Income convergence: fresh evidence from the Nordic countries

Liew, Venus Khim-Sen and Ahmad, Yusuf

Universiti Malaysia Sabah

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VENUS KHIM-SEN LIEW
Labuan School of International Business and Finance, Universiti Malaysia Sabah, Jalan Sungai Pagar, 87000 Labuan F.T., Malaysia.
*E-mail: **venusliew@ums.edu.my***

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

Abstract
Using the recently developed linearity test and non-linear unit root test, this study shows that the income gaps of Finland, Norway and Sweden with respect to Denmark are non-linear but stationary with no significant trend effect, implying the Nordic countries have already attained steady state of income equality, a state beyond catching up as identified earlier in Oxley and Greasley (1999). This fresh evidence strengthens the finding of Nordic Convergence Club by these authors.

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1. INTRODUCTION

The two stages of income convergence—catching up (narrowing of income gap between two contrasting economies over time) and long run convergence (the steady state of no income gap)—may be identified via time series stationary tests, see Oxley and Greasley (1995, 1997, 1999). Specifically, the rejection of the null hypothesis in the stationary tests (Dickey-Fuller, Phillips-Perron, etc.) with significant (insignificant) trend implies catching up (long run convergence). Notably, previous studies are confined to linear testing frameworks. Lately, the findings of non-linearity in the income gaps in Liew and Lim (2005) alert us on the urgent need of attention in this area of study. They also demonstrated that linear augmented Dickey-Fuller (ADF) and non-linear (Kapetanois, Shin and Snell (2003) (hereafter KSS) tests results can be in sharp contrast, when non-linearity is present in the income gaps.

In the spirit of Liew and Lim (2005), the current paper intends to further explore the usefulness of KSS test in detecting the two stages of income convergence in the Nordic countries (Sweden, Denmark, Finland and Norway), in which evidence of a Nordic Convergence Club consisting of Sweden, Denmark and Finland but not Norway has been provided by Oxley and Greasley (1999).

The remainder of this paper is structured as follows: Section 2 discussed the method for the identification of long run convergence and catching up. Section 3 describes the

linearity test. Section 4 presents and interprets the estimated results. Concluding remarks are offered in the final section.

2. IDENTIFYING CATCHING UP AND LONG RUN CONVERGENCE

As usual, one can de-mean and de-trend a given income gap series, $y_t = \log Y_{pt} - \log Y_{rt}$ where Y_p and Y_r are the real per capital gross domestic products of the relatively poorer and richer economies respectively, by regressing y_t on a constant and a trend terms using the least squares (OLS) method to obtain:

$$\tilde{y}_t = y_t - \hat{\alpha} - \hat{\beta}t \,, \tag{1}$$

where $\tilde{y}_t$ is the de-mean and de-trend y_t.

Following Liew and Lim (2005), $\tilde{y}_t$ may be subjected to the following KSS test:

$$\Delta\tilde{y}_t = \delta\tilde{y}_{t-1}^3 + \sum_{k=1}^{p}\theta_k\Delta\tilde{y}_{t-k} + e_t \,, \tag{2}$$

in which the maintain hypothesis is δ=0 (income divergence) and the alternative hypothesis is δ<0 (income convergence). Remarkably, decision is based on the $t-$statistic, which is not asymptotically distributed but empirical *p*-values may be bootstrapped.

This study attempts to show that given evidence of income convergence by the above KSS test, one can further classify it into long run convergence and catching up, thorough examining the OLS results in Eq. (1). Specifically, rejection of the maintain hypothesis of KSS test would imply long run convergence provided $\hat{\beta}$ is insignificantly different from zero, otherwise the result favors evidence of catching up.

3. TESTING FOR LINEARITY OF INCOME GAP SERIES

With the recent discovering of non-linearity in various economic data such as exchange rate, interest rate, consumer price index, stock price, balancing item, just to name some, upon the availability of advance econometric methods, and the evidence of malfunctioning of linear testing methods in the presence of non-linearity (Kapetanios *et al*., 2003; Liew *et al*. 2003, 2004; Liew and Lim, 2005), it is crucial to first determine whether the time series (income gap in this case) under study is linear or non-linear in nature prior to the application of stationary tests. This will reduce the risk of drawing irrelevant inferences from inappropriate empirical methods (Tang *et al*., forthcoming). In this context, Liew and Lim (2005) detected that the existence of non-linearity in Asian income gaps using the formal linearity test of Luukkonen, Saikkonen and Teräsvirta (1988) (hereafter LST):

$$y_t = \phi_0 + \left(\sum_{m=0}^{2} \sum_{n=1}^{k} \phi_{mn} y_{t-n} y_{t-d}^{m} \right) + \phi_3 y_{t-d}^{3} + \varepsilon_t \,, \tag{3}$$

in which the maintain hypothesis of linearity ($\phi_{2n} = \phi_3 = 0$ for all n) is tested against the alternative hypothesis of non-linearity using the *F*-type test statistic. Note that *k*, the optimal autoregressive lag length and *d*, the optimal delay lag length, have to be determined empirically based on sample data. In this study, $k \in \{1,...,4\}$ and $d \in \{1,...,4\}$ are chosen to optimize the *F*-test statistic.

4. DATA AND RESULTS

The data used are the annual real gross domestic products (GDP) per capital of Denmark, Finland, Sweden and Norway covering the period 1950 to 2000, which is available in the Penn World Data[†]. A plot of the data (in log) in Fig. 1 reveals that Denmark is the leader in this sample period of study in terms of GDP, with Sweden overtaking Denmark only from 1993 onwards. So, Denmark is considered as relatively richer than other individual Nordic countries in this study[‡].

[Insert Fig. 1 here]

Fig. 2. depicts that the income gaps of these countries with respect to Denmark cannot be characterized as linear in dynamic. Application of the LST formal linearity test, in which the results are depicted in Table 1, confirms the present of non-linearity in these series.

[†] Available at http://www.bized.ac.uk/dataserv/penndata/penn.htm. [Accessed on: 10 March 2006].
[‡] Based on the same principle, Sweden is regarded as leader of the Nordic countries in Oxley and Greasley (1999), which examine sample period from 1900 to 1987. Notably, long run convergence, catching up and divergence have been identified, respectively, in the case of Denmark, Finland and Norway as compared to Sweden in this study. This inclusion of all the three possibilities in the income convergence study makes Nordic countries an interesting avenue of study. In particular, the current study allows one to know the progress of these countries from the perspective of income convergence after some thirteen years had past.

[Insert Fig. 2 here]

[Insert Table 1 here]

With the evidence of non-linearity, KSS test instead of linear stationary testing procedures is applied in this study, as practiced in Liew and Lim (2005)[§]. Prior to the KSS test procedure, it is vital to remove mean and trend components from the income gaps. OLS regression is applied to serve this purpose and the results are summarized in Table 2. The negative constant values ($\hat{\alpha}$) as shown in Table 2 indicating that on average, these individual countries have lower GDP than Denmark. However, the bootstrapped *p*-values suggest that all these countries have no significant income gaps with Denmark[**]. Besides, bootstrapped *p*-values of the estimated coefficients of trend term ($\hat{\beta}$) also show that trend effect is not significant in any of these income gaps.

[Insert Table 2 here]

[§] Nonetheless, out of curiosity, few commonly applied linear tests are performed and the results may be summarized as follows: Augmented Dickey-Fuller and Phillip-Perron tests provide evidence of catching up in Sweden and income divergence in Finland and Norway. On the other hand, Kwiatkowski-Phillips-Schmidt-Shin test suggests catching up, whereas Ng and Perron test suggest income divergence in all cases. Remarkably, none of these results show any indication of long run convergence. For robustness, inference from this study should not be drawn from these linear tests results, however.

[**] All *p*-values in this study are computed from 4999 bootstrapped series.

The results of testing for the stationarity in the de-meaned and de-trended income gaps are depicted in Table 3. It is obvious from Table 3 that all income gaps are non-linear stationary by the bootstrapped *p*-values, implying evidence of are either long run convergence or catching up in these Nordic countries. Taking these results together with the earlier findings of non-significant trend effect in the income gaps series, it may now be concluded that long run convergence should be the case. This conclusion is in sharp contrast to the findings from linear tests as reported in Footnote 3, which fail to detect any evidence of long run convergence at all albeit the mixed results. There is no element of surprise here, however, as Liew and Lim (2005) have demonstrated the low power of linear stationary tests in non-linearity income gap series.

[Insert Table 3 here]

5. CONCLUDING REMARKS

The relevance of non-linear KSS stationary test of (Kapetanois, Shin and Snell (2003) in the study of income convergence have been illustrated in Liew and Lim (2005). The current study demonstrates that one may further differentiate the two stages of income convergence—long run convergence and catching up— based on KSS test in conjunction with OLS results. Particularly, rejection of the maintain hypothesis of income divergence by the KSS test would imply long run convergence provided the trend effect in the OLS equation is insignificantly different from zero, otherwise the result favors evidence of catching up. Nordic countries, whereby long run convergence, catching up and divergence have been respectively identified in the case of Denmark, Finland and

Norway as compared to Sweden, using carefully selected conventional stationary tests (Oxley and Greasley, 1999), are re-examined here. Results obtained show that: First, correspond to the finding of non-linearity in Asian countries (Liew and Lim, 2005), income gaps in the Nordic countries are also found to be non-linear in nature. Second, KSS test had detected evidence of long run convergence in all the income gaps under study, whereas the commonly applied stationary tests failed to do so.

It is noteworthy that besides further exploring the usefulness of KSS test, this study provides fresh evidence to the literature and has few major implications: First, linearity matters in the study of income convergence. In this circumstance, results from linear stationary tests make sense only for linear income gap series. Second, as implied by the first point, evidence of non-linearity in income gaps suggests that non-linear rather than linear tests should be applied in the study of income convergence. As a result, it is imperative to employ formal linearity test to examine whether the income gap of interest is linear or non-linear in nature. Last but not least, the fresh results from non-linear test and more recent data indicate that Nordic economies have gone beyond catching up such that they have already attained steady state of income equality. Thus, this study strengthens the finding of the Nordic Convergence Club as identified in Oxley and Greasley (1999).

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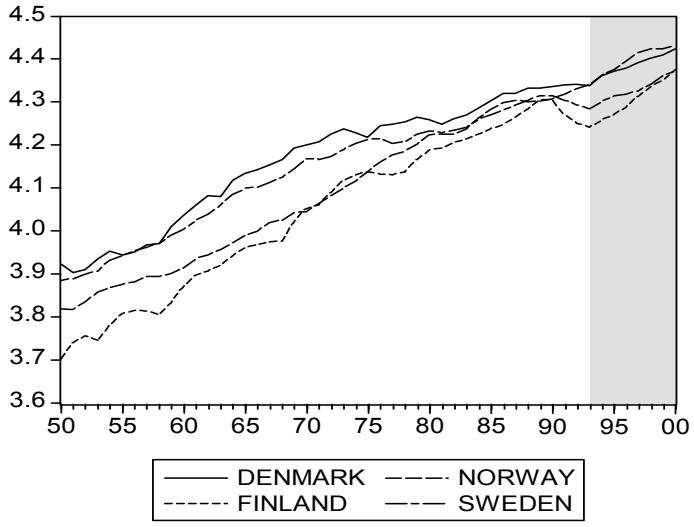

Fig. 1 *Logarithm of real GDP per capital for Nordic Countries*

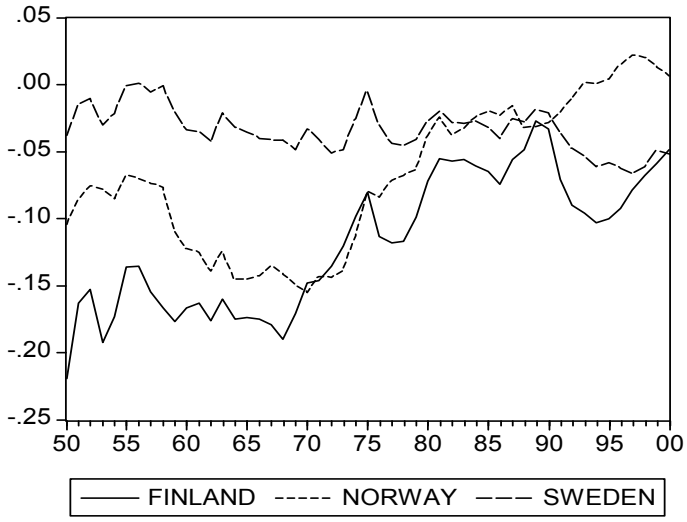

Fig. 2 *Income gaps for Finland, Norway and Sweden with respect to Denmark*

Table 1. *Linearity test results*

Country	k	d	F-statistics [p-value]
Finland	1	1	11.0375 [0.0018]*
Norway	1	4	5.7216 [0.0209]**
Sweden	1	3	7.6916 [0.0798]***

Note: Asterisks (*,**,***) denote rejection of the maintain hypothesis in favor evidence of non-linearity at 1, 5 and 10% significance level respectively.

Table 2. *OLS regression results*

Country	$\hat{\alpha}$ [p-value]	$\hat{\beta}$ [p-value]
Finland	-0.4409 [0.3380]	0.0066 [0.7762]
Norway	-0.3263 [0.6512]	0.0065 [0.9806]
Sweden	-0.0406 [0.5320]	-0.0014 [0.9988]

Table 3. *KSS test results*

Country	Optimum lag	$t-$statistics [p-value]
Finland	1	-3.0766 [0.0024]*
Norway	3	-2.7549 [0.0017]*
Sweden	1	-4.3200 [0.0002]*

Note: Asterisk (*) denotes rejection of the maintain hypothesis of non-stationary (income divergence) at 1% significance level.