of advanced economies, the null hypothesis accepted that there is no convergence in a large data set. Nazir et al. (2010) analyze the convergence hypothesis for 1979-2005, for the sample of four Pakistani provinces: Punjab, Sindh, Khyber Pukhtoonkhwa and Baluchistan, further dividing in three sub-periods (1979-1988), (1988-1998) and (1998-2005). The empirical result shows no absolute β-convergence and σ-convergence in Pakistan and also in rural-urban areas. By applying OLS, Fixed Group, and GMM estimator techniques for the panel data framework, they found only conditional convergence.

IV. MATERIALS AND METHODS

IV.I. ECONOMETRIC METHODOLOGY

IV.I.I. Cross-Sectional Analysis: Sigma (σ)Convergence

We have estimated the following model to empirically test the sigma ($\boldsymbol{\sigma}$) convergence in case of SAARC countries (see, Chowdhury, 2004)

$$\boldsymbol{\sigma_t = \alpha + \beta t + \mu_t} \quad \ldots\ldots\ldots\ldots\ldots (\boldsymbol{i})$$

Where α and β are the parameters and μ_t is a random error term. The value of parameter β should be significantly negative ($\beta < 0$) in case of sigma (σ) convergence, whereas positive value ($\beta \geq 0$) implies non-convergence. To find out the value of σ_t we used Y_{it} as the natural logarithm of real GDP per capita for economy.

Where $i\,(i = 1,2,3, \ldots N)\ stands\ for\ each\ country\ and\ t\ stands\ for\ time\ period,$ and σ_t is the standard deviation of Y_{it} across *i* at time *t.*

Absolute/Unconditional Beta (β)Convergence

The following model is estimated to test the absolute β convergence:

$$\boldsymbol{\left(Y_{it} - Y_{i,t-T}\right) = \alpha + \beta Y_{i,t-T} + \mu_t} \quad \ldots\ldots\ldots\ldots\ldots (\boldsymbol{ii})$$

Where α and β are the parameters, μ_t is stochastic error term and Y_{it} as the natural logarithm of real GDP per capita.

Where $i(i = 1,2,3, \ldots N)\ stands\ for\ each\ country\ and\ t\ stands\ for\ end\ time\ period,$ (t-T) is the beginning of the time interval.

By equation (ii) a significant negative value for ($\beta<0$) indicates the existence of beta (β) convergence, while ($\beta\geq0$) indicates non-convergence.

Conditional Beta (β)Convergence

conditional beta convergence (β^c) can be formulated by introducing a set of control variables x_i, investment; saving rate; population growth rate, and trade liberalization indicator. The control variables determine the steady-state growth of per capita GDP. The following model is estimated to test β^c:

$$\boldsymbol{\left(Y_{it} - Y_{i,t-T}\right) = \alpha + \beta Y_{i,t-T} + \gamma x_i + \mu_t} \quad \ldots\ldots\ldots\ldots\ldots (\boldsymbol{iii})$$

Where α and β are the parameters, μ_t is stochastic error term and Y_{it} as the natural logarithm of real GDP per capita for economy.

Where $i(i = 1,2,3, \ldots N) stands\ for\ each\ country\ and\ t\ stands\ for\ end\ time\ period,$(t-T) is the beginning of the time interval.

Referring to equation (iii) a significant negative β indicates that the convergence holds conditionally when $\gamma\neq0$.

IV.I.II. Panel Data Analysis: The Arguments of Levin, Lin & Chu against β-cross sectional regression

Following Arielle Beyaert (2003), consider N economies which have eventual access to all existing technical knowledge. Let $Y_{n,t}$ be the natural logarithm of output per-capita for country n in period t, valued at constant 2005 and international prices $, with n=1,….., N, t=1,…., T. According to the non-stochastic neo-classical model, these economies will share parallel growth paths, as expressed in the following expression:

$$\boldsymbol{\lim_{i\to\infty}(Y_{n,t+i} - a_{t+i}) = \mu_n \qquad n = 1, \ldots, N} \qquad (\boldsymbol{1})$$

Where a_t is the common trend followed by the economies and μ_n is a parameter which indicates the relative position of economy n balanced growth path concerning their common trend a_t. The parameter $\mu_n$should be non zero but,

$$\frac{1}{N}\sum_{n=1}^{N}\mu_n = 0$$

Eliminating the non-stochastic assumption, (1) becomes

$$\lim_{i\to\infty} E(Y_{n,t+i} - a_{t+i}) = \mu_n \qquad n = 1, \dots, N \qquad (1')$$

The common trend a_t is not observed. This variable can, however, be canceled out. Averaging over the N economies in $(1')$ and considering that

$$\frac{1}{N}\sum_{n=1}^{N}\mu_n = 0, (1')$$

Implies

$$\lim_{i\to\infty} E(\bar{Y}_{t+i} - a_{t+i}) = 0 \qquad n = 1, \dots, N \qquad (2)$$

Whereas,

$$\bar{Y}_t = \frac{1}{N}\sum_{n=1}^{N} Y_{n,t}$$

Subtracting (2) from $(1')$ yields,

$$\lim_{i\to\infty} E(Y_{n,t+i} - \bar{Y}_{t+i}) = \mu_n \qquad n = 1, \dots, N \qquad (3)$$

So, if the N economies share parallel growth paths, the deviations of their per capita output from their cross-sections average is expected to eventually tend to a constant, in which case the economies are said to converge. The convergence would be absolute if $\mu_n = 0\ \forall_n$; otherwise, it would be conditional. Note that (3) holds if and only $(Y_{n,t+i} - \bar{Y}_{t+i})$ is stationary, whereas $Y_{n,t+i}$ is non-stationary.

The typical cross-sectional regression to determine whether (absolute or conditional) convergence takes place is

$$g_n = \alpha + \beta Y_{n0} + \gamma' X_n + v_n \qquad n = 1, 2, \dots, N \dots\dots\dots (4)$$

Whereas, $g_n = (Y_{n,T} - Y_{n,0})/T$is the average growth of per capita output of economy n between time 0 and T, whereas X_n is the vector of variables that controls the cross- economy heterogeneity, reflecting different national or regional stationary states and where α, $\beta$and $\gamma'$are parameters and v_n an error term. For convergence, β should be negative, to reflect that initially poor economies grow more quickly than initially richer ones. The convergence would be absolute if $\gamma' = 0$ and conditional if$\gamma' \neq 0$. This is checked applying OLS on $(4)$and testing $\beta < 0$ and $\gamma = 0$. This approach is mainly associated with the names of Barro and Sala-i- Martin (1991, 1992) and is known in the literature as the β-convergence regression.

However, Evans & Karras (1996, 1997) shows that inference based on OLS estimates of β and γin $(4)$are invalid unless the following process applies to each country:

$$Y_{n,t} - \overline{Y_t} = \delta_n + \lambda(Y_{n,t-1} - \bar{Y}_{t-1}) + U_{n,t} \dots\dots\dots (4')$$

Whereas,

$$\delta_n = \xi' x_n$$
$$\lambda = (1 + \beta T)^{1/T}$$

With $U_{n,t}$ serially uncorrelated with constant variance σ_n^2. This means that in each country $(Y_{n,t} - \bar{Y}_t)$ should follow an AR (1) process, which should moreover be that identical in all countries. This seems highly improbable; it is more reasonable to accept that the data generating process be:

$$\lambda_n(L)(Y_{n,t} - \overline{Y_t}) = \delta_n + U_{n,t} \dots\dots\dots (5)$$

Where the lag polynomial $\lambda_n(L)$ maybe of order higher than 1, with coefficients that may differ across the economies.

IV.II. THE PROCEDURE PROPOSED BY LEVIN, LIN & CHU

Taking these facts into account, an alternative procedure to test for β-convergence by Levin, Lin & Chu is then proposed. The polynomial l $\lambda_n(L)$can be written as $\lambda_n(L) = \pi_n(L)D(L)$ where $\pi_n(L)$have all its roots outside the unit circle and $D(L) = 1$or $(1 - L)$on whether the economies converge or diverge. Equation (5) then becomes:

$$\pi_n(L)D(L)(Y_{n,t} - \overline{Y_t}) = \delta_n + U_{n,t} \dots\dots\dots (5')$$

Approximating $\pi_n(L)$by a q-degree polynomial, with q finite, equation $(5')$can be written as

$$\boldsymbol{\Delta(Y_{n,t} - \overline{Y_t}) = \delta_n + \rho_n(Y_{n,t-1} - \overline{Y}_{t-1}) + \sum_{i=1}^{p} \varphi_{n,i}\, \Delta(Y_{n,t-i} - \overline{Y}_{t-i}) + U_{n,t}} \ldots\ldots\ldots (\mathbf{6})$$

With $\boldsymbol{\rho_n = 0}$, $\boldsymbol{\varphi_{n,i} = \pi_{n,i}}$, $\boldsymbol{p=q}$ if $\boldsymbol{D(L) = 1 - L}$, (i.e. if the economies diverge), but with

$$\boldsymbol{\rho_n = (\sum_{i=1}^{p+1} \pi_{n,i} - 1)}$$

Negative

$$\boldsymbol{\varphi_{n,i} = -\sum_{j=i+1}^{p+1} \pi_{n,j}}$$

p=q-*1*if $\mathrm{D(L)} = 1$ (i.e. if the economies converge).

Evans and Karras (1996) base their testing procedure on a modification of Levin Lin (1992, 1993) test for unit roots in panel data considering under the assumption of no cross-sectional correlation. The testing procedure is as follows:

(1) Apply OLS to (6) to obtain an estimate $\hat{\sigma}_n$ of $\sigma_n^2 = V(U_{n,t})$ and use it to transform the data to $\hat{z}_{n,t} = (Y_{n,t} - \overline{Y}_t)/\hat{\sigma}_n$

(2) Obtain the OLS estimate of $\rho$and its t-ratio $\tau(\hat{\rho})$applying OLS to

$$\boldsymbol{\Delta\hat{Z}_{n,t} = \delta_n + \rho\hat{Z}_{n,t-1} + \sum_{i=1}^{p} \varphi_{n,i}\, \Delta\hat{Z}_{n,t-i} + \hat{U}_{n,t}} \ldots\ldots\ldots\ldots (\mathbf{7})$$

(3) If the t-ratio of step (2) is sufficiently negative, reject H_0: $\rho_n = 0\ \forall_n$in favor of H_1:$\rho_n < 0\ \forall_n$. If $H_0$is rejected, the economies converge

(4) If the $H_0$is rejected, test H_0':$\delta_n = 0\ \forall_n$against H_1':$\delta_n \neq 0$ for some n in equation(6); for that purpose, we estimate the following equations

$$\boldsymbol{\Delta\left(Y_{n,t} - \overline{Y}_t\right) = \delta_n + \rho\left(Y_{n,t-1} - \overline{Y}_{t-1}\right) + \sum_{i=1}^{p} \varphi_{n,i}\, \Delta\left(Y_{n,t-i} - \overline{Y}_{t-i}\right) + U_{n,t}} \ldots (\mathbf{8})$$

$$\boldsymbol{n = 1, \ldots\ldots\ldots, N}$$

and compute

$$\boldsymbol{\Phi(\delta) = \frac{1}{N-1} \sum_{n=1}^{N} [\tau(\delta_n)]^2}$$

And reject H_0 *if* $\Phi(\delta)$ is too large, in which case convergence would be conditional.

For convergence, what is indeed required is $\rho_n < 0$ for all *n*, and this is what considered as an alternative of the Levin, Lin & Chu test. As just said, convergence requires stationarity around the mean of the output series of all countries in the sample. So, the hypothesis of stationarity might be taken as the null, whereas I (1) hypothesis would be left for the alternative. This is precisely what is done in the panel stationarity tests developed by Hadri (2000). The strategy would be:

I. If LLC procedure rejects the null of overall unit root and Hadri test accepts the null of overall stationarity, convergence takes place
II. If LLC procedure accepts the null of overall unit root and Hadri test rejects the null of overall stationarity, all the countries are diverging OR convergence wouldn't occur
III. If both tests reject the null, some subgroups of countries are converging, and it is worthwhile analyzing subgroups
IV. If both tests accept the null, more data are necessary in order to discriminate between the rival hypotheses.

In applying the tests, a choice must be made as to the value of ρ in equations (6)and(7). We carried out the estimation for $\rho = 0$ to 7 and applied tests, Hadri and Levin Lin & Chu procedures, of no autocorrelation of the residuals. In none of the estimated model, the residuals are whitened with$\rho = 0$. Note that this indicates that the generating process of $(Y_{n,t} - \overline{Y}_t)$is not AR (1). Thus, one of the required conditions for the "conventional approach" to β-convergence is violated, and the more general approach advocated by Levin Lin & Chu is justified.

The results by applying the tests on the whole group of 6 selected SAARC countries are reproduced in the results and discussions chapter. In the analysis, the bootstrap probability values for the null H_0: $\rho = 0$of no convergence against the alternative H_1: $\rho < 0$of convergence are given for all values of ρ from $\rho = 1$ to $\rho = 7$.

IV.III. DATA SOURCES

We have selected the balanced panel data of annual per capita GDP for six SAARC countries over the period 1972-2012, using International Financial Statistics (IFS) and World Development Indicators (WDI) as data sources.
To empirically test Absolute/ Unconditional Beta (β) convergence, Sigma (σ) convergence, and Conditional Beta (β) convergence, we used the following variables given in the Table-2.

Table-2
Descriptions of Variables and Data Sources

Variable	Description	Source
GDP (2005 $)	GDP (constant 2005 $)	WDI
	GDP Growth	WDI/IFS
GRGDP	Per Capita Real GDP	WDI
PCRGDP	Total Population	WDI
POP	Population Growth Rate	WDI
PGR	Gross Fixed Capital Formation (% of GDP)	WDI
GFCF	Gross domestic savings (% of GDP)	WDI/IFS
GDS	(Imports+Exports)/GDP	WDI/IFS
Trade Openness		

Following six countries (See Table-3) were selected to test the sigma convergence, absolute beta, and conditional beta convergence:

Table-3: List of Selected SAARC Economies

Bangladesh	Nepal
Bhutan	Pakistan
India	Sri Lanka

We have selected the balanced panel comprising annual data of per capita real GDP for six SAARC countries over the period 1972-2012, using International Financial Statistics, and World Development Indicators. Afghanistan and Maldives are excluded from the analysis of convergence due to data constraints. The data of Afghanistan are not available up-to 2000 however, Maldives data are only available from the year 1984 onward. In certain cases (Absolute Sigma (σ)Convergence) Bhutan is also excluded from the analysis due to data limitations of real GDP per capita before the year 1984.

V. RESULTS AND DISCUSSIONS

V.I. Cross-Sectional Analysis: Sigma Convergence

The result of Sigma (σ) convergence by estimating equation ($\boldsymbol{i}$)is reported in Table-4. Applying the simple OLS technique reveals high R^2 and significant positive (β >0) coefficient. The model also predicts positive autocorrelation.

Table-4: Results of Sigma (σ) Convergence Hypothesis

Variable	Coefficients	Std. Error	t-Statistic	Prob.**
A	4.555309	0.016041	283.9764	0.0000
B	0.041586	0.000690	60.24279	0.0000
R^2	0.989368	Mean D.Var		5.387023
Adjusted R^2	0.989095	S.D. D.Var		0.500831
S.E	0.052299	AIC		-3.016122
DW stat	0.290438	Prob		0.000000

**level of significance 5%

Table-5: Regression Results of Sigma (σ) Convergence Hypothesis (Based on the Cochrane-Orcutt Procedure)

Variable	Coefficient	Std. Error	t-Statistic	Prob.**
A	0.286686	0.014000	20.47709	0.0000
B	0.045945	0.005917	7.765406	0.0000
R^2	0.613434	Mean D.Var		0.389970
Adjusted R^2	0.603262	S.D. D.Var		0.043890
S.E	0.027645	AIC		-4.290045
DW stat	1.747283	Prob		0.000000

**level of significance 5%

The result of Sigma (σ) convergence by estimating equation (***i***) is reported in Table-5. Applying the Cochrane-Orcutt procedure for serial correlation the result yields higher R^2 than the simple OLS technique but again the sing of the coefficient is positive ($\beta > 0$) and highly significant. Hence we are unable to accept the hypothesis of Sigma (σ) convergence across the SAARC countries.

We also estimated equation(***i***) by using the coefficient of variation as a dependent variable rather than the standard deviation. Results in Table-6 also show that β is positive i.e. $\beta > 0$ and is statistically significant indicating non-convergence.

Table-6: Results of Sigma (σ) Convergence Hypothesis (Based on CV)

Variable	Coefficient	Std. Error	t-Statistic	Prob.**
A	0.358293	0.005488	65.29112	0.0000
B	0.005561	0.000236	23.54854	0.0000
R^2	0.934292	Mean D.Var		0.469512
Adjusted R^2	0.932607	S.D. D.Var		0.068918
S.E	0.017891	AIC		-5.161449
DW stat.	0.409456	Prob.		0.000000

**level of significance 5%

We can conclude from here that we cannot find evidence of sigma convergence in the case of SAARC countries. Next, we move to test the Absolute Beta (β) convergence hypothesis.

V.II. BETA CONVERGENCE

Table-7: Regression Results of Beta (β) Convergence Hypothesis: (When Bhutan is included)

(A)

	1990- 2012	1990
Bangladesh	327.87	269.63
Bhutan	1417.58	643.09
India	703.71	403.09
Nepal	166.23	233.47
Pakistan	277.06	525.39
Sri Lanka	1174.10	710.13
	Beta	Intercept
Coefficients	2.17	-328.97
Std. Errors	0.76	377.36
	0.67	331.71
t-statistic	2.86	-0.87

(B)

	1980-1995	1980
Bangladesh	55.93	243.51
Bhutan	482.84	325.14
India	177.65	291.82
Nepal	79.34	185.14
Pakistan	190.86	396.76
Sri Lanka	322.98	543.50
	Beta	**Intercept**
Coefficients	0.68	-8.10
Std. Errors	0.54	188.78
	0.28	152.30
t-statistic	1.26	-0.04

(C)

	2000-2012	2000
Bangladesh	247.988	349.505
Bhutan	1069.081	991.591
India	529.868	576.929
Nepal	102.876	296.824
Pakistan	205.234	597.217
Sri Lanka	832.489	1051.743
	Beta	**Intercept**
Coefficients	1.11	-218.32
Std. Errors	0.25	175.27
	0.83	175.77
t-statistic	4.48	-1.25

(D)

	1988-2005	1988
Bangladesh	160.341	260.782
Bhutan	699.872	559.119
India	364.444	375.672
Nepal	97.216	224.238
Pakistan	184.778	509.018
Sri Lanka	573.641	668.763
	Beta	**Intercept**
Coefficients	1.10	-128.73
Std. Errors	0.43	198.93
	0.62	169.01
t-statistic	2.55	-0.65

Table-8: Regression Results of Beta (β) Convergence Hypothesis: (When Bhutan is excluded)

	1972-2000	**1972**
Bangladesh	130.23	219.28
India	312.89	264.04
Nepal	113.67	183.16
Pakistan	271.96	325.26
Sri Lanka	643.57	408.73
	Beta	**Intercept**
Coefficients	2.23	-329.13
Std. Errors	0.50	145.99
t-statistic	4.44	-2.25

V.III. ABSOLUTE/UNCONDITIONAL BETA (B) CONVERGENCE

The estimation result of Unconditional Beta (β) convergence using equation (***ii***) is reported in Table-7 & 8. Five-time periods have been selected, that are 1972, 1980, 1988, 1990, and 2000 and regressions have been run using cross-sectional and simple OLS procedure also compared with initial periods. Empirical results of all the tables indicate that the estimated value of beta is statistically significant and positive (β>0) throughout the period under analysis. However, a negative value of beta (β<0) is required for evidence of convergence, but in the given time and selected sample there is no absolute beta convergence in the SAARC countries. The evidence does not support beta convergence in the selected sample of SAARC Countries. Before 1984, data on real per capita GDP for all eight

SAARC economies were not available (e.g., Afghanistan, Bhutan, and the Maldives). In the first four tables, Bhutan is included but in the fifth table, it is excluded from the sample. However, the results after excluding Bhutan do not differ from the routine wise sample and hence show no evidence of convergence among the SAARC countries.
Thus, the results of our study are not consistent with both the basic growth model of Solow-Swan (1956) and the endogenous growth theory.

V.IV. PANEL ESTIMATION

Table-9: Results based on Levin, Lin & Chu Test

Method	**Statistic**	**Prob.****
Levin, Lin & Chu t*	10.368	1.00

** Probabilities are computed assuming asymptotic normality

The above estimates of Levin Lin & Chu (LLC) procedure accept the null of the unit root which shows no evidence of convergence among the 6 selected SAARC countries. The probability value, by incorporating the maximum lags of the real GDP per capita, also indicates no convergence or simply divergence among the SAARC economies.

Table-10: Results based on Hadri Test

Method	**Statistic**	**Prob.****
Hadri Z-stat	8.220	0.110
Hetroscedastic Consistent Z-stat	8.376	0

** Probabilities are computed assuming asymptotic normality

The results of the Hadri Z-stat technique rejected the null of overall stationarity of no unit root which shows no evidence of convergence among the 6 selected SAARC countries. The probability value also indicates no convergence, or simply divergence, among the SAARC economies. Moreover, the errors are also Heteroscedastic which explains that variance is fluctuating as $\boldsymbol{\sigma_i^2}$.

Hence, the above-estimated results are highly consistent with our strategy that LLC procedure accepted the null of overall unit root and Hadri test rejected the null of no unit root which indicates that all the countries are diverging OR convergence doesn't exist. Because no evidence of Absolute β-convergence is found thus we are unable to proceed further for Sigma σ-convergence or the Conditional β-convergence. Finally, the results of our study are not consistent with the basic growth model of Solow-Swan (1956) which ensures the conditional convergence. The empirical findings are also not compatible with the endogenous growth theories which favor unconditional convergence.

V.CONCLUSIONS AND POLICY IMPLICATIONS

Three concepts of convergence have been revealed in this study, namely Absolute/ Unconditional Beta (β) convergence, Sigma (σ) convergence, and Conditional Beta (β) convergence. Data for annual per capita GDP in 2005 international prices ($) from 1972-2012 of six SAARC countries are extracted from the World Bank (WDI) data and International Financial Statistics (IFS). The convergence of all types is tested for six selected South Asian countries representing SAARC using the sample periods data. The analysis is made by applying the cross-sectional technique and by panel estimation procedure. Firstly, by applying the cross-section technique the results of sigma (σ) convergence inclusive of OLS estimates revealed high R^2 and significant positive (β>0) coefficient. Our model also suffered positive autocorrelation which is solved by applying the Cochrane-Orcutt procedure. The empirics after this procedure revealed high R^2 than OLS but the value of β remains the same as positive and highly significant which implies non-convergence. Likewise, the result of absolute β-convergence by applying the cross-sectional analysis shows a positive statistically significant value of β which gives no strong evidence of convergence among the SAARC countries for the sample period. Five initial periods have been selected namely, 1972, 1980, 1988, 1990, and 2000also declared that before 1984, data on real per capita GDP for all 8 SAARC countries were not available (e.g., Afghanistan, Bhutan, and the Maldives). However, the results after excluding Bhutan not differ from the routine wise sample and hence show no evidence of convergence among the SAARC countries.

Secondly, we applied the panel data approach to testing the convergence of per capita GDP among the six SAARC countries. In the panel framework, we have applied two techniques to test the convergence hypothesis among the SAARC economies. The first one is Levin, Lin, and Chu procedure and the other is Hadri Z-stat technique to investigate the convergence process. Empirical results of both procedures show no evidence of convergence among the SAARC countries.

Finally, the procedures such as cross-sectional and panel applied on the data for 1972-2012 of SAARC countries show no evidence of convergence, including any sub-sample. Hence, the dispersion in real per capita income levels is increasing over time in the SAARC countries. Because no evidence of Absolute β-convergence and Sigma σ-convergence is found thus we are unable to proceed further for Conditional β-convergence. Thus the results of our study are not consistent with the basic growth model of Solow-Swan (1956) which ensures conditional convergence. The empirical findings are also not compatible with the endogenous growth theories which favor unconditional convergence.

Economic growth is spurred by the accumulation of human and physical capital which is possible only through technological advancement. Experience shows that economies that have grown faster are successful in creating conditions for the long-run per capita income growth. Thus, there exist many economic and non-economic factors that hinder or successes the process of growth and convergence.

The government may be able to play an active role in policymaking, political and economic stability, and full employment for the long-run growth. Factors such as economic, non-economic, macroeconomic stability, high saving, and investment, liberalized trade regimes to promote efficiency in trade and encouragement of domestic competition lead towards a high growth rate, and hence there are more chances for the system to converge. Quality institutes, political stability, good governance, promotion of education, training, and R&D play a dominant role in the sustainable development of any economy. Reduction in corruption, improved transparency, and proper use of natural and mineral resources through efficient technology to extract these are major factors for the long-run economic growth.

South Asian economies may adopt the above-mentioned policy measures to achieve high and sustainable development. They may opt as a package or to pick the options that are most feasible for the economy. The problems such as religion and ethnicity are not easy to tackle that they can't pave the way for international trade relations among SAARC economies.

But these problems can be solved by mutual help. SAARC countries may experience various cultural exchange programs for civil society, encourage interaction between countries to help the people understand concepts like diversity, and help them accept heterogeneity as a leading world norm. Exchange programs for schools, colleges, and universities may be funded by the governments of SAARC nations which gives an insight in the youth of the countries to set aside parochialism and work together in their internal societies for the benefit of the nation as a whole.

Lastly, the models for the European Union and NAFTA (North American Free Trade Agreement) may be studied by the respective countries to enhance cooperation at the governmental level. Lack of regional integration could be one of the main impediments for the collective economic growth of the region. There may be healthy research in leading think tanks of the nations to discuss the possibilities of concepts like common currency, joint transportation infrastructure, deregulation, etc. This may help the peoples of all nations and would expand horizons for all individuals as a collective whole.

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