E C O N O M I C S B U L L E T I N

Income Divergence? Evidence of Non−linearity in the East Asian Economies

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Abstract

This study examines the issue of income convergence in the East−Asian economies from the non−linear point of view. It is shown in this study that the income gaps between Japan and the rest of the East−Asian economies exhibit nonlinearities. It is further shown that after taking non−linearity into consideration, China, Indonesia, Malaysia, Thailand and the Philippines exhibit divergence behaviour with respect to Japan's income, whereas Hong Kong, Korea, Taiwan and Singapore show otherwise.

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1. Introduction

Income convergence, which refers to the narrowing of income differential among poorer and richer economies, may be investigated by the time-series stationary property of the differential series. Specifically, a finding of stationarity is taken as evidence of stable long-run co-movement between the two countries' incomes thereby implying income convergence over time. Otherwise, the result would be interpreted as income divergence (Bernard and Durlauf, 1996). One commonly employed stationary test in the testing of income convergence is the augmented Dickey-Fuller (*ADF*) test (Dickey and Fuller, 1979). It has been widely reported that empirical evidence based *ADF* test is generally in favor of income divergence (see for example, Li and Papell, 1999). Nonetheless, as Li and Papell (1999) and some other authors have empirically demonstrated, *ADF* test is biased towards the non-rejection of stationary thereby producing results that favor income divergence. In this respect, among others, Li and Papell (1999) are able to provide more evidence of convergence, after properly taken care of the structural breaks in their proposed stationary tests, in the OECD economies, as compare to the *ADF* counterparts.

The current study contributes to the existing literature of income convergence by looking at the same old issue from a new perspective — non-linear point of view. This attempt is motivated by the findings of Liew *et al*. (2003), who argue that linear testing procedure may fail in the non-linear context, and also Liew *et al*. (2004), who show empirically that non-linear stationary tests of Kapetanois *et al*. (2003) perform better than *ADF* in detecting stationarity in the presence of non-linearity. As such, this study examines the income convergence hypothesis the context of Japan and the rest of East-Asian economies in the non-linear perspective[1].

Distinguish from conventional testing procedures, we start our empirical investigation by first conducting a formal linearity test of Luukkonen *et al*. (1988). As the results of this test suggest the presence of non-linearity, we then apply the Kapetanois *et al*. (2003) non-linear test of stationarity.

2. Luukkonen *et al*. (1988) (*LST*) Linearity Test

This study adopts the Luukkonen *et al*. (1988) (*LST*) linearity test in our context to determine whether the logarithm differences of real per capita GDP between the two sample countries, $(\ln Y_{jt} - \ln Y_{At})$ exhibits linear or non-linear behaviour:

$$(\ln Y_{it} - \ln Y_{At}) = \alpha_0 + \sum_{j=0}^{2}\sum_{k=1}^{p}\alpha_{jk}(\ln Y_{it-k} - \ln Y_{At-k})(\ln Y_{it-k} - \ln Y_{At-k})^j + \alpha_3(\ln Y_{it-d} - \ln Y_{At-d})^3 + \omega_t \quad (1)$$

[1] Sample period of study covers 1960 to 1997. As is a common practice, income variable is proxy by real per capital gross domestic product, denominated in common currency, obtained from Penn World Table of Heston, Summers and Aten (2001).

where Y_{jt} is the GDP of individual country under investigation and Y_{At} is the GDP of Japan. α_0, α_{jk} ($j = 0, 1, 2$; $k = 1, \ldots, p$) and α_3 are parameters to be estimated and under the null hypothesis, ω_t is the stochastic error term with zero mean and constant variance assumption, p stands for the autoregressive lag length whereas d is called the delay parameter. Note that p and d have to be determined empirically based on sample data, see Liew *et al*. (2003) in this regard.

Under linearity, the null hypothesis of $\alpha_{2k} = \alpha_3 = 0$ for all k, implying the absence of non-linearity, against the alternative hypothesis of the existence of a type of non-linearity known as Smooth Transition Autoregressive (STAR) process, see Luukkonen *et al*. (1988) and Teräsvirta (1994) for other details. The F-type test statistic is employed to accomplish this test. The results of this *LST* linearity test are reported in Table 1.

3. Kapetanois et al. Non-linear Stationary (*KSS*) Tests

Applying to our context of study, Kapetanois *et al*. (2003) (*KSS*) non-linear stationary test, which enables us to detect the presence of non-stationarity against non-linear but globally stationary STAR process, can be represented by:

$$\Delta(\ln Y_{it} - \ln Y_{At}) = \delta(\ln Y_{it-1} - \ln Y_{At-1})^3 + \mu_t \qquad (2)$$

or

$$\Delta(\ln Y_{it} - \ln Y_{At}) = \sum_{k=1}^{p} \beta_k \Delta(\ln Y_{it-k} - \ln Y_{At-k}) + \delta(\ln Y_{it-1} - \ln Y_{At-1})^3 + \upsilon_t \qquad (3)$$

where μ_t and υ_t are stochastic error terms each with zero mean and constant variance assumption.

Specifications (2) and (3) correspond to the conventional Dickey-Fuller (DF) and augmented Dickey-Fuller (ADF) stationary tests with no intercept and trend terms in the non-linear framework. Results of simulation study show that these non-linear stationary tests produce are robust results if the data generating process of the series under study is in fact non-linear in nature (Kapetanois *et al*. 2003).

The null hypothesis of $H_0 : \delta = 0$ (divergence) against the alternative of $H_1 : \delta > 0$ (convergence) can be test using the t statistics. For the brevity of reporting, the t statistics estimated from Equations (2) and (3) are reported as t_{KSS1} and t_{KSS2} respectively in Table 2 for $p = 8$, as is practiced in Liew *et al*. (2004). However, as suggested in Kapetanois *et al*. (2003), we also conduct test of Equation (3) for $1 \le p \le 12$ and report the maximum test statistics as $\boldsymbol{t_{KSS3}}$. This measure is taken to make sure that the non-rejection of the null hypothesis of *KSS* test, is not due to the restrictive assumption of fixing $p = 8$ *in*

priori. All these *KSS* test statistics are to be compared with the same set of critical values simulated by the authors as conventional *t* critical values are no more applicable in this non-linear framework due to the asymptotically distribution of δ which has been proven non-normal. For comparison, results from *ADF* test will also be displayed in the same table.

4. Results and Discussions

From Table 1, it is observed that the null hypothesis of the absence of non-linearity in all cases has been rejected by the *F* statistics at less than 1% significance level. This finding suggests that the data generating process of income differentials between Japan and all other East-Asian economies under study cannot be taken as linear in nature. Hence, the conventional *ADF* test, — which do not account for non-linearity — is no doubt inappropriate to be employed to examine the issue of income convergence the context of Japan and all the rest of East-Asian economies.

Table 1
Results of LST Linearity Test

Country	*p*	*d*	*F*	*msv*	*Q*
China	1	12	21.138	0.001	0.137
Hong Kong	1	6	10.422	0.003	0.392
Indonesia	1	8	23.021	0.000	0.583
Korea	1	12	21.586	0.000	0.786
Malaysia	1	12	15.061	0.000	0.210
Taiwan	1	12	22.736	0.000	0.859
Thailand	1	9	19.474	0.000	0.802
The Philippines	1	6	6.018	0.028	0.751
Singapore	1	11	28.388	0.000	0.927

Notes: The marginal significance value of the *F* statistic is denoted as *msv*. Ljung-Box portmanteau statistic is applied to test for the presence of serial correlation up to 20 lags and its marginal significance value is denoted as *Q*. The optimal autoregressive lag length *p* is determined by inspecting the PACF of the series. The optimal delay parameter *d* is chosen from the one that minimizes the marginal significance value of the *F* test statistic.

By the t_{KSS1} test statistics as reported in Table 2, the null hypothesis of non-stationary cannot be rejected in all cases even at 10% level. Nonetheless, the Portmanteau Q statistics suggests that this test statistics should not be interpreted as the model's residuals are contaminated with serial autocorrelation in most cases. As for the t_{KSS2} test results, evidence of non-divergence is found in the case of Korea only. However, the results of t_{KSS3} test — which allows the computer programme to detect the optimal autoregressive lag *p* rather than fixing it in priori — reveal that Korea is not the only country in this region that has rejected the divergence null hypothesis, but there are also evidences in favour of income convergence from Hong Kong, Taiwan and Singapore. These findings

are in sharp contrast to the results of the *ADF* test, which suggest that all economies under study actually diverge with Japan in terms of income.

Table 2
Results of Stationary Tests

Country	Linear Test		Non-linear Tests					
	ADF(*p*)	*Q*	$t_{KSS1}(8)$	*Q*	$t_{KSS2}(8)$	*Q*	$t_{KSS3}(p)$	*Q*
China	–1.026(1)	0.995	0.015	0.005	–1.513	0.509	–1.942(12)	0.509
Hong Kong	–0.132(2)	0.420	–1.142	0.433	–1.835	0.435	–3.094(10)[b]	0.435
Indonesia	–1.364(1)	0.761	–0.139	0.000	–1.249	0.556	–2.212(12)	0.556
Korea	0.098(8)	0.843	–0.940	0.001	–2.703[a]	0.731	–2.879(12)[a]	0.731
Malaysia	–2.009(1)	0.847	–0.194	0.008	–0.805	0.905	–0.839(6)	0.983
Taiwan	–1.995(1)	0.760	–1.329	0.000	–2.488	0.996	–2.853(10)[a]	0.997
Thailand	–0.161(1)	0.970	–0.400	0.012	–0.557	0.997	–2.208(12)	0.997
The Philippines	0.399(6)	0.191	2.036	0.014	0.255	0.927	1.454(10)	0.927
Singapore	–1.097(1)	0.964	–1.553	0.857	–1.378	0.558	–2.992(5)[b]	0.558

Notes: *p* refers to the optimal autoregressive lag length of the implied test. For the *ADF* test, *p* is automatically determined by computer programme based on the minimum Akaike information criterion (*AIC*). As for the first and second *KSS* tests, *p*=8 is fixed in advance. In the third *KSS* test, *p* is chosen from the one that maximizes the test statistics. The 10%, 5% and 1% critical values for *ADF* test statistics are, respectively, –2.87, –3.23 and –3.69 (Mckinnon, 1996). As for *KSS* test, the corresponding critical values are –2.66, –2.93 and –3.48. Superscripts [a] and [b] denotes significant at 10 and 5 percent levels respectively. Portmanteau statistic is applied to test for the presence of serial correlation up to 20 lags and its marginal significance value denoted as *Q*.

Another finding worth pointing out is that most of the optimal lag lengths in the *KSS* test are larger than the fixed value of 8 as adopted in t_{KSS1} and t_{KSS2}. This warrants us that we may failed to detect stationarity in due to inadequate fixing of lag length as is the case of Hong Kong, Taiwan and Singapore.

Overall, the results of *ADF* test of stationary produce evidence in favour of income divergence between Japan and all other East-Asian economies under study. Nonetheless, based on a more robust stationary test, namely the *KSS* test, it is found that only China, Indonesia, Malaysia, Thailand and the Philippines exhibit divergence behaviour with respect to Japan's income, whereas Hong Kong, Korea, Taiwan and Singapore show otherwise[2].

[2] Hong Kong, Korea, Taiwan and Singapore are renowned as the "Four Asian Dragons", whereas Indonesia, Malaysia, Thailand and the Philippines are named the "Four Asian Tigers".

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