Income convergence? Evidence of non-linearity in the East Asian Economies: A comment

Venus Khim-Sen Liew and Yusuf Ahmad

March 2006

Title: Income convergence? Evidence of Non-linearity in the East Asian Economies: A Comment[ψ]

Authors: Venus Khim-Sen Liew[a*] and Yusuf Ahmad[b]

Institutional Affiliations:

[a]*Labuan International Campus,*
Universiti Malaysia Sabah,
P.O.Box 80594,
87015 Labuan, Malaysia.

[b]*East Asia: Poverty Reduction and Economic Management Division,*
the World Bank,
1818 H Street, N.W.,
Washington,
DC 20433 U.S.A

Abstract:

This study demonstrates the usefulness of Kapetanois et al. (2003) test in differentiating the two stages of income convergence—long run convergence and catching up. A re-examination of the "Four Asian Dragons" economies, in which their income differentials with respect to Japan have been identified as non-linear stationary in Liew and Lim (2005), reveals that the economy of Hong Kong, Korea and Singapore are catching up, while Taiwan has yet to catch up, with the Japan economy.

JEL Classifications: C32, F43, O40

Key Words: long run convergence, catching up, non-linear, stationary tests, income differentials.

[ψ] We, not our institutions, are responsible for the views expressed in this paper.

[*] Corresponding author. Address: Labuan International Campus, Universiti Malaysia Sabah, P.O.Box 80594, 87015 Labuan, Malaysia. Telephone: +6087466716. Fax: +6087460477. E-mail: venusliew@yahoo.com.

Income convergence? Evidence of Non-linearity in the East Asian Economies: A Comment

1. Introduction

The income convergence hypothesis states that despite the differences in initial income, poorer and richer economies may eventually converge in term of economic growth rate. The validity of this hypothesis may be studied via, among others, subjecting the time series of income differential between poorer and richer economies to stationary test (see for instance, Bernard and Durlauf 1995). In this respect, a stationary income differential is taken as evidence of income convergence between the two contrasting economies. This interesting issue of income convergence has drawn the attention of many empirical researchers and policy-makers. Nonetheless, income convergence hypothesis has previously been scrutinized using linear testing framework in the literature and effort from non-linear perspective is little.

The work of Liew and Lim (2005), which breaks through the linear testing environment, demonstrate that, in sharp contrast to the non-linear approach, the linear (Augmented Dickey-Fuller) stationary test was incapable of detecting any income divergence between Japan and all other East-Asian economies under studies. Remarkably, the authors detected the presence of non-linearity in the income differentials of Japan and the rest of East-Asian economies based on formal linearity test procedure of Luukkonen, Saikkonen and Teräsvirta (1988). They further adopted the recently developed non-linear stationary test of Kapetanois, Shin and Snell (2003)

(known as KSS test hereafter) and found that the "Four Asian Tigers— Indonesia, Malaysia, Thailand and the Philippines"—exhibit divergence behaviour with respect to Japan's income, as oppose to the "Four Asian Dragons"—Hong Kong, Korea, Taiwan and Singapore—which show otherwise.

The findings of Liew and Lim (2005) warrant us that neglecting the plausible non-linearity in the study of income convergence may lead one to unreliable conclusions. Consequently, it is important to include formal linearity and non-linear stationary testing procedures in future research. In line with this new direction of research, the current paper intends to point out that although the non-linear stationary test adopted in Liew and Lim (2005) is very useful to detect income divergence behaviour, important information is overlook while processing the time series to be tested. Specifically, upon revealing that an income differential of two contrasting economies is non-linear stationary, one may at most conclude that the two economies do not diverge in terms of income. It is impossible to identify from the KSS test results alone on whether the two economies are in the process of converging (or the so-called catching up) or have already achieved long run convergence.

2. Income Divergence, Long Run Convergence and Catching Up

There are two stages of income convergence: First, long run convergence, which refers to the attainment of long-run steady-state equilibrium in the income differential; and second, catching up, the situation whereby narrowing of income gap

between two contrasting economies is observed over time but the convergence process is yet to be completed (Oxley and Greasley 1995). Time series (linear) tests enable one to distinguish between long run convergence—the income differential is stationary in level—and catching up—the income differential is stationary in trend. Thus by adopting the linear augmented Dickey-Fuller stationary test with constant and trend, the following conclusion may be drawn:

(1) Income divergence: If the null hypothesis of non-stationary cannot be rejected.

(2) Long run convergence: Given the null hypothesis of non-stationary has been rejected and the trend term is statistically insignificant.

(3) Catching up: Given the null hypothesis of non-stationary has been rejected with statistically significant trend term.

In this respect, the non-linear stationary test procedures of Kapetanois, Shin and Snell (2003), although has been shown (Liew and Lim 2005 and elsewhere) to be more robust than conventional Dickey-Fuller test in the presence of non-linearity, it makes no conclusion on long run convergence or catching up. In essence, KSS test requires one to de-mean or de-mean and de-trend, whichever applicable, the time series (income differential in this case) before subjecting it to the stationary test. Hence, to retrieve the missing information in the treated series, this paper proposes to perform a joint analysis of KSS test results together with the results of the least square (OLS) regression of running the income differential on a constant and trend term—which

has been done merely to obtain the de-meaned and de-trended income differential, and not for interpretation of regression results previously. By doing so, it is suggested that the following conclusion may be drawn:

(1) Income divergence: If the null hypothesis of non-stationary cannot be rejected.

(2) Long run convergence: If the trend term from the OLS result is statistically insignificant, and the rejection of null hypothesis of non-stationary by the KSS test.

(3) Catching up: If the trend term from the OLS result is statistically significant, and the rejection of null hypothesis of non-stationary by the KSS test.

In light of this, the current paper presents addition empirical evidence on the four economies of interest, that is, Hong Kong, Korea, Taiwan and Singapore, in which the null hypothesis of non-stationary has been rejected in favour non-linear stationary, in Liew and Lim (2005).

3. Additional Empirical Evidence

In Liew and Lim (2005), the income differentials under tested has been de-meaned and de-trended using the OLS procedure of regressing each income differential on a constant and linear trend terms. The OLS results for the same sample period 1960 to 1997 is retrieved in the current work and reported in Table 1.

Table 1: OLS Estimators (Linear Trend)

Economies	Constant (a)		Coefficient of t (b)	
	$\hat{a}$	CI	$\hat{b}$	CI
Hong Kong	-0.571	(-0.650, -0.549)	0.018	(0.016, 0.020)
Korea	-1.501	(-1.629, -1.462}	0.023	(0.019, 0.028)
Singapore	-0.701	(-0.763, -0.673)	0.022	(0.020, 0.025)
Taiwan	-1.437	(-1.533, -1.409)	0.025	(0.022, 0.027)

Notes: OLS model: $(\ln Y_{it} - \ln Y_{At}) = a + bt + \varepsilon_t$, where Y_{At} and Y_{it} are, respectively, the real per capital gross domestic product of Japan and individual country under study. t refers to the time measured in 1, 2, ..., 38 accordingly for the years 1960, 1961, …., 1997. $\hat{a}$ and $\hat{b}$ are the OLS estimators of a and b respectively. CI refers to the Bootstrapped 5% Confidence Intervals.

It is observed in Table 1 that all the estimated constants are significantly negative in sign, as the bootstrapped 5% confidence intervals only contain negative values. This implies that, on average, the individual economies involved have smaller income than Japan, the benchmark economy in the region. More importantly, all the estimated coefficients are significantly positive in sign, as the bootstrapped confidence intervals contain only positive values. This reveals that as time passes, these income differentials are upward adjusting (towards zero differential). In other words, Table 1 suggests that the pair wise income gaps between Japan and the relevant individual economies are narrowing over time. These findings, taken together with the KSS results of Liew and Lim (2005), which is reproduced in Table 2 in this current paper, may now allow us to conclude that the economy of "Four Asian Dragons" of Hong Kong, Korea, Taiwan and Singapore are catching up with the Japan economy.

Table 2: KSS Test Results (Linear Trend)[#]

Economies	Mean and Linear Trend Removed	
	Optimum Lag, p	t-statistics
Hong Kong	10	-3.094[V]
Korea	12	-2.879[X]
Singapore	5	-2.992[V]
Taiwan	10	-2.853[X]

Notes: [#] Reproduced from Table 2 of Liew and Lim (2005). KSS test is performed by estimating the equation $\Delta(\ln Y_{it} - \ln Y_{At}) = \sum_{k=1}^{p} \beta_k \Delta(\ln Y_{it-k} - \ln Y_{At-k}) + \delta(\ln Y_{it-1} - \ln Y_{At-1})^3 + \nu_t$. Note that the income differentials involved here have been de-meaned and de-trended in advance. The null hypothesis of non-stationary ($\delta = 0$, implying divergence) is tested against the alternative hypothesis of non-linear stationary ($\delta < 0$, implying either catching up or long run convergence) using the reported t-statistics. Superscripts X and V denote significant at 10 and 5% respectively. The critical values for KSS test are -2.66, -2.93 and -3.48 respectively for 10, 5 and 1% significance level. See Liew and Lim (2005) for other details.

Notably, apart from linear trend, non-linear trend is also a common feature in most economic time series data. In light of this, the current paper also attempts to abstract the mean and the squares of trend (as proxy of non-linear trend) from the original income differentials of the four economies. The OLS results are summarized in Table 3.

Table 3: OLS Results (Non-linear Trend)

Economies	Constant (a)		Coefficient of t^2 (b)	
	$\hat{a}$	CI	$\hat{b} \times 10^{-3}$	CI ($\times 10^{-3}$)
Hong Kong	-0.454	(-0.492, -0.428)	0.454	(0.406, 0.499)
Korea	-1.370	(-1.430, -1.366)	0.616	(0.569, 0.665)
Singapore	-0.553	(-0.586, -0.515)	0.560	(0.510, 0.611)
Taiwan	-1.280	(-1.316, -1.265)	0.647	(0.607, 0.683)

Note: OLS model: $(\ln Y_{it} - \ln Y_{At}) = a + bt^2 + \varepsilon_t$, where Y_{At} and Y_{it} are, respectively, the real per capital gross domestic product of Japan and individual country under study. t refers to the time measured in 1, 2, ..., 38 accordingly for the years 1960, 1961, …., 1997. $\hat{a}$ and $\hat{b}$ are the OLS estimators of a and b respectively. CI refers to the bootstrapped 5% confidence intervals.

Similar to Table 1, the estimated constants are also significantly negative, where the coefficients of t^2 are significantly positive. Besides, it is obvious from the corresponding confidence intervals of $\hat{a}$ (the OLS estimator of the constant term) that the income differentials for all the four economies, on average, are significantly smaller in magnitude in the non-linear trend case as compared to the case of linear trend. Another interesting feature is that the upward-adjusting process (narrowing the income gap) is much slower in non-linear trend as compared to the linear trend, in the estimated sample period. This is observed from the fact that the $\hat{b}$ (the OLS estimator of the trend term) in Table 3 has smaller magnitude than those in Table 2[1]. Given these contrasting results and implications, it would be interesting to know whether the adjustment follows linear or non-linear fashion. To address this issue, the income differentials series are first plotted for preliminary examination. Figures 1 through 4 clearly illustrate that the income differential series in all cases are exhibit non-linear trend. To confirm this in-formal finding through graphical inspection, the coefficient of determination (R^2) and root mean square error (RMSE) criterion are considered. Table 4 depicts that the coefficient of determination (R^2) values of the OLS models with t^2 is always higher than those with t in all cases, indicating the better predictive power of the non-linear trend. However, the last inference may not be conclusive since it has been reported previously that the estimated models do not follow the OLS assumptions. As such, the in sample forecast errors are computed for model selection purpose. Based on the root mean square error

[1] For instance, in the year 1961, the adjustment in Taiwan is 0.0492 ($=0.0246\times 2$) in linear trend, as opposed to 0.0024 ($=0.0006\times 2^2$) in the non-linear trend. Similarly, in the year 1997, the adjustment in Taiwan is 0.9348 ($=0.0246\times 38$) in linear trend, as opposed to 0.8664 ($=0.0006\times 38^2$). However, it should be noted that the rate of adjustment in the linear trend is constant, whereas rate of adjustment in the non-linear fashion as proxy by t^2 is increasing at increasing (in plain language, the adjustment process is becoming faster and faster over time).

(RMSE) criterion, the non-linear model has out-performed the linear model in the sample period under study for all the four economies. All in all, it is suggested that our conclusion should be based on the non-linear rather than linear trend in these four economies. Subsequently, the KSS test needs to be re-estimated based on non-linear trend and the results are summarized in Table 5.

Figure 1: Income Differential: Hong Kong

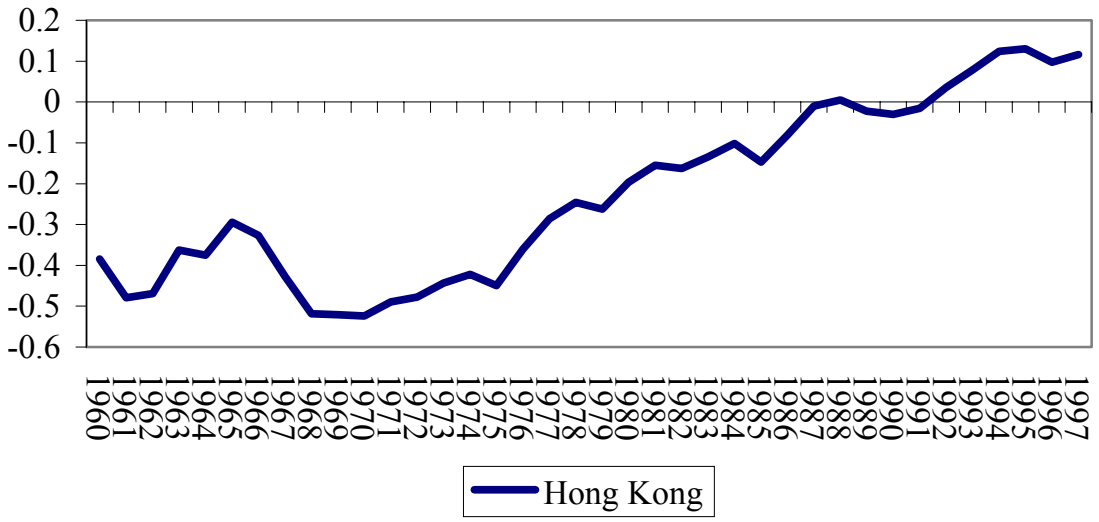

Figure 2: Income Differential: Korea

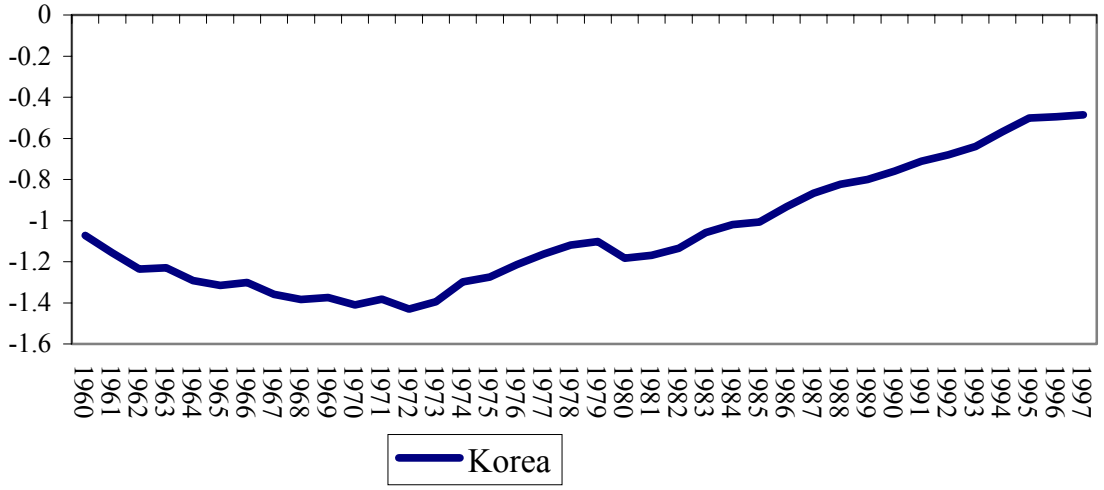

Figure 3: Income Differential: Taiwan

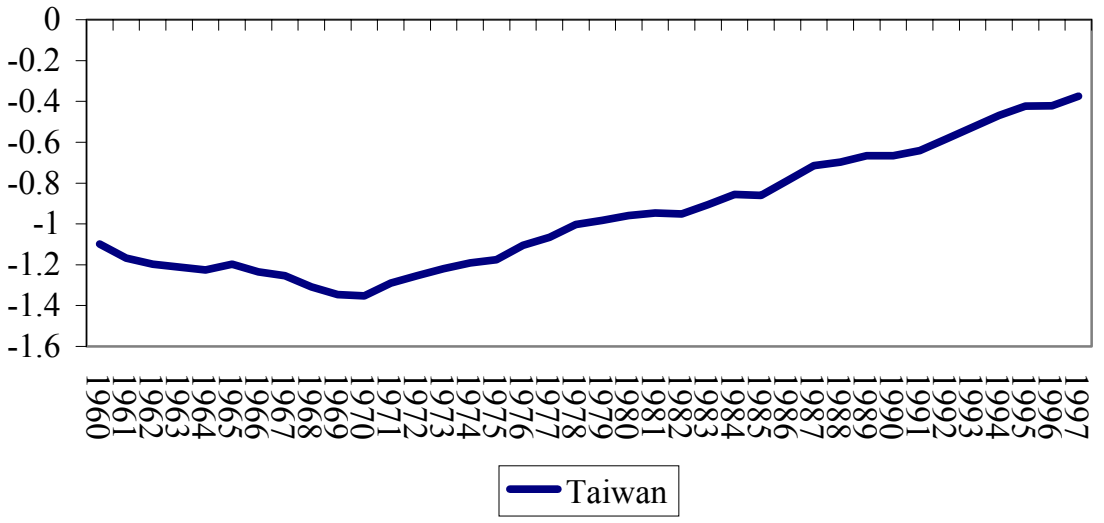

Figure 4: Income Differential: Singapore

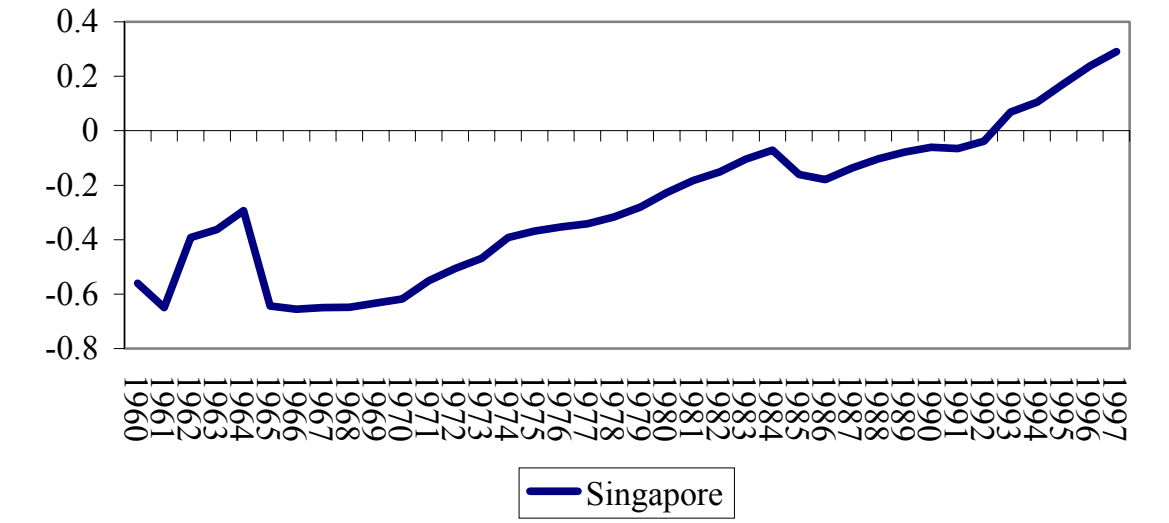

Table 4: Predictive Power of OLS Models

Economies	Linear Trend Model		Non-linear Trend Model	
	R^2	RMSE	R^2	RMSE
Hong Kong	0.834	0.834	0.892	0.070
Korea	0.747	0.747	0.902	0.090
Singapore	0.833	0.833	0.874	0.094
Taiwan	0.856	0.856	0.954	0.063

Table 5: KSS Test Results (Non-linear Trend)

Economies	Mean and Non-linear Trend Removed	
	Optimum Lag, p	t-statistics
Hong Kong	3	-2.860^{X}
Korea	1	-2.787^{X}
Singapore	4	-10.407^{I}
Taiwan	5	-2.016

Notes: Superscripts X and I denote significant at 10 and 1% respectively. The critical values for KSS test are -2.66, -2.93 and -3.48 respectively for 10, 5 and 1% significance level. Refer to notes to Table 2 for other details.

Table 5 shows that, in the case of Hong Kong, Korea and Singapore, the null of non-stationary may be rejected at conventional level of significance in favour of stationary in the non-linear sense. These results, taken together with the significant non-linear trend as depicted in Table 3, enable us to conclude that these three economies are catching up with the Japan, and that the speed of adjustment to narrow the income gap is going on at a faster and faster rate over time. Therefore, it can be expected in the near future that these three economies will eventually converge with Japan in terms of income or output. On the other hand, the new KSS result reveals that income divergence behaviour is detected in the case of Taiwan, as the null of non-stationary cannot be rejected even at 10% level for her income differential. This is in sharp contrast with the previous result obtained from the linear trend. Nonetheless, this result need not be taken pessimistically as it has been shown in Table 3 that there exists an element of upward adjustment process in the income differential. Thus, there is reason to believe that eventually Taiwan will catch the train labeled 'catching up', which brings along the other three Asian Dragons, heading all the way to the entrance of 'income convergence' club.

4. Concluding Remarks

In an attempt to break through the conventional linear time series testing environment concerning the validation of income convergence hypothesis, Liew and Lim (2005) have demonstrated the usefulness of the non-linear stationary test developed by Kapetanois, Shin and Snell (2003) (denoted as KSS test) to detect income divergence. The current paper points out that KSS test alone does not differentiate the two levels of income convergence—long run converging and catching up. Rather, this task may be easily

performed by the linear stationary tests as such the Dickey-Fuller test. Nonetheless, linear test may not be useful in the presence of non-linearity in the income differentials. To empower the usefulness of KSS test in the study of income convergence, this paper suggests that the KSS test results should be interpreted together with the results of the OLS regression that serves the purpose of removing mean and trend. As such, failing to reject of the null hypothesis of non-stationary in the KSS test would mean income divergence. On the other hand, rejection of the null hypothesis in favour of non-linear stationary implies either catching up or long run convergence. To identify the two stages of convergence, the OLS results come into play. In particular, given the rejection of the null hypothesis of KSS test, significant trend in the OLS results implies catching up. Otherwise, long run convergence.

This paper re-examines the "Four Asian Dragons" economies, in which their income differentials with respect to Japan have been identified as non-linear stationary in Liew and Lim (2005). The major conclusion from the addition results of this paper is that, from output point of view, economy of Hong Kong, Korea and Singapore are catching up, while Taiwan has yet to catch up, with the Japan economy.

References

Bernard, A.B. and Durlauf, S.N. (1995). Convergence in International Output, *Journal of Applied Econometrics*, **10**, 97 – 108.

Kapetanios, G., Shin, Y and Snell, A. (2003). Testing for a Unit Root in the Nonlinear STAR Framework, *Journal of Econometrics*, **112**, 359–379.

Liew, V.K.S. and Lim, K.P. (2005). Income divergence? Evidence of Non-linearity in the East Asian Economies, *Economics Bulletin*, **15(1)**, 1–7.

Luukkonen, R., Saikkonen, P. and Teräsvirta, T. (1988). Testing Linearity against Smooth Transition Autoregressive Models, *Biometrika*, **75**, 491–499.

Oxley, L. and Greasley, D. (1995). A Time Series Perspective on Convergence: Australia, UK and USA since 1870, *The Economic Record*, **71**, 259–270.