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Abstract
This paper uses two panel unit root procedures to test stochastic convergence for 14 states in Malaysia, for the period 1960-2003. Stochastic convergence implies that idiosyncratic country-specific factors cannot explain long-run economic growth, and that shocks to relative regional real per capita Gross Domestic Product (GDP) have temporary effects. In this case, real per capita GDP differentials between states are stationary. Thus, stochastic convergence implies that regional differences across states are not persistent, and that long-run movements in a state's GDP are driven by common technology shocks. The result indicates that the null hypothesis of no convergence in GDP per capita across the 14 states in Malaysia can be rejected. From the policy perspective, this study suggests that previous regional development policies were able to reduce income disparity between the 14 states in Malaysia.

Panel Tests of Stochastic Convergence in the States of Malaysia: Some Empirical Evidence

Muzafar Shah Habibullah* and V Sivabalasingam**

This paper uses two panel unit root procedures to test stochastic convergence for 14 states in Malaysia, for the period 1960-2003. Stochastic convergence implies that idiosyncratic country-specific factors cannot explain long-run economic growth, and that shocks to relative regional real per capita Gross Domestic Product (GDP) have temporary effects. In this case, real per capita GDP differentials between states are stationary. Thus, stochastic convergence implies that regional differences across states are not persistent, and that long-run movements in a state's GDP are driven by common technology shocks. The result indicates that the null hypothesis of no convergence in GDP per capita across the 14 states in Malaysia can be rejected. From the policy perspective, this study suggests that previous regional development policies were able to reduce income disparity between the 14 states in Malaysia.

Introduction

Economic growth and equality remains an important issue in the economic agenda of many countries. Although different countries have different perceptions of what equality is and how best to achieve it, by and large, there is a consensus that extreme inequality of income, wealth or opportunity is unfair, and that efforts should be made to raise the income of the poorest members of the society. Accordingly, in their quest to achieve both development and equity at the same time, policies and strategies are continuously being formulated and implemented across the globe. Malaysia, a federation of 13 states and three Federal Territories, is no exception. The 13 states in the Federation are Perlis, Kedah, Kelantan, Terengganu, Penang, Perak, Pahang, Selangor, Negeri Sembilan, Melaka, Johore, Sabah and Sarawak, while the Federal Territories are Kuala Lumpur and Putrajaya in West Malaysia, and Labuan in East Malaysia. These states can be categorized into two, namely the more-developed states and the less-developed states.[1] Thus, recognizing the importance of achieving regional equality in Malaysia, the government has instituted several policies and strategies since

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[1] The more-developed states are Johore, Melaka, Negeri Sembilan, Perak, Penang and Selangor, while the less-developed states are Kedah, Kelantan, Pahang, Perlis, Sabah, Sarawak and Terengganu. The Federal Territories of Kuala Lumpur and Putrajaya are categorized as more-developed, while the Federal Territory of Labuan is classified as less-developed.

independence, to close the gap between the states in Malaysia. These policies and strategies, which are reported in the eight volumes of the 5-Year Malaysia Plan, reflect the sincerity of the Malaysian government in eradicating, if not elevating, the problem of regional imbalances.

The objective of the present paper is to assess whether or not economic convergence has been a characteristic of economic growth in Malaysia, over the long term. The notion of economic convergence usually refers to the process in which national economies display increasing similarities in the patterns of their performance. Since the poorer countries are generally considered to have capital-labor ratios below their long-run optimum, and lagging behind in adopting the available technology, their rate of returns on fixed investments should be higher than in the richer states. Consequently, there should be a systematic tendency for the poorer states to grow faster than the richer states, until they have caught-up with the levels of per capita income in the latter. This is the so-called convergence hypothesis.

The paper moves on to discuss the method used to estimate stochastic convergence for the 14 states in Malaysia. Further, the paper discusses the empirical results before concluding.

Methodology

Tests of convergence within regions in a country and between international economies, have been receiving increasing attention. The analysis to carry out test of convergence is based on the following equation:

$$\frac{1}{T}\left[\log\left(\frac{y_{i,t+T}}{y_{i,0}}\right)\right] = \alpha - \beta \ \log(y_{i,0}) + \varepsilon_{i,t} \qquad ...(1)$$

where $\log(y_{i,0})$ is the logarithm of country *i*'s initial GDP per capita at time $t = 0$. The Left Hand Side (LHS) of Equation 1 denotes the average growth rates in GDP per capita for the period 0 to *T*. If we find $\beta > 0$, then we say that the data set exhibits absolute (unconditional) β convergence (see for example, Baumol, 1986; DeLong, 1988; Dowrick and Nguyen, 1989; Grier and Tullock, 1989; Barro and Sala-i-Martin, 1991, 1992 and 1995; and Mankiw *et al.*, 1992).

However, the usage of Equation 1 for testing convergence has been criticized by Quah (1993), Bernard and Durlauf (1995) and Evans (1998). They suggest the use of time-series methods (the so-called stochastic convergence) to evaluate convergence, since the cross-sectional approach is subject to bias. In a time-series approach, stochastic convergence asks whether permanent movements in one country's per capita income are associated with permanent movements in another country's income, that is, it examines whether common stochastic elements matter, and how persistent the differences among countries are. Thus, stochastic convergence implies that income differences among countries cannot contain unit roots. In other words, per capita income among countries is stat ionary. Empirical studies on testing stochastic convergence were carried out, among others, by Campbell and Mankiw (1989), Cogley (1990), Bernard (1991), Carlino and Mills (1993), Bernard and Durlauf (1995), Greasly and Oxley (1997), St. Aubyn (1999), and Cellini and Scorcu (2000).

Following Evans and Karras (1996), stochastic convergence occurs if relative log per capita GDP (y_{it}) follows a stationary process, where $y_{it} = \log Y_{it} - \log \bar{y}_t$, and Y_{it} is the log of real per capita GDP for country i and is $I(1)$, and $\bar{y}_t = \sum_{i=1}^{N} Y_{it}$. Stochastic convergence is tested by using the conventional univariate Augmented Dickey-Fuller (ADF) regression of the following form:

$$\Delta y_{it} = \alpha_i + \beta_i y_{it-1} + \sum_{j=1}^{p} \theta_{ij} \Delta y_{it-j} + \varepsilon_{it}, \qquad t=1,...,T \qquad ...(2)$$

for $i = 1,..., N$ series, and $j = 1,..., p$ ADF lags. The null hypothesis is that y_{it} follows a non-stationary process and the series do not converge stochastically.

However, one important drawback of the ADF unit root test procedures is that the power of the test is quite low. Some authors recognized that the power could be significantly improved if panel data is used instead of a univariate time-series (Im *et al.*, 1997 and Levin *et al.*, 2002). For the panel unit root test procedures, Im *et al.* (1997) proposed a *t*-bar statistic, which is based on the average of the individual ADF *t*-statistics. For a sample of *N* groups observed over *T* time periods, the panel unit root regression of the ADF test is written as:

$$\Delta y_{it} = \alpha_i + \beta_i y_{it-1} + \sum_{j=1}^{p_i} \gamma_{ij} \Delta y_{it-j} + \varepsilon_{it}, \qquad i=1,...,N, \qquad t=1,...,T \qquad ...(3)$$

The null hypothesis of a unit root in the panel data is defined as:

$$\beta_i = 0, \text{ for all } i \qquad ...(4)$$

against the alternatives that all series are stationary processes

$$\beta_i < 0,\ i = 1,2,...,N_1;\ \beta_i < 0,\ i = N_1 + 1,\ N_2 + 2,...,N \qquad ...(5)$$

This equation of the alternative hypothesis allows for $\beta_i = \beta < 0$ for all *i*. To test the hypothesis, Im *et al.* (1997) proposed a standardized *t*-bar statistic given by:

$$\psi_{\bar{t}} = \frac{\sqrt{N}\left\{\bar{t}_{NT} - (1/N)\sum_{i=1}^{N} E\left[t_{i,T}(p_i,0)\middle|\beta_i = 0\right]\right\}}{\sqrt{(1/N)\sum_{i=1}^{N} Var\left[t_{i,T}(p_i,0)\middle|\beta_i = 0\right]}} \qquad ...(6)$$

where,

$$\bar{t}_{NT} = \frac{1}{N}\sum t_{i,T}(p_i,\beta_i) \qquad ...(7)$$

and $t_{i,T}(p_i,\beta_i)$ is the individual *t*-statistic for testing $\beta_i = 0$, for all *i*. $E\left[t_{i,T}(p_{i,}0)\middle|\beta_i = 0\right]$ and

$Var\left[t_{i,T}(p_i,0)\middle|\beta i=0\right]$ are reported in Table 2 of Im *et al.* (1997). Under the null hypothesis, the standardized *t*-bar statistic $\psi_{\bar{t}}$ is asymptotically distributed as a standard normal distribution [$\psi_{\bar{t}}$ ~ $N(0,1)$]. The Im *et al.* (1997) panel unit root test was derived, assuming that the series are independently generated, and they suggested subtracting the cross-sectional means to remove common time-specific effects. This assumes that the error term in Equation 3 consists of two random components, $\varepsilon_{it} = \delta_t + v_{it}$, where v_{it} is the idiosyncratic random component and δ_t is a stationary time-specific effect that accounts for correlation in the errors across economies.

Another commonly used panel unit root test is the one based on Fisher (1932). Maddala and Wu (1999) proposed the test statistic, which is based on combining the *p*-values of the test statistics (of β_i) of N independent ADF regressions, from Equation 2. The test statistic [the Fisher test $P(\lambda)$] is as follows:

$$P(\lambda) = -2\sum_{i=1}^{N}\log(\pi_i), \quad \text{...(8)}$$

where π_i is the *p*-value of the test statistic for unit *i*. The Fisher test statistic $P(\lambda)$ is distributed as a chi-squared distribution with $2N$ degree of freedom.

Sources of Data

The data used in this study are annual observations on per capita GDP in constant (2000) prices for 14 states, as regional units. These states are Perlis, Kedah, Kelantan, Terengganu, Penang, Perak, Pahang, Selangor, Negeri Sembilan, Melaka, Johore, Sabah, Sarawak and Wilayah Persekutuan. The samples cover the period 1960-2003. Data for states' GDP at constant prices are collected from the various issues of the 5-Year Malaysia Plan. A complete range of time-series data for states' per capita GDP were interpolated, using information on time, time-squared and lagged states' per capita GDP. Figure 1 plots the time-series per capita GDP for each of the 14 states, including the national average for comparison. In all cases, per capita states' GDP indicate an increasing trend. Except for Melaka, Sabah and Sarawak, the impact of the 1985 recession and the 1997 financial crisis are clearly felt by other states in Malaysia.

Empirical Results

Before testing for convergence, based on Equation 2, it is essential to determine the order of integration for each of the state's income series. The standard ADF test was used to test the presence of unit roots in the logarithm of states' per capita income. The results of the ADF test are reported in Table 1, with series in levels are run with constant and trend, while series in first differences are run with constant only. The chosen lag length is selected, based on SIC.[2] The estimated *t*-statistics for the ADF test reported in Table 1, indicate that all states' per capita income (including the national average per capita income) series are processes. The null hypothesis of unit root cannot be rejected at the 5% level of significance for series in levels,

[2] Schwar3 info Criterion. In this study, we used EViews5.1 and the software automatically selects the optimal lag length based on SIC.

Figure 1: Trends in States' Per Capita GDP

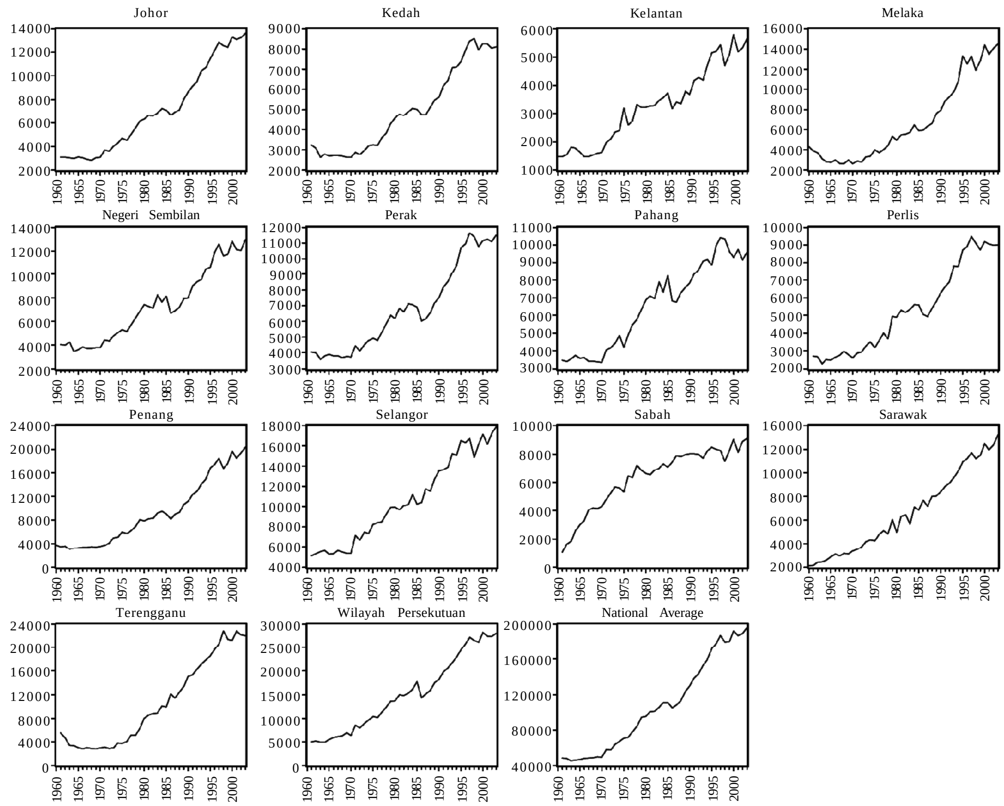

Table 1: Result of Unit Root Test for State Per Capita Income Series

Per Capita Income by State	Levels (Constant and Trend)	Lag Length	First Difference (Constant)	Lag Length
Johore	–2.26	0	–5.36	0
	[0.44]		[0.00]*	
Kedah	–2.64	4	–5.08	0
	[0.26]		[0.00]*	
Kelantan	–2.66	9	–6.84	1
	[0.25]		[0.00]*	
Melaka	–2.34	1	–7.69	0
	[0.40]		[0.00]*	
Negeri Sembilan	–2.78	0	–7.47	0
	[0.21]		[0.00]*	
Perak	–2.40	2	–5.74	0
	[0.36]		[0.00]*	
Pahang	–2.70	0	–7.92	0
	[0.24]		[0.00]*	

(Contd...)

Table 1: Result of Unit Root Test for State Per Capita Income Series (...contd)				
Per Capita Income by State	**Levels (Constant and Trend)**	**Lag Length**	**First Difference (Constant)**	**Lag Length**
Perlis	–2.56	0	–7.12	0
	[0.29]		[0.00]*	
Penang	–2.05	0	–6.87	0
	[0.55]		[0.00]*	
Selangor	–2.84	1	–9.44	0
	[0.18]		[0.00]*	
Sabah	–2.79	0	–8.11	0
	[0.20]		[0.00]*	
Sarawak	–1.76	2	–7.81	1
	[0.70]		[0.00]*	
Terengganu	–3.03	2	–6.30	0
	[0.13]		[0.00]*	
Wilayah Persekutuan	–2.77	0	–7.80	0
	[0.21]		[0.00]*	
National Average	–2.60	0	–5.62	0
	[0.28]		[0.00]*	

Note: All unit root estimations were done using EViews5.1, which automatically selects lag length based on SIC as default, and this was used throughout the analysis. The square brackets contain the *p*-values;

* denotes statistically significant at 5% level. Critical values for unit root test are referred to MacKinnon (1996).

while for series in first difference, the null hypothesis can be rejected at 5% level of significance. In other words, the states' per capita income series achieve stationarity after first differencing.

Having determined that all states' per capita GDP are integrated of order one, that is, they are $I(1)$ processes, the study proceeded to the testing of stochastic convergence by using Equation 2. This is done by employing the ADF unit root test on the differential between each state's per capita GDP and the national average per capita GDP. The result is presented in

Table 2: Univariate ADF Unit Root Test for Convergence				
Relative States' Per Capita Income to National Average	**Constant**	**Lag Length**	**Constant and Trend**	**Lag Length**
Johore	–1.81	0	–3.18	0
	[0.36]		[0.10]	
Kedah	–3.16	0	–3.15	0
	[0.02]*		[0.10]	
Kelantan	–1.41	2	–4.06	0
	[0.56]		[0.01]*	

(Contd...)

Table 2: Univariate ADF Unit Root Test for Convergence *(...contd)*				
Relative States' Per Capita Income to National Average	**Constant**	**Lag Length**	**Constant and Trend**	**Lag Length**
Melaka	–1.60	1	–3.40	0
	[0.47]		[0.06]	
Negeri Sembilan	–1.71	1	–2.71	1
	[0.41]		[0.23]	
Perak	–1.60	0	–1.87	0
	[0.47]		[0.64]	
Pahang	–0.00	1	–2.61	1
	[0.95]		[0.27]	
Perlis	–3.32	0	–4.40	0
	[0.01]*		[0.00]*	
Penang	–0.14	1	–4.13	0
	[0.93]		[0.01]*	
Selangor	–1.53	0	–6.15	9
	[0.50]		[0.00]*	
Sabah	–4.13	0	–7.91	0
	[0.00]*		[0.00]*	
Sarawak	–5.25	0	–5.45	0
	[0.00]*		[0.00]*	
Terengganu	–1.05	0	–3.99	0
	[0.72]		[0.01]*	
Wilayah Persekutuan	–3.17	0	–2.83	0
	[0.02]*		[0.19]	

Note: All unit root estimations were done using EViews5.1, which automatically selects lag length based on SIC as default, and this was used throughout the analysis. The square brackets contain the *p*-values;

* denotes statistically significant at 5% level. Critical values for unit root test are referred to MacKinnon (1996).

Table 2. The result of the estimated Equation 2 was reported with the inclusion of both the deterministic components—with constant alone, and with both constant and trend. Out of the 28 analyses of convergence presented in Table 2, only 12 cases exhibited the presence of stochastic convergence, depending on the deterministic components included in Equation 2. However, for the states of Perlis, Sabah and Sarawak, stochastic convergence is present in both accounts—with constant only, and with both constant and trend.

On the other hand, Table 3 reports the results of the two panel unit root tests with constant only, and with both constant and trend. The results are reported for the whole sample period 1960-2003, as well as for two sub-samples 1960-1980 and 1981-2003, to evaluate the robustness of the empirical findings. Estimated *t*-bar statistics for the Im-Pesaran-Shin (IPS) test and λ values for the Fisher $P(\lambda)$ test, with their accompanying *p*-values, were reported.

Table 3: Result of Panel Unit Root Tests

Sample Period	Im-Pesaran-Shin Test, $\psi_{\bar{t}}$		Maddala-Wu Test, $P(\lambda)^{b}$	
	Constant	**Constant and Trend**	**Constant**	**Constant and Trend**
1960-2003	–2.62 (0-2)	–8.34 (0-9)	63.06 (0-2)	128.04 (0-9)
	[0.00]*	[0.00]*	[0.00]*	[0.00]*
1960-1980	–7.45 (0-4)	–2.17 (0-4)	116.09 (0-4)	49.12 (0-4)
	[0.00]*	[0.01]*	[0.00]*	[0.01]*
1981-2003	–2.04 (0-2)	–3.81 (0-2)	54.55 (0-2)	69.49 (0-2)
	[0.02]*	[0.00]*	[0.00]*	[0.00]*

Note: [a] Under the null hypothesis, the standardized t-bar statistic $\psi_{\bar{t}}$ (the IPS test statistic), is asymptotically distributed as a standard normal distribution. Lag length chosen is based on SIC which is automatically selected by EViews5.1. The numbers in round brackets denote the range of lag length, while those in square brackets denote p-values. The p-values are estimated from the one-tail test of the standardised normal distribution;

[b] Under the null hypothesis, the Fisher test statistic $P(\lambda)$ is distributed as a chi-squared distribution with $2N$ degree of freedom. Lag length chosen is based on SIC, automatically selected by EViews5.1. The p-values are estimated from a chi-squared distribution with $2N$ degree of freedom;

* denotes statistically significant at 5% level.

In contrast to the earlier findings from the univariate ADF unit root tests, for the panel unit root tests, in all three cases of the sample periods, the null hypothesis of no convergence can be rejected at the 5% level of significance. Results in Table 3 show that all states converge stochastically, and this implies that the long-run trend is well-approximated by the panel average.

Conclusion

The study of stochastic convergence has received much attention in the last decade. However, most of the empirical analyses have tested stochastic convergence in international economic contexts. Thus, the objective of the present study is to answer empirically, the question of convergence in GDP per capita, across the Malaysian states, for the period 1960-2003, using a time-series framework. Upon testing the time-series properties of the states' per capita GDP, by using the standard ADF test, it was found that all states' income series are I (1) processes.

Based on the stochastic convergence definition suggested by Evans and Karras (1996), and two commonly used panel unit root testing procedures proposed by Im *et al.* (1997) and Maddala and Wu (1999), the present findings strongly support stochastic convergence hypothesis for the 14 Malaysian states. The whole sample period was also split into two sub-periods 1960-1980 and 1981-2003, in order to test the robustness of the results to the changes in the sample. Results for both the sub-sample periods strongly support stochastic convergence. ❒

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