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A stochastic convergence analysis for selected East Asian and Pacific countries: A Fourier unit root test approach

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Abstract. *The main aim of this study is to analyze stochastic convergence dynamics for selected East Asian and Pacific countries over the period 1960–2010, using a recently introduced unit root test with a Fourier function capable of capturing unknown form for structural breaks. Our test results show that we cannot reject the stochastic convergence hypothesis for Australia, Fiji, Korea, Nepal, Pakistan, Philippines, and Thailand.*

Keywords: stochastic convergence, Fourier function, stationarity, East Asian countries, structural breaks.

JEL Classification: C12, O47.
REL Classification: 8E.

1. Introduction

Economic growth differentials among countries and determinants of long-run economic growth have been very important topics among economists and for economic growth theories. After they languished in the 1960s, economic growth theories flourished again in the late 1980s. The new approach, called endogenous growth theory, focused on models of the determination of long-run growth. On the other hand, the older approach, the neoclassical growth model, focused on the empirical implications for convergence across economies (Barro and Sala-i-Martin, 2004).

East Asian and Pacific countries such as Japan, Australia, New Zealand, Korea, Hong Kong, Malaysia, Singapore, Thailand, Indonesia, China, and India are strong engines of global growth with healthy economic development structures and characteristics thanks to appropriate economic policies, strong saving-investment structures, qualified human capital, high productivity, and technological progress. In this context, it is vital to analyze the dynamics of economic growth and convergence structures surrounding this region. Jin (2009) states that East Asian economies, which are highly dependent on international trade, were not only hit hard by the Asian financial crisis of 1997–1998 but also vulnerable to the worldwide high-tech crisis in 2001. Jin (2009) also claims that facing such economic crises caused many Asian governments to recognize the importance of education in sustaining high economic growth. In particular, education increases the number of competent workers, enables the creation of new technologies domestically, and facilitates the absorption of advanced technologies from overseas, and hence economies with more educated human capital grow faster than other countries. Genc, Miller and Rupasingha (2011) state that empirical techniques for convergence tests fall into four main categories. These categories include sigma convergence; beta convergence, which is divided into the two versions of absolute (unconditional) and conditional beta convergence; and finally stochastic convergence.

Barro and Sala-i-Martin (2004) explain that sigma (σ) convergence concerns the measure of cross-sectional dispersion. If the dispersion measured by the standard deviation of the logarithm of per capita income or product across a group of countries or regions declines over time, convergence occurs.

There are two versions of beta (β) convergence. First, absolute (unconditional) convergence applies if a poor economy – defined without the conditioning of any other economic characteristics – tends to grow faster than a rich one, so that the poor country tends to catch up to the rich country in terms of levels of per capita income or product. Conditional beta convergence occurs when all the economies do not share the same parameters, and therefore, differ in terms of their steady state positions. If the steady states are different, an economy grows faster the further it evolves from its own steady state.

The final category is stochastic convergence. Time-series methods are used to determine whether random shocks to a regional economy persist in time (see Genc, Miller et al. 2011: pp. 369-377; Campbell and Mankiw, 1989: pp. 319-333). To test the convergence hypothesis, time-series methodology plays an important role, especially in testing for conditional stochastic convergence. Kutan and Yiğit (2005) claim that conditional stochastic convergence, which does not require each country to converge to the same steady state, is applicable when per capita income disparities between countries follow a mean-stationary process, i.e., relative per capita income shocks lead only to transitory deviations from any tendency toward convergence. A cross section of regions meets the test of stochastic convergence if the region's deviation of per capita income or earnings relative to that of the nation is characterized by a non-zero mean stationary stochastic process. Time-series methods to test convergence have some advantages especially if heterogeneity exists across the economies.

In this study, we aim to analyze stochastic convergence dynamics for selected East Asian and Pacific countries using a Fourier unit root test approach for the period 1960-2010.

2. Econometric methodology

Since Perron's seminal paper (1989), which emphasized that ignoring structural breaks while using unit root tests can give biased results, numerous studies have introduced new unit root tests into the literature that take into consideration the effect of such breaks. But the number and form of structural breaks in these studies are given a priori. Unit root tests developed by Zivot and Andrews (1992) and Perron (1997) restrict the number of structural breaks to one, whereas Lumsdaine and Papell (1997) and Lee and Strazicich (2003) extend this number to two. In these studies, the form of the breaks is sharp. On the other hand, Kapetanios, Shin and Snell (2003) and Leybourne, Newbold and Vougas (1998) allow for smooth breaks. That is, generally the nature of structural breaks is not known a priori; using an incorrect specification regarding the number, form, or duration of structural breaks, however, can be problematic.[(1)]

Christopoulos and Leon-Ledesma (2011) develop a Fourier unit root test to circumvent such problems given that only a small number of low-frequency components from a Fourier approximation can capture the behavior of an unknown function (see Gallant, 1981: pp. 211-245; Becker, Enders et al., 2004: pp. 899-906; Becker, Enders et al., 2006: pp. 381-409). By using the Fourier unit root test, we do not need to specify the number, form, or duration of the breaks; the unknown number and form of breaks can be approximated.

The Fourier unit root test is comprised of three steps. For the first step, we estimate the following model:

$$y_t = \alpha_0 + \sum_{k=1}^{G} \alpha_1^k \sin\left(\frac{2\pi kt}{T}\right) + \sum_{k=1}^{G} \alpha_2^k \cos\left(\frac{2\pi kt}{T}\right) + v_t \tag{1}$$

Here k shows the number of frequencies, t is the trend term, T is sample size, π is 3.1416, and $v_t \sim N(0,\sigma)$. Ludlow and Enders (2000) showed that a single frequency in Equation 1 is enough to approximate the Fourier expansion, so Equation 1 can be rewritten as follows:

$$y_t = \alpha_0 + \alpha_1 \sin\left(\frac{2\pi kt}{T}\right) + \alpha_2 \cos\left(\frac{2\pi kt}{T}\right) + v_t \tag{2}$$

Because the value of k, representing appropriate frequency, is not generally known a priori, Equation 2 must be estimated using all frequencies in the interval $k = [0.1, 0.2, 0.3, ..., 4.8, 4.9, 5]$ and choosing the k that gives the minimum value of the Bayesian information criterion. The reason for considering fractional frequencies is that integer frequencies imply that the breaks are temporary, whereas fractional frequencies imply permanent breaks.

In the second step, we proceed to the unit root testing. Given Model 2, we can show the null hypothesis of the unit root as follows:

$$H_0 : v_t = \mu_t,\ \mu_t = \mu_{t-1} + h_t$$

Where h_t is assumed to be a stationary process, the mean of which is zero. Therefore, we can apply the unit root test by employing the OLS residuals obtained in Equation 2:

$$\Delta v_t = \beta_1 v_{t-1} + \sum_{j=1}^{p} \delta_j v_{t-j} + u_t \tag{3}$$

Where u_t is a white noise error term. It is clear that Equation 3 is a standard ADF regression, thus the null of unit root $H_0 : \beta_1 = 0$ is tested against the alternate $H_0 : \beta_1 \neq 0$ using the standard t-test. The necessary critical values are tabulated in Table 1 of Christopoulos and Leon-Ledesma (2011) for different values of *k*.

Only for the case where the null of the unit root is rejected can we proceed to the third step in which we test the significance of trigonometric terms. This condition is necessary because the F statistic used to test for the presence of trigonometric terms has low power if the data are nonstationary. The null hypothesis for testing the presence of trigonometric terms is $H_0 : \alpha_1 = \alpha_2 = 0$. Rejection of the null hypothesis shows that the variable under investigation is stationary around a nonlinear deterministic function. The critical values for the F-test are tabulated in Becker, Enders and Lee (2006).

3. Data and empirical results

To test the stochastic convergence hypothesis among Asia-Pacific countries we test the stationarity of **real gross domestic product per worker** to the ratio of the mean. We obtained data containing the series of Australia, Bangladesh, China, Fiji, Hong Kong, India, Indonesia, Japan, Korea, Malaysia, Nepal, New Zealand, Pakistan, Papua New Guinea, Philippines, Singapore, Sri Lanka, and Thailand from Penn World Table 6.3 over the 1960-2010 period.

We first choose the optimal frequency by estimating Equation 2 for all the possible fractional frequencies in the interval [0–5] using increments 0.1. The second column of Table 1 shows the optimal frequencies, and the third column shows the minimum Bayesian information criteria. For all countries, we find the frequency close to 1. We also present the time paths of the series with the Fourier approximations in the Appendix I. All the estimated Fourier functions seem to fit well the swings in the series.

Table 1. *Test Results of the Fourier Unit Root Test*

Country	k	minBIC	FADF	Fu(k)
Australia	0.2	-3.56	-4.02**	470.10*
Bangladesh	0.1	-3.41	-2.79	1224.06
China	0.4	-2.35	-3.31	1839.88
Fiji	0.4	-2.41	-3.81***	410.45*
Hong Kong	0.2	-2.64	-3.48	465.86
India	0.1	-2.96	-1.97	100.12
Indonesia	0.8	-2.11	-3.46	83.53
Japan	0.1	-3.20	-2.95	328.39
Korea	0.5	-3.81	-3.69***	2452.65*
Malaysia	0.3	-2.97	-3.58	361.41
Nepal	0.1	-3.68	-4.35**	540.20*
New Zealand	0.4	-3.13	-3.20	1207.69
Pakistan	0.1	-3.16	-3.77***	67.28*
Papua N. G.	0.6	-1.86	-2.91	276.21
Philippines	0.7	-2.42	-4.26**	353.05*
Singapore	0.3	-3.32	-3.54	776.83
Sri Lanka	0.3	-3.05	-3.39	266.81
Thailand	0.6	-2.49	-4.72*	330.13*

In the second step, we applied the unit root test using Equation 3 and presented the test results in the fourth column of the table. Because we can reject the null of the unit root for Australia, Fiji, Korea, Nepal, Pakistan, Philippines, and Thailand, we tested the presence of an unknown form for breaks using the F-test. The test results showed that the trigonometric terms are significant, and the series are stationary around a nonlinear deterministic function, which validates the convergence hypothesis for Australia, Fiji, Korea, Nepal, Pakistan, Philippines, and Thailand.

4. Conclusion

The main aim of this study is to analyze stochastic convergence dynamics for selected East Asian and Pacific countries over the period 1960–2010, using a recently introduced unit root test with a Fourier function capable of capturing unknown form for structural breaks. Our test results show we cannot reject the stochastic convergence hypothesis for Australia, Fiji, Korea, Nepal, Pakistan, Philippines, and Thailand. As a result, these countries follow their own steady-state path, and income disparities among these countries follow a mean-stationary process, i.e., relative per capita income shocks lead only to transitory deviations from any tendency toward convergence.

Note

(1) The procedures developed by Kapetanios (2005) and Lee, Strazicich and Meng (2012) allow the researcher to determine the number of breaks endogenously but the breaks are limited to the sharp form.

References

Barro, R.J. and Sala-i-Martin, X. (1992b). "Regional growth and migration: A Japan–united states comparison", *Journal of the Japanese and International Economies*, 6, pp. 312-346

Barro, R.J. and Sala-i-Martin, X. (1991). "Convergence across states and regions", *Brookings Papers on Economic Activity*", no. 1, pp. 107-182

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

Barro, R.J. and Sala-i-Martin, X. (2004). "Economic Growth", *The MIT Press*, Second Edition

Barro, R.J. (1991). "Economic growth in a cross section of countries", *Quarterly Journal of Economics*, 106, pp. 407-443

Baumol, William J. (1986). "Productivity growth, convergence, and welfare: What the long-run data show", *American Economic Review*, 76, pp. 1072-1085

Becker, R., Enders, W., Hurn, S. (2004). “A general test for time dependence in parameters”, *Journal of Applied Econometrics*, 19, pp. 899-906

Becker, R., Enders, W. and Lee, J. (2006). “A stationarity test in the presence of unknown number of smooth breaks”, *Journal of Time Series Analysis*, 27, pp. 381-409

Bernard, A.B. and Durlauf, S.N. (1995). “Convergence in international output”, *Journal of Applied Econometrics*, 10(2), pp. 97-108

Bernard, A.B. and Durlauf S.N. (1996). “Interpreting tests of the convergence hypothesis”, *Journal of Econometrics*, 71 (1-2), pp. 161-173

Campbell, J.Y. and Mankiw, N.G. (1989). “International evidence on the persistence of economic fluctuations”, *Journal of Monetary Economics*, 23(2), pp. 319-333

Carlino, G.A. and Mills, L. (1993). “Are us regional incomes converging? A time series analysis”, *Journal of Monetary Economics*, 32(2), pp. 335-346

Carlino, G.A. and Mills L. (1996a). “Testing neoclassical convergence in regional incomes and earnings”, *Regional Science and Urban Economics*, 26(6), pp. 565-590

Carlino, G.A. and Mills L. (1996b). “Convergence and the US states: A time series analysis”, *Journal of Regional Science*, 36(4), pp. 597-616

Christopoulos, D.K. and Leon-Ledesma, M.A. (2011). “International output convergence, breaks, and asymmetric adjustment”, *Studies in Nonlinear Dynamics & Econometrics*, 15(3), pp. 1-31

DeLong, J.B. (1988). “Productivity growth, convergence, and welfare: Comment”, *American Economic Review*, 78, pp. 1138-1154

Dixon, C. and Drakakis-Smith, D. (1995). “The Pacific Asian region: Myth or reality?”, *Geografiska Annaler. Series B, Human Geography*, 77(2), pp. 75-91

Drysdale, P. and Huang, Y. (1997). “Technological catch-up and economic growth in East Asia and the Pacific”, *Economic Record*, 73, pp. 201-211

Gallant, R. (1981). “On the bias in flexible functional form and an essentially unbiased form: the flexible fourier form”, *Journal of Econometrics*, 15 (2), pp. 211-245

Genc, I.H., Miller, J.R., Rupasingha, A. (2011). “Stochastic convergence tests for US regional per capita personal income; Some further evidence: A research note”, *The Annals of Regional Science*, 46(2), pp. 369-377

Han, G., Kalirajan, K. and Singh, N. (2002). “Productivity and economic growth in East Asia: Innovation, efficiency and accumulation”, *Japan and the World Economy*, 14(4), pp. 401-424

Jayanthakumaran, K. and Lee, S.W. (2013). “Evidence on the convergence of per capita income: a comparison of founder members of the association of South East Asian nations and the South Asian association of regional cooperation”, *Pacific Economic Review*, 18(1), pp. 108-121

Jin, J.C. (2009). “Economic research and economic growth: Evidence from East Asian economies”, *Journal of Asian Economics*, 20(2), pp. 150-155

Kang, M., Kim, H.H., Lee, H., and Lee, J. (2010). “Regional production networks, service offshoring, and productivity in East Asia”, *Japan and the World Economy*, 22(3), pp. 206-216

Kapetanios, G. (2005). “Unit root testing against the alternative hypothesis of up tom structural breaks”, *Journal of Time Series Analysis*, 26, pp. 37-49

Kapetanios, G., Shin, Y. and Snell, A. (2003). “Testing for a unit root in the nonlinear STAR framework”, *Journal of Econometrics*, 112(2), pp. 359-379

Kim, J., and Lau, L.J. (1996). “The sources of Asian Pacific economic growth”, *The Canadian Journal of Economics*, 29 (Special Issue: Part 2), pp. 448-454

Kutan, A.M. and Yigit, T.M. (2005). "Real and nominal stochastic convergence: Are the new EU members ready to join the euro zone?", *Journal of Comparative Economics*, 33(2), pp. 387-400

Kwon, J.K. and Kang, J.M. (2011). "The East Asian model of economic development", *Asian-Pacific Economic Literature*, 25(2), pp. 116-130

Lee, J. and Hong, K. (2012). "Economic growth in Asia: Determinants and prospects", *Japan and the World Economy*, 24(2), pp. 101-113

Lee, J. and Strazicich, M.C. (2003). "Minimum LM unit root test with two structural breaks", *Review of Economics and Statistics*, 63, pp. 1082-1089

Lee, J., Strazicich, M.C. and Meng, M. (2012). "Two-step LM unit root tests with trend breaks", *Journal of Statistical and Econometric Methods*, 1(2), pp. 81-107

Leybourne, S., Newbold, P., Vougas, D. (1998). "Unit roots and smooth transitions", *Journal of Time Series Analysis*, 19, pp. 83-97

Li, H. and Xu, Z. (2007). "Economic convergence in seven Asian economies", *Review of Development Economics*, 11(3), pp. 531-549

Lu, Shu-Shiuan (2012). "East Asian growth experience revisited from the perspective of a neoclassical model", *Review of Economic Dynamics*, 15(3), pp. 359-376

Ludlow, J. and Enders, W. (2000). "Estimating non-linear ARMA models using Fourier coefficients", *International Journal of Forecasting*, 16, pp. 333-347

Lumsdaine, R.L. and Papell, D.H. (1997). "Multiple trend breaks and the unit root hypothesis", *Review of Economics and Statistics*, 79 (2), pp. 212-218

Perron, P. (1989). "The great crash, the oil price shock, and the unit root hypothesis", *Econometrica*, 57, pp. 1361-1401

Perron, P. (1997). "Further evidence on breaking trend functions in macroeconomic variables", *Journal of Econometrics*, 80 (2), pp. 355-385

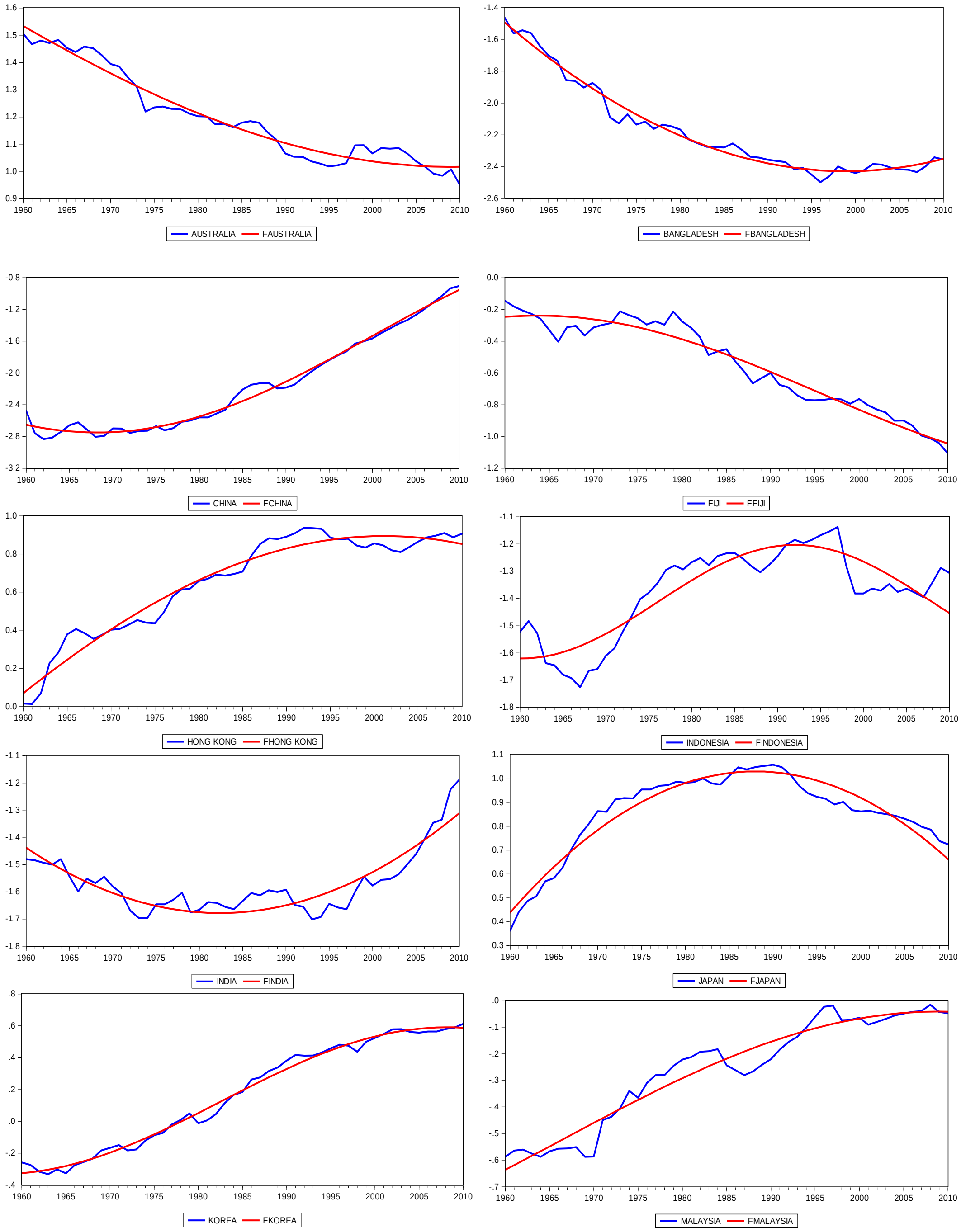
Perron, P. and Vogelsang, T.J. (1992). "Nonstationarity and level shifts with an application to purchasing power parity", *Journal of Business and Economic Statistics*, 10, pp. 301-320

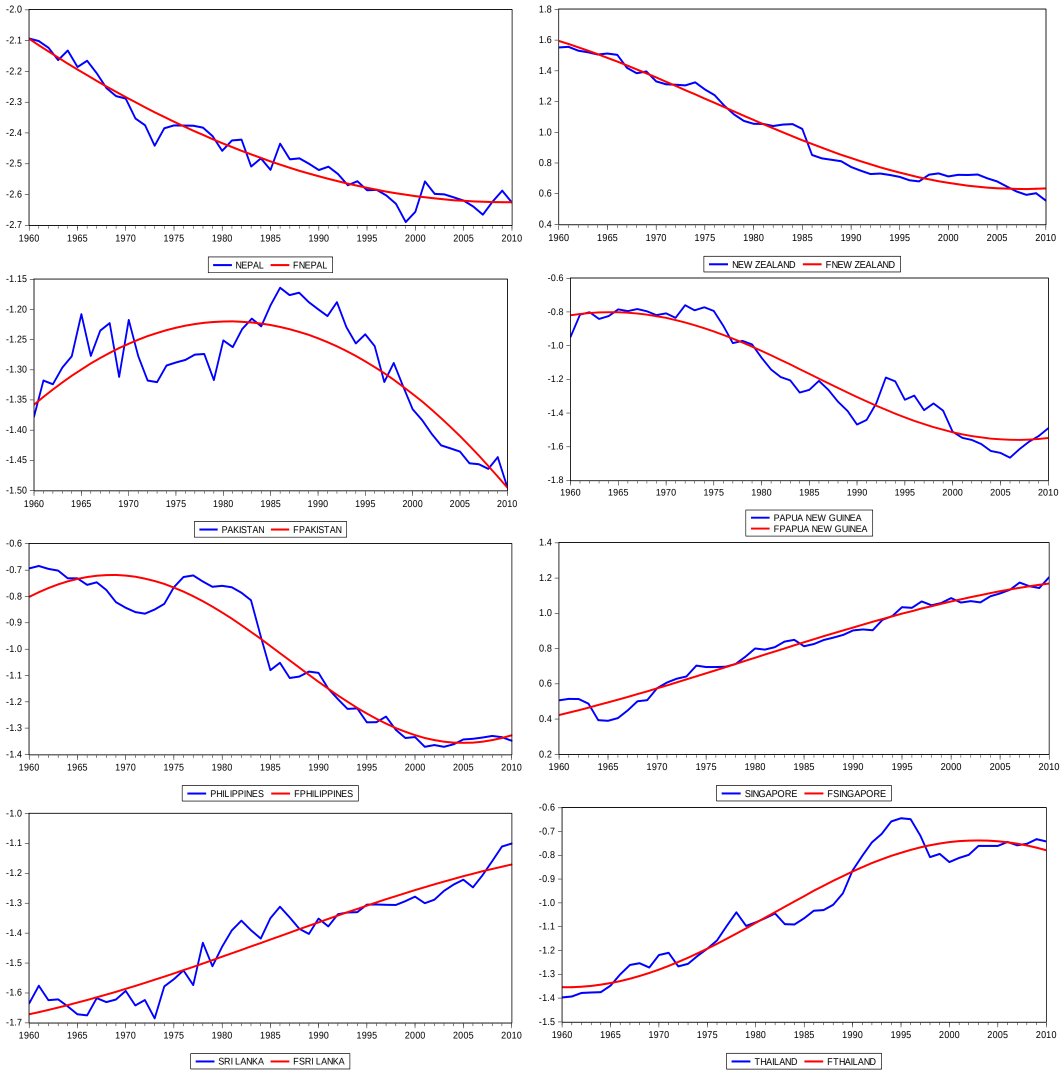
Sarwar, S., Siddiqi, M.W. and Butt, A.R. (2013). "Role of institutions and economic growth in Asian countries", *Developing Country Studies*, 3(2), pp. 80-90

Taylor, A.M. (1995). "Growth and convergence in the Asia-Pacific region: on the role of openness, trade and migration", *NBER Working Paper,* No. 5276, pp. 1-45

Zivot, E. and Andrews, K. (1992). "Further evidence on the great crash, the oil price shock, and the unit root hypothesis", *Journal of Business and Economic Statistics*, 10(10), pp. 251-270

Appendix I: Relative output and the Fourier functions

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