Transit Stud Rev (2012) 19:3–11
DOI 10.1007/s11300-012-0225-7

FAR EAST AND ASIAN STUDIES

Are Asian Per Capita GDP Stationary? Evidence from First and Second Generation Panel Unit Root Tests

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Received: 30 October 2011 / Accepted: 24 February 2012 / Published online: 1 May 2012

Abstract This study examines stationarity characteristics of per capita GDP of a panel of 17 Asian countries and sub-panels. We employed a series of panel unit root tests that assume cross sectional independence and cross sectional dependence. The results of the second-generation tests reveal stationarity of per capita GDP for the entire Asian panel, as well as the East Asian and High Income Asian sub-panels. However, we find weak evidence for stationarity for the South Asian panel. The stationarity properties of the East Asian countries were strongly consistent with the idea that business cycles have stationary fluctuations around a deterministic trend, and vice versa hold for the South Asian panel.

Keywords Asia · Panel unit root tests · Per capita GDP

JEL Classifications C23 · C33

Introduction

Both Neo-Keynesian and Monetarist economists assume that the business cycles are a transitory phenomena, and output returns to its natural rate in long run. However,

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Nelson and Plosser (1982) questioned this view and found that US historical time series were non-stationary stochastic process with no tendency to return to the trend line. After this historical article, many studies examined the time series properties of the macroeconomic variables by using different unit root tests, a few among them are Stocks and Watson (1986), Perron and Phillips (1987), Campbell and Mankiw (1987), Evans (1989), Nelson and Murray (2000) for the US, whereas Rapach (2002), Cheung and Chinn (1996), Kormendi and Meguire (1990), Cogley (1990), Fleissig and Strauss (1999), Ohara (1999) and Duck (1992) analyzed the same for the other developed countries.

A few studies tested for stationarity of per capita GDP under a panel framework for developing countries, among these notable contributions are David and Papell (1998), Li (2000), Smyth and Inder (2004), Smyth (2003), Aguirre and Ferreira (2001), Narayan (2004), Narayan (2008). This study aims at reexamining the mean reversion properties of Asian per capita GDP by employing both first generation and second-generation panel unit root tests. As pointed out by Breitung and Pesaran (2008), Baltagi (2005), given the availability of shorter univariate time series data, the power of the unit root tests can be increased by the use of panel data. Depending on the context, panel unit root tests employ the assumption of interdependence or independence across countries. Thus, while the first generation test assumes independence of countries, the second-generation tests relax this assumption.

The study uses both first and second-generation tests. For the first generation tests, we employ the Levin et al. (2002, hereafter LLC) test, the Im et al. (2003, hereafter IPS) test and the Maddala and Wu (1999, hereafter MW) test. For the second-generation tests, we use the Moon and Perron (2004, hereafter MP) test, Pesaran (2007) test and Choi (2006) test. We find that the second-generation tests reveal stationarity of per capita GDP for the entire Asian panel as well as the East Asian and High Income Asian sub-panels. However, the South Asian panel gives weak evidence for stationarity in case of both first and second-generation unit root tests.

Methodology

Following Breitung and Pesaran (2008), Baltagi (2005), for increasing the power of the unit root test, we use panel data analysis. We divide these tests in two groups, namely, ‘first generation unit root test’ and ‘second generation unit’ root tests. The first generation of panel unit root tests employed in this study included LLC (2002) test, the IPS (2003) test and the MW (1999). The second generation tests are the MP (2004) test, (2004) test, Pesaran (2007) test and Choi (2006) test. The main difference between the two generations of tests lies in the cross-sectional independence assumption. Thus, while the first generation tests assume that all cross-sections are independent, the second-generation tests relax this assumption. In addition, the latter are more useful when co-movements are observed in the national business cycles of the countries in the same economic area (Hurlin 2010). The LLC (2002) test employs the following adjusted t-statistic:

$$t_{\hat{\partial}}^{*} = \frac{t_{\alpha} - (NT)\hat{S}_N \sigma_{\tilde{\varepsilon}}^{-2} \sigma_{\hat{\alpha}} \mu_T^{*}}{\sigma_T^{*}} \quad (1)$$

where $\hat{S}_N$ is the average of individual ratios in the long-run to short-run variance for country i; $\sigma_{\tilde{\varepsilon}}$ is the standard deviation of the error term in Eq. (2); $\sigma_{\hat{\alpha}}$ is the standard deviation of the slope coefficients in Eq. (2); σ_T^* is the standard deviation adjustment; μ_T^* is the mean adjustment.

The IPS (2003) test employed a standardized t_bar statistic that is based on the movement of the Dickey–Fuller distribution:

$$Z_{t\_bar} = \frac{\sqrt{N}\left\{t\_bar - N^{-1}\sum_{i=1}^{N} E(t_{iT})\right\}}{\sqrt{N^{-1}\sum_{i=1}^{N} Var(t_{iT_i})}} \quad (2)$$

where $E(t_{iT})$ is the expected mean of $E(t_{iT})$, and $Var(t_{iT_i})$ is the variance of t_{iT}.

The MW (1999) test is based on the combined significance levels (p values) from the individual unit root tests. According to MW (1999), if the test statistics are continuous, the significance levels $\pi_i(\mathrm{i} = 1, 2, \ldots .\mathrm{N})$ are independent and uniform (0, 1) variables. The MW (1999) test uses combined p values, or P_{MW}, which can be expressed as:

$$P_{MW} = -2\sum_{i=1}^{N} \log \pi_i \quad (3)$$

where $-2\sum \log \pi_i$ has a χ^2 distribution with the 2N degree of freedom. Furthermore, Choi (2001) suggested the following standardized statistic:

$$Z_{MW} = \frac{\sqrt{N}\left\{N^{-1}P_{MW} - E[-2\log(\pi_i)]\right\}}{\sqrt{Var[-2\log(\pi_i)]}} \quad (4)$$

Under the cross-sectional independence assumption, this statistic converges to a standard normal distribution (Hurlin 2010).

Among the second-generation unit root tests, this paper used: (1) the MP (2004) test (2) the Pesaran test (2007) and (3) the Choi test (2006). The MP (2004) test use a factor structure to model cross-sectional dependence. Their model assumes that error terms are generated by r common factors and idiosyncratic shocks.

$$y_{it} = \alpha_i + y_{it}^0 \quad (5)$$

$$y_{it}^0 = \rho_i y_{it-1}^0 + \upsilon_{it} \quad (6)$$

$$\upsilon_{it} = \lambda_i^{'} F_t + e_{it} \quad (7)$$

where F_t is a r × 1 vector of common factors and λ_i is a vector of factor loadings. The idiosyncratic component e_{it} is assumed to be i.i.d. across i and over t. The null hypothesis corresponds to the unit root hypothesis H_0: $\rho_i = 1$; where $i = 1,\ldots,N$ whereas under the alternative the variable y_{it} is stationary for at least one cross-sectional unit. For testing, under the data are de-factored and then the panel unit root test statistics based on de-factored data are proposed.

MP (2004) test treat the factors as nuisance parameters and suggest pooling de-factored data to construct a unit root test. The intuition is as follows: In order to eliminate the common factors, panel data are projected onto the space orthogonal of the factor loadings. By doing this, the de-factored data and its residual do not retain cross-sectional dependencies. This allows us to define standard pooled t-statistics, as in IPS (2003) test, and to show their asymptotic normality. Following the above let $\hat{\rho}^{+}_{pool}$ pool be the modified pooled OLS estimator using the de-factored panel data. Then, MP (2004) define two modified t-statistics, which have a standard normal distribution under the null hypothesis:

$$t_{\alpha} = \frac{T\sqrt{N}(\rho^{+}_{pool} - 1)}{\sqrt{2\gamma_e^4/w_e^4}} \underset{T,N\rightarrow\infty}{\overset{d}{\rightarrow}} N(0,1) \tag{8}$$

$$t_b = T\sqrt{N}(\rho^{+}_{pool} - 1)\sqrt{\frac{1}{NT^2}trace(Z_{-1}Q_{\wedge}Z'_{-1})\frac{w_e^2}{\gamma_e^4}} \underset{T,N\rightarrow\infty}{\overset{d}{\rightarrow}} N(0,1) \tag{9}$$

where w_e^2 denotes the cross-sectional average of the long-run variances $w_{e_i}^2$ of residuals e_{it} and γ_e^4 denotes the cross-sectional average of $w_{e_i}^4$. MP (2004) propose feasible statistics t_α^* and t_b^* based on an estimator of the projection matrix and estimators of long-run variances $w_{e_i}^2$.

In Pesaran's (2007) test, the augmented Dickey-Fuller (ADF) regressions are augmented with the cross-sectional average of lagged levels and first-differences of the individual time series. This allows the common factor to be proxied by the cross-section mean of y_{it} and its lagged values. The Pesaran test uses cross-sectional augmented ADF statistics, (denoted as CADF), which are given below:

$$\Delta y_{i,t} = \alpha_i + b_i y_{i,t-1} + c_i \bar{y}_{t-1} + d_i \Delta\bar{y}_i + e_{i,t} \tag{10}$$

where a_i, b_i, c_i, and d_i are slope coefficients estimated from the ADF test in country i; $\bar{y}_{t-1}$ is the mean value of lagged levels, and $\Delta\bar{y}_i$ is the mean value of first-differences; $e_{i,t}$ is the error term.

Pesaran (2007) suggested modified IPS (2003) statistics based on the average of individual CADF, which is denoted as a cross-sectional augmented IPS (CIPS). This is estimated from:

$$CIPS = \frac{1}{N}\sum_{i=1}^{N} t_i(N,T) \tag{11}$$

where t (N, T) is the t-statistic of the OLS estimate of in Eq. (5). The next test in this study is the Choi test that combines p values from ADF tests in which their non-stochastic trend components and cross-sectional correlations are eliminated using the Elliott et al.'s (1996) GLS-based de-trending and the conventional cross-sectional demeaning for panel data (Choi 2006). Based on this statistic, Choi (2006) suggested the Fisher's type statistics in the following form:

$$P_m = -\frac{1}{\sqrt{N}}\sum_{i=1}^{N}[\ln(P_i) + 1] \quad (12)$$

$$Z = \frac{1}{\sqrt{N}}\sum_{i=1}^{N}\Phi^{-1}(P_i) \quad (13)$$

$$L^* = \frac{1}{\sqrt{\pi^2 N/3}}\sum_{i=1}^{N}\ln(P_i/1 - p_i) \quad (14)$$

where P_i is the asymptotic p values of the Dickey-Fuller-GLS statistic for country i and where $\Phi(\cdot)$ is the cumulative distribution of a standard normal variable. Under the null hypothesis, all these statistics have a standard normal distribution.

Data and Variables

We have used an annual per capita GDP data of a panel of 17[1] Asian countries (namely Bangladesh, Cambodia, China, Hong Kong, India, Indonesia, Japan, Malaysia, Myanmar, Pakistan, Philippines, Singapore, South Korea, Sri Lanka, Taiwan, Thailand, and Vietnam) over the period 1950–2009. The data were taken from The Conference Board (2011) Total Economy Database accessed from http://www.conference-board.org/data/economydatabase. We have done the analysis for the full panel of 17 Asian countries and the sub panels: South Asia (India, Pakistan, Bangladesh and Srilanka), East Asia (Indonesia, South Korea, Malasia, Myanmar, Philippines, Thailand, Vietnam, China and Cambodia), and High Income Asian countries (Japan, Hong Kong, Singapore, South Korea, and Taiwan).

Results of First Generation Panel Unit Root Test

We employed the first generation tests for the entire Asian panel, South Asian panel, East Asian panel, and the high-income Asian country panel. The results are given in Table 1. The LLC (2002) test does not give evidence to reject the null hypothesis of unit root for the entire Asian panel, the East Asian panel, and the South Asian panel at the 5 % significance level. Nevertheless, for high-income Asian countries, the test statistics are significant at 1 %, indicating mean reversion in per capita GDP of high-income Asian countries.

However, the LLC (2002) test is criticized for its assumption of taking ρ to be homogeneous across i's, i.e., all the cross sections have a unit root property. The IPS (2003) test goes a step further and relaxes this assumption by allowing for a heterogeneous ρ. However, it does so by taking the average of the individual unit root test statistic, and tests for the presence of unit root across all the cross sections as its null hypothesis, against the alternative of an absence of unit root.

[1] Our sample size is restricted to 17 countries due to availability of comparable data.

Table 1 First-generation panel unit root tests

Types of test statistic	Test statistic	1 % CV	5 % CV	10 % CV
Asia (full panel)				
LLC test statistic computed in Eq. (1)	2.1971	−2.3263	−1.6449	−1.2816
IPS test statistic computed in Eq. (2)	10.5581	−2.3263	−1.6449	−1.2816
MW test statistic computed in Eq. (3)	10.8859	56.0609	48.6024	44.9032
Choi test statistic computed in Eq. (4)	−2.8030	2.3263	1.6449	1.2816
South Asia				
LLC test statistic computed in Eq. (1)	5.6302	−2.3263	−1.6449	−1.2816
IPS test statistic computed in Eq. (2)	8.5653	−2.3263	−1.6449	−1.2816
MW test statistic computed in Eq. (3)	0.1629	20.0902	15.5073	13.3616
Choi test statistic computed in Eq. (4)	−1.9593	2.3263	1.6449	1.2816
East Asia				
LLC test statistic computed in Eq. (1)	−1.4202	−2.3263	−1.6449	−1.2816
IPS test statistic computed in Eq. (2)	−27.5479	−2.3263	−1.6449	−1.2816
MW test statistic computed in Eq. (3)	15.2018	13.2767	9.4877	7.7794
Choi test statistic computed in Eq. (4)	3.9604	2.3263	1.6449	1.2816
High income countries				
LLC test statistic computed in Eq. (1)	−4.3675	−2.3263	−1.6449	−1.2816
IPS test statistic computed in Eq. (2)	−0.3557	−2.3263	−1.6449	−1.2816
MW test statistic computed in Eq. (3)	13.1428	23.2093	18.3070	15.9872
Choi test statistic computed in Eq. (4)	0.7028	2.3263	1.6449	1.2816

Source: authors' calculation

The results of the IPS (2003) test provide evidence to reject the null hypothesis of unit root for the East Asian panel. In case of high-income Asian countries, the IPS (2003) test indicates unit root across all cross sections, which is contrary to the results obtained by the LLC (2002) test. However, for all other cases, the results are similar to the LLC test. The MW (1999) test uses combined significance levels, and rejects the null hypothesis of unit root only in the case of the East Asian panel, and hence supports the findings of IPS (2003) test. Finally, the Choi (2001) test gives findings that are similar to the IPS (2003) and MW (1999) tests.

The first generation panel unit root test is criticized for assuming cross-sectional independence. This assumption is relaxed under the second-generation panel unit root tests. The results of second-generation panel unit root tests applied to the entire Asian panel, South Asian panel, East Asian panel, and the high-income Asian country panel are given in Table 2. The first MP test[2] shows stationarity for the entire Asian panel, for the subpanel of East Asian countries and for the high-income Asian countries, as it rejects the null hypothesis of unit root at 1 % level of significance in all the three cases. For South Asia, the null hypothesis is rejected at the 10 % level of significance. The second MP test gives the same result as obtained

[2] Note that Moon and Perron (2004) have given two unit root tests. We refer to them as first MP test and second MP test.

Table 2 Second-generation panel unit root tests

Types of test statistic	Test statistic	1 % CV	5 % CV	10 % CV
Asia (full panel)				
First Moon Perron's test computed in Eq. (8)	−11.0882	−2.3263	−1.6449	−1.2816
Second Moon Perron's test computed in Eq. (9)	−11.5136	−2.3263	−1.6449	−1.2816
Pesaran's CIPS test (2007) computed in Eq. (11)	−0.6323	−2.4196	−2.2388	−2.1372
First Choi's test statistic computed in Eq. (12)	−2.8471	2.3263	1.6449	1.2816
Second Choi's test statistic computed in Eq. (13)	4.7144	−2.3263	−1.6449	−1.2816
Third Choi's test statistic computed in Eq. (14)	5.0695	−2.3263	−1.6449	−1.2816
South Asian panel				
First Moon Perron's test computed in Eq. (8)	−1.4234	−2.3263	−1.6449	−1.2816
Second Moon Perron's test computed in Eq. (9)	−1.1171	−2.3263	−1.6449	−1.2816
Pesaran's CIPS test (2007) computed in Eq. (11)	−0.8729	−2.5454	−2.3356	−2.2156
First Choi's test statistic computed in Eq. (12)	−1.8360	2.3263	1.6449	1.2816
Second Choi's test statistic computed in Eq. (13)	4.1592	−2.3263	−1.6449	−1.2816
Third Choi's test statistic computed in Eq. (14)	4.8622	−2.3263	−1.6449	−1.2816
East Asian panel				
First Moon Perron's test computed in Eq. (8)	−8.0148	−2.3263	−1.6449	−1.2816
Second Moon Perron's test computed in Eq. (9)	−2.9636	−2.3263	−1.6449	−1.2816
Pesaran's CIPS test (2007) computed in Eq. (11)	−2.51	−2.5454	−2.3356	−2.2156
First Choi's test statistic computed in Eq. (12)	2.0516	2.3263	1.6449	1.2816
Second Choi's test statistic computed in Eq. (13)	0.9076	−2.3263	−1.6449	−1.2816
Third Choi's test statistic computed in Eq. (14)	1.6828	−2.3263	−1.6449	−1.2816
High income countries				
First Moon Perron's test computed in Eq. (8)	−8.8261	−2.3263	−1.6449	−1.2816
Second Moon Perron's test computed in Eq. (9)	−4.5829	−2.3263	−1.6449	−1.2816
Pesaran's CIPS test (2007) computed in Eq. (11)	−1.9084	−2.5454	−2.3356	−2.2156
First Choi's test statistic computed in Eq. (12)	−0.8494	2.3263	1.6449	1.2816
Second Choi's test statistic computed in Eq. (13)	0.4554	−2.3263	−1.6449	−1.2816
Third Choi's test statistic computed in Eq. (14)	0.4123	−2.3263	−1.6449	−1.2816

Source: authors' calculation

from first MP test. However, the CIPS test (Pesaran 2007) rejects the null hypothesis of unit root for the East Asian panel only at 5 % level of significance. Choi's first test,[3] second test and the third test do not reject the null hypothesis of unit root for either the entire Asian panel or its subpanels.

Conclusion

Since the presence of unit root in output data provides information about the behaviour of business cycles, this study intended to examine the unit root property

[3] Note that Choi (2006) has given three test statistics for testing of unit root. We refer to them as the first Choi test, second Choi test and third Choi test.

of per capita GDP of 17 Asian countries using panel unit root tests. We used the first generation and the second-generation panel unit root tests, both for the period 1950–2009. After analyzing the entire panel of 17 Asian countries, we divided the panel into East Asia, South Asia, and High Income Asian countries. For the entire Asian panel, with the exception of first MP and second MP test, we were unable to reject the null hypothesis of unit root, either by the first generation or second-generation unit-root test. By using LLC (2002) test, we are able to reject the null hypothesis of unit root, but only for the high-income Asian countries. We find that the IPS (2003) test, the MW (1999) test and the Choi test reject the null hypothesis of unit root, but only for East Asian countries. Further, the use of the first and second MP test shows stationarity for the entire Asian panel, the subpanel of East Asian countries and the high-income Asian countries. However, the CIPS test (Pesaran 2007) rejects the null hypothesis of unit root for the East Asian panel only. Choi's first test, second test and third test do not reject the null hypothesis of unit root, for the entire Asian panel or its subpanels. Our results reveal that the South Asian panel is the only panel in which none of the unit root test were able to reject the null hypothesis of unit root.

Our results have implications for policymaking and econometric modelling. Our results, in large part, are consistent with the view that business cycles are stationary fluctuations around a deterministic trend—particularly for East Asian countries—as most of the unit root test reject the null hypothesis of unit root. These results also imply that in most cases, shocks will have only a transitory effect on per capita income for the East Asian countries. For East Asian countries, the econometric modeling involving per capita income and other macro variables for the sample period considered does not enable estimation of long-run relationship as existing in cointegration. Whereas for South Asian panel, panel cointegration tests involving per capita incomes can be undertaken since per capita income for South Asian panel is nonstationary.

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