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Income Convergence Experiences among Asian Economies: An Empirical Investigation

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Abstract: This article investigates the growth and regional disparity scenario that Asian economies have been facing in the contemporary period. It attempts to investigate whether or not there exists income convergence across Asian economies over the period of 1990 to 2017 and also identifies the potential determinants. It empirically investigates the role of per capita income levels for the Asian countries by using β-convergence, σ-convergence and club convergence estimation method. Using a panel data framework, this article investigates the possible determinants of the conditional convergence by undertaking the problem of endogeneity through different econometric models. The results confirm that the income gap among the countries appears to decline over time and there is a possibility of having unconditional convergence in the long run. The analysis supports the view of trade liberalisation and recommends investing in the human capital and infrastructure to narrow down the regional disparity in Asia.

Keywords: Convergence, Divergence, Income, Trade, Asia

JEL codes: D3, O4, F15

Introduction

The literature on cross-country growth has concentrated on whether the countries are 'catching up' over time in terms of income per capita once the structural differences across countries have been accounted for.

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With the advent of globalisation, the issue of income convergence has become a gravity of discussion as over the time countries are experiencing inequality of income and assets (Kanbur et al., 2014; Piketty, 2014). Asia is no exception. It witnesses rise in growth, leading to a significant reduction of extreme poverty as well as wage inequality among countries (Urata, 2017; ADB, 2019). However, the countries have been facing the challenges of equity in income in one hand, and the question of 'catching up' with the richer economies by the poorer ones is also heavily discussed, on the other. The diversity of countries across Asia is an ideal case to test convergence (or divergence) hypotheses with the help of neoclassical growth models since the diversity is reflected not only in case of geographical space, population and resource endowment but also visible in the income and growth rates. As Asian countries have been experiencing a rise in income over the years[1], not only at the regional level but also at the national level, further integration of trade and investment between countries can be expected to enhance growth and development. While the trade liberalisation coupled with an increase in trade openness among the developing countries have paid in narrowing down the development gap, its impacts on the income gap are rather mixed. In one hand, trade liberalisation improves wage inequality, whereas income inequality, on the other, can undermine the growth process, cause social conflict and negate the benefits of economic integration (Wan et al., 2006; Urata, 2017). Therefore, a study on the regional economic scenario of Asian countries has its own merit, particularly to assess whether this income gap is amplifying some threshold level. The empirical literature more often than not have either focused on cross-section income or used panel methods to analyse economic growth. This paper exclusively investigates the per capita income gap for the Asian countries by using β-convergence, σ-convergence and club convergence estimation method. Besides, it tries to find the determinants for the conditional convergence with the help of different econometric models to control endogeneity problem exists in the data set. We analyse the convergence phenomenon with the use of more advanced econometrics techniques in order to get more accuracy in the findings.

Asia comprises a diverse set of economies whose annual average growth rate varies from 0.59 percent to 8.93 percent for the period 1990 to 2017. The regional inequality consists of inequality within individual economies as well as income gaps across countries from the 1990s. For some high income economies (e.g. Australia, New Zealand), it lies at 1.6 percent, whereas the growth rate varies from 5.05 to 8.93 percent for some countries like China, Bhutan, Myanmar, etc. In terms of growth rates for the period 1990 to 2017, Bhutan, India and Bangladesh are the top three countries in South Asia. China outperforms other East Asian countries by registering an average growth rate of 8.93 percent, while Japan hovers around 0.92 percent growth in the same period. In Southeast Asia, the diversity of economies is also visible and country like Brunei Darussalam has come up with negative (-0.59 percent) growth. Other economies in Southeast Asia lie in between these two ranges over the period of 1990 to 2017 (see Appendix 1). Commensurate with this growth experiences, it is clear that some relatively poor economies have excelled in their performance by joining middle income group, while there are others who linger in the relatively low economies but experienced rapid growth. Such diversity in the growth patterns automatically leads to the question of convergence (or divergence), i.e. whether relatively poor economies are 'catching up' with the relatively richer ones over time.

To delve into the regional disparity across economics over time, one needs to test empirically the neoclassical growth theory. Income convergence denotes the narrowing of per capita income gap among countries over time. Convergence requires that relatively poorer countries grow faster than richer countries. The underlying notion of (conditional) convergence emerges from the Solow-Swan (1956) growth model. The main mechanism behind the convergence approach is the assumption of diminishing returns. A combination of diminishing marginal returns to capital with the differences in relative endowments of capital between richer and poorer countries encourages to grow poorer countries to the same steady state where the flow of capital from the former to the latter.

In view of the above, this article aims to analyse whether the Asian countries have witnessed income convergence (or divergence) over the period 1990 to 2017. The notion of convergence is measured with β-convergence, σ-convergence and club convergence estimation method to know the overall and the individual variability. These three estimation methods are employed to study the presence of convergence (or divergence). Further assessment of income convergence (or divergence) is tested with the help of a number of determining factors such as human capital, technology proficiency and trade openness. We also observe whether or not open economies are integrating themselves while competing with each other. To do this analysis, we primarily use the regression-based approach developed by Barro and Sala-i-Martin (1991, 1992) in the following two distinct ways:

First, we investigate the β-convergence phenomenon. Then, in order to confirm the phenomenon of convergence, we also carry out the test for σ-convergence. Lastly, non-parametric estimation based on the approach of Quah (1993, 1997) has been employed to analyse the behaviour, movement or persistence of specific sub-groups within the distribution.

Second, the study employs a panel data analysis to identify a set of determinants of income disparity and a variety of estimation techniques to judge the robustness of the results.

The rest of the article is organised as follows. We present the literature in Section 2. Section 3 introduces the methodology and the data used in the analysis. Empirical results are reported in Section 4, followed by conclusions in Section 5.

Literature Review

The concept of convergence emerges from the Solow-Swan (1956) growth model, and, following Barro (1991), where the main argument is to regress per capita income growth on initial income and other conditioning variables to identify the presence of convergence. A negative coefficient on initial income is interpreted as poor countries growing faster than richer ones. Developing countries with low capital to labour ratio follow diminishing returns to capital and therefore have relatively high marginal products of capital. As a result, low income countries tend to grow faster and there is a tendency to convergence at the same steady state. The key assumption lies under the Solow model is that cross country growth is linear, (Durlauf and Johnson, 1995) and some new growth theories challenge this assumption of linearity (Azariadis and Drazen, 1990). According to them, there may be multiple steady-state equilibria and countries may belong to different groups with different convergence patterns. Therefore a non-linear specification is required for modelling cross-country growth and convergence (Durlauf and Johnson, 1995).

The endogenous growth models introduced by Romer (1986), Lucas (1988) and others relaxed the neoclassical assumption of diminishing returns to reproducible factors. Romer (1986) introduced the idea of knowledge where investment returns in knowledge can improve the outcome and as a result, countries having skilled labour grow faster and the importance of R&D came into production procedure. Lucas (1988) continued this notion with human capital accumulation through learning-by-doing and education. These differences in the endowment can permanently make a disparity in the outcome across countries in the long run. However, this hypothesis is neither explains the cross-country difference in income per capita nor rates of growth. Assumption of the constant returns to capital including human capital and the stock of knowledge of the endogenous growth models can result in the accumulation of reproducible factors accompany cross-country differences in trend growth rates. Among the theories explaining the differences are countries that have different market structures, government policies, technologies, and so forth.

Barro and Sala-i-Martin (1991, 1992) and Mankiw *et al.* (1992) argued that economies follow the predictions of neoclassical growth models and per capita income converges across economies. All of these studies examine the cross-sectional relationship between the growth rate of per capita income and the level of per capita income at some initial point. They conclude that per capita income converges once the relationship is found negative. However, tests based on cross-sectional regressions are claimed to have omitted variable bias. The panel framework can provide dramatic improvements in statistical power compared to performing a separate unit root test for each individual time series. The panel unit-root test advanced by Quah (1992, 1994) and Levin and Lin (1992, 1993) were widely used in several applications to convergence hypothesis. Im-Pesaran-Shin (1997) considered the more general cases where errors are serially correlated and heterogeneous across countries and where the errors in different regressions contain a common time-specific component. Evans and Karras (1996) developed a different framework for the test that allows differences in trend growth rates across economies with heterogeneous intercepts valid under much less restrictive conditions. Using Monte Carlo methods, Goddard and Wilson (2001) suggested that a panel estimator outperforms well in case of both the unconditional and conditional cross-sectional and pooled OLS estimators in the presence of heterogeneous individual effects. The results in previous studies are generally favourable for the neoclassical stochastic growth model in the developed country group and for the endogenous growth models in a large sample of countries including both developed and developing countries.

A set of empirical literature has endorsed positive relation between inequality and growth (Forbes, 2000; Banerjee and Duflo, 2003), and there is a claim in the literature that inequality hampers growth (Berg and Ostry, 2011; Dabla-Norris *et al.*, 2015). Asia has witnessed an increased inequality in recent decades keeping into account the rise of two large economies, namely, China and India (Jain-Chandra *et al*., 2016; De and Halder, 2016; ADB, 2019). This rising levels of inequality can have a favourable impact on the growth if that can circulate evenly across the regions within those countries. Otherwise, this may hamper the well-being of the region. To understand this symptom, the current study has attempted to test the convergence hypothesis among Asian economies with the help of β-convergence and σ-convergence. We also test club convergence with the help of non-parametric distribution estimation developed by Quah (1993, 1997). More specifically, this article tries to test the relation between initial per capita income and per capita income growth by employing a convergence test and analyse the potential determinants of inequality, if exist. Our approach follows Barro and Sala-i-Martin (1995), although we have included trade openness as a conditional variable so as to be consistent with the open economic framework of the neoclassical growth models. We first test unconditional convergence (without conditions) and then conditional convergence (with conditions) in a panel data framework to know the determinants with the help of econometric tools and a large number of data from different countries. Therefore, we have studied the current levels and trends of per capita income among the selected Asian economies with the help of panel data regressions and explain the results with the estimated determinants.

Data and Methodology

The two main convergence concepts discussed in the classical literature are namely, β-convergence and σ-convergence (Barro and Sala-i-Martin, 1991, 1992). Now to explain this concept, imagine a situation where we have per capita GDP for a set of economies. Absolute β-convergence prevails when capital-abundant regions will grow slower than capital-scarce ones. We estimate convergence in growth of per capita GDP, assuming $y_{i,t,t+T} \equiv \log(y_{i,t+T} / y_{i,t}) / T$, is the i's annualized growth rate of the economy over the period of t and $t + T$. Therefore, the equation we estimate is as follows:

$$y_{i,t,t+T} = a - b \log \ (y_{i,t}) + \ u_{i,t,t+T} \tag{1}$$

where $\log(y_{i,t})$ is the logarithm of economy i's initial level of per capita GDP, i.e. GDP per capita in time t. $u_{i,t,t+T}$ is the usual error term. Now when we find $b > 0$, then the economy exhibits absolute β-convergence.

For σ-convergence, a group of economies are having σ-convergence if the dispersion of per capita GDP tends to decline over a given time period. If σ is the standard deviation of per capita GDP then from the initial period t to the period $t + T$, $\sigma_{t+T} < \sigma_t$ must hold. Therefore, this deals with only one aspect of the cross-section distribution of per capita income at each point in time; and it is unable to reveal the whole distribution dynamics of income.

Further Barro and Sala-i-Martin (1991, 1992) expanded this approach and focused on the initial conditions. According to them, the growth rate of an economy is inversely related to the distance from its steady state. There are two types of β-convergence. If regional economies share the same steady state due to the neoclassical assumption of diminishing returns to scale, the presence of a significant negative coefficient in a regression of the growth rate on initial income is called unconditional convergence (also called 'absolute' β-convergence). Alternatively, if we run cross-section regression on initial income, holding other factors affecting growth constant, a negative coefficient may signify conditional convergence (Sala-i-Martin, 1996). In both cases, the speed of convergence is inversely related to the distance of an economy forms its own steady-state. Barro and Sala-i-Martin (1991, 1992) used a log-linear form of the transition dynamics in a traditional growth model. The estimating equation is modified as follows:

$$y_{i,t,t+T} = \left(\frac{1}{T}\right)\log\left(y_{i,t+T}\right) - \log\left(y_{i,t}\right) = a - \left(1 - e^{-\beta T}\right)\left(\frac{1}{T}\right)\log\left(y_{i,t}\right) + u_{i,t,t+T} \quad (2)$$

where the growth rate is the difference between $\log(y_{i,t+T})$ and $\log(y_{i,t})$ divided by T length of interval and b = $\left(1 - e^{-\beta T}\right)\left(\frac{1}{T}\right)$ where β is the speed of convergence.

To test the convergence of economies converging to the same steady states, Barro and Sala-i-Martin (1991, 1992) recommended that a group of economies with the same level of technology and the same institutional setup had to be identified. It is likely that unconditional β-convergence may be found among these economies. If the assumption of the same steady state is relaxed i.e., convergence is tested among economies with heterogeneous technology and institutional environments, one can expect conditional β-convergence. To test conditional β-convergence, a vector X of variables that control for the cross-country variation in the steady-state values is added and then the equation (2) can be written as follows.

$$\left(\frac{1}{T}\right)\log\left(y_{i,t+T}/y_{i,t}\right) = a - \left(1 - e^{-\beta T}\right)\left(\frac{1}{T}\right)\log y_{i,t} + \psi X_{i,t} + u_{i,t,t+T} \quad (3)$$

Many empirical studies have estimated the convergence of income and identified some econometric problems like non-linearity of growth dynamics or multiple steady-states in growth dynamics (Azariadis and Drazen, 1990; Levin and Renelt, 1992; Durlauf and Johnson, 1995; Bernard and Durlauf, 1996). One very important point here to mention is that neoclassical models are linear, whereas the endogenous growth models are non-linear. Any attempt to empirically test endogenous growth theory with an econometric method derived from a linear model can produce erroneous results (Bernard and Durlauf, 1996; Azariades and Drazen, 1990). Barro and Sala-i-Martin (1991, 1992) and Sala-i-Martin (1996) accepted that one of the most important ingredients of the concept of convergence is the decrease in the dispersion of per capita income over time, of which, β-convergence is unable to explain the phenomenon of decreasing dispersion of per capita income. Hence, they introduced the concept of σ-convergence. The concepts of σ-convergence and β-convergence are, of course, related such way that if we take the sample variance of $\log(y_{i,t})$ from equation (1) then we will get the relation between σ- and β-convergence by linking σ_t and σ_{t+T} which actually depend on β.

But, β- and σ- convergence are unable to explore the presence of mechanisms of polarizations, cluster of economies with similar per capita GDP as these represent a summary or an 'average' measures (Quah, 1997). We can solve this problem with the help of club convergence hypothesis, where we estimate a conditional density function using kernel density function (see Appendix 2). Under the presence of heterogeneity in an economy, this approach is able to capture individual variability, and, therefore, it is genuine to address the characteristics of some specific clusters or sub-groups within the entire distribution.

We develop a panel dataset for the period 1990 to 2017 by considering five-year intervals, which provides six cross-section time points[2]. Our estimable equation is rewritten as follows:

$$y_{i,t,t+T} = a - b\log(y_{i,t}) + \sum_{i=1}^{n} \psi_i X_{i,t} + \alpha_i + \delta_t + u_{i,t,t+T} \quad (4)$$

where α_i is the country-specific fixed effect, δ_t is the time dummy and $X_{i,t}$ is the set of potential determinants considered in this study. The negative coefficient estimated for $\log(y_{i,t})$ indicates convergence and the rate of convergence β is obtained from the estimate for $b = \left(1 - e^{-\beta T}\right)\left(\frac{1}{T}\right)$. The independent variables are instrumented by their values lagged one time period. This implies that when we take the growth rate over the period 1994 to 2000, the independent variables consider the initial levels, i.e. 1990 to 1994 growth rates. Using this one-period lagged variable, the likelihood of overestimating the speed of convergence due to simultaneity bias can be avoided (Caselli *et al.*, 1996). To control the possibility of heterogeneity and the endogeneity bias involved in growth regressions, we introduce 'core' and 'additional' variables which are statistically robust (following Sala-i-Martin, 1996; Durlauf and Quah, 1999). Considering these issues, the control variables chosen for this study are some economic, institutional and political factors (see Appendix 3) as is common in more eclectic 'Barro-type' convergence regression. Our exogenous variables used in the study are initial level of per capita income, human capital, population, and government expenditure to GDP, health, technology proficiency, urbanisation and measure of international openness.

The variable initial level of per capita income is the log of per capita GDP at the beginning of the five-year periods and may be viewed as a proxy for the steady-state level of physical capital or the initial level of resource endowments (Barro, 1997). Another important variable considered in the study is human capital where we use average years of school attainment (Barro and Lee, 2001). For a given level of initial per capita GDP, rise in the level of human capital is expected to increase the steady-state level of per capita GDP by improving the ability of the labourers to adopt the new skill and technologies (Barro and Sala-i-Martin, 1995). The next independent variable is the population growth rate. In the neoclassical growth model, as population growth increases, the steady-state level of *y* declines through lowering of the capital-labour ratio, assuming capital must be speed over a greater population. Government expenditure has been used in many studies. This is assumed that increase in the government spending and tax distort incentives tend to depress the steady-state level of output per effective worker and thereby reduce the growth rate for given values of the state variables (Barro and Sala-i-Martin, 1995). In contrast, government expenditure may be a proxy of investment in fundamental social and economic infrastructure, and, therefore, can be considered as an important variable for economic growth. Other than these we have more control variables like life expectancy to represent the level of health. Life expectancy at birth turns out to have the most explanatory power. Endogenous growth models accept the role of technology proficiency in long-term growth rates (Romer, 1990). We use the Research and Development (R&D) expenditure as a percentage of GDP as a proxy of technological proficiency in the economy. We consider the percentage of the urban population as a proxy of urbanisation. This variable tries to indicate the concentration of power and wealth agglomerated in the urban area. The explanatory variables also include a measure of the extent of international openness. Poorer economies that are relatively open to trade are generally thought to be in a better position to import capital, ideas, and technology and thus catch up with the richer economies. They are more able to exploit their comparative advantages and employ resources more efficiently. Accordingly, openness ought to raise the steady-state level of y and increase the speed of convergence (Sachs and Warner, 1995). We use the ratio of exports plus imports as a percentage of GDP.

In this article, we have taken data from the World Bank's World Development Indicator (WDI) to test the income convergence across 32 countries selected from several Asian sub-regions. In our study, we have included South Asian countries (Bangladesh, Bhutan, India, Nepal, Pakistan, Sri Lanka); East Asian countries (China, Japan, Korea, Mongolia); Southeast Asian countries (Brunei, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam); countries of Central Asia (Armenia, Azerbaijan, Georgia, Iran, Kazakhstan, Kyrgyz Republic, Tajikistan, Turkey, Turkmenistan, Uzbekistan); and Pacific countries (Australia, Fiji, New Zealand)[3]. We have tested the regional inequality across these sub-regions over the period of 1990 to 2017 with the help of panel data model. We have made an unbalanced panel for the Asian countries as all the observations are not uniformly available for all countries of interest.

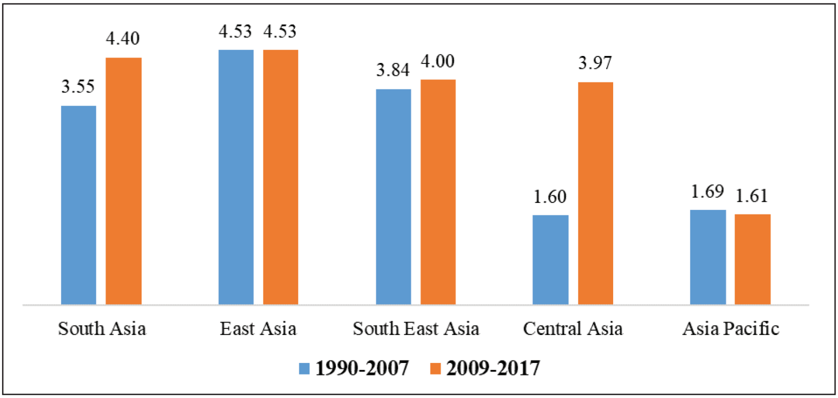
Analysis and Results

According to the convergence hypothesis, countries with a relatively higher (or lower) initial value of per capita income will have a lower (or higher) growth rate. In the context of Asian economies, there is diversity not only in terms of the income and growth rates but also across geographical space, population and resource endowment. We have captured some of the variations here as well.

First, we have plotted a histogram of the annual average growth rate of per capita GDP of Asian regions in Figure 1. In our time frame, i.e. 1990-2017, the Asian economies suffered a transitory setback in the wake of the Global Financial Crisis (GFC) during 2007-2008. To capture the impact (if any) we compare the growth performance across regions for two periods, namely, 1990-2007 and 2009-2017. Illustrated in Figure 1, East Asia has witnessed the highest growth rate among the Asian regions in 2009-2017, followed by South Asia and Southeast Asia, respectively[4].

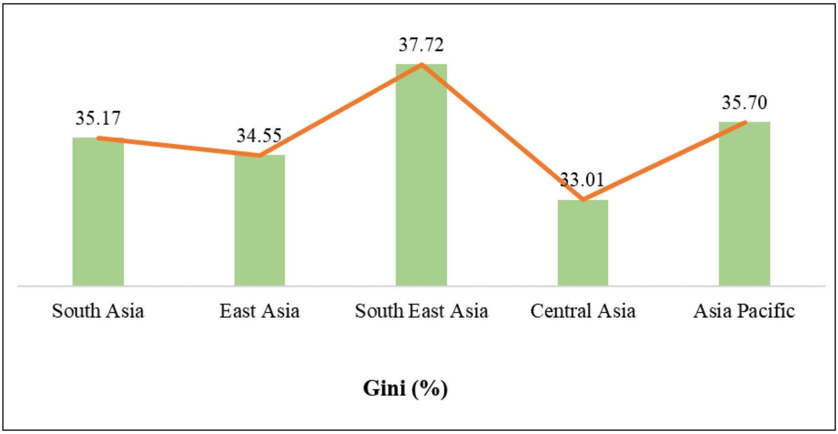
Before going into the test for convergence in per capita income, let's review the income inequality trends of the Asian economies followed by inequality in GDP per capita and population across countries. To have a comprehensive view of inequality, we plot Gini coefficients of different countries in Figure 2. It is clearly evident from Figure 2 that Southeast Asia is having the highest inequality, whereas Central Asia has the lowest inequality in terms of Gini coefficient.

Figure 1: Growth Rate of per Capita GDP during 1990 to 2017



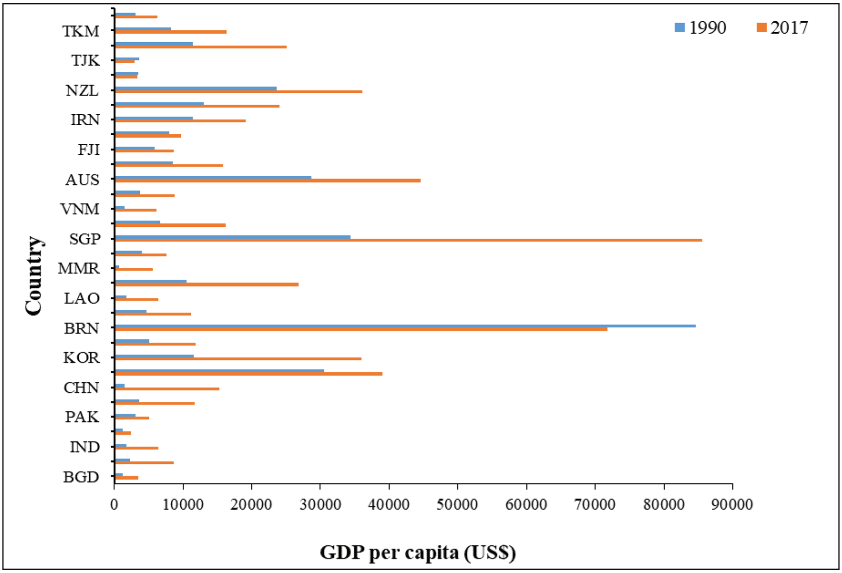
Source: Drawn by Authors.

Figure 2: Inequality by Asian Economies, 2017



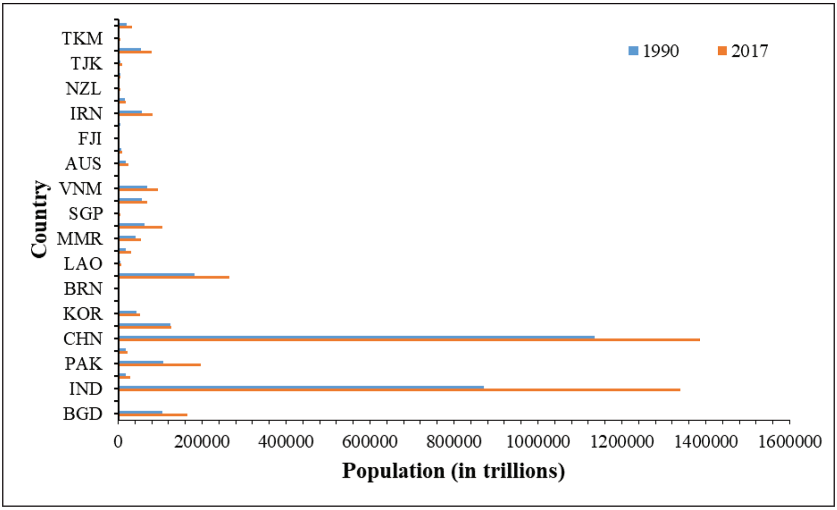
Source: Drawn by Authors.

Figure 3: Inequality in GDP per Capita



Source: Drawn by Authors.

Figure 4: Inequality in Population



Source: Drawn by Authors.

This confirms the disparity in initial income and the inequality over time with the growth of income. We see this inequality across the per capita income and population endowment if we compare the initial and latest. Figures 3 and 4 show the difference across countries in per capita income between 1990 and 2017 (Figure 3), followed by population (Figure 4). Therefore inequality prevails in the income and the endowment across the Asian countries.

Test of Convergence or Divergence

In order to study convergence (or divergence) in income, we analyse the relationship between the growth rates of per capita income (PCI) in a particular period with that of the initial PCI for a country. In the literature of growth empirics, the notion of convergence is estimated by mainly β-convergence, σ-convergence and club convergence.

For the exercise of unconditional-convergence (without conditions), the estimation equation is as follows:

$$\left(\frac{1}{T}\right)\log\left(y_{i,t+T}/y_{i,t}\right) = a - \left(1 - e^{-\beta T}\right)\left(\frac{1}{T}\right)\log\left(y_{i,t}\right) + u_{i,t,t+T} \quad (5)$$

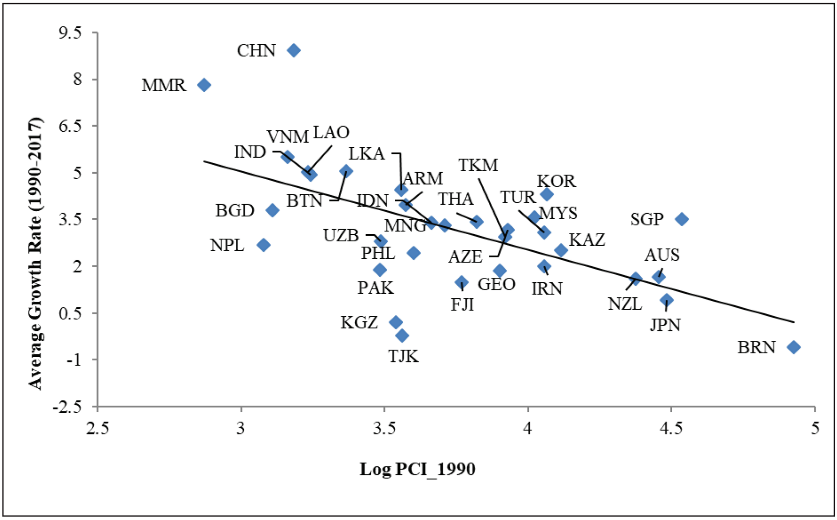
where $\log(y_{i,t})$ is the logarithm of economy *i*'s initial level of per capita GDP, i.e. GDP per capita in time *t*. $u_{i,t,t+T}$ is the usual error term and β is the speed of convergence. First, we have tried to test absolute convergence by reviewing the growth rate of PCI in the entire period 1990-2017 on the natural log of the initial per capita income and found negative coefficient (see Figure 5(a)). Then, we have estimated the other two models; one for the period 1990-2007 and another for the period of 2009-2017(see Figure 5(b)). The average growth rate of PCI in the period of 1990-2007 is regressed on the initial PCI. The estimated results show a statistically significant negative relationship between the growth rates, thereby implying that the countries witnessed a higher growth rate in the initial period had experienced a lower growth rate in the later period of 1990-2007. We have employed a similar exercise relating the average growth rate of the period 2009-2017 to the initial PCI, which also shows a negative relationship. Between the two periods, the higher the value of the coefficient for the later period signifies the further convergence. Theoretically, convergence would translate into a negative relationship where the countries with a lower initial income would experience faster growth than the ones starting with the higher initial income. Coefficients are reported in Table 1.

Table 1: Results of Absolute Convergence

Year	1990-2017	1990-2007	2009-2017
β	0.054	0.050	0.057
Intercept	12.50	11.20	14.32
R^2	0.36	0.19	0.41

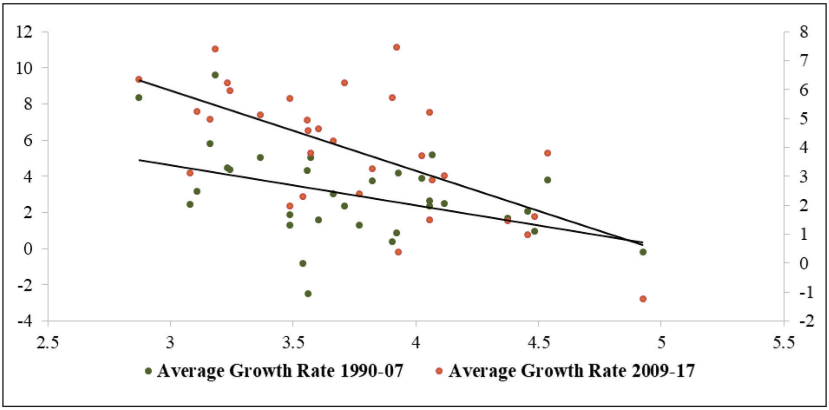
Notes: estimation results are for β (not for b), where β estimated from b = $(1 - e^{-\beta T})\left(\frac{1}{T}\right)$.
Source: Authors' calculation.

Figure 5(a): Test for β-convergence, 1990 to 2017



Source: Drawn by Authors.

Figure 5(b): Test for β-convergence, 1990 to 2007 and 2009 to 2017



Source: Drawn by Authors.

In order to confirm the phenomenon of convergence, we now test the σ-convergence with the help of our baseline estimating equation:

$$y_{i,t,t+T} = a - b \log (y_{i,t}) + u_{i,t,t+T} \quad (6)$$

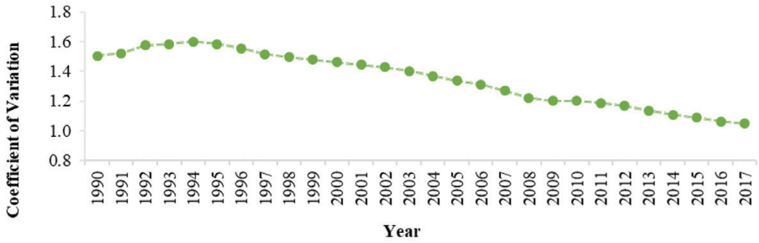
Table 2 presents cross-sectional standard deviations of the log of per capita GDP. The finding of σ-convergence amongst the economies is very important. The results are plotted in Figure 6. We find that there has been mild evidence of σ-convergence amongst Asian economies between 1990 and 2017, with σ decreasing from about 1.5 to 1. A close look at the σ trend shows that σ coefficient has declined consistently over time. Thus, the evidence of β-convergence together with the trend of σ coefficient confirms the evidence of unconditional-convergence among the Asian countries.

Table 2: Results of σ-Convergence

Year	1990	1995	2000	2005	2010	2017
σ	1.5	1.6	1.5	1.3	1.2	1.0

Source: Authors' calculation.

Figure 6: Test for σ-convergence

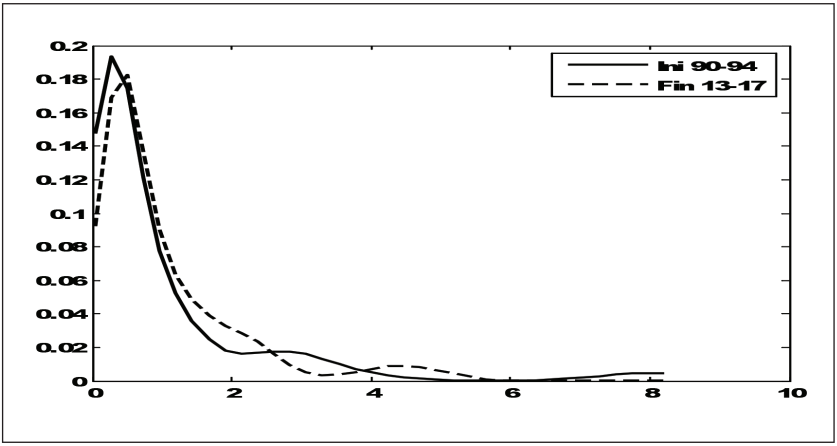


Source: Drawn by Authors.

The aforesaid results confirm the presence of income convergence among the Asian economies, but unable to admit the presence of mechanisms of polarizations, i.e. how different incomes are concentrating over time. In order to analyse the dynamics of the process in which different economies' income concentrates under the presence of heterogeneity over the time we employ non-parametric estimation based on the approach of Quah (1993, 1997). This is a two-step method, where in the first step, we estimate kernel density plots for the initial and the final period to identify the change in the location and shape of the distribution over time. In the next step, we plot 3-dimensional conditional density plot and its 2-dimensional counter plot through which we get to know how the distribution has evolved over time with the condition of the initial distribution[5]. Therefore, conditional density helps us to identify whether there is a change in the distribution by analysing the location and shape in the initial and the final period. This also makes us understand which part of the distribution persists and which part moves over time using the conditional density plots.

First, the kernel density plot for the initial 5-year interval i.e. 1990-1994 and final 5-year duration i.e.2013-2017 have been presented in Figure 7. It reveals that while most of the countries are clustered around the value zero in both the periods, the distribution took a shift towards the right in the later periods as compared to the initial years. This change in shape primarily suggests that a number of countries having low per capita income in the initial years are now joining relatively higher position with the increase in the per capita income in the later years.

Figure 7: Kernel Density Plots for the Initial and Final Periods

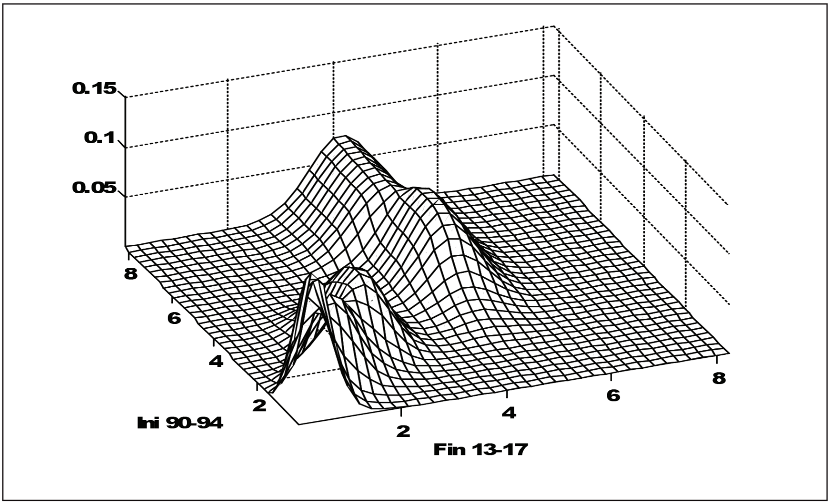


Source: Drawn by Authors.

Second, we estimate the conditional distribution of the entire periods to understand the persistence and mobility of the distribution. For this, we have estimated 3-dimensional plots of the conditional density and its 2-dimensional contour plot using the kernel density plots. Using this stochastic kernel, convergence can be analysed from the shape of the 3-dimensional plot. The main diagonal of this diagram is of importance, as this helps in confirming the presence or absence of persistence. If most of the probability mass concentrates around the 45-degree line, then we can conclude the presence of persistence, i.e. elements of the cross-section distribution remain unchanged over the periods. If most of the mass concentrates along the 1-value in the axis for the final year and parallel to the axis for the initial year, it indicates convergence towards equality. Therefore, when the mass of the distribution moves clock-wise in the positive range indicates a decline in the per capita income and a clock-wise movement in the negative range implies an increase in the per capita income relative to the initial distribution and vice versa.

In Figure 8, we present the 3-dimensional plot of the conditional density and its corresponding counter-plot is given in Figure 9. These two figures jointly show mobility or persistence of the parts of the distribution during 1990-1994 and 2013-2017. The y-axis of the 3-dimensional plot of the conditional distribution shows the distribution of the Asian countries in the initial years, the x-axis presents the distribution of the final years and the z-axis presents the probability of transition of the parts of initial distribution that evolves as a part of the final distribution. This shows that there is a distributional change in the initial 5-year interval with the final 5-year interval. In our case, we see that there is some mobility in the part of the conditional distribution with convergence towards equality (see Figure 8).

Figure 8: 3-dimensional Plot of the Conditional Density for the Initial and Final Periods



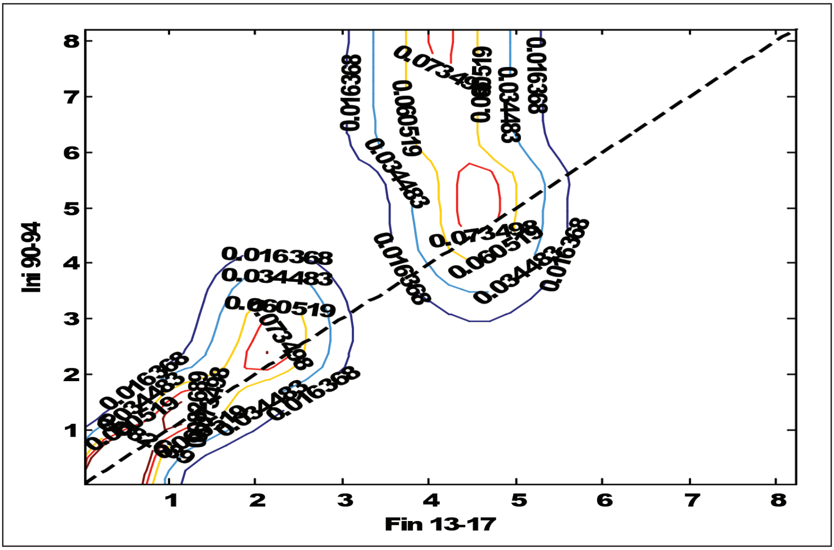
Source: Drawn by Authors.

Table 4: Results of Conditional *β*-convergence

Variables	(1)	(2)	(3)	(4)	(5)	(6)
GDP	-11.827*** (2.314)	-18.332*** (2.756)	-11.699*** (2.350)	-11.269*** (2.579)	-11.422*** (2.266	-16.717*** (2.765)
HCL	1.485** (0.442)	0.783** (0.458)	1.499*** (0.445)	1.566** (0.473)	1.271** (0.438)	0.756* (0.464)
POP	-0.689 (0.594)	-0.251 (0.578)	-0.692 (0.596)	-0.747 (0.609)	-0.480 (0.585)	-0.188 (0.573)
GOV	0.059*** (0.012)	0.043*** (0.012)	0.0595*** (0.012)	0.061*** (0.012)	0.050*** (0.012)	0.033** (0.012)
HLT		0.676*** (0.171)				0.751*** (0.171)
TEC			-0.380 (1.122)			-0.505 (1.089)
URB				-0.047 (0.095)		-0.147 (0.095)
OPN					0.038** (0.013)	0.041** (0.013)
Constant	34.745*** (7.375)	18.158** (8.203)	34.379*** (7.474)	34.433***	32.122***	12.091 (8.230)
Country effect	Yes	Yes	Yes	Yes	Yes	Yes
Time effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	192	192	192	192	192	192
R^2	0.46	0.73	0.68	0.65	0.59	0.68
β	0.051	0.059	0.050	0.050	0.051	0.057
Selection of model						
Hausman test (FE vs. RE)						24.85
Chi^2 ($Prob>chi^2$)						0.004

Notes: Absolute t-statistics for two-tailed tests are recorded in the parentheses. We have conducted Hausman test to differentiate between fixed effects model and random effects model and random effect is rejected in favour of fixed effect. .* denotes statistically significant at 10 percent level, ** denotes statistically significant at 5 percent level, and *** denotes statistically significant at 1 percent level.

Figure 9: 2-dimensional Plot of the Conditional Density for the Initial and Final Periods



Source: Drawn by Authors.

Some countries are having low per capita income and could not able to evolve as the developed countries, and, therefore, some lies along with the 45-degree line. Some others have fallen back and some middle income countries are reached to the higher income groups, that is why we got another clustered towards equality. To confirm the phenomenon, we run a similar exercise for the period 1990-1994 and 2003-2007 as well as 2003-2007 and 2013-2017. It also helps us to capture the financial slowdown after the global financial crisis (see Appendix 4). The results of the distribution approach analysis before (GFC) during 2007-2008 (i.e. as per our analysis 1990-1994 and 2003-2007) and after (i.e. 2003-2007 and 2013-2017) crisis confirm that after the crisis the shape of the kernel density plot has struck as compared to the before scenario (see Figure (a) in Appendix 4). The resultant slowdown of the few countries due to the global financial crisis is much clear in the 3-dimensional and 2-dimensional plot (see Figure (b) in Appendix 4). Further, we observe that few countries have moved and reached to the higher income group, while some unable to catch up the new distribution and as a result, there are two clusters in the 2-dimensional plot which was not visible in the before crisis setup (see Figure (c) in Appendix 4).

Potential Determinants of Convergence

In the foregoing section, we have found empirical evidence of unconditional-convergence (absolute convergence) of selected Asian countries with the help of β- and σ- convergence and club convergence tests. To confirm the speed of the convergence, we employ a variety of estimation techniques, namely, Trimmed Least Squares (TRIM), a robust estimator which discards data outliers; an Ordinary Least Squares estimator (OLS) for pooled data; and Generalised Least Squares with time as well as country dummy variables (GLS)[6] to allow for individual-specific effects and time effects. The regression estimates for β-convergence for a variety of data sets under six different groups of countries are reported in Table 3 where the results are based on the following estimation equation:

$$\left(\frac{1}{T}\right)\log\left(y_{i,t+T}/y_{i,t}\right) = a - \left(1 - e^{-\beta T}\right)\left(\frac{1}{T}\right)\log y_{i,t} + \psi X_{i,t} + u_{i,t,t+T} \quad (7)$$

Table 3: Results of Unconditional *β*-convergence

Regions	TRIM	OLS	GLS
Asia	0.023*** (0.322)	0.022*** (0.424)	0.036* (1.982)
South Asia	0.024 (0.978)	0.023 (0.904)	0.023 (1.255)
East Asia	0.039*** (0.925)	0.036*** (1.334)	0.029 (2.482)
Southeast Asia	0.025*** (0.573)	0.024*** (0.492)	0.011 (0.761)
Central Asia	0.025* (1.147)	0.018 (0.186)	0.053* (5.495)
Asia-Pacific	0.002 (0.597)	0.004 (0.634)	0.032 (3.327)
Country	---	---	Yes

Notes: estimation results are for β (not for b), where β estimated from b = $\left(1 - e^{-\beta T}\right)\left(\frac{1}{T}\right)$. T is the length of time between two observations, i.e. in our case, it is 5.* denotes statistically significant at 10 percent level and *** denotes statistically significant at 1 percent level.

Source: Authors' calculation.

The coefficient of per capita GDP is consistently negative and statistically significant, supporting the unambiguous existence of β-convergence. The first row relates to the total sample of the Asian countries considered in this study. Each column represents the estimate for β and its standard error (in parentheses). Correcting for outliers in the data, TRIM results show that the estimated speed of convergence for the Asian countries is 0.023 and turns out statistically significant. We get a significant result in the OLS regression with 0.022 speed of convergence. On the other, GLS estimate taking into account the cross-sectional heteroscedasticity and time-wise autocorrelation indicates the speed of convergence[7]. What follows Asia as a region has observed converging over time. The estimated results also confirm to that fact that poor economies grew faster than rich ones in the Asian region.

Given the heterogeneity of Asian economies, it is encouraging to investigate whether Asian economies have been converging toward the same, or at least similar, steady states, and that they form another 'convergence club' (Baumal, 1986). Also, there is a consensus in the neoclassical literature that holding constant variables that proxy for the steady state, the economy predicts a negative *partial* correlation between growth and the initial level of income. This raises another question of what are the determinants of such convergence among diversifying countries. Therefore, we also test for conditional β-convergence including some variables that distinguish the countries endowment. Our estimable equation is rewritten as follows:

$$\left(\frac{1}{T}\right)\log\left(y_{i,t+T}/y_{i,t}\right) = a - \left(1 - e^{-\beta T}\right)\left(\frac{1}{T}\right)\log(y_{i,t}) + \sum_{i=1}^{n}\psi_i X_{i,t} + \alpha_i + \delta_t + u_{i,t,t+T} \quad (8)$$

The β-convergence regressions presented in Table 4 are conducted to estimate the potential determinants. Selection of random effects and fixed effects models are based on Hausman (1978) testing. The technique captures both individual-specific effects and time-effects, and deals with the expected problem of endogeneity. Table 4 presents the estimated results for the fixed effect model with country and time fixed effect.

In the first column of Table 4, we add those core variables which are traditionally recognised as determinants of growth in the neo-classical literature, namely, human capital (HCL), population (POP), government expenditure (GOV). Then, gradually we have added other important explanatory variables, which are popularly known as 'Barro-type' convergence variables. Estimates for core variables have shown expected sign and statistically significant. Except for the population, all other variables have come out to be significant. It is interesting to note that although the population is statistically insignificant in all the six models, human capital has turned out as a positive and significant variable in all the models. This suggests that given the level of initial per capita GDP, increase in the level of human capital is expected to elevate the steady-state level of per capita GDP by improving the ability of the labourers to adopt new skill and technologies. The result for government expenditure for GDP is positive and statistically significant in all the models. A positive sign of government expenditure suggests that investment has been positively related to the country's economic growth.

In columns 2 to 5 of Table 4, we gradually have included other control variables one by one to see the effect of these variables, if any. These variables are initial endowments which are expected to change the long run output of a country. Although population has found insignificant in our model but life expectancy has turned out as important determinant of steady state. Technology and urbanisation have shown negative sign and are insignificant as well. We could not find technology proficiency and urbanisation as an important variable to contribute to income convergence. Our variable of interest openness to trade is positive and significant. Therefore, increase in trade openness among the developing countries has paid in narrowing down the income gap.

The last column in Table 4 has included all the important variables considered in the study. We see that notably government expenditure, human skill and life expectancy are important to define economic growth for a country. In particular, openness to trade coefficient has come out positive and significant in all the cases, implying that trade across countries drives convergence across countries. Therefore, Asian economies would benefit from continuing with their commitment to free trade.

The speed of convergence comes out to be 5.1 percent per annum when only core variables are included. This becomes 5.7 percent when all important variables are included in the regression model. The change in speed, therefore, suggests that Asian economies are converging to similar long-run per capita GDP levels. It can also be said that relatively high growth potential economies are in the process of converging with the economically leading economies in Asia.

Although the results of the above analysis are showing the long run convergence, this is limited to be interpreted as causal or accurate since one cannot rule out the possibility of the existence of endogeneity. Whereas the aforesaid results are based on the assumption of no correlation among explanatory variables, it is argued that OLS and fixed effects models cause biased and inconsistent estimates due to endogeneity and unobserved heterogeneity.

Empirical studies on per capita income differences across countries are almost always used 2SLS estimation since this is the core method for dealing with endogenous variables. Keeping in mind the above theoretical backdrop, we will estimate the following econometric model for estimation to check robustness of our results. The estimating equation is as follows:

$$y_{i,t,t+T} = a_1 \log(y_{i,t}) + a_2 \log(y_{i,t+T}) + \sum_{i=1}^{n} \psi_i X_{i,t} + \rho' Z_{i,t} + \eta_i + \mu_t + u_{i,t,t+T} \quad (9)$$

where $Z_{i,t}$ be the vector of instrumental variables affecting the model and η_i is the time invariant fixed effect capturing heterogeneity of country specific characters and μ_t is the time dummies and other notations are as per earlier definition.

On the estimation of panel data models, system-GMM facilitates taking account of the time series dimension of the data, non-observable country specific effects, the inclusion of a lagged dependent variable among the explanatory variables, and the possibility that all explanatory variables are endogenous. Therefore for system-GMM we will start with the following estimating equation:

$$\log(y_{i,t}) = a_i + b_1\log(y_{i,t-1}) + b_2\log(y_{i,t-2}) + \psi_i X_{i,t} + \rho' Z_{i,t} + u_{i,t,t+T} \quad (10)$$

The above equation stands as lagged form in the previous period where $Z_{i,t}$ a set of instruments is and $X_{i,t}$ is our control variables and rest are the same as before. Now after eliminating the country-specific effects using first differences, we estimate the equation (11):

$$\log(y_{i,t}) = a_i + b_2\Delta\log(y_{i,t-2}) + \psi_i \Delta X_{i,t} + \rho' \Delta Z_{i,t} + \Delta u_{i,t,t+T} \quad (11)$$

To remedy for the panel estimations, we report results using the Blundell and Bond (1998) estimators as well as 2SLS estimation, which address the potential endogeneity of the regressor, and incorporate (implicitly) fixed effect. The results of different econometric models (two-stage least square (2SLS) and system-GMM) are reported in Table 5, where problems associated with the endogeneity have been controlled. We interpret the results with consciously and carry robustness check of our previous results found in the Table 4.

Table 5: Results of IV Estimation

Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
GDP	-0.355 (1.023)*	0.366 (1.845)	-1.619 (0.922)*	-3.503 (2.814)*	-1.921 (0.833)**
HCL	0.007 (0.007)	0.042 (0.008)***	0.012 (0.005)*	0.056 (0.008)	-0.002 (.005)
POP	-0.549 (0.343)	-0.556 (0.348)	-0.537 (0.340)	-0.585 (0.382)	-0.541 (.341)***
GOV	0.245 (0.010)*	0.259 (0.011)*	0.022 (0.011)	0.032 (0.013)*	0.230 (0.010)*
HLT	0.623 (0.004)***				0.033 (0.005)***
TEC		-0.231 (0.037)***			-0.039 (0.023)*
URB			-0.017 (0.009)***		-0 .012 (0.001)*

Table 5 continued...

...Table 5 continued

OPN				0.002 (0.000)***	0.004 (0.000)
Constant	3.944 (3.932)*	3.607 (0.109)***	8.553 (3.583)*	10.124 (0.353)*	12.604 (2.825)**
Instrumented variable	HLT	TEC	URB	OPEN	HLT, TEC, URB, OPEN
Observations	192	192	192	192	192
R^2	0.85	0.76	0.76	0.66	0.80
Wald chi^2 (Prob>chi^2)	87.53 (0.00)	127.13 (0.00)	131.42 (0.00)	120.46 (0.00)	216.36 (0.00)
Test of over-identification					
Sargan chi^2 (Prob>chi^2)	4.344 (0.037)	17.703 (0.019)	90.118 (0.076)	48.79 (0.027)	
Hansen's J chi^2 (Prob>chi^2)					13.326 (0.004)

Notes: Dependent variable is the growth rate of per capita income. Model (1) to Model (4) is estimated using 2SLS (Instrumental Variable) method. Model (5) is based on GMM Panel Regression (Blundell and Bond (1998) Method). * denotes statistically significant at 10 percent level, ** denotes statistically significant at 5 percent level, and *** denotes statistically significant at 1 percent level.

We see that the results of all models are better fitted as the R^2 has increased after correcting the endogeneity problem. We first formulate the models 1 to 4 by applying each instrument separately for 2SLS estimation and then model 5 based on system-GMM (Blundell and Bond, 1998) for the panel estimation. We assume that there is endogeneity between gross domestic products with the development indicators, such as government expenditure to GDP, technology proficiency, and urbanisation etc. All the results of the instrumental variable estimation support the neoclassical growth theory and negative sign of GDP confirm the convergence (except in the Model 2).

The population has turned out as insignificant in all models and human capital has shown the mixed results. The sign of government expenditure for GDP is positive and statistically significant in all the models (except in Model 3). Life expectancy is an important determinant for the steady state and it is significant. Trade openness has shown expected results using different instrumental estimation. In both cases, Model 4 under 2SLS and Model 5 under system-GMM have come out positive and significant. Therefore, our results of the panel data model provide significant and robust estimates. Findings confirm that the income gap among the countries appears to decline over time and there is a possibility of convergence.

Conclusions

The primary question posed in this paper is whether there exists convergence of income in Asian economies in the post-globalisation period. Over time there is an expansion of the economic size of the Asian economies and there exists variation in income growth among the countries in the region. This article has exclusively investigated whether there exists income convergence across Asian economies by using β-convergence, σ-convergence and club convergence estimation methods. Later, we have tried to find the determinants for the conditional convergence (if any) with panel data by using different econometric techniques. This article has also analysed the income convergence phenomenon by using more advance econometrics techniques with the traditional estimates to get more accuracy in the findings.

Absolute convergence in the sense of the per capita incomes across countries has been recorded during 1990-2017. We also have estimated our result by dividing the time period into two parts - before and after the *global financial crisis* and experienced strong evidence of 'catching up' by the lower income countries especially after 2007. The estimates for σ-convergence and unconditional β-convergence further confirm the ambiguity of the result of absolute convergence of the heterogeneous sample of the Asian economies. We have used a non-parametric distribution dynamic approach for the heterogeneity across economies and attempted to know the presence of mechanisms of polarizations, the cluster of areas with similar characteristics. This also confirms the convergence of equality. The evidence of convergence is more prominent in post-2007 as some developed countries have slowed down, whereas some developing countries have managed to cope up their concentration.

Further, the conditional β-convergence results indicate that openness to trade and initial endowment of income are the significant determinants of the income convergence in Asia. Besides, human skill, health and government investment in social and economic infrastructure are also important determinants for economic growth and future convergence. We estimate two-stage least squares (2SLS) and system-GMM to control the endogeneity problem and the results support the phenomenon of the income convergence in the long run.

Asia has already experienced spectacular growth and shows the possibility of unconditional convergence in Asia. However, there is no involuntary mechanism to have future convergence. The sharing of the benefits of growth is possible when countries are integrated internally. Our findings confirm that free trade is a positive predictor for the poorer economies as they are generally thought to be in a better position to import capital, ideas, and technology and thus able to converge with the richer economies in the long run. Further our findings support the view that investment in human capital, health situation and government expenditure can significantly contribute to the growth of income.

Endnotes

1 See, Kanbur, *et al.* (2014), Jain-Chandra, *et al.* (2016), De and Halder (2016).

2 This has the advantage of smoothing business-cycle fluctuations by making the data less prone to serial correlation than the yearly data used.

3 We could not take Afghanistan, Maldives in South Asia and Cambodia in Southeast Asia due to data unavailability during time frame.

4 We exclude the Global Financial Crisis (GFC) years, in particular 2008.

5 See Appendix 2 for the method of estimation of the kernel density plots and conditional density using a kernel density estimator.

6 GLS takes account of cross-sectional heteroskedasticity and time-wise autocorrelation. Use of country dummy variables permits differences in individual economies' production functions to enter the model.

[7] An F-test confirms that the country dummy variables are highly statistically significant, indicating that country-specific effects are indeed important in accounting for convergence.

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Appendix 1: Basic Statistics

Block	Country	Code	Size, (sq. km)	Population (billion) 2017	GDP per capita (US$) 1990	GDP per capita (US$) 2017	Annual Average Growth Rate (%)
South Asia	Bangladesh	BGD	147570	1646698	1287.93	3523.98	3.81
	Bhutan	BTN	38394	8076	2325.24	8708.60	5.05
	India	IND	3287263	13391801	1754.86	6426.67	4.95
	Nepal	NPL	147181	293050	1197.95	2442.80	2.69
	Pakistan	PAK	796095	1970160	3054.95	5034.71	1.88
	Sri Lanka	LKA	65610	214440	3612.34	11669.08	4.46
East Asia	China	CHN	9596961	13863950	1526.41	15308.71	8.93
	Japan	JPN	377930	1267858	30582.43	39002.22	0.92
	Korea, Rep.	KOR	100210	514662	11632.60	35938.37	4.32
	Mongolia	MNG	1564110	30756	5122.53	11840.85	3.31
South East Asia	Brunei Darussalam	BRN	5765	4287	84672.39	71809.25	-0.59
	Indonesia	IDN	1472639	2639914	4625.38	11188.74	3.40
	Lao PDR	LAO	236800	68582	1708.03	6397.36	5.02
	Malaysia	MYS	330803	316243	10551.66	26808.16	3.58
	Myanmar	MMR	676578	533706	742.97	5591.60	7.82
	Philippines	PHL	300000	1049181	4010.20	7599.19	2.43
	Singapore	SGP	716	56123	34344.67	85535.38	3.52
	Thailand	THA	513120	690375	6650.44	16277.67	3.44
	Vietnam	VNM	331212	955408	1452.88	6171.88	5.51
Central Asia	Armenia	ARM	29843	29305	3742.44	8787.58	3.97
	Azerbaijan	AZE	86600	98624	8513.31	15847.42	3.18
	Georgia	GEO	69000	37171	8006.50	9745.08	1.86
	Iran, Islamic Rep.	IRN	1648195	811628	11392.56	19082.62	2.01
	Kazakhstan	KAZ	2455034	180376	13050.49	24055.59	2.51
	Kyrgyz Republic	KGZ	199900	62015	3474.67	3393.47	0.20
	Tajikistan	TJK	143100	89213	3644.67	2896.91	-0.23
	Turkey	TUR	747272	807450	11400.18	25129.34	3.07
	Turkmenistan	TKM	488100	57581	8316.76	16389.02	2.95
	Uzbekistan	UZB	447400	323872	3071.02	6253.10	2.79
Asia Pacific	Australia	AUS	7692024	245989	28658.37	44648.71	1.66
	Fiji	FJI	18274	9055	5891.29	8702.98	1.49
	New Zealand	NZL	270467	47939	23671.27	36085.84	1.60

Notes: PPP GDP is gross domestic product converted to international dollars using purchasing power parity rates. Data are in constant 2011 international dollars.

Growth rate = $\{\sum_{t=1}^{T}(\log y_t - \log y_{t+T}\}/T$

Source: Authors' calculation and compilation. World Development Report (2016), World Development Indicator (World Bank); GDP per capita based on purchasing power parity (PPP

Appendix 2: Estimation of Conditional Distribution using Kernel Density Function

In distribution dynamics method we use kernel density estimators, which is a nonparametric technique to estimate the probability density function (PDF) of a random variable. Let us assume that $(x_1, x_2, \dots \dots \dots, x_n)$ are independently and identically distributed sample drawn from a distribution with an unknown density *f*. The kernel density estimator of the density *f* can be written as:

$$\hat{f}_h(x) = \frac{1}{n}\sum_{i=1}^{n} K_h(x - x_i) = \frac{1}{nh}\sum_{i=1}^{n} K\left(\frac{x - x_i}{h}\right)$$

where *K*(•) is a kernel. The kernel is a non-negative function and integrates to one. *h* is a smoothing parameter known as bandwidth.

Now to estimate the stochastic kernel (the conditional density function) using kernel density estimator, the accuracy depends on the choice of the kernel function and the bandwidth matrix (Silverman, 1986; Wand and Jones, 1995). Here, we use the bivariate Gaussian kernel function is of the form:

$$k(x) = \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}(xx')^2}$$

The next step is the selection of the bandwidth should be chosen according to some global error criteria (Wand and Jones, 1995). The common practice is to minimize mean integrated square error *(MISE)* between estimated density and actual density.

$$MISE = \mathrm{E}\int \{\hat{f}_x - f_x\}^2 dx$$

However, *MISE* depends on the bandwidth in a very complicated way, and it is very difficult to interpret it in terms of bias and variance. Accordingly, Wand and Jones (1995) suggests using its asymptotic approximation *(AMISE)*, which is related to the bandwidth in a very simple way. *AMISE* can be calculated using the first two terms of Taylor's series expansion of the *MISE*. Then, the *AMISE* of the kernel estimator can be defined as:

$$AMISE = (nh)^{-1} R(K) + \frac{1}{4} h^4 \sigma^4{}_k R(f'')$$

where $R(K) = \int K(x)^2 \, dx$ is a measure of the roughness of the kernel function *(K)*. The first term in the above equation is the integrated variance, which is proportional to $(nh)^{-1}$. The second term is the integrated square bias and proportional to h^4.

The second step is to choose a form of the bandwidth matrix. There is two different dimensions of the data in our analysis *viz*., per capita state domestic income for the initial distribution and the final distribution. It will not be a very good idea to choose a single bandwidth for both the dimensions since the observations in both the periods are different (so as the distributions). Therefore, it is better to use two different bandwidths for the two different dimensions. Hence, we are using diagonal bandwidth matrix ($H = diag(h_x, h_y)$), where two different bandwidths will take care of the smoothing in different dimensions. Following Wand and Jones (1995) we use a diagonal bandwidth matrix and adopt product kernel for our analysis.

The estimates of the joint and the marginal densities in equation becomes

$$\hat{\varphi}_{t,t+s}(w,z) = \frac{1}{n h_w h_z} \sum_{i=1}^{n} k\left(\frac{\|w - w_i\|}{h_w}\right) k\left(\frac{\|z - z_i\|}{h_z}\right)$$

And

$$\hat{\varphi}_t(w) = \frac{1}{n h_w} \sum_{i=1}^{n} k\left(\frac{\|w - w_i\|}{h_w}\right)$$

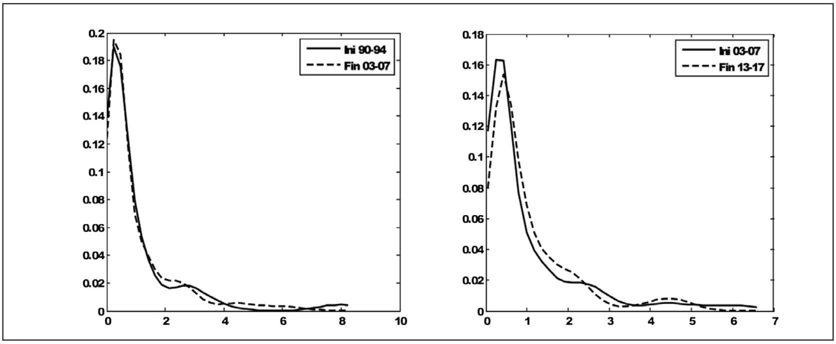
respectively, where $\|w - w_i\|$ and $\|z - z_i\|$ are the Euclidian distance matrices. h_w and h_z represent the bandwidths. Here the kernel function is the product of two kernels. Each estimated using the bandwidths h_w and h_z respectively.

Appendix 3: Variable Definitions and Data Sources

Variable	Definition	Expected Sign	Source
$y_{i,t,t+T}$	Growth rate of per capita GDP	NA	World Development Indicator (World Bank)
Initial per capita Income (GDP)	Log of per capita GDP	Negative	World Development Indicator (World Bank)
Human Capital (HCL)	Average years of school attainment, age 15+	Positive	World Development Indicator (World Bank)
Population (POP)	Population growth rate	Negative	World Development Indicator (World Bank)
Government expenditure to GDP (GOV)	Government expenditure as a percentage of GDP	Positive/ Negative	World Development Indicator (World Bank)
Health (HLT)	Life expectancy at birth	Positive	World Development Indicator (World Bank)
Technology proficiency (TEC)	Research and Development expenditure as a percentage of GDP	Positive	World Development Indicator (World Bank)
Urbanisation (URB)	Percentage of urban population to the total	Negative	World Development Indicator (World Bank)
Openness (OPN)	Total trade (exports + imports) as a percentage of GDP	Positive	World Development Indicator (World Bank)

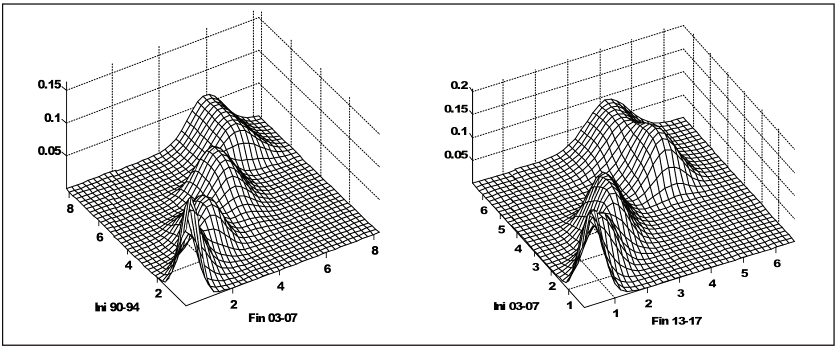
Source: Compiled by Authors.

Appendix 4: Distribution Dynamics Plots



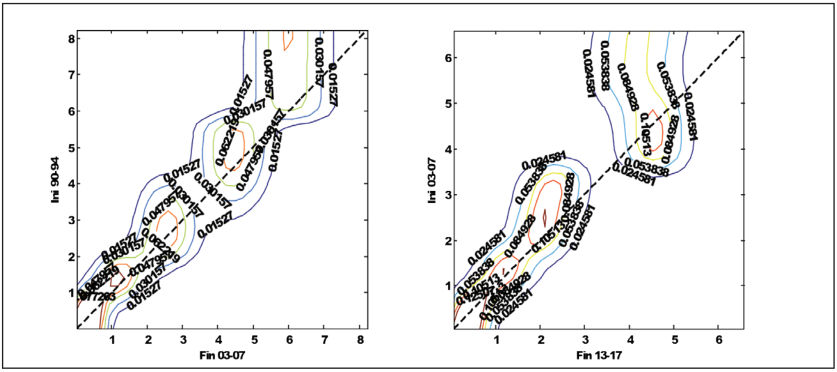
Source: Drawn by Authors.

Figure (a): Kernel Density Plots Before and After Crisis



Source: Drawn by Authors.

Figure (b): 3-dimentional Plot of the Conditional Density Before and After Crisis



Source: Drawn by Authors.

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