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Which Countries are Catching up? New Evidences Using Flexible Fourier Stationary Test

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Abstract

In this paper, we tested the catching up hypothesis toward USA using Becker et al. (2006) flexible Fourier KPSS stationary test over the period 1960-2009. The mentioned test could control for unknown number and form of structural breaks using a selected frequency component of a Fourier function. Our results show almost poor countries stay poor and almost rich countries stay rich. South Korea, Hong Kong, Singapore, Taiwan, India, Malaysia and China could escape lag deadlock and the countries like Central African Republic, Congo, Cote d`Ivoire, the Gambia, Guinea, Haiti, Kenya, Rwanda, and Senegal diverged from USA and moved into poverty trap.

Keywords: Convergence Hypothesis, Catching up Hypothesis, Time Series Model, Flexible Fourier Stationary Test.

1- Introduction

An important prediction of the neoclassical growth theory is "Income Convergence Hypothesis". It is defined as, the tendency of countries towards equalization over time in terms of per capita income. This theory predicts that the substitution possibility and the diminishing return for factors force the economy to converge to the equilibrium capital and income level (Islam, 2003).

In the empirical works on the convergence hypothesis, researchers have used different concepts of convergence such as absolute convergence, conditional convergence, and catching up hypothesis as well as different methodologies like cross-sectional approach, distribution approach, and time

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series approach. The absolute convergence refers to the notion that economies will converge toward the same per capita income in the long run steady state. In other words, according to the absolute convergence, poverty, at international level, will disappear by itself. The conditional convergence implies that the economies will converge to their own steady state. According to the conditional convergence, the differences between economies in terms of per capita income will not disappear even in the long run steady state.

The Cross-section and the time series approaches investigate absolute and conditional notions of the convergence hypothesis. In addition, through the use of the time series approach, researchers tested the catching up hypothesis (Loewy and Papell, 1996; Li and Papell, 1999; Strazicich, et al., 2004; Cunado and Gracia, 2006; King and Ramlogan, 2008). In the cross-sectional approach, the per capita income growth rate is regressed on initial per capita income and a negative (partial) or reverse correlation between two variables is interpreted as evidence of the absolute (conditional) convergence.

As noted by Islam (2003), the distribution approach focuses on the dispersion of the per capita income among countries. Sigma convergence is one version of the distribution approach which is calculated by the standard deviation. If the cross-country standard deviation of the per capita income decreases over time, it is indicative of the fact that sigma convergence exists.

The time series framework of the convergence hypothesis was introduced by Carlino and Mills (1993) and is usually examined by unit root or stationary tests. Hence, its empirical validity depends on advances in the econometrics of the unit root or stationary tests.

As noted by Cunado and Gracia (2006), when deterministic terms are not allowed in the unit root or stationary test, the absolute convergence is tested. When an intercept is entered into the unit root or stationary tests, the conditional convergence or deterministic convergence is tested. When the unit root or stationary tests allow the intercept and linear trend, the stochastic convergence or the catching up hypothesis is tested. Despite all this, it must be stated that When we tested the absolute convergence, our decisions was made based only on unit root test results. But when we tested the catching up hypothesis, our decisions was made in two steps. First, we had to test the existence of unit root in any series (necessary condition) and then estimated the trend function (sufficient condition).

Having gone through the previous empirical works on the time series approach of convergence hypothesis, we found two important points which are as follows: First, they all used various unit root and/or stationary tests such as Augmented Dicky and Fuller (1979) (hereafter ADF), Phillips and Perron (1988) (hereafter PP), Zivot-Andrews (1992) (hereafter ZA), Lumsdain and Papell (1997) (hereafter LP), Lee and streazicich (2003), and Carrion-i-Silvestre, et al. (2009).

Second, they all focused on specific regions such as Latin America (King and Ramlogan, 2008), the Middle East and North Africa (Guetat and Serranito, 2007) and Sub Saharan Africa (Cunado and Gracia, 2006) or specific groups such as OECD countries (Strazicich, et al., 2004; Li and Papell, 1999) and so on. We found that only one paper, Li (1999), tested the convergence hypothesis among more than 100 countries using time series approach. Li (1999) collected the real per capita GDP of 113 countries and divided them to eight income subgroups. Then, he tested the catching up hypothesis for each country toward aggregate real per capita GDP of its subgroup using the ADF unit root test and KPSS stationary test. His decision was based only on combined application of ADF and KPSS tests. However, his study suffers from two shortcomings. First, as noted above, testing the catching up hypothesis is done in two steps; testing the unit root hypothesis (necessary condition) and the estimation of trend function (sufficient condition). But, Li (1999) tested only the necessary condition of catching up hypothesis and did not investigate the sufficient condition. Second, in order to test the unit root hypothesis, he used the ADF and KPSS tests simultaneously and used their conventional critical values that were tabulated by MacKinnon (1991) and Kwiatkowski, et al. (1992, Table 1). But as noted by Carrion-i-Silvestre, et al. (2001), when we use the ADF and KPSS tests simultaneously, we cannot use their conventional critical values and must calculate new critical values for the joint confirmation hypothesis (JCH) of the unit root.

New data and advances in the econometrics of stationary tests continue to motivate additional work on Li (1999). To this end, first, we use a new stationary test namely flexible Fourier stationary test that is a Kwiatkowski, et al. (1992) (KPSS hereafter) type of stationary test which was developed by Becker, Enders, and Lee (2006) (BEL hereafter). In comparison to other unit root and stationary tests such as those of Busetti and Harvey (2001),

Kurozumi (2002), Harvey and Mills (2003), and Busetti and Taylor (2003), Carrion-i-Silvestre, et al. (2005) stationary tests (they are KPSS type of stationary tests with structural breaks), Lumsdain and Papell (1997), Clemente, et al. (1998), Vogelsang and Perron (1998), Kapetanios (2005) unit root tests (they are DF type of unit root tests with structural breaks), Lee and Strazicich (2003), and Westerlund (2009) unit root test (they are LM type of unit root tests) that use dummy variables to capture the possibility of changes and thus require the break(s) to be sharp, the BEL stationary test uses the selected frequency component of a Fourier function to approximate the deterministic component of model and is thus able to control the breaks of an unknown form and number.

Also, the BEL stationary test offer two other advantages when compared with other unit root tests in testing the convergence hypothesis. While the BEL stationary test is a KPSS type stationary test, its null hypothesis is stationary, but in DF and LM type's unit root tests, the null hypothesis is non-stationary. Thus, through the use the BEL test, we are able to test the convergence hypothesis directly. In addition, as noted in the neoclassical economic growth literature, the income per capita dynamics around the balanced growth path is non-linear, but we do not have any information about its form. One of the most important advantages of the BEL stationary test is that it allows the model to be time dependent in parameters and hence we do not have to select a specific form for nonlinearity dynamics.

Second, in order to investigate the sufficient condition of catching up hypothesis, we estimated a flexible trend function.

The remainder of this paper is organized as follows: Section 2 describes data and the methodology used. The empirical results are discussed in the section 3, and conclusion is presented in the final section.

2- Data and methodology

2-1- Data

The purpose of this study is to investigate any evidence regarding the real GDP per capita of the 109 countries catching up process toward USA over the period between 1960 to 2009. We obtained data from the Penn World Table Version 7 of Heston, et al. (2011). We do not consider countries which

do not provide data for all years within the period mentioned above. The countries which is included our research are listed in the Table 1.

2-2- Methodology

According to this sense of the convergence hypothesis, country i will be converged toward country j (as leader or benchmark country) if and only if:

$$\lim_{n\to\infty}\left(y_{i,t+n} - \propto y_{j,t+n} \middle| \xi_t\right) = 0 \qquad (1)$$

Where y is logarithm the relative real GDP per capita and ξ_t is the information set at time t. i and j denote country i and country j respectively. We define three versions of the convergence hypothesis by using equation (1). If $\propto$=1, it shows absolute convergence. In order to test this definition, researchers use unit root or stationary test without intercept and linear trend. If $\propto \neq 0$ and the series $(y_{i,t} - y_{j,t})$ is level stationary, it is called conditional convergence or deterministic convergence. If $\propto \neq 0$ and the series $(y_{i,t} - y_{j,t})$ is trend stationary, it is said stochastic convergence or catching up process. As noted by Li and Papell (1999, P: 268), stochastic convergence is the weakest definition of convergence hypothesis under the time series framework. “This definition, however, is open to criticism because the presence of a time trend allows for the permanent per capita output differences” (P: 268).

As described above, the necessary condition for the catching up process is that the differences of the logarithm per capita GDP level of each country with respect to that of the USA should be stationary. To this end, we use the BEL stationary test that was described in subsection 2.2.1. Furthermore, the sufficient condition of the catching up process is described in subsection 2.2.2.

2-2-1- Necessary Condition: BEL Stationary Test

BEL developed the standard Kwaitowski, Phillips, Schmidt and Shin (KPSS) (1992) stationary test with a Fourier function that allows the deterministic term in regression to be a time-dependent function. Hence, the test does not need to pre-specify the number and form of structural breaks. They could control unknown numbers and form of structural breaks through

the use of a selected frequency component of a Fourier function. Therefore, this test is suitable for various series with various types of smooth structural breaks with unknown numbers and forms.

According to the BEL, the time series y_t is generated as follows:

$$y_t = \gamma Z_t + \zeta_t + v_t, \qquad \zeta_t = \zeta_{t-1} + e_t \tag{2}$$

Where v_t are stationary errors and e_t are i.i.d with variance σ_e^2. The null of stationary implies that $\sigma_e^2 = 0$. Z_t is a matrix of deterministic and trigonometric component; $Z_t = 1, t, \sin\left(\frac{2k\pi t}{T}\right), \cos\left(\frac{2k\pi t}{T}\right)$.

In order to calculate the BEL statistics, we must obtain the residual from the following equation:

$$y_t = \alpha + \beta t + \gamma_1 \sin\left(\frac{2k\pi t}{T}\right) + \gamma_2 \cos\left(\frac{2k\pi t}{T}\right) + \varpi_t \tag{3}$$

By using the residual series from equation (3), we can calculate the test statistics which is as follows:

$$\tau(k) = \frac{1}{T^2} \frac{\sum_{t=1}^{T} S_t(k)^2}{\bar{\varrho}^2} \tag{4}$$

Where $S_t(k) = \sum_{j=1}^{t} \hat{\varpi}_j$ and $\hat{\varpi}_j$ are the ordinary least square (OLS) residuals obtained from regression (3). $\bar{\varrho}^2$ is the long run variance. BEL estimated the long-run variance by choosing a truncation lag parameter l and a set of weights $\omega_j, j = 1, \ldots, l$ from the following equation;

$$\bar{\varrho}^2 = \xi_0 + 2\sum \omega_j \xi_j \tag{5}$$

Where ξ_j is the j[th] sample autocovariance of the residuals $\hat{\varpi}_t$ from equations (3).

In empirical works, researchers suggested various methods for the choice of the kernel. In this paper, however, we follow Carrion-i-Silvestre and

Sansó (2006a) who compared different procedures to establish a boundary rule and demonstrated that the proposal in Sul, et al. (2005) is the best one in terms of size and power. Therefore, we use the Sul, et al.'s (2005) method in this study.

In order to determine the optimum frequency, we follow Beck, et al. in such a way that we first determine the maximum frequency which is equal to five and then calculate the sum of squared residuals (SSR hereafter) for any frequency. The optimum frequency is the one that minimizes the SSR.

As it can be seen in equation (3), the conventional KPSS test is one variety of BEL in which trigonometric component is ignored. As noted by BEL (p. 391) "the usual KPSS-type stationary tests will diverge when nonlinear trends are ignored. This leads to over-rejections of the true stationary null hypothesis in favour of the false unit-root hypothesis." In order to test the presence of the nonlinear terms, BEL offered a F test which is as follows:

$$F(k) = \frac{SSR_{liner} - SSR_{nonlinear}(k) \big/ 2}{SSR_{nonlinear}(k) \big/ (T-q)} \tag{6}$$

Where $SSR_{nonlinear}(k)$ denotes the SSR from equation (3), q is the number of regressors, and SSR_{linear} denotes the SSR from the regression without the nonlinear terms. As noted by BEL, the presence of the nuisance parameters causes that the distribution of F(k) not to be non-standard. Hence, in this paper, we calculate the critical values for any series. To this end, first we generated 5000 random series by using the Gauss (version 10.0.0) RNDN procedure and under the null of linearity. Then using optimum frequency of any actual series, we calculated the F-statistic for any of 5000 pseudo series. Finally, we obtained the critical values from sorted vector of pseudo F-statistic.

2-2-2- Sufficient Condition

As noted by Tomljanovich and Vogelsang (2002) and Cunado and Gracia (2006), the trend stationary is a necessary condition for the catching up

hypothesis. In order to investigate the sufficient conditions for the catching up process, first, we calculated the derivation of y from equation (3) for countries for which the null of trend stationary is not rejected.

$$\frac{dy_t}{dt} = \hat{\beta} + \hat{\gamma}_1\left(\frac{2k\pi}{T}\right)\cos\left(\frac{2k\pi t}{T}\right) - \hat{\gamma}_2\left(\frac{2k\pi}{T}\right)\sin\left(\frac{2k\pi t}{T}\right) \qquad (7)$$

Where $\hat{\beta}$, $\hat{\gamma}_1$, and $\hat{\gamma}_2$ are OLS coefficients that were obtained from regression (3).

The real GDP per capita of all countries (except Luxembourg and Switzerland) is less than that of the USA real GDP per capita in 1960. Hence, we can say that there exists evidence of catching up process or stochastic convergence, if, and only if the derivation of y in equation (7) - $\frac{dy_t}{dt}$ – is be positive. However, if it is negative, we conclude that the divergence process has occurred.

3- Results

In order to examine the catching up hypothesis toward the USA, we first tested the stationary of GDP per capita gap series by three univarivare unit root tests such as, ADF, PP, and Sollis (2009) and also two stationary tests namely, Carrion-i-Silvestre, et al. (2005) (CBL hereafter) and BEL. The results of ADF, PP, Sollis (2009) unit root tests and also the CBL stationary test are presented in Table 1.

As it can be seen, in Table 1, according to the ADF and PP unit root tests results, the null hypothesis of unit root is rejected for only four countries namely, Denmark, Burkina Faso, Benin, and Algeria (at 1%). This result is consistent with that of existing literature and could be due to the low power of these univariate unit root tests when the relative per capita real GDP is highly persistent. This result implies that most of GDP per capita gap series follows the random walk processes during the sample period; therefore, we can not test the sufficient condition for catching up hypothesis. In order to improve the low power of ADF and PP unit root tests, we applied the Sollis (2009) nonlinear unit root test and the CBL stationary test that allows for breaks in the intercept and slope of linear trend. In order to run the CBL stationary test, we set maximum break points at 8 and computed its critical

values by using Monte Carlo simulation and 20000 replications. Having used the Sollis (2009) nonlinear unit root test, we rejected the null hypothesis of unit root test for only 15 out of 109 GDP per capita gap series and for other series, the null hypothesis of unit root was not rejected. The CBL stationary test results show that the null hypothesis of stationary was not rejected only for 9 out of 109 GDP per capita gap series at 10% and for 13 of 109 GDP per capita gap series at 5%. As it can be seen, we are not able to investigate the sufficient condition of catching up hypothesis for most of countries available in the sample.

Table 1: The Results of ADF, PP, and Sollis (2009) Unit Root Tests and CBL Stationary Test

Countries	ADF	PP	Sollis (2009)	CBL	Countries	ADF	PP	Sollis (2009)	CBL
Algeria	-2.666[9]	-3.818**[3]	4.011[8]	0.4431	Japan	-2.548[0]	-2.327[3]	3.544[8]	0.0377
Argentina	-0.523[0]	-0.92[2]	1.515[7]	0.2297	Jordan	-1.88[0]	-2.195[3]	6.303*[5]	0.1561
Australia	-0.159[0]	0.077[8]	2.235[0]	0.278	Kenya	-2.686[0]	-2.74[2]	1.351[9]	0.0278*
Austria	-1.731[0]	-1.848[3]	4.787[8]	0.0347	Korea	-1.972[0]	-2.14[2]	1.619[0]	0.1815
Bangladesh	-0.265[0]	1.451[23]	2.971[6]	0.1026	Lesotho	-3.01[0]	-3.018[3]	5.11[0]	0.1416
Barbados	-1.663[0]	-1.711[1]	1.217[8]	0.2188	Luxembourg	-1.46[0]	-1.46[0]	1.599[8]	0.2359
Belgium	-2.236[0]	-2.236[0]	6.143*[5]	0.0437	Madagascar	-2.767[0]	-2.905[2]	4.635[0]	0.0741
Benin	-3.903**[0]	-3.966**[2]	1.859[6]	0.0254*	Malawi	-2.062[0]	-2.042[6]	4.858[4]	0.0685
Bolivia	-0.817[1]	-1.008[3]	0.199[0]	0.0696	Malaysia	-2.324[1]	-2.119[3]	4.266[0]	0.0392
Botswana	-1.165[0]	-1.168[1]	1.881[0]	0.0257*	Mali	-3.76**[1]	-4.143**[23]	1.776[7]	0.0321*
Brazil	-1.645[0]	-1.777[3]	7.983**[8]	0.1686	Mauritania	-2.521[0]	-2.477[4]	1.516[5]	0.0793
Burkina Faso	-3.849**[0]	-3.85**[3]	4.716[4]	0.1563	Mauritius	-4.697***[3]	-2.355[3]	0.118[7]	0.2424
Burundi	-2.061[0]	-1.908[2]	5.711*[10]	0.0521	Mexico	-2.447[1]	-1.899[1]	3.998[0]	0.1492
Cameroon	-2.893[4]	-1.55[4]	4.595[3]	0.0557	Morocco	-3.904**[0]	-3.908**[2]	1.526[5]	0.0284*
Canada	-2.043[1]	-1.668[1]	3.893[4]	0.2192	Mozambique	0.787[0]	0.787[0]	2.958[1]	0.1091
Cape Verde	-0.1[4]	-1.956[2]	1.104[8]	0.1183	Namibia	-1.846[0]	-1.887[5]	6.78**[0]	0.0753
Central African R.	-1.078[0]	-1.278[2]	1.467[0]	0.0448	Nepal	-2.257[1]	-1.326[7]	3.224[0]	0.0419*
Chad	-0.838[0]	-1.027[1]	0.558[0]	0.0539*	Netherlands	-2.372[1]	-1.71[0]	5.281[5]	0.0237
Chile	-1.175[0]	-1.326[2]	1.032[0]	0.0388	New Zealand	-1.409[1]	-0.583[5]	1.056[7]	0.3241
China	-2.132[0]	-2.147[4]	1.801[0]	0.0917	Nicaragua	-2.414[0]	-2.402[2]	3.279[8]	0.1598
Colombia	-1.902[0]	-2.034[2]	1[0]	0.0254*	Niger	-1.888[0]	-1.791[2]	2.539[0]	0.0247*
Comoros	-2.879[0]	-2.902[2]	4.228[0]	0.0477	Nigeria	-0.655[0]	-1.075[3]	3.348[10]	0.2999
Congo Dem	-1.719[0]	-1.892[3]	13.253***[5]	0.0295*	Norway	-2.371[1]	-2.201[5]	5.453[5]	0.0404

Countries	ADF	PP	Sollis (2009)	CBL	Countries	ADF	PP	Sollis (2009)	CBL
Rep.									
Congo Republic of	-1.47[0]	-1.661[2]	2.28[3]	0.0566	Pakistan	-1.894[0]	-2.023[3]	2.686[8]	0.0441
Costa Rica	-1.097[1]	-1.088[4]	3.83[8]	0.0239*	Panama	-2.288[1]	-2.161[3]	0.791[5]	0.0573*
Cote d Ivoire	-2.506[0]	-2.469[2]	5.595*[6]	0.1504	Papua New Guinea	-2.389[0]	-2.451[2]	1.944[0]	0.0424*
Cyprus	-2.562[1]	-2.341[3]	7.244**[9]	0.1372	Paraguay	-1.413[1]	-1.47[4]	7.309**[9]	0.077
Denmark	-4.071**[0]	-4.116**[1]	3.234[1]	0.0535	Peru	-0.669[2]	-0.848[5]	0.328[1]	0.0685
Dominican Republic	-2.345[1]	-1.65[0]	6.447*[3]	0.036	Philippines	-1.855[1]	-1.6[2]	5.616*[5]	0.0265*
Ecuador	-1.247[0]	-1.699[4]	5.249[5]	0.027	Portugal	-2.091[1]	-2.066[2]	5.925*[8]	0.0283
Egypt	-2.951[1]	-2.158[0]	5.617*[0]	0.1756	Puerto Rico	-2.356[1]	-2.23[2]	3.622[10]	0.107
El Salvador	-1.337[1]	-1.03[4]	2.781[6]	0.1532	Romania	-1.516[1]	-1.843[4]	6.762**[7]	0.038
Equatorial Guinea	-1.114[1]	-0.6[2]	2.295**[3]	0.0278*	Rwanda	-2.809[0]	-2.809[0]	4.99[9]	0.052
Ethiopia	0.064[0]	0.496[2]	6.738**[8]	0.0299*	Senegal	-1.279[0]	-0.538[22]	3.115[0]	0.0366*
Fiji	-2.151[0]	-2.427[3]	6.623[2]	0.05	Seychelles	-3.364*[0]	-3.148[6]	9.048***[0]	0.0386
Finland	-2.473[1]	-2.175[1]	3.02[8]	0.0362	Singapore	-1.385[0]	-1.923[3]	3.047[0]	0.0242
France	-1.942[0]	-1.942[0]	6.82**[8]	0.1594	South Africa	-1.113[1]	-0.845[2]	0.99[0]	0.0603
Gabon	-2.225[1]	-2.297[3]	3.437[5]	0.1222	Spain	-2.505[1]	-3.702**[2]	2.551[7]	0.1496
Gambia The	0.344[0]	0.344[0]	1.591[0]	0.4368	Sri Lanka	-0.903[0]	-0.903[0]	0.88[0]	0.0426
Ghana	-2.612[0]	-2.738[2]	4.216[10]	0.2438	Sweden	-1.654[2]	-2.089[5]	2.848[0]	0.0394*
Greece	-2.32[3]	-2.342[4]	4.313[9]	0.053	Switzerland	-2.68[1]	-2.741[2]	8.096**[9]	0.0355
Guatemala	-1.467[1]	-1.653[4]	4.866[1]	0.1173	Syria	-3.001[0]	-3.079[3]	1.669[8]	0.0453
Guinea	-1.676[0]	-1.694[3]	1.92[0]	0.0798	Taiwan	0.287[0]	0.108[2]	0.269[0]	0.0273*
GuineaBissau	-2.457[0]	-2.585[2]	4.947[0]	0.2533	Tanzania	1.237[0]	1.401[3]	3.984[0]	0.1421
Haiti	-1.235[0]	-1.669[4]	5.834*[4]	0.0316	Thailand	-2.469[1]	-2.058[3]	1.951[0]	0.091

Countries	ADF	PP	Sollis (2009)	CBL	Countries	ADF	PP	Sollis (2009)	CBL
Honduras	-1.217[0]	-1.474[3]	3.012[2]	0.1504	Togo	-2.836[0]	-2.829[1]	3.183[0]	0.1013
Hong Kong	-2.258[1]	-1.681[2]	1.473[5]	0.154	Trinidad Tobago	0.9[0]	0.474[3]	3.016[7]	0.0742*
Iceland	-2.088[0]	-2.114[3]	2.431[0]	0.1322	Turkey	-2.991[0]	-3.083[1]	3.409[0]	0.0635
India	1.019[0]	2.59[15]	2.871[5]	0.1276	Uganda	0.668[0]	0.323[2]	2.372[10]	0.223
Indonesia	-2.98[1]	-2.207[3]	5.623*[0]	0.0492	UK	-2.564[0]	-2.58[1]	3.512[2]	0.2737
Iran	-1.912[1]	-1.664[3]	3.198[10]	0.2637	Uruguay	-3.498*[1]	-2.001[1]	2.681[9]	0.3379
Ireland	-2.428[1]	-1.62[3]	5.771*[9]	0.158	Venezuela	-1.935[0]	-2.088[1]	4.293[7]	0.0186*
Israel	-2.365[3]	-2.521[1]	5.986*[2]	0.0296	Zambia	0.38[0]	-0.359[4]	0.47[2]	0.0613
Italy	-1.107[0]	-0.799[6]	1.696[10]	0.0628*	Zimbabwe	-1.587[1]	-1.048[1]	3.037[0]	0.0394
Jamaica	-1.948[1]	-1.787[3]	2.11[0]	0.1143					

Critical values:

Unit root tests	10%	5%	1%
Sollis (2009)	5.415	6.546	8.799
ADF	-3.238	-3.603	-4.374
PP	-3.238	-3.603	-4.374

1) *, **, and *** denote the unit root hypothesis is rejected at 10%, 5%, and 1% respectively.
2) The critical values for Sollis (2009) non-linear unit root tests are tabulated in Table 1 of Sollis (2009).
3) We compute finite sample critical values for CBL stationary test by Monte Carlo simulation and 20000 replications. To save space, we do not report the results of these three tests, but available upon requests. Maximum break was fixed at 8.
4) The number in bracket indicates optimum lag length for the ADF and Sollis (2009) unit root tests and the truncation for the Bartlett Kernel, as suggested by the Newey-West test (1987) for PP unit root test.

We prepared the BEL stationary test results in Table 2. In order to run the test, a grid-search was performed to find the best frequency, as there was no a priori knowledge concerning the shape of the breaks in the data. As it can be seen in the first column, for 87 series, a single frequency minimizes the residual sum of squares for most series. For 12 series, using two frequencies, for nine series, using three frequencies and for only one series, using five frequencies minimizes the residual sum of squares. The significant F statistics showed in the third column of Table 2 also indicates that both sine and cosine terms should be included in the estimated model.

The fourth and 11^{th} columns in Table 2 reports the results of stationary test with a nonlinear Fourier function based on the estimated frequencies. We calculated its critical values with 5000 replication. The results show that the stationary hypothesis was rejected for only four countries namely Burkina Faso, Lesotho, Puerto Rico, and Uruguay. For other countries, we cannot reject the null hypothesis. As can be noticed, the BEL stationary test has more power than other unit root and stationary tests that were applied in this study. Also, if we compare the results with those of the previous studies on time series approach of convergence hypothesis such as Li (1999), Li and Papell (1999), Strazicich, et al. (2004), Lee, et al. (2005), Cunado and Gracia (2006) and King and Ramlogan (2008), it can be seen that, we can reject the unit root hypothesis more than those studies and are able to investigate the sufficient condition for more countries (105 of the 109 countries) in our sample.

Table 2: Flexible Fourier KPSS stationary test results

Country	frequency [Truncation lag]	F statistic	Bartlett	Critical Values for Flexible Fourier KPSS test			Country	frequency [Truncation lag]	F statistic	Bartlett	Critical Values for Flexible Fourier KPSS test		
				90%	95%	99%					90%	95%	99%
Algeria	2 [3]	16.891	0.146	0.151	0.183	0.255	Japan	1 [2]	106.924	0.033	0.155	0.189	0.275
Argentina	1 [2]	22.508	0.034	0.150	0.187	0.261	Jordan	2 [1]	24.534	0.074	0.153	0.188	0.265
Australia	1 [2]	41.481	0.043	0.151	0.186	0.253	Kenya	2 [1]	4.542	0.078	0.131	0.163	0.238
Austria	1 [4]	62.273	0.096	0.157	0.190	0.275	Korea, Republic of	1 [1]	32.003	0.021	0.081	0.105	0.147
Bangladesh	1 [1]	101.590	0.017	0.080	0.100	0.145	Lesotho	3 [2]	13.623	0.171	0.151	0.179	0.257
Barbados	1 [4]	141.496	0.095	0.151	0.181	0.264	Luxembourg	1 [2]	42.244	0.036	0.144	0.175	0.241
Belgium	1 [2]	46.817	0.032	0.151	0.183	0.262	Madagascar	3 [1]	19.289	0.039	0.160	0.191	0.271
Benin	5 [1]	7.758	0.054	0.157	0.190	0.263	Malawi	1 [3]	100.102	0.056	0.149	0.182	0.253
Bolivia	1 [1]	21.334	0.011	0.078	0.099	0.144	Malaysia	3 [1]	16.311	0.026	0.083	0.104	0.160
Botswana	1 [1]	43.794	0.019	0.078	0.101	0.140	Mali	1 [1]	10.864	0.035	0.084	0.107	0.167
Brazil	1 [3]	110.674	0.063	0.153	0.181	0.248	Mauritania	1 [1]	97.558	0.039	0.081	0.103	0.143
Burkina Faso	2 [1]	23.620	0.260	0.103	0.132	0.199	Mauritius	1 [4]	25.896	0.121	0.156	0.185	0.263
Burundi	1 [2]	68.025	0.044	0.151	0.190	0.276	Mexico	1 [2]	33.932	0.052	0.158	0.191	0.260
Cameroon	1 [1]	23.630	0.024	0.080	0.100	0.143	Morocco	1 [3]	39.143	0.076	0.150	0.182	0.268
Canada	1 [2]	67.008	0.061	0.154	0.185	0.253	Mozambique	1 [3]	102.984	0.080	0.155	0.186	0.263
Cape Verde	1 [4]	30.829	0.127	0.153	0.180	0.256	Namibia	1 [2]	79.849	0.045	0.156	0.191	0.267
Central African Republic	1 [3]	13.082	0.066	0.155	0.188	0.266	Nepal	1 [2]	44.698	0.055	0.151	0.182	0.257
Chad	1 [2]	39.065	0.036	0.154	0.188	0.277	Netherlands	2 [2]	25.380	0.080	0.158	0.192	0.267
Chile	1 [4]	106.047	0.106	0.149	0.184	0.269	New Zealand	1 [2]	45.588	0.045	0.151	0.185	0.264
China Version 2	1 [2]	42.506	0.034	0.153	0.186	0.264	Nicaragua	1 [1]	53.520	0.019	0.079	0.100	0.141
Colombia	3 [1]	12.055	0.041	0.125	0.151	0.216	Niger	1 [1]	26.507	0.031	0.081	0.101	0.150
Comoros	1 [2]	156.134	0.055	0.156	0.192	0.286	Nigeria	1 [2]	24.280	0.049	0.158	0.193	0.260
Congo, Dem. Rep.	1 [1]	29.358	0.020	0.080	0.102	0.144	Norway	1 [2]	17.833	0.045	0.147	0.183	0.262
Congo,	1 [4]	82.259	0.114	0.152	0.185	0.258	Pakistan	1 [1]	35.897	0.015	0.080	0.104	0.148

Country	frequency [Truncation lag]	F statistic	Bartlett	Critical Values for Flexible Fourier KPSS test			Country	frequency [Truncation lag]	F statistic	Bartlett	Critical Values for Flexible Fourier KPSS test		
				90%	95%	99%					90%	95%	99%
Republic of Costa Rica	1 [2]	44.042	0.030	0.158	0.194	0.257	Panama	1 [2]	13.710	0.047	0.155	0.189	0.270
Cote d`Ivoire	1 [1]	111.469	0.036	0.079	0.097	0.141	Papua New Guinea	1 [1]	24.002	0.019	0.077	0.097	0.140
Cyprus	1 [2]	20.500	0.041	0.151	0.185	0.260	Paraguay	1 [3]	49.679	0.060	0.153	0.187	0.259
Denmark	1 [2]	15.548	0.048	0.154	0.187	0.262	Peru	1 [2]	64.579	0.076	0.157	0.189	0.271
Dominican Republic	2 [3]	17.488	0.093	0.160	0.195	0.271	Philippines	2 [2]	19.568	0.046	0.158	0.193	0.269
Ecuador	1 [1]	29.681	0.018	0.082	0.103	0.149	Portugal	1 [2]	23.368	0.042	0.158	0.192	0.265
Egypt	1 [2]	15.898	0.038	0.162	0.195	0.277	Puerto Rico	2 [3]	28.634	0.181	0.155	0.191	0.274
El Salvador	1 [3]	47.379	0.058	0.153	0.187	0.265	Romania	1 [2]	181.761	0.048	0.152	0.180	0.250
Equatorial Guinea	1 [2]	119.714	0.047	0.157	0.191	0.260	Rwanda	2 [1]	15.824	0.081	0.103	0.126	0.180
Ethiopia	1 [1]	67.445	0.026	0.079	0.101	0.144	Senegal	1 [1]	69.921	0.049	0.079	0.101	0.143
Fiji	2 [1]	18.575	0.046	0.116	0.153	0.233	Seychelles	3 [2]	13.975	0.134	0.149	0.183	0.259
Finland	1 [2]	22.395	0.066	0.159	0.197	0.270	Singapore	1 [3]	24.095	0.073	0.165	0.196	0.278
France	1 [2]	136.080	0.041	0.150	0.183	0.270	South Africa	1 [2]	74.419	0.062	0.157	0.195	0.271
Gabon	1 [2]	46.309	0.038	0.159	0.192	0.269	Spain	1 [2]	23.718	0.035	0.157	0.191	0.275
Gambia	1 [1]	14.783	0.015	0.080	0.101	0.148	Sri Lanka	1 [4]	11.254	0.100	0.161	0.192	0.270
Ghana	1 [3]	15.703	0.068	0.164	0.194	0.266	Sweden	1 [2]	30.831	0.075	0.152	0.187	0.258
Greece	1 [4]	255.818	0.072	0.155	0.183	0.254	Switzerland	1 [4]	11.733	0.143	0.153	0.183	0.261
Guatemala	1 [3]	49.018	0.073	0.154	0.187	0.263	Syria	2 [3]	12.833	0.070	0.163	0.198	0.261
Guinea	2 [2]	13.602	0.116	0.160	0.193	0.261	Taiwan	1 [1]	120.546	0.022	0.078	0.097	0.140
Guinea-Bissau	3 [1]	13.614	0.053	0.150	0.181	0.252	Tanzania	1 [1]	85.186	0.023	0.080	0.101	0.144
Haiti	1 [1]	18.925	0.015	0.078	0.099	0.137	Thailand	1 [2]	16.673	0.035	0.157	0.194	0.272
Honduras	1 [1]	21.328	0.025	0.082	0.100	0.145	Togo	1 [1]	54.680	0.025	0.080	0.099	0.140
Hong Kong	1 [4]	86.536	0.076	0.153	0.185	0.263	Trinidad &Tobago	1 [3]	106.241	0.063	0.154	0.185	0.277
Iceland	1 [2]	26.510	0.058	0.157	0.191	0.267	Turkey	3 [1]	13.586	0.063	0.105	0.128	0.182
India	1 [1]	51.002	0.010	0.080	0.101	0.144	Uganda	1 [1]	227.707	0.021	0.079	0.098	0.140

Country	frequency [Truncation lag]	F statistic	Bartlett	Critical Values for Flexible Fourier KPSS test			Country	frequency [Truncation lag]	F statistic	Bartlett	Critical Values for Flexible Fourier KPSS test		
				90%	95%	99%					90%	95%	99%
Indonesia	3 [3]	18.567	0.120	0.162	0.191	0.262	United Kingdom	1 [4]	27.097	0.101	0.153	0.184	0.254
Iran	1 [2]	40.258	0.038	0.153	0.188	0.264	Uruguay	3 [2]	27.140	0.233	0.156	0.191	0.269
Ireland	1 [2]	39.265	0.036	0.160	0.194	0.259	Venezuela	1 [1]	23.428	0.016	0.080	0.101	0.143
Israel	1 [4]	21.859	0.068	0.152	0.183	0.256	Zambia	1 [1]	76.731	0.018	0.079	0.102	0.144
Italy	1 [2]	133.877	0.051	0.149	0.181	0.251	Zimbabwe	1 [2]	26.728	0.042	0.156	0.188	0.260
Jamaica	1 [2]	15.239	0.036	0.156	0.188	0.264							
Critical values for F statistic													
Optimum frequency		90%	95%	97.50%	99%								
1		2.6133	3.4245	4.2956	5.427								
2		2.5584	3.4319	4.4208	5.5116								
3		2.5814	3.423	4.2368	5.2564								
5		2.5968	3.34	4.2234	5.3125								

1- *, **, and *** denote the unit root hypothesis is rejected at 10%, 5%, and 1% respectively.
2- The critical values for Sollis (2009) non-linear unit root tests are tabulated in Table 1 of Sollis (2009).
3) We compute finite sample critical values for CBL stationary test by Monte Carlo simulation and 20000 replications. To save space, we do not report the results of these three tests, but available upon requests. Maximum break was fixed at 8.
4) The number in bracket indicates optimum lag length for the ADF and Sollis (2009) unit root tests and the truncation for the Bartlett Kernel, as suggested by the Newey-West test (1987) for PP unit root test.
5) Source: Authors findings

In order to investigate the sufficient condition for the catching up process, we calculated the derivation of y from equation (7) for every year. Then we calculated its average for every decade i.e. 1960_s, 1970_s, …, 2000_s. In order to determine the catching up process or the divergence process, we used the methodology that was described in subsection 2.2.2. We denoted catching up and divergence by C and D respectively. The results are presented in Table 3. In this table, the numbers in the parenthesis and bracket are logarithm the initial relative real GDP per capita in every decade and the average of the derivation of y from equation (7) in every decade, respectively.

Table 3: Catching up and divergence classification in any decade

Income group	Country	1960s	1970s	1980s	1990s	2000s
Low Income	Bangladesh	(-14.6) [-0.025] D	(-19.7) [-0.031] D	(-24.4) [-0.009] D	(-30.8) [0.01] C	(-38.2) [0] C
	Benin	(-14.6) [-0.011] D	(-19.6) [-0.011] D	(-24.1) [-0.011] D	(-30.6) [-0.011] D	(-38) [-0.011] D
	Botswana	(-14.9) [0.056] C	(-19.4) [0.064] C	(-22.1) [0.041] C	(-25.8) [0.018] C	(-30.6) [0.027] C
	Burkina Faso	-	-	-	-	-
	Burundi	(-15.2) [0.001] C	(-20.1) [0.004] C	(-24.7) [-0.014] D	(-31.2) [-0.029] D	(-38.8) [-0.019] D
	Chad	(-14.6) [-0.014] D	(-19.6) [-0.038] D	(-24.5) [-0.026] D	(-30.9) [0.006] C	(-38.4) [0.013] C
	Comoros	(-14.7) [0] C	(-19.2) [-0.001] D	(-23.7) [-0.028] D	(-30.3) [-0.045] D	(-38.2) [-0.027] D
	Congo, Republic of	(-14.6) [0.013] C	(-19.2) [0.027] C	(-23.3) [0.002] C	(-29.2) [-0.027] D	(-36.9) [-0.02] D
	Equatorial Guinea	(-14.9) [0.08] C	(-19.8) [-0.051] D	(-24.3) [-0.012] D	(-31) [0.143] C	(-33.3) [0.2] C
	Ethiopia	(-15) [0] C	(-20) [-0.029] D	(-24.6) [-0.032] D	(-31.2) [-0.005] D	(-38.7) [0.015] C
	Ghana	(-14.8) [0.012] C	(-19.5) [-0.016] D	(-24.3) [-0.029] D	(-30.8) [-0.009] D	(-38.3) [0.016] C
	Guinea-Bissau	(-15.1) [-0.035] D	(-20.2) [0.022] C	(-24.7) [-0.023] D	(-31.2) [-0.007] D	(-38.7) [0.012] C
	India	(-14.7) [0.006] C	(-19.6) [-0.007] D	(-24.1) [0.003] C	(-30.2) [0.022] C	(-37.3) [0.024] C
	Indonesia	(-14.7) [-0.002] D	(-19.6) [0.04] C	(-23.5) [0.009] C	(-29.3) [0.017] C	(-36.3) [0.035] C
	Lesotho	-	-	-	-	-
	Malawi	(-15.1) [0.041] C	(-19.8) [0.006] C	(-24.2) [-0.044] D	(-31) [-0.041] D	(-38.6) [0.012] C
	Mali	(-14.9) [-0.021] D	(-20) [-0.011] D	(-24.5) [0.003] C	(-30.9) [0.002] C	(-38.4) [-0.012] D
	Mauritania	(-14.9) [0.038] C	(-19.2) [0.003] C	(-23.7) [-0.035] D	(-30.4) [-0.022] D	(-37.9) [0.022] C
	Morocco	(-14.7) [0.026] C	(-19) [0.012] C	(-23) [-0.008] D	(-29.3) [-0.006] D	(-36.6) [0.015] C
	Mozambique	(-15.1) [0.013] C	(-20.1) [-0.028] D	(-24.6) [-0.034] D	(-31.2) [0.003] C	(-38.7) [0.032] C
	Nepal	(-14.8) [-0.019] D	(-19.8) [-0.015] D	(-24.4) [-0.003] D	(-30.8) [0] D	(-38.1) [-0.011] D
	Niger	(-14.7) [-0.026] D	(-19.7) [-0.044] D	(-24.4) [-0.041] D	(-31.1) [-0.022] D	(-38.7) [-0.012] D
	Pakistan	(-14.7) [0.007] C	(-19.3) [0.012] C	(-23.6) [0] C	(-29.7) [-0.011] D	(-37.3) [-0.006] D
	Sri Lanka	(-14.7) [0.011] C	(-19.4) [0.007] C	(-23.6) [0.01] C	(-29.7) [0.017] C	(-36.3) [0.017] C
	Tanzania	(-15) [0.011] C	(-19.9) [-0.018] D	(-24.4) [-0.025] D	(-31) [-0.001] D	(-38.5) [0.021] C
	Togo	(-14.7) [0.007] C	(-19.2) [-0.015] D	(-23.8) [-0.046] D	(-30.6) [-0.043] D	(-38.3) [-0.01] D
	Uganda	(-14.8) [-0.009] D	(-19.7) [-0.045] D	(-24.5) [-0.031] D	(-31.1) [0.014] C	(-38.4) [0.027] C
	Zimbabwe	(-15.2) [-0.036] D	(-20.1) [0.001] C	(-24.7) [-0.011] D	(-31.3) [-0.054] D	(-38.8) [-0.07] D

Income group	Country	1960s	1970s	1980s	1990s	2000s
Middle Income	Algeria	(-11.4) [-0.028] D	(-16.5) [0.007] C	(-20.3) [-0.022] D	(-26.7) [-0.011] D	(-34.2) [0.001] C
	Bolivia	(-12.7) [-0.008] D	(-17.7) [-0.024] D	(-21.8) [-0.026] D	(-28.8) [-0.011] D	(-36) [0] C
	Brazil	(-12.6) [0.03] C	(-16) [0.018] C	(-17) [-0.013] D	(-24.5) [-0.02] D	(-31.4) [0.007] C
	Cameroon	(-14.2) [0.003] C	(-19.2) [0.006] C	(-23.1) [-0.016] D	(-29.7) [-0.033] D	(-37.5) [-0.021] D
	Cape Verde	(-14.4) [0.006] C	(-19.1) [-0.01] D	(-24) [-0.001] D	(-30) [0.021] C	(-36.7) [0.025] C
	Central African Republic	(-14.4) [-0.021] D	(-19.5) [-0.033] D	(-24.2) [-0.043] D	(-30.9) [-0.037] D	(-38.5) [-0.024] D
	Chile	(-11.7) [-0.015] D	(-15.9) [-0.02] D	(-20) [0.006] C	(-26) [0.028] C	(-29.7) [0.015] C
	China	(-14.6) [0.012] C	(-19.6) [0.005] C	(-23.9) [0.027] C	(-29.8) [0.049] C	(-35.9) [0.039] C
	Colombia	(-13) [-0.007] D	(-17.4) [0.01] C	(-20.9) [-0.003] D	(-27) [0.001] C	(-33.4) [0.007] C
	Congo, Dem. Rep.	(-14.3) [-0.017] D	(-19.4) [-0.034] D	(-24.3) [-0.08] D	(-30.9) [-0.091] D	(-39.1) [-0.052] D
	Costa Rica	(-10.4) [0.012] C	(-14) [-0.008] D	(-16.7) [-0.02] D	(-24.2) [-0.007] D	(-30.2) [0.013] C
	Cote d`Ivoire	(-14.5) [0] C	(-19) [-0.003] D	(-23.5) [-0.023] D	(-30) [-0.033] D	(-37.7) [-0.019] D
	Cyprus	(-12.1) [0.01] C	(-14.5) [0.026] C	(-15.9) [0.023] C	(-16.5) [0.006] C	(-21.9) [-0.002] D
	Dominican Republic	(-13.1) [-0.006] D	(-17.6) [0.022] C	(-20.8) [-0.008] D	(-26.9) [0.012] C	(-31.9) [0.01] C
	Ecuador	(-12.6) [0.018] C	(-17.3) [0.008] C	(-19.4) [-0.015] D	(-26.9) [-0.02] D	(-34.4) [0.001] C
	Egypt	(-14.4) [-0.005] D	(-19.1) [0.011] C	(-23.3) [0.024] C	(-29) [0.016] C	(-35.3) [-0.002] D
	El Salvador	(-12) [0.001] C	(-16.3) [-0.02] D	(-20.7) [-0.022] D	(-27.6) [-0.001] D	(-33.7) [0.012] C
	Fiji	(-13.5) [-0.005] D	(-18) [0.005] C	(-21.5) [-0.022] D	(-27.9) [0.012] C	(-35) [-0.016] D
	Gabon	(-10.9) [0.036] C	(-11.5) [0.014] C	(-12) [-0.03] D	(-20.7) [-0.036] D	(-28.1) [0.005] C
	Gambia, The	(-14.5) [-0.005] D	(-19.6) [-0.029] D	(-24.2) [-0.03] D	(-30.8) [-0.007] D	(-38.4) [0.009] C
	Guatemala	(-12.5) [0.016] C	(-16.4) [-0.001] D	(-19.3) [-0.021] D	(-26.9) [-0.017] D	(-33.7) [0.006] C
	Guinea	(-14.5) [-0.036] D	(-19.7) [-0.018] D	(-24.2) [-0.024] D	(-30.8) [-0.033] D	(-38.4) [-0.012] D
	Haiti	(-13.5) [-0.015] D	(-18.8) [-0.014] D	(-22.7) [-0.029] D	(-29.8) [-0.039] D	(-37.7) [-0.031] D
	Honduras	(-13.2) [0.003] C	(-18.1) [-0.004] D	(-21.8) [-0.019] D	(-28.5) [-0.02] D	(-36.2) [-0.007] D
	Hong Kong	(-12.1) [0.034] C	(-13.4) [0.045] C	(-11.2) [0.03] C	(-9) [0.009] C	(-10.6) [0.011] C
	Iran	(-11) [0.042] C	(-11.5) [-0.019] D	(-19.4) [-0.051] D	(-25.6) [-0.009] D	(-31.4) [0.048] C
	Jordan	(-12.8) [-0.041] D	(-17.7) [0.005] C	(-20.2) [-0.016] D	(-27.8) [-0.027] D	(-35.5) [0.012] C

Income group	Country	1960s	1970s	1980s	1990s	2000s
	Kenya	(-14.4) [-0.021] D	(-19.5) [-0.018] D	(-23.9) [-0.015] D	(-30.4) [-0.022] D	(-38) [-0.014] D
	Korea, Republic of	(-13.7) [0.025] C	(-17.5) [0.043] C	(-19.8) [0.049] C	(-20.2) [0.035] C	(-20.2) [0.02] C
	Madagascar	(-14.6) [-0.031] D	(-19.5) [-0.026] D	(-24.3) [-0.016] D	(-30.7) [-0.037] D	(-38.4) [-0.014] D
	Malaysia	(-14) [0.012] C	(-18.4) [0.042] C	(-20.9) [0.012] C	(-25.6) [0.031] C	(-29.5) [0.03] C
	Mauritius	(-13.2) [-0.015] D	(-18.5) [0.002] C	(-22.1) [0.026] C	(-26.6) [0.025] C	(-31.7) [-0.001] D
	Mexico	(-10.8) [0.017] C	(-14.1) [0.004] C	(-15.7) [-0.013] D	(-22.8) [-0.01] D	(-28.6) [0.009] C
	Namibia	(-12.4) [0.007] C	(-16) [-0.019] D	(-20.6) [-0.034] D	(-27.8) [-0.016] D	(-35.2) [0.009] C
	Nicaragua	(-12.9) [0.012] C	(-16.8) [-0.029] D	(-22) [-0.061] D	(-29.5) [-0.041] D	(-37.1) [0.004] C
	Nigeria	(-13.9) [0.007] C	(-19.1) [-0.034] D	(-23.6) [-0.042] D	(-30.5) [-0.007] D	(-38) [0.023] C
	Panama	(-13.3) [0.02] C	(-17) [0.013] C	(-19.8) [0] D	(-26) [-0.001] D	(-32.2) [0.011] C
	Papua New Guinea	(-14.6) [0.015] C	(-19.1) [0.011] C	(-23) [-0.009] D	(-29.8) [-0.017] D	(-37) [-0.003] D
	Paraguay	(-13.6) [0.002] C	(-18.4) [0.013] C	(-21.4) [-0.002] D	(-27.8) [-0.023] D	(-35.8) [-0.021] D
	Peru	(-11.7) [0.015] C	(-15.3) [-0.021] D	(-19.5) [-0.037] D	(-27.6) [-0.012] D	(-34.2) [0.02] C
	Philippines	(-14.1) [-0.022] D	(-18.9) [0.007] C	(-22.9) [-0.024] D	(-29.6) [-0.003] D	(-36.8) [-0.005] D
	Portugal	(-11.4) [0.023] C	(-13) [0.021] C	(-14.2) [0.008] C	(-16.7) [0.002] C	(-19.9) [0.011] C
	Romania	(-13.9) [0.07] C	(-17.3) [0.041] C	(-17.6) [-0.017] D	(-24.7) [-0.024] D	(-33.1) [0.03] C
	Rwanda	(-14.6) [-0.05] D	(-19.7) [0.002] C	(-24.3) [-0.034] D	(-30.9) [-0.028] D	(-38.5) [-0.002] D
	Senegal	(-14) [-0.026] D	(-19.2) [-0.036] D	(-24) [-0.023] D	(-30.5) [-0.005] D	(-37.9) [-0.006] D
	Seychelles	(-11.8) [0.002] C	(-15.4) [0.037] C	(-15.3) [0.011] C	(-18.6) [0.017] C	(-21.7) [0.033] C
	Singapore	(-11.1) [0.033] C	(-13.7) [0.044] C	(-10.7) [0.036] C	(-8.7) [0.021] C	(-0.9) [0.019] C
	South Africa	(-11.6) [0.011] C	(-15.2) [-0.013] D	(-19) [-0.027] D	(-26.2) [-0.011] D	(-33.3) [0.012] C
	Syria	(-13.8) [-0.018] D	(-18.7) [0.013] C	(-22) [-0.024] D	(-29.1) [0.004] C	(-35.7) [-0.004] D
	Taiwan	(-13.6) [0.036] C	(-17) [0.051] C	(-17.7) [0.046] C	(-18) [0.029] C	(-15.9) [0.023] C
	Thailand	(-14.5) [0.012] C	(-18.9) [0.03] C	(-22.6) [0.035] C	(-27.2) [0.02] C	(-33.4) [0.006] C
	Turkey	(-12.2) [-0.005] D	(-16.1) [0.005] C	(-19.7) [0.002] C	(-24.7) [-0.003] D	(-30.8) [0.009] C
	Uruguay	-	-	-	-	-
	Zambia	(-13.6) [0.015] C	(-18.2) [-0.05] D	(-23.4) [-0.073] D	(-30.4) [-0.022] D	(-38.3) [0.032] C
High Income	Argentina	(-9.2) [0.003] C	(-12.7) [-0.017] D	(-16.5) [-0.023] D	(-24.8) [-0.007] D	(-30) [0.009] C
	Australia	(-2.3) [0.006] C	(-2.3) [-0.001] D	(-3) [-0.003] D	(-5.9) [0.004] C	(-6) [0.009] C

Income group	Country	1960s	1970s	1980s	1990s	2000s
	Austria	(-4.8) [0.013] C	(-4.6) [0.012] C	(-2.8) [0.003] C	(-3.8) [-0.003] D	(-5.5) [0.004] C
	Barbados	(-7.8) [0.027] C	(-6.2) [0.019] C	(-4.2) [-0.009] D	(-9.8) [-0.019] D	(-15.8) [0.004] C
	Belgium	(-5.2) [0.013] C	(-4.6) [0.009] C	(-3.3) [-0.001] D	(-5.4) [-0.003] D	(-7.7) [0.006] C
	Canada	(-2.4) [0.009] C	(-2.5) [0.003] C	(-1.4) [-0.005] D	(-4) [-0.004] D	(-5.7) [0.005] C
	Denmark	(-3.3) [0.003] C	(-2.7) [0.003] C	(-3.8) [0] D	(-5.3) [-0.002] D	(-6.1) [0] D
	Finland	(-6.4) [0.017] C	(-6.6) [0.01] C	(-6.1) [-0.001] D	(-7.2) [-0.001] D	(-10.9) [0.011] C
	France	(-5.3) [0.013] C	(-4.8) [0.01] C	(-4) [-0.002] D	(-6.2) [-0.007] D	(-9.9) [0.002] C
	Greece	(-9.3) [0.04] C	(-8.2) [0.014] C	(-7.6) [-0.015] D	(-13.8) [-0.006] D	(-17.6) [0.028] C
	Iceland	(-4.9) [0.02] C	(-6.3) [0.014] C	(-1.3) [0] D	(-3.7) [-0.002] D	(-5.7) [0.01] C
	Ireland	(-8.5) [0.015] C	(-10.3) [0.002] C	(-11.1) [0.008] C	(-14.2) [0.026] C	(-8.4) [0.03] C
	Israel	(-8.3) [0.019] C	(-8.1) [0.01] C	(-9.9) [-0.005] D	(-13.6) [-0.005] D	(-16) [0.009] C
	Italy	(-6.6) [0.008] C	(-6.1) [0.014] C	(-5.4) [0.004] C	(-6.7) [-0.007] D	(-10.3) [-0.005] D
	Jamaica	(-9.8) [-0.013] D	(-13) [-0.022] D	(-18.9) [-0.016] D	(-24.2) [-0.003] D	(-30.5) [-0.002] D
	Japan	(-9.3) [0.032] C	(-5.7) [0.031] C	(-4.6) [0.005] C	(-3.1) [-0.01] D	(-8.2) [0.007] C
	Luxembourg	(1.9) [0.002] D	(2.3) [0.001] D	(2.3) [0.015] D	(11.7) [0.024] D	(23.5) [0.016] D
	Netherlands	(-2.2) [0.001] C	(-1.4) [0.005] C	(-0.8) [-0.007] D	(-3.5) [0.009] C	(-2.8) [-0.005] D
	New Zealand	(-1.6) [-0.005] D	(-4.2) [-0.014] D	(-7.7) [-0.012] D	(-12.1) [-0.001] D	(-15.5) [0.003] C
	Norway	(-3.2) [0.01] C	(-2.9) [0.013] C	(0.9) [0.009] D	(0.7) [0.005] D	(5.7) [0.005] D
	Puerto Rico	-	-	-	-	-
	Spain	(-9.1) [0.021] C	(-8.5) [0.011] C	(-9.6) [-0.001] D	(-11.7) [0.002] C	(-13.6) [0.016] C
	Sweden	(-2.1) [0.006] C	(-1.3) [-0.003] D	(-2.7) [-0.008] D	(-5.1) [-0.003] D	(-8.5) [0.006] C
	Switzerland	(3.5) [-0.002] C	(5.5) [-0.004] C	(4.7) [-0.009] C	(3.3) [-0.011] C	(-2.8) [-0.006] D
	Trinidad &Tobago	(-9) [0.042] C	(-10.8) [-0.019] D	(-12.5) [-0.033] D	(-22.4) [0.019] C	(-24.1) [0.066] C
	United Kingdom	(-2.6) [-0.002] D	(-4.7) [-0.003] D	(-6) [0.001] C	(-7.2) [0.004] C	(-8.9) [0.002] C
	Venezuela	(-8.8) [0.006] C	(-11.5) [-0.014] D	(-15.4) [-0.033] D	(-23.8) [-0.024] D	(-30.9) [0] D

1- C and D denote catching up and divergence. The numbers in the parenthesis and bracket are logarithm the initial relative real GDP per capita in any decade and the average of the derivation of y from equation (7) in any decade, respectively.
2- Source: Authors findings

The highest number of catching up process occurred over 1960s and then in 2000_s. The highest number of divergence process occurred over 1980s and 1990s. 12 countries namely, Benin, Central African Republic, Congo, Dem. Rep., Guinea, Haiti, Jamaica, Kenya, Luxembourg, Madagascar, Nepal, Niger, and Senegal have been diverging from USA over all decades. We presented their relative income dynamics and fitted nonlinearities in Figure 1. As it is indicated in Figure 1, the divergence process of the Luxembourg is different from those of other countries. In 1960, the real GDP per capita of the Luxembourg was higher than that of the USA. Dynamics of its relative GDP per capita show that the ratio has grown over the period 1960-2009. But, the relative GDP per capita of other countries decreased over the period 1960-2009. In other words, Luxembourg experienced an upward divergence and other countries experienced a downward divergence.

12 countries such as, Botswana, China, Hong Kong, Ireland, Korea, Malaysia, Portugal, Seychelles, Singapore, Sri Lanka, Taiwan, and Thailand experienced the catching up over all decades. We represented their relative GDP per capita dynamics and fitted nonlinearities in Figure 2. As it can be seen, the real GDP per capita of Ireland and Singapore were less than the USA, but, in 2009, their real GDP per capita exceeded than of the USA. It is worth mentioning the relative real GDP per capita of other countries remained less than one until 2009.

In order to investigate more, we divided our sample into three groups, namely low-income countries, middle-income countries, and high-income countries according to their percentiles of 0.25 and 0.75 of real per capita GDP in years 1960 and 2009 (in the first column of Table 3, we classified the countries according to their real per capita GDP in year 1960). The low-income countries are countries with GDP per capita less than percentile 0.25. Middle- income countries are countries with GDP per capita between percentile 0.25 and 0.75. High-income countries group contains countries with GDP per capita higher than percentile 0.75.

Comparing the countries in the three groups based on their 1960 and 2009 real per capita GDP shows that 77% of countries with low GDP per capita in 1960 remain in the low- income group in 2009. Also, analyzing the

catching up process in low income group shows that nine countries such as Botswana, Republic of Congo, Equatorial Guinea, India, Indonesia, Mauritania, Morocco, Pakistan, and Sri Lanka had the potential to catch up and move from low-income group to middle-income group over the period 1960-2009. Seri Lanka could catch up toward USA in all decades, India and Indonesia could catch up in four decades and Botswana, Republic of Congo, Equatorial Guinea, Mauritania, Morocco, and Pakistan experienced catching up process in three decades. Other countries in the low-income group experienced divergence from the USA for at least 3 sequential decades.

75 percent of middle-income countries in 1960 remained in the group in 2009. Analyzing the catching up process in middle income group shows that nine countries such as, Central African Republic, Congo, Cote d`Ivoire, the Gambia, Guinea, Haiti, Kenya, Rwanda, and Senegal that were in the middle-income group in 1960, experienced divergence process for at least over four decades and hence fell into low-income group in 2009. Four countries such as Hong Kong, Korea, Singapore, and Taiwan caught up toward USA in all decades and could enter high-income countries group.

Comparing the countries in the high income group in 1960 and 2009 shows that 84 percent of countries in high-income group in 1960 remained fixed. All countries in the high income group except for Luxembourg, New Zealand, Argentina, Barbados, Jamaica, and Venezuela experienced upward convergence. Luxembourg could increase its relative GDP per capita and was, thus, diverged to the top. In 1960, New Zealand had GDP per capita higher than that of USA, but, its relative GDP per capita decreased over the period 1960-2009 and hence it experienced a downward convergence. Four countries such as, Argentina, Barbados, Jamaica, and Venezuela also experienced downward movement from high-income countries group to middle-income group over the period 1960-2009. It is worth mentioning that Jamaica was diverged from USA over all decades.

4- Conclusions

One of the oldest controversies in the economic growth literature is Convergence hypothesis. According to this hypothesis, income per capita inequality will disappear in long run. This paper examined the GDP per capita catching up process of 109 countries toward USA's GDP per capita through the use of time series model of convergence hypothesis and

univariate stationary test over the period between 1960 to 2009. Toward this end, we used the Becker, et al. (2006) flexible Fourier KPSS stationary test that could control an unknown number and form of structural breaks through the use of a selected frequency component of a Fourier function. Having used this test, we could reject the unit root hypothesis for 105 countries and could, thus, analyze the catching up process for the most countries.

Our results show that 75% of poor countries in 1960 remained poor and 88% of rich countries remained rich. Some countries such as Hong Kong, Korea, Singapore, and Taiwan could catch up toward USA and entered rich countries club. In contrast, some countries such as Argentina, Barbados, Jamaica, and Venezuela could not stay in the high-income countries and fell into middle-income group. Other countries such as Benin, Central African Republic, Congo, Dem. Rep., Guinea, Haiti, Kenya, Madagascar, Nepal, Niger, and Senegal were diverging from USA over all decades and fell into low-income group.

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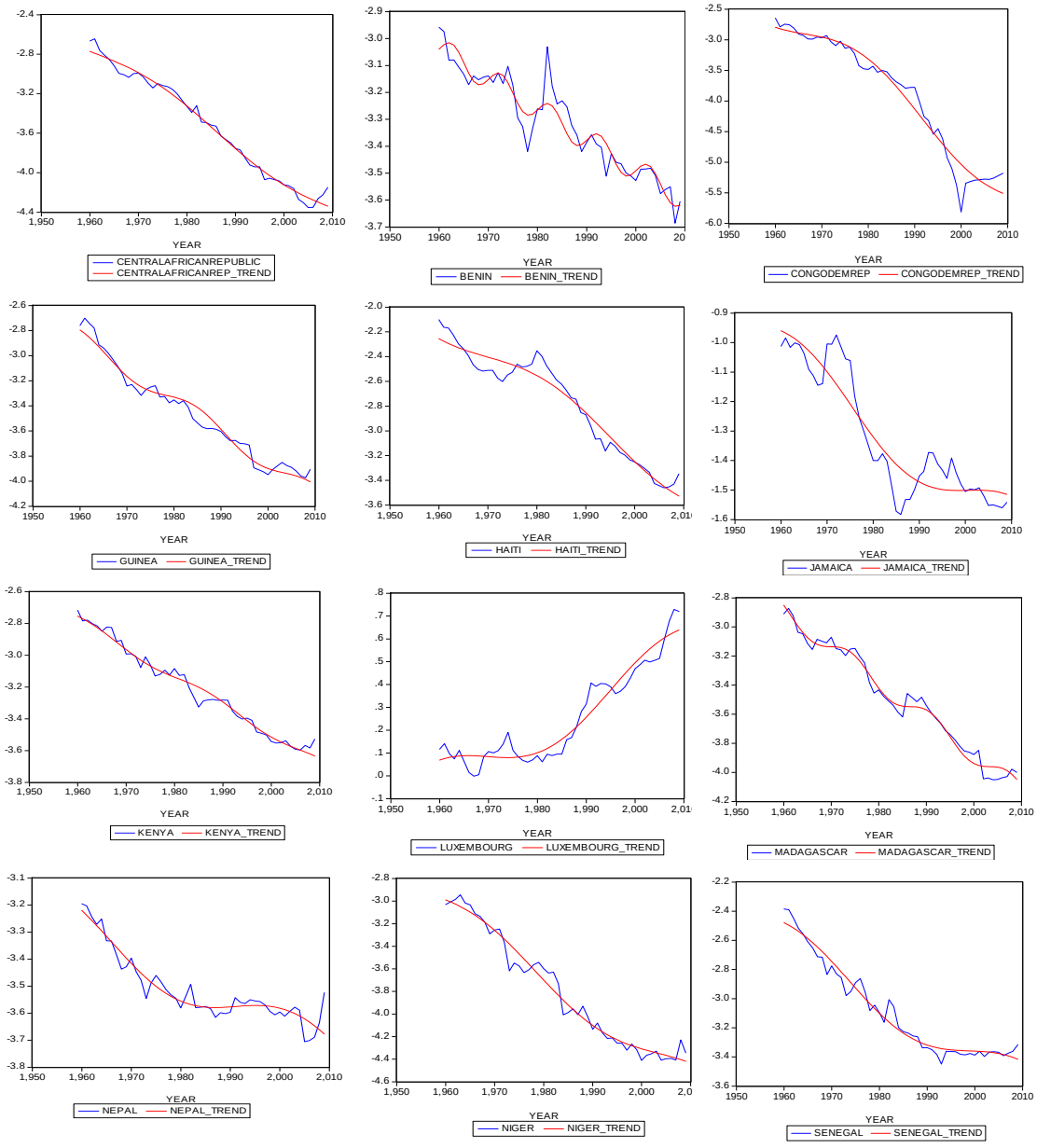

Figure 1: Relative GDP per capita series and fitted nonlinearities divergence

Blue line: the actual relative GDP per capita series.
Red line: fitted nonlinearities.

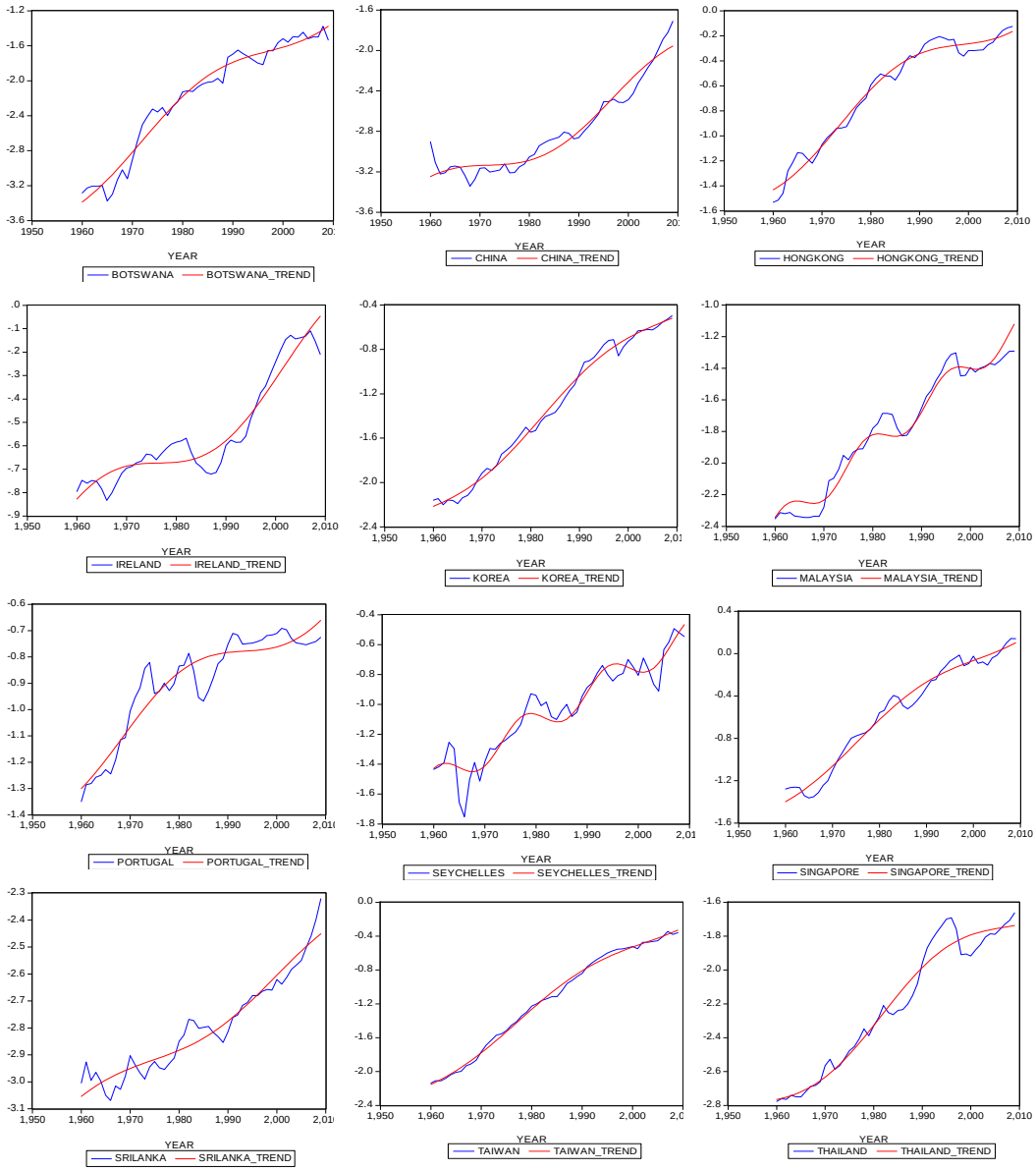

Figure 2: Relative GDP per Capita Series and Fitted Nonlinearities Convergence Process

Blue line: the actual relative GDP per capita series.
Red line: fitted nonlinearities.