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

# Is Per Capita Real GDP Stationary? Evidence from Selected African Countries Based on More Powerful Nonlinear (Logistic) Unit Root Tests

Tsangyao Chang
*Department of Economics, Feng Chia University, Taichung, Taiwan*

Chien−Chung Nieh
*Department of Banking and Finance, Tamkang University, Taipei Taiwan*

Ching−Chun Wei
*Department of Finance, Providence University, Taichung, Taiwan*

## *Abstract*

In this study we use a more powerful nonlinear (logistic) unit root test advanced by Leybourne et al. (1998) to investigate the time−series propertities of per capita real GDP for 26 selected African countries for the period 1960−2000. We strongly reject the null of unit root process for over one−third the countries. These empirical results have important policy implications for selected African countries.

**Citation:** Chang, Tsangyao, Chien−Chung Nieh, and Ching−Chun Wei, (2005) "Is Per Capita Real GDP Stationary? Evidence from Selected African Countries Based on More Powerful Nonlinear (Logistic) Unit Root Tests." *Economics Bulletin*, Vol. 3, No. 24 pp. 1−9
**Submitted:** May 4, 2005. **Accepted:** May 4, 2005.
**URL:** http://www.economicsbulletin.com/2005/volume3/EB−05C20014A.pdf

## 1. INTRODUCTION

Since the seminal work of Nelson and Plosser (1982), many studies have devoted to investigating the non-stationarity of important macroeconomic variables. The time-series properties of real output levels have been of special interest to researchers. Nelson and Plosser (1982) points out that the modeling of real output levels as either a trend stationary or a difference stationary process has important implications for macroeconomic policy, modeling, testing and forecasting. Studies on this issue are critical not only for empirical researcher but also for policymakers. In particular, this investigation can help determine whether fiscal and/or monetary stabilization policies would likely have only temporary effects on real output levels.

Most of the empirical studies to date support the existence of a unit root in real output levels, critics have claimed that this conclusion may be due to the low power of the conventional unit root tests employed. Recently, there is a growing consensus that macroeconomic variables exhibit nonlinearities and, consequently, conventional unit root tests, such as the ADF test, have low power in detecting mean reversion. To solve this problem, non-stationary tests based on a nonlinear framework must be applied.

This empirical study contributes to this line of research by determining whether a unit root process characterizes real output levels in selected African countries. We test the non-stationarity of per capita real GDP for 26 African countries using the nonlinear (logistic) unit root test of Leybourne et al. (1998). We can strongly reject the unit root process for more than one-third of the countries examined, indicating a unit root in real output levels holds true for only 15 of the 26 countries.

## 2. DATA

This empirical study uses annual per capita real GDP for 26 selected African countries over the 1960 – 2000. The data are obtained from the Penn World Tables (PWT) 6.1 of Heston, Summers and Aten (2002) and summary statistics are given in Table 1. The per capita real GDP data sets indicate that Gabon and Tanzania have the highest and lowest average per capita income, respectively.

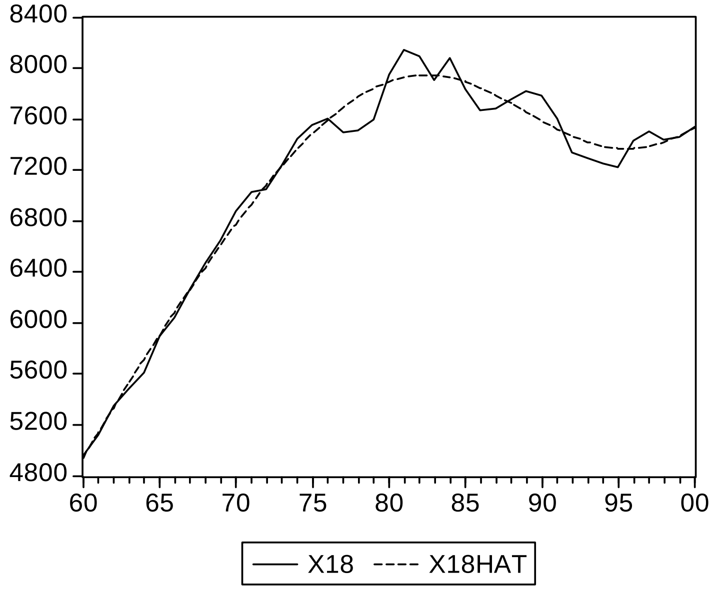
Jarque-Bera test results indicate that most of the 26 countries data sets are approximately normal with the exception of Gabon, Kenya, Mauritius, Uganda, South Africa and Zimbabwe. Figures 1 plots the actual values and fitted smooth transition of per capita real GDP for South Africa, a leading country in terms of higher political and economic status in Africa Due to space constraints, we do not report the figures for the rest of countries, but are available upon requests.

Table 1. Summary Statistics of Per Capita Real GDP Data Sets

| Area's Name | Mean | Std | Maximum | Minimum | Skewness | Kurtosis | J-B |
|---|---|---|---|---|---|---|---|
| 1. Botswana | 3472.1 | 2123.9 | 7880 | 945 | 0.3658 | 1.9108 | 2.942 |
| 2. Central African Republic | 1693.2 | 439.1 | 2240 | 895 | -0.4057 | 1.8029 | 3.573 |
| 3.Cote d'Ivoire | 2237.1 | 372.86 | 3048 | 1624 | 0.4415 | 2.4624 | 1.826 |
| 4. Gabon | 7490.9 | 1822.7 | 10408 | 3027 | -0.8801 | 3.001 | 5.293** |
| 5. Ghana | 1170.6 | 145.2 | 1551 | 822 | -0.048 | 0.625 | 0.683 |
| 6. Gambia | 1157.5 | 161.3 | 1440 | 748 | -0.463 | 3.079 | 1.471 |
| 7. Kenya | 1117.8 | 177.8 | 1336 | 754 | -0.756 | 2.097 | 5.296** |
| 8. Madagascar | 1044.9 | 158.1 | 1279 | 799 | -0.119 | 1.558 | 3.651 |
| 9. Mali | 840 | 81.34 | 1009 | 743 | 0.512 | 1.905 | 3.839 |
| 10. Mozambique | 1290.1 | 409.1 | 2116 | 748 | 0.278 | 1.598 | 3.891 |
| 11.Mauritius | 6919.9 | 3039 | 13932 | 3158 | 0.779 | 2.380 | 4.808* |
| 12.Niger | 1195.9 | 327.6 | 1751 | 795 | 0.441 | 1.683 | 4.292 |
| 13.Nigeria | 1024.1 | 120.2 | 1328 | 707 | -0.062 | 3.677 | 0.811 |
| 14.Rwanda | 932.8 | 145.6 | 1194 | 569 | -0.178 | 2.333 | 0.958 |
| 15.Senegal | 1567.1 | 107.1 | 1818 | 1377 | 0.533 | 2.598 | 2.215 |
| 16. Tanzania | 530.6 | 88.2 | 799 | 363 | 0.102 | 2.700 | 0.225 |
| 17. Uganda | 658.6 | 115.7 | 941 | 443 | 0.911 | 3.633 | 6.359** |
| 18. South Africa | 7123.6 | 860.1 | 8145 | 4962 | -1.171 | 3.261 | 9.473*** |
| 19. Zambia | 1175 | 205.3 | 1521 | 814 | -0.256 | 1.813 | 2.858 |
| 20. Zimbabwe | 2328.7 | 556.1 | 2983 | 1232 | -0.963 | 2.437 | 6.884** |
| 21.Burundi | 714.9 | 113.4 | 879 | 453 | -0.591 | 2.291 | 3.244 |
| 22.Burkina Faso | 780.6 | 106.2 | 967 | 612 | -0.034 | 1.626 | 3.223 |
| 23.Ethiopia | 580.6 | 49.38 | 673 | 447 | -0.406 | 2.645 | 1.342 |
| 24.Guinea | 2554.6 | 206.5 | 2994 | 2243 | 0.379 | 2.119 | 2.304 |
| 25. Guinea - Bissau | 546 | 127.6 | 887 | 320 | 2.562 | 3.112 | 2.212 |
| 26.Lesotho | 1186.3 | 263.9 | 1592 | 698 | -0.408 | 1.737 | 3.862 |

Note: Std denotes standard deviation and J-B denotes the Jarque-Bera Test for Normality. ***, **, and * indicate significance at the 0.01, 0.05 and 0.10 levels, respectively.

Figure 1. Actual Values of Per Capita Real GDP and Fitted Smooth Transition - South Africa




## 3. METHODOLOGY and EMPIRICAL RESULTS

### 3.1. Leybourne, Newbold and Vougas's (1998) Nonlinear (Logistic) Unit Root Tests

Following Leybourne et al. (1998), we consider the following three logistic smooth transition regression models:

Model A: $Y_t = \alpha_1 + \alpha_2 S_t(\gamma,\tau) + v_t$ (1)

Model B: $Y_t = \alpha_1 + \beta_1 t + \alpha_2 S_t(\gamma,\tau) + v_t$ (2)

Model C: $Y_t = \alpha_1 + \beta_1 t + \alpha_2 S_t(\gamma,\tau) + \beta_2 t S_t(\gamma,\tau) + v_t$ (3)

where $v_t$ is a zero-mean I(0) process, $S_t(\gamma,\tau)$ is the logistic smooth transition function, based on a sample of size T, where

$$S_t(\gamma,\tau) = [1+\exp\{-\gamma(t-\tau T)\}]^{-1} \quad \gamma > 0 \tag{4}$$

The S function controls the smooth transition between regimes. The parameter $\tau$ determines the timing of the transition midpoint, for example, for $\gamma > 0$, we have $S_{-\infty}(\gamma,\tau) = 0$, $S_{+\infty}(\gamma,\tau) = 1$ and $S_{\tau T}(\gamma,\tau) = 0.5$. The speed of transition is then determined by the parameter, $\gamma$. If $\gamma$ is small, then the transition is slow-- $S_t(\gamma,\tau)$ takes a long period of time to traverse the interval (0,1). In the limiting case, with $\gamma = 0$, $S_t(\gamma,\tau) = 0.5$ for all t. On the other hand, for large values of $\gamma$, $S_t(\gamma,\tau)$ traverses the interval (0,1) very rapidly> As $\gamma$ approaches $+\infty$, this function changes value from 0 to 1 instantaneously at time $t = \tau T$.

If we assume that $v_t$ is a zero-mean I(0) process, then Model A implies $Y_t$ is stationary around a mean which changes from $\alpha_1$ to $\alpha_1+\alpha_2$. Model B also allows the intercept to change from $\alpha_1$ to $\alpha_1+\alpha_2$, but includes a fixed slope term. Model C is the most flexible. Model C allows the intercept to change from $\alpha_1$ to $\alpha_1+\alpha_2$ and allows the slope parameter to change, with the same speed of transition, from $\beta_1$ to $\beta_1+\beta_2$. If $\gamma$ < 0, the initial and final model states are reversed but the interpretation of the parameters remains the same.

The tests of the Leybourne et al. (1998) are based on the following hypothesis:

$$\text{Ho: } Y_t = U_t, U_t = K + U_{t-1} + \varepsilon_t, U_0 = \varphi \quad (5)$$

Ha: Model A, Model B or Model C, (6)

where $\varepsilon_t$ and $v_t$ are both assumed to be stationary autoregressive moving average (ARMA) processes with zero mean. The test statistics are calculated in two steps:

Step 1. Using a nonlinear least squares (NLS) algorithm, estimate the deterministic component of the model and compute residuals ($\hat{v}_t$) from Models A, B or C.

Step 2. Compute the ADF statistic, the t-ratio associated with $\hat{\rho}$ in the ordinary least squares (OLS) regression,

$$\Delta\hat{v}_t = \hat{\rho}\hat{v}_{t-1} + \sum_{i=1}^{P}\hat{\theta}_i\Delta\hat{v}_{t-i} + \hat{\eta}. \quad (7)$$

The ADF statistics are denoted by $S_\alpha$, $S_{\alpha(\beta)}$ and $S_{\alpha\beta}$, respectively, if the residuals are calculated from Models A, B or C. Leybourne et al. (1998) provide critical values for the tests calculated using Monte Carlo simulation.

## 3.2. Empirical Results

For comparison, we first apply several conventional unit root tests to examine the null of a unit root in the output level for each province. We select the lag order of the test based on the Schwarz Criterion (SC). The results in Table 2 clearly indicate that the ADF, DF-GLS (Elliott et al., 1996), the P-P and NP (Ng and Perron, 2001) tests all fail to reject the null of non-stationarity of real per capita GDP for all 26 countries. The KPSS test also yields the same results. Table 3 presents Leybourne et al.'s (1998) nonlinear (logistic) unit root test results and the corresponding Model A, B, or C selected based on Schwarz Criterion. The empirical results strongly reject the unit root process for over one-third of the data series indicating a unit root in real output levels holds true only for 15 out of 26 countries studied here. These results indicate that per capita real GDP, for over one-third of the countries in Africa, follow a steady rate of growth and policy innovations must have temporary effects.

Table 2. Univariate Unit Root Tests (ADF, DF-GLS, P-P, KPSS and NP)

| Country | ADF | DF-GLS | P-P | KPSS | NP |
|---|---|---|---|---|---|
| 1. Botswana | 2.979(0) | 1.279(1) | 2.918[2] | 0.785[5]*** | 2.071(1) |
| 2. Central African Republic | -0.377(0) | 0.178(0) | -0.300[1] | 0.748[5]*** | 0.526(0) |
| 3. Cote d'Ivoire | -1.481(0) | -1.014(0) | -1.631[4] | 0.191[5] | -1.396(0) |
| 4. Gabon | -2.566(0) | -0.795(1) | -2.594[13] | 0.562[5]** | -0.701(1) |
| 5. Ghana | -2.437(2) | -1.408(0) | -2.491[4] | 0.291[4]* | -3.557 (0) |
| 6. Gambia | -1.779(0) | -1.135(0) | -1.788[3] | 0.358[5]* | -2.063(0) |
| 7. Kenya | -1.722(0) | -0.068(0) | -1.727[3] | 0.699[5*] | -0.585(0) |
| 8. Madagascar | -0.517(0) | 0.119(0) | -0.575[3] | 0.723[5]** | 0.583(0) |
| 9. Mali | -2.269(0) | -1.679(0) | -2.393[2] | 0..071[4] | -4.649(0) |
| 10. Mozambique | -0.935(0) | -1.016(4) | -0.981[3] | 0.621[5]** | -2.973(4) |
| 11. Mauritius | 3.312(0) | 2.772(1) | 2.917[2] | 0.744[5]** | 3.201(1) |
| 12. Niger | -0.998(0) | -0.325(0) | -1.007[1] | 0.732[5]** | -0.135(0) |
| 13. Nigeria | -1.934(0) | -2.038(0) | -1.926[4] | 0.309[3] | -8.986(0)** |
| 14. Rwanda | -2.011(0) | -2.037(0) | -1.969[2] | 0.204[5]* | -6.983(0)* |
| 15. Senegal | -3.106(0)** | -1.834(0) | -2.992[2] | 0.604[5]** | -4.872(0) |
| 16. Tanzania | -2.461(0) | -1.807(0) | -2.334[1] | 0.194[5] | -5.060(0) |
| 17. Uganda | 0.116(0) | 0.278(0) | 0.495[6] | 0.602[5]** | 0.978(0) |
| 18. South Africa | -2.973(1)** | -0.612(1) | -3.615[1]** | 0.532[5]** | -0.741(0) |
| 19. Zambia | -0.588(0) | -0.639(0) | -0.407[3] | 0.654[5]** | -1.346(0) |
| 20. Zimbabwe | -2.047(0) | -0.828(0) | -2.273[12] | 0.626[5]** | -0.682(0) |
| 21. Brundi | -1.806(0) | -1.436(0) | -1.662[2] | 0.255[5] | -3.632(0) |
| 22. Burkina Faso | -0..250(0) | -0.307(0) | 0.034[3] | 0.742[5]*** | -0.589(0) |
| 23. Ethiopia | -2.001(3) | -1.667(3) | -2.217[1] | 0.202[5] | -10.125(3)*** |
| 24. Guinea | -1.324(0) | -1.250(0) | -1.531[2] | 0.173[5] | -3.036(0) |
| 25. Guinea-Bissau | -2.108(0) | -1.909(0)* | -2.013[3] | 0.612[5]** | -6.603(0)* |
| 26. Lesotho | -1.247(0) | 0.141(0) | -1.111[33] | 0.735[5]** | 0.369(0) |

Note: ***, **, and * indicate significance at the 0.01, 0.05 and 0.10 levels, respectively. The number in parentheses indicates the lag order selected based on the Schwarz Criterion. The number in the brackets indicates the lag truncation for the Bartlett Kernel, as suggested by the Newey-West test

(1994). The critical values for the KPSS are taken from Kwiatkowski et al. (1992). The NP test was based on the MZa statistic.

Table 3. Nonlinear (Logistic) Unit Root Tests

| Area's Name | t-statistic | K | SC | Model |
|---|---|---|---|---|
| 1. Botswana | -.4.791 | 2 | 13.966 | C |
| 2. Central African Republic | -3.669 | 0 | 12.0258 | C |
| 3. Cote d'Ivoire | -4.521 | 0 | 11.701 | C |
| 4. Gabon | -6.441* | 0 | 15.971 | C |
| 5. Ghana | -3.794 | 2 | 12.024 | C |
| 6. Gambia | -4.813*** | 0 | 11.171 | B |
| 7. Keyna | -5.228** | 0 | 10.886 | A |
| 8. Madagascar | -2.453 | 0 | 10.326 | C |
| 9. Mali | -3.406 | 0 | 11.771 | C |
| 10. Mozambique | -4.444 | 4 | 12.477 | C |
| 11. Mauritius | -3.268 | 0 | 14.794 | A |
| 12. Niger | -3.232 | 0 | 11.669 | B |
| 13. Nigeria | -5.094** | 1 | 12.133 | C |
| 14. Rwanda | -3.447 | 0 | 11.904 | C |
| 15. Senegal | -5.175** | 0 | 11.405 | B |
| 16. Tanzania | -5.398*** | 0 | 10.829 | C |
| 17. Uganda | -4.653*** | 1 | 10.746 | B |
| 18. South Africa | -5.201** | 1 | 12.757 | B |
| 19. Zambia | -4.549 | 0 | 11.285 | B |
| 20. Zimbabwe | -5.361*** | 1 | 13.820 | C |
| 21. Burundi | -3.639 | 0 | 11.594 | C |
| 22. Burkina Fasco | -5.387*** | 0 | 10.005 | A |
| 23. Ethiopia | -6.249* | 4 | 9.706 | C |
| 24. Guinea | -2.746 | 0 | 12.887 | B |
| 25.Guinea-Bissau | -3.852 | 0 | 12.004 | B |
| 26.Lesotho | -4.494 | 1 | 11.916 | B |

Note: ***, **, and * indicate significance at the 0.10, 0.05 and 0.01 levels, respectively. Critical values are taken from Leybourne et al. (1998). SC indicates Schwarz Criterion and K is the order of lag-length. Models A, B. or C are selected based on Schwarz Criterion.

It is worth noting is that the results here are not consistent with those Cheung and Chinn (1996) and Rapach (2002), which support the notion of non-stationaity in real GDP for various panels of OECD countries. Our results, nevertheless, are consistent with those of Fleissig and Strauss (1999) who find that per capita real GDP for OECD countries was trend stationary using three different panel-based unit root tests

A major policy implication of our study is that a stabilization policy may only have some temporary effects on the output levels of most of the African countries studied here.

## 4. CONCLUSIONS

In this empirical study, we employ the Lebyourne et al, (1998) nonlinear (logistic) unit root tests to assess the non-stationarity properties of per capita real GDP from 26 selected African countries over the 1960 to 2000 period. The application of Lebyourne et al's (1998) test indicates a unit root in real output levels is not supported for most the provinces studied. Finally, our study implies that fiscal and/or monetary stabilization policies would only have temporary effects on the real output levels of over one-third African countries under study.

## References

Cheung, Ying-Wong and Menzie David Chin. (1996) "Deterministic, Stochastic, and Segmented Trends in Aggregate Output: A Cross-Country Analysis" *Oxford Economic Papers*, **48**, 134-162.

Elliott, G..; T J. Rothenberg, and J H. Stock. (1996) "Efficient Tests for an Autoregressive Unit Root" *Econometrica,* **64**, 813-836.

Fleissig, Adrian R. and Jack Strauss. (1999) "Is OECD Real Per Capita GDP Trend or Difference Stationary? Evidence from Panel Unit root Test" *Journal of Macroeconomics,* **21, 4**, 673-690.

Kwiatkowski, Denis.; Peter Phillips., Peter Schmidt and Yongcheol Shin. (1992) "Testing the Null Hypothesis of Stationarity Against the Alternative of A Unit Root: How Sure Are We That Economic Time Series Have A Unit Root?" *Journal of Econometrics*, **54**, 159-178.

Leybourne, Stephen., Paul Newbold and Dimitrios Vougas. (1998) "Unit Roots and Smooth Transitions" *Journal of Time Series Analysis*, **19, 1**, 83-97.

Nelson, C. and C Plosser.. (1982) “Trends and Random Walks in Macroeconomic Time Series” *Journal of Monetary Economic*s, **10**, 139-162.

Newey, Whitney and Kenneth West.. (1994) “Automatic Lag Selection in Covariance Matrix Estimation” *Review of Economic Studies*, **61**, 631-653.

Ng, Serena. and Pierre Perron. (2001) “Lag length Selection and the Construction of Unit Root Tests with Good Size and Power” *Econometrica*, **69(6)**, 1519-1554.

Perron, P. (1989) “The Great Crash, the Oil Price Shock and the Unit Root Hypothesis” *Econometrica*, **57(6)**, 1361-1401.

Rapach, D E. (2002) “Are Real GDP Levels Nonstationary? Evidence from Panel Data Tests” *Southern Economic Journal*, **68**, 473-495.