University of Wollongong

Economics Working Paper Series 2007

http://www.uow.edu.au/commerce/econ/wpapers.html

Pair-Wise Output Convergence in East Asia and the Pacific: An Application of Stochastic Unit Root Test

Khorshed Chowdhury

and

Girijasankar Mallik

WP 07-07

August 2007

Pair-Wise Output Convergence in East Asia and the Pacific: An Application of Stochastic Unit Root Test

Khorshed Chowdhury*
School of Economics
University of Wollongong
Wollongong, NSW 2522
Australia

e-mail: khorshed@uow.edu.au

Tel: 61-2-42214024
Fax: 61-2-42213725

and

Girijasankar Mallik
School of Economics and Finance
University of Western Sydney
Locked Bag 1797, Penrith South DC, NSW 1797
Australia

email: g.mallik@uws.edu.au

Tel: 61-2-9685 9664
Fax: 61-2-9685 9105

* for all correspondence contact Khorshed Chowdhury, School of Economics, University of Wollongong, Wollongong, NSW 2522, Australia, email:khorshed@uow.edu.au, Tel: 61-2-42214024, Fax: 61-2-42213725.

Pair-Wise Output Convergence in East Asia and the Pacific: An Application of Stochastic Unit Root Test

Abstract

The objective of this paper is to examine time series cross-country output convergence in eleven counties of East Asia and the Pacific. Specifically, we modelled the cross-country output differences as a Stochastic Unit Root *(STUR) processes a la Granger and Swanson (1997). Since, STUR commonly occur in economic theory as well as in everyday macroeconomic applications, therefore,* modelling cross-country output differences *as STUR is considered pertinent and superior in terms of performance and forecasting. Leybourne et al. (1997) test has been applied that has a null hypothesis of exact unit roots against an alternative of STUR. The presence of a constant unit root in output differences implies divergence while the presence of a stochastic unit root implies convergence. Using the output-differences between Japan and the 10 other countries, we find output convergence only for the Japan-New Zealand and Japan-Taiwan country-pairs. Alternatively, using the output-differences between Australia (reference country) and the other 10 sampled countries; we fail to find any evidence of convergence.*

Key words: Per Capita GDP, Convergence, Deterministic unit root; STUR

JEL Classification: C21, O18

Pair-Wise Output Convergence in East Asia and the Pacific: An Application of Stochastic Unit Root Test

Introduction

The concept of convergence is defined in the literature as implying "forces accelerating the growth of nations who were latecomers to industrialization and economic development give rise to a tendency towards convergence of levels of per capita product or, alternatively of per worker product" Baumol (1986:1075). David Hume contended that transfer of technology to be a driving force for convergence of poorer and richer countries by enlarging the size of their markets. Convergence of income is a natural outcome of the neoclassical growth models and its validity is of paramount importance for economic welfare. The empirical as well the theoretical literature on convergence is vast and a comprehensive review can be found in Islam (2003) with a mixed bag of results. Islam (2003:309) attributes the wide array of empirical results due to many different interpretations of convergence. The following taxonomy indicates some of the different ways in which convergence has been understood:

(a) Convergence within an economy vs. convergence across economies;

(b) Convergence in terms of growth rate vs. convergence in terms of income level;

(c) β-convergence vs. σ-convergence;

(d) Unconditional (absolute) convergence vs. conditional convergence;

(e) Global convergence vs. local or club-convergence;

(f) Income-convergence vs. TFP (total factor productivity)-convergence; and

(g) Deterministic convergence vs. stochastic convergence.

Islam (2003:16) writes about the progression of the study of convergence as follows:

“From a chronological point of view, the study of convergence began with the notion of ‘absolute convergence’ and then moved to the concept of ‘conditional convergence.’ Both these concepts were initially studied using the notion of ‘β-convergence.’ The notion of σ-convergence arose later. Alongside emerged the concepts of ‘club-convergence,’ ‘TFP-convergence,’ and the time series notions of convergence. There was also a chronological progression from the ‘informal cross-section’ to ‘formal cross-section,’ and then on to ‘panel’ approach to convergence study. The ‘time-series’ and the ‘distribution’ approaches developed alongside”

For large samples of countries that cut across regions and income levels, most of the evidence fails to support absolute convergence. Although large samples of countries do not display convergence, the evidence of convergence is somewhat stronger for smaller groups of countries specially among countries at similar income levels. Ben David (1998) and Chatterji (1992) find empirical evidence of convergence among the world’s richest and poor countries although they fail to do so for middle-income countries. In response to Ben David (1998) and Chatterji (1992), Chowdhury (2005a, 2005b) tested the “bi-modality” and failed to find absolute and conditional convergence in poorer countries of South Asia and middle income counties of ASEAN. Galor (1996) and Quah (1997) provide theoretical justifications for the convergence club hypothesis, according to which convergence will occur among subsets as opposed to broad samples of countries.

The central objective of this study is to empirically examine convergence in 11 countries of East Asia and the Pacific region by modelling the cross-country output differences as a stochastic unit root process (STUR). This approach is adopted for two reasons. First, empirical work following this approach is few and far between and secondly, the standard unit root tests suffer from power deficiency and fail to reject the null hypothesis of output divergence. The sampled countries include: Australia (Aus), Hong Kong (HK), Indonesia (Ind), Japan (Jap), Korea (Kor), Malaysia (Mal) New Zealand (NZ), Philippines (Phi), Singapore (Sin), Taiwan (Tai) and Thailand (Tha). Thus far no studies have been done for the above countries by selecting Japan and Australia as the reference (leader) countries.

The structure of the paper is as follows. In section II we measure the dynamics of relative economic performance of the sampled countries on the basis of an ordinal index. In Section III we define the concepts of deterministic convergence vs. stochastic convergence and test for the presence or absence of STUR. The presence of a deterministic unit root in cross-country output-differences indicates output divergence, while the presence of STUR in the data implies convergence. In Section IV we conclude the paper.

Section II Dynamics of Relative Economic Performance

The leading macroeconomic indicators for the sampled countries do not provide us with a comprehensive picture of the general performance of a particular economy. As an illustration, a particular country X may have done exceedingly well in terms of GDP growth rate while experiencing a very high inflation rate, a deterioration in the current account balance and an increase in external debt Hence, these cardinal indicators cannot offer an unambiguous interpretation of overall performance without being subject to value judgements. Value judgements, as is well known, are subjective and often lead to arbitrariness. Therefore, other measures must be devised to obviate the difficulties of translating cardinal measures into some form of objective measurement.

Of the many such indices[1], Borda's Rule is one such measure that is proposed which is relatively value free and does not suffer from arbitrariness. Moreover, it is simple to calculate and construct and have intuitive appeal.

Borda Rule

Let A = {i}, i = 1, 2, ... n, denote a set of countries whose relative performance is to be judged; and S = {j}, j = 1, 2, ... m denote a set of measurable attributes/or indicators/or characteristics to be used in judging the performance. Let country i's performance with respect to characteristic j be evaluated by a ranking process in a descending order. Country i is said to perform better than country k in respect of the characteristic j if and only if $a_j^i < a_j^k$, while an equal performance would imply $a_j^i = a_j^k$.

The Borda score of the i-th country (i =1, 2, ... n) with respect to j (measurable) characteristics (atrributes/indicators) (j = 1, 2, ... m) can be defined as:

$$B^i = \sum_{j=1}^{m} (n - a_j^i) \qquad (1)$$

The computation and logic of the Borda score is very simple. For example, if country i for the j characteristic has the best performance among all n countries, the i-th country's score for the j-th characteristic is (n-1). The country with the next best performance gets a score of (n-2) and the country with the worst performance receives a score of (n - n = 0). Summing up over the entire j characteristic gives the Borda score for each individual country.

By calculating the Borda score for each country, we can rank countries in terms of their performance. The country with the highest Borda score is deemed to be the best performer with ranking downward implying a poorer performance. The Borda score eliminates arbitrariness in ranking. As Dasgupta (1994:3) writes, “The

Borda measure allows good performance in respect of one criterion to compensate for poor performance in respect of another, for it is the *total Borda* score that counts. The *number* of characteristics in which one country may have out-performed another is given no weights as such".

Both Borda and Copeland (not considered here) rules provide us with complete ordering. But these rules are not without their limitations, though these are considered minor. As Dasgupta (1994:9) writes, "In common with most positional rules the Borda Rule is not necessarily independent of irrelevant alternatives .... The Copeland rule, too, is subject to this objection". However, the Borda and Copeland rule have their relative merits and do provide a complete order. Dasgupta (1994:10) concludes by commenting that "these limitations not withstanding, the ranking rules proposed and extensions or modifications of them, could we believe, help in understanding a little more clearly what measuring relative performance really involves".

Empirical Evaluation of Economic Performance

The above suggested rule was applied to assessing the relative performance of the sampled countries over the period 1960-2004. The countries were ranked on the basis of economic indicators. The economic indicators chosen were: (i) real GDP per capita; (ii) private consumption share in real GDP; (iii) investment share of real GDP; (iv) government consumption as a percentage of GDP; (v) degree of openness (X + M/GDP) and (vi) GDP per worker. We would have liked to include more characteristics[2] but non-availability of data for Hong Kong and Taiwan prevented us from doing so. The economic characteristics chosen for each country is broad based which capture the trends and performance of a given country. Data were extracted from Penn World Table Version 6.2.

The Borda Rankings of the eleven sample countries are given in Table 1. Australia's performance remained steady throughout and by the end of the sample period has improved its ranking to be first among the sampled countries. Hong Kong's performance was also very steady. Indonesia's ranking improved in the mid-1990's but deteriorated in later years. Indonesia's ranking of economic performance was at the bottom of the pack and still remains in the bottom.

Initially, Japan's position in terms of economic performance was fifth but deteriorated from mid -1960's to 2000. In 2004, Japan reverted to its pristine position of fifth. South Korea's ranking hovered around eighth or ninth but dramatically improved to fifth position in 1985. Malaysia showed improvement in its performance up to 1995 but its ranking deteriorated since 1995. New Zealand displayed a sterling performance by occupying the pole position up to 1985. Since then its position has slipped down to fourth.

Philippines' economic performance was not good during the sampled period. Its position deteriorated from sixth to ninth by mid – 1970's and slipped to tenth position by 1985. Since then Philippines remained in ninth position overall. Singapore's performance remained steady oscillating between first, second, third, fourth and fifth. Taiwan's position remained steady throughout the sampled period. Lastly, Thailand was the most improved performer by climbing up to seventh position from its initial position of tenth.

Table 1 Borda Ranking

Country	**1960**	**1965**	**1970**	**1975**	**1980**	**1985**	**1990**	**1995**	**2000**	**2004**
Australia	4	3	3	3	3	1	3	3	3	1
Hong Kong	1	2	2	3	2	3	1	1	1	2
Indonesia	11	10	10	11	11	11	11	9	11	11
Japan	5	8	8	8	7	5	7	7	6	5
South Korea	9	9	9	5	8	5	10	9	7	8
Malaysia	8	3	4	7	6	8	4	4	9	9
New Zealand	1	1	1	1	1	1	5	4	4	4
Philippines	6	6	6	9	9	10	9	9	9	9
Singapore	3	5	5	2	4	4	2	2	1	3
Taiwan	7	6	6	6	5	7	6	6	5	6
Thailand	10	11	11	10	10	9	8	8	7	7

Section III Deterministic Convergence vs. Stochastic Convergence

Bernard and Durlauf (1996), Carlino and Mills (1993), Evans (1996), and Evans and Karras (1996a), Li and Papell (1999), and others have investigated convergence using time series econometric methods. It is contended that 'within convergence' is inherently a time series concept. But researchers have also used time series analysis to examine 'across convergence' too. From this perspective, two economies, *i* and *j*, are said to converge if their per capita outputs, y_{it} and y_{jt} satisfy the following condition:

$$\lim_{k \to \infty} E(y_{i,t+k} - a y_{j,t+k} / I_t) = 0 \qquad (2)$$

where, I_t denotes the information set at time t. This definition of convergence is unambiguous for a two-economy situation. This is not so when convergence is considered in a sample of more than two economies. In multi-country situations researchers have often taken deviations from a reference economy as the measure of convergence. With this assumption, y_{it} in equation (2) is replaced by y_{1t}, where 1 is the index for the reference country. When, $a = 1$, equation (2) represents a variant of unconditional convergence. On the other hand, if $a \neq 1$ then equation (2) may represent a variant of conditional convergence. Within this methodology a distinction is made between 'deterministic' and 'stochastic convergence' based on whether 'deterministic' or 'stochastic' trend is allowed in testing for unit root in the deviation series. Recent studies on unit root processes (e.g., Granger and Swanson, 1997 and Ludlow and Enders, 2000) have argued that the linear decay in the autoregressive models fail to capture the asymmetric and time varying adjustment of macroeconomic variables. This view is also shared by Leybourne *et al.* (1996:435) who argue, "We share this view and contend that fixed-coefficients unit roots models as representations of many observed economic time series may, in reality, be insufficiently flexible.” They go on to suggest that the autoregressive unit root paradigm is best represented by an ARMA model that exhibits stochastic coefficient variations in its AR polynomial around a unit root mean.

Granger and Swanson (1997) proposed a class of nonlinear processes (having a root that is not constant) which have a stochastic root varying around unity. “In this way, the process is stationary for some periods, and mildly explosive for others. However, on average, the series may seem to be *I(1)*, according to standard tests” (Granger and Swanson, 1997:36). The Stochastic Unit Root (STUR) “…are seen to arise naturally in economic theory, as well as in everyday macroeconomic applications”. Granger and Swanson (1997:36) are of the opinion that “…. many economic series appear to be modelled well as STUR processes, based on a forecasting analysis which compares four types of models: (i) random walk (with drift) processes; (ii) fixed parameter autoregressive processes; (iii) time-varying parameter models (using a Kalman filter for estimation); and (iv) STUR processes. In particular, STUR models perform well at multi-step ahead forecast horizons.” As to the statistical inference, since the standard unit root tests cannot easily distinguish between constant unit roots and stochastic unit roots, they propose to use an alternative test that has a null hypothesis of exact unit roots and an alternative of STUR.

In this paper we perceive the cross-country output differences as a STUR process. It is well known that standard unit root tests (Augmented Dickey-Fuller (ADF), and Phillips-Perron (PP)) suffer from power deficiency against alternatives of near or stochastic unit root processes and these tests often fail to reject the null of output divergence. When the output difference follows a STUR process, the output paths of two economies actually tend to converge. Therefore, if an exact unit root model for output differences is rejected in favour of a STUR model, the convergence hypothesis implied by the neoclassical growth theory is vindicated.

Let us define the cross-country output-difference as $x_t = (y_{it} - y_{jt})$ where $y_{i,t}$ is the log real per-capita GDP of country *i*. A nonzero mean or a unit root in x_t would imply nonconvergence. The nonconvergence hypothesis can be tested by using the ADF test, which considers an exact unit root as the null hypothesis and a less-than-one root as the alternative.

A variable (x_t) is said to follow a STUR process if:

$$x_t = \alpha_t x_{t-1} + \varepsilon_t \qquad (3)$$

where, $E(\alpha_t) = 1, \varepsilon_t :$ *iid* $N(0, \sigma_\varepsilon^2)$. If $\alpha_t = 1, \forall\, t \Rightarrow x_t :$ *an exact unit root*.

Since, $\psi_t = \varepsilon_t / \alpha_t x_{t-1}$ is relatively small, (3) can be re-written as $\log x_t = \log x_{t-1} + \beta_t + \psi_t = E(\beta_t) + \log x_{t-1} + [\beta_t - E(\beta_t) + \psi_t]$, where, $\beta_t = \log \alpha_t$. Therefore, the evolution of $\log x_t$ is equivalent to a random walk with a downward drift, namely, $\log x_t$ approaches $-\infty$ with a probability of unity. Equivalently, x_t converges to zero and the output-difference would disappear in the long run. Therefore, if $\alpha_t = 1$, i.e., $\beta_t = 0$, outputs diverge, but if α_t is stochastic with mean one, outputs converge.

Granger and Swanson (1997:40) are of the opinion that, "…. the properties of STUR processes are often markedly different from comparable properties of perfect unit root processes. Another characteristic of stochastic unit roots is that they are quite difficult to distinguish from perfect unit roots. This is not surprising given that evidence presented below indicates that variances of stochastic unit roots are often quite small. In this sense the usual power failures associated with unit root tests should apply." Given the complexity mentioned above, we resort to the STUR test developed by Leybourne *et al*. (1997). The null hypothesis of this test is an exact unit root while the alternative is a STUR.

Let, $\alpha_t : i.i.d(0,\omega^2)$ and $\varepsilon_t : i.i.d(\sigma_\varepsilon^2)$. Under the null $\omega^2 = 0$, x_t is an AR process with an exact unit root. Alternatively, if $\omega^2 > 0$, then x_t is a STUR process.

Leybourne *et al*. (1997) test statistic for the STUR test is derived by running the following equation and saving the residuals ε_t.

$$\Delta x_t = \beta + \gamma t + \sum_{i=1}^{p} \phi_i \Delta x_{t-i} + \varepsilon_t \tag{4}$$

The test statistic is given by:

$$\hat{H}_T = T^{-3/2} \sigma_\varepsilon^{-2} \kappa^{-1} \sum_{t=p+3}^{T} (\sum_{j=p+2}^{t-1} \hat{\varepsilon}_j)^2 (\hat{\varepsilon}_t^2 - \sigma_\varepsilon^2) \tag{5}$$

where ε_t is the residual from the regression of Δx_t on a constant, a trend and p lags of ε_t, $\hat{\sigma}_\varepsilon^2 = \frac{1}{T}\sum_{t=1}^{T} \hat{\varepsilon}_t^2$ *and* $\kappa^2 = \frac{1}{T}\sum_{t=1}^{T} (\hat{\varepsilon}_t^2 - \hat{\sigma}_\varepsilon^2)^2$. The critical values of this test for various sample sizes are reported in Table A3 of the Appendix.

Results

The data are annual log real per capita GDP (base year = 2000) PPP adjusted dollars for 11 countries from 1960 to 2004. The data is extracted from Penn World Table (version 6.2). We have used Eviews 5.1 software for econometric analyses. However, the STUR statistic was calculated by writing a separate programme. In testing for cross-country output convergence, we use the output-differences between (1) Japan and the other 10 countries and (2) Australia and the other 10 countries, a total of 20 country-pairs[3]. We have conducted the ADF, PP and STUR tests. The results are summarised in Tables 2 and 3. These calculated values are to be compared to the critical values given in Tables A2 and A3 in the Appendix.

Table 2 Unit Root Tests for Log Per-Capita Output Differences
(Japan as leader)

Countries	ADF		PP		STUR	
	C	C &T	C	C &T	Lag 2	Lag 4
Jap-Aus	-2.49	-0.52	-4.00*	-1.04	0.15	0.16
Jap-HK	-0.41	-1.88	-0.41	-2.07	0.03	-0.03
Jap-Ind	-1.29	-3.02	-1.33	3.23**	-0.88	0.06
Jap-Kor	1.33	-3.39***	0.70	-4.20*	-0.03	-0.01
Jap-Mal	0.23	-3.12	0.87	-3.00	-0.05	0.15
Jap-NZ	-4.16*	-0.45	-3.48**	-0.59	0.32**	0.32**
Jap-Phi	-2.94**	-0.11	-4.07*	-1.52	-0.12	-0.11
Jap-Sin	0.06	-3.81**	-0.44	-3.69*	-0.14	-0.05
Jap-Tai	-0.66	-2.18	-0.69	-2.59	0.05	0.28**
Jap-Tha	1.02	-2.60	0.72	-3.31***	-0.11	0.12

Note:
i) C = constant only, C & T = constant and trend.
ii) *, ** & *** imply significant at 1%, 5% and 10% level.
iii) Critical values for ADF, PP and STUR tests are given in Tables A2 & A3 in the Appendix.

On the basis of Table 2 we can conclude that the output differences of the country pairs are nonstationary on the basis of ADF and PP tests. Because of power deficiency of ADF and PP tests which fail to distinguish between exact (deterministic) and stochastic unit roots, we have performed the STUR test following the methodology developed by Leybourne *et al.* (1997). Similar results are also observed from STUR statistic, which confirm that the output differences follow an exact unit root process except for Japan-New Zealand and Japan-Taiwan. These results suggest that New Zealand and Taiwan's per capita RGDP are converging to the per capita real GDP of Japan over the sample period.

In Table 3 we examined the same for all sample countries under study by considering Australia as a reference country. Overall we found that none of the ten countries' per capita income is converging with that of Australia. However, we found convergence for Australia-Japan and Australia-Hong Kong pairs on the basis of the PP test.

Table 3 Unit Root Tests for Log Per Capita Output Differences
(Australia as leader)

Countries	ADF		PP		STUR	
	C	C &T	C	C &T	Lag 2	Lag 4
Aus-Jap	-2.49	-0.52	-4.00*	-1.04	0.15	0.16
Aus-HK	-3.24	0.37	-3.00**	0.34	0.21	-0.14
Aus-Ind	-1.03	-0.50	-0.89	-1.38	-0.21	-0.07
Aus-Kor	-1.02	-0.29	-0.94	-0.80	0.01	0.07
Aus-Mal	-0.24	-2.40	-0.34	-2.69	-0.27	0.10
Aus-NZ	-1.40	-2.43	-1.35	-2.23	0.06	0.10
Aus-Phi	-1.09	-2.12	-1.11	-2.12	-0.05	-0.05
Aus-Sin	-1.21	-0.36	-1.16	-0.84	-0.07	-0.06
Aus-Tai	-1.28	-1.86	-1.20	-1.44	-0.09	-0.01
Aus-Tha	-1.97	1.75	-2.37	3.26	-0.06	-0.02

Note:
i) C = constant only, C & T = constant and trend.
ii) *, ** & *** imply significant at 1%, 5% and 10% level.
iii) Critical values for ADF, PP and STUR tests are given in Tables A2 & A3 in the Appendix.

IV Conclusion

In this paper we have examined time series cross-country output convergence in eleven counties of East Asia and the Pacific by employing a flexible concept of unit roots. Specifically, we modelled the cross-country output differences as a STUR process *a la* Granger and Swanson (1997). Granger and Swanson (1997) proposed a class of nonlinear processes (having a root that is not constant) which have a stochastic root varying around unity. The properties of STUR processes are often markedly different from comparable properties of exact unit root processes. Thus, the STUR process is stationary for some periods, and mildly explosive for others. STUR commonly occur in economic theory as well as in everyday macroeconomic applications. Hence, many economic series are better modelled as STUR processes because of their superior performance in terms of forecasting.

The presence of an exact unit root in output differences implies nonconvergence while the presence of a stochastic unit root implies convergence. Using the output-differences between Japan (reference country) and the other 10 sampled countries; we find output convergence only for the Japan-New Zealand and Japan-Taiwan country-pairs. Alternatively, using the output-differences between Australia (reference country) and the other 10 sampled countries; we fail to find any evidence of convergence among the sampled countries.

---

[1] The Copeland Rule is an alternative measure of ranking where the Copeland score can be defined in the following manner. Compare country $i^* \in A$ with $i \in A$, $i \neq i^*$. If for a majority of characteristics i^* performs better than i, then i^* is awarded a score of +1. If for a majority of characteristics i performs better than i^*, i^* is given a score of -1. If there is a tie, i^* scores 0. The sum of all such scores gives the Copeland score of country i^*. The Copeland Rule allows us to rank countries according to their Copeland scores. The Copeland score is based on the absolute majority rule where the size of the majority plays no major role. The Copeland rule takes into account the number of characteristics by which a particular country out-performs another country.

[2] These include inflation rate; budgetary position as a ratio of GDP and current account balance as a ratio of GDP.

[3] We have considered Japan and Australia as alternative reference countries. Japan is the second largest economy in the world and for its enormous contribution to the Asian countries in terms of technology transfer and offshore production. On the other hand, Australia is an emerging economic power in the region in terms of economic performance as evidenced in Section II.

Appendix

Table A1: Detailed Calculation of Borda Score and Rank

1960

Country	*Borda Score*	*Rank*	*Percent*
Hong Kong	38	1	90%
New Zealand	38	1	90%
Singapore	36	3	80%
Australia	34	4	70%
Japan	31	5	60%
Philippines	29	6	50%
Taiwan	28	7	40%
Malaysia	26	8	30%
South Korea	24	9	20%
Thailand	23	10	10%
Indonesia	18	11	0%

1975

Country	*Borda Score*	*Rank*	*Percent*
New Zealand	42	1	100%
Singapore	35	2	90%
Australia	34	3	70%
Hong Kong	34	3	70%
South Korea	33	5	60%
Taiwan	32	6	50%
Malaysia	31	7	40%
Japan	28	8	30%
Philippines	26	9	20%
Thailand	18	10	10%
Indonesia	17	11	0%

1965

Country	*Borda Score*	*Rank*	*Percent*
New Zealand	43	1	100%
Hong Kong	35	2	90%
Australia	34	3	70%
Malaysia	34	3	70%
Singapore	33	5	60%
Philippines	30	6	40%
Taiwan	30	6	40%
Japan	29	8	30%
South Korea	27	9	20%
Indonesia	18	10	10%
Thailand	17	11	0%

1980

Country	*Borda Score*	*Rank*	*Percent*
New Zealand	39	1	100%
Hong Kong	38	2	90%
Australia	37	3	80%
Singapore	34	4	70%
Taiwan	33	5	60%
Malaysia	31	6	50%
Japan	30	7	40%
South Korea	29	8	30%
Philippines	26	9	20%
Thailand	18	10	10%
Indonesia	15	11	0%

1970

[4]*Country*	*Borda Score*	*Rank*	*Percent*
New Zealand	43	1	100%
Singapore	35	2	90%
Hong Kong	34	3	70%
Taiwan	34	3	70%
Australia	32	5	60%
South Korea	31	6	50%
Malaysia	29	7	40%
Japan	27	8	30%
Philippines	25	9	20%
Indonesia	20	10	0%
Thailand	20	10	0%

1985

Country	*Borda Score*	*Rank*	*Percent*
Australia	40	1	90%
New Zealand	40	1	90%
Hong Kong	37	3	80%
Singapore	33	4	70%
Japan	30	5	50%
South Korea	30	5	50%
Taiwan	29	7	40%
Malaysia	28	8	30%
Thailand	26	9	20%
Philippines	20	10	10%
Indonesia	17	11	0%

Table A1 continued

	1990				2000		
Country	*Borda Score*	*Rank*	*Percent*	*Country*	*Borda Score*	*Rank*	*Percent*
Hong Kong	43	1	100%	**Hong Kong**	42	1	90%
Singapore	35	2	90%	**Singapore**	42	1	90%
Australia	34	3	80%	**Australia**	35	3	80%
Malaysia	33	4	70%	**New Zealand**	33	4	70%
New Zealand	32	5	60%	**Taiwan**	30	5	60%
Taiwan	31	6	50%	**Japan**	29	6	50%
Japan	30	7	40%	**South Korea**	27	7	30%
Thailand	26	8	30%	**Thailand**	27	7	30%
Philippines	24	9	20%	**Malaysia**	25	9	10%
South Korea	23	10	10%	**Philippines**	25	9	10%
Indonesia	19	11	0%	**Indonesia**	18	11	0%

	1995				2004		
Country	*Borda Score*	*Rank*	*Percent*	*Country*	*Borda Score*	*Rank*	*Percent*
Hong Kong	43	1	100%	**Australia**	40	1	100%
Singapore	38	2	90%	**Hong Kong**	36	2	90%
Australia	32	3	80%	**Singapore**	35	3	80%
Malaysia	31	4	60%	**New Zealand**	33	4	70%
New Zealand	31	4	60%	**Japan**	31	5	50%
Taiwan	30	6	50%	**Taiwan**	31	5	50%
Japan	29	7	40%	**Thailand**	28	7	40%
Thailand	27	8	30%	**South Korea**	26	8	30%
Indonesia	23	9	0%	**Malaysia**	24	9	10%
South Korea	23	9	0%	**Philippines**	24	9	10%
Philippines	23	9	0%	**Indonesia**	22	11	0%

Table A2: Critical Values for ADF and PP Tests

Test Method	NO C	C	C and T
ADF: 1%	-2.62	-3.59	-4.19
ADF: 5%	-1.95	-2.93	-3.52
ADF: 10%	-1.61	-2.60	-3.19
PP: 1%	-2.62	-3.59	-4.19
PP: 5%	-1.95	-2.93	-3.52
PP: 10%	-1.61	-2.60	-3.19

Table A3: Critical Values for $\hat{H}_T$

T	10%	5%	1%
50	0.161	0.215	0.349
100	0.142	0.192	0.320
200	0.127	0.176	0.299
500	0.114	0.161	0.278
1000	0.104	0.149	0.261

Source: Table 1 Leybourne *et al*. (1997:441)

References

Abramovitz, M. 1986, "Catching Up, Forging Ahead and Falling Behind", *Journal of Economic History*, 46(2): 385-406.

Abramovitz, M. 1990, "The Catch-Up Factor in Postwar Economic Growth", *Economic Inquiry*, 28: 1-18.

Arrow, K. J., 1951, *Social Choice and Individual Values*, Cowles Foundation and Wiley, New York.

Arrow, K. J. and H. Raynaud, 1986, *Social Choice and Multicriterion Decision Making*, MIT Press, Cambridge, Ma.

Barro, R. and X. Sala-i-Martin, 1992, "Convergence", *Journal of Political Economy*, 100(2): 223-251.

Barro, R. and X. Sala-i-Martin, 1995, *Economic Growth*, McGraw-Hill, New York.

Baumol, W.J. 1986, "Productivity Growth, Convergence and Welfare: What the Long- Run Data Show?", *American Economic Review*, 76(5): 1072-1085.

Ben David, D., 1998, "Convergence Clubs and Subsistence Economies", *Journal of Development Economics,* 55: 155-171.

Bernard, Andrew and Steven N. Durlauf,1996, "Interpreting Tests of the Convergence Hypothesis", *Journal of Econometrics*,71: 161–173.

Bernard, Andrew and Steven N. Durlauf, 1995, "Convergence in International Output",*Journal of Applied Econometrics* 10: 97–108.

Carlino, G. A. and L. O. Mills, 1993, "Are the US Regional Incomes Converging? A Time Series Analysis", *Journal of Monetary Economics*, 32: 335–346.

Chatterji, M., 1992, "Convergence Clubs and Endogenous Growth", *Oxford Economic Review Policy,* 8: 57-69.

Chowdhury, K., 2005a, "What's Happening to Per Capita GDP in the ASEAN Countries? *Applied Econometrics and International Development,* Vol. 5, No. 3: 49-68.

Chowdhury, K., 2005b, "Convergence of Per Capita GDP in South Asia". *International Journal of Applied Business and Economic Research*, Vol. 3, No. 2: 133-150.

Chowdhury, K., 2003 "Empirics for World Income Distribution: What Does the World Bank Data Reveal?" *The Journal of Developing Areas*, 36(2): 59-83.

Dasgupta, A. K. 1994, "Measuring Relative Economic Performance, An Ordinal Approach", Department of Economics Seminar, University of Wollongong, Wollongong, NSW.

De la Fuente, A., 1997, "The Empirics of Growth and Convergence: A Selective Review", *Journal of Economic Dynamics and Control*, 21: 23-73.

Deininger, K. and L. Squire, 1996, "A New Data Set Measuring Income Inequality", *World Bank Economic Review*, Vol. 10, No. 3: 565-591.

Dowrick, S. and D.T. Nguyen, 1989, "OECD Comparative Economic Growth 1950-1985: Catch-Up and Convergence", *American Economic Review,* 79(5): 1010-1030.

Dowrick, S. and J. Quiggin, 1994, "International Comparisons of Living Standards and Tastes: A Revealed Preference Analysis", *American Economic Review,* 84 (1): 332-341.

Dowrick, S. and J. Quiggin, 1997, "True Measures of GDP and Convergence", *American Economic Review,* 87: 41-64.

Ludlow, J. and W. Enders, 2000, "Estimating Nonlinear ARMA Models Using Fourier Coefficients", *International Journal of Forecasting*, 16: 333–47.

Evans, P. 1996, “Using Cross-country Variances to Evaluate Growth Theories”, *Journal of Economic Dynamics and Control*, 20: 1027–1049.
Evans, P. and G. Karras, 1996, “Convergence Revisited”, *Journal of Monetary Economics* 37: 249–265.
Fishburn, P. C., 1984, “Discrete Mathematics in Voting and Group Choice”, *SIAM Journal of Algebraic and Discrete Methods*, 5, 263-275.
Galor, O., 1996, “Convergence? Inferences from Theoretical Models”, *Economic Journal,* 106: 1056-1069.
Granger, C. W. J. and N. R. Swanson, 1997, “An Introduction to Stochastic Unit-root Processes”, *Journal of Econometrics*, 80: 35–62.
Heston, A., R. Summers, and B. Aten, 2006, *Penn World Table Version 6.2*, Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania.
Islam, N. 2003, “What Have We Learnt From The Convergence Debate? *Journal of Economic Surveys,* Vol. 17(3), 309-362.
Leybourne, S. J., B. P. M.McCabe, and A. R. Tremayne, 1996, “Can Economic Time Series be Differenced to Stationarity?”, J*ournal of Business and Economic Statistics*, 14: 435–46.
Levy-Livermore, A. and K. Chowdhury, 1998, “Trends in Intercountry Income Differences: World Levels and Decomposition Between and Within Regions”, in A. Levy-Livermore (ed.) *The Globalization of the World Economy*, Edward Elgar, Cheltenham, UK.
Levy, A. and K. Chowdhury, 1995, "A Geographical Decomposition of Inter-country Income Inequality" *Comparative Economic Studies,* 37(4): 1-17.
Maddison, A., 1987, "Growth and Slowdown in Advanced Capitalist Economies: Techniques of Quantitative Assessment", *Journal of Economic Literature*, 25: 649-698.
Maddison, A., 1991, *Dynamic Forces in Capitalist Development: A Long Run Comparative View*, Oxford University Press, New York.
Mankiw, N.G., D. Romer and D.N. Weil, 1992, "A Contribution to the Empirics of Economic Growth", *The Quarterly Journal of Economics*, 107: 407-437.
Nuxoll, D.A., 1994, “Differences in Relative Prices and International Differences in Growth Rates” *American Economic Review,* 84 (5): 1423-1436.
Perotti, R., 1994, “Income Distribution, Politics and Growth”, *American Economic Review*, 84:311-316.
Persson, T. and G. Tabellini, 1994, “Is Inequality Harmful for Growth?” *American Economic Review*, 84:600-621.
Li, Q. and D. Papell, 1999, “Convergence of International Output: Time Series Evidence for 16 OECD Countries”, *International Review of Economics and Finance*, 8: 267–80.
Quah, D., 1997, “Empirics for Growth and Distribution: Stratification, Polarization, and Convergence Clubs”, *Journal of Economic Growth*, 2: 27-59.
Quah, D., 1996, “Empirics for Economic Growth and Convergence”, *European Economic Review*, 40: 1353-1375.
Rassekh, F., 1998, “The Convergence Hypothesis: History, Theory and Evidence”, *Open Economies Review*, 9: 85-105.
Romer, P.M., 1986, "Increasing Returns and Long-Run Growth," *Journal of Political Economy*, 94: 1002-1037.
Sala-i-Martin, X., 1996, "The Classical Approach to Convergence Analysis," *The Economic Journal*, 106: 1019-1036.

Temple, J., 1999, “The New Growth Evidence”, *Journal of Economic Literature,* XXXVII (1): 112-156.
Zind, R.G., 1991, "Income Convergence and Divergence Within and Between LDC Groups", *World Development*, 19(6): 119-146.