Economics Bulletin

Volume 29, Issue 4

Are Per Capita Real GDP Series in African Countries Non-stationary or Non-linear? What does Empirical Evidence Reveal?

Vasudeva N. R. Murthy
College of Business Administration, Creighton University

Emmanuel Anoruo
Coppin State University

Abstract

This paper extends the applied time series literature in economic development, by testing whether the per capita real GDP time series in 27 African countries are non-stationary or non-linear and globally stationary over the relatively long period from 1960 to 2007. Using the non- linear unit root tests developed recently by Kapetanios, Shin and Snell (2003) the results show that in one-third of the countries, the series are stationary with non-linear mean reversion. Policy implications are indicated.

The authors are grateful to the Editor, Professor John Conley and an anonymous referee for their insightful comments and suggestions. The usual disclaimer applies.

Citation: Vasudeva N. R. Murthy and Emmanuel Anoruo, (2009) "Are Per Capita Real GDP Series in African Countries Non-stationary or Non-linear? What does Empirical Evidence Reveal? ", *Economics Bulletin*, Vol. 29 no.4 pp. 2492-2504.

Submitted: Aug 18 2009. **Published:** October 02, 2009.

1. Introduction

The study of time series- properties of important macroeconomic variables, such as per capita real gross domestic product (PRGDP) has become very important for analyzing the impact of economic policies, econometric modeling and forecasting. It has been shown in the time series econometric literature that if the moments of the statistical distribution of a time-series or a data generating process depend on time and hence the series is non-stationary in its level, and if that series receives any shocks or experiences policy interventions, then the series will not be reverting to its mean path. Instead, the series will wander away. Furthermore, using such series in regression modeling would yield spurious statistical test results. Therefore, economic analysts and policy makers are interested in statistically discerning whether the PRGDP series of an economy of interest has the presence of a unit root and hence is non-stationary. In the literature, although there are many econometric attempts to study the time series properties of the PRGDP series of several developed economies and some developing countries, a limited number of studies dealing with the phenomenon are available for African countries [see Rapach (2002), Carrion-i-Silvestre (2005), Gaffelo et al. (2005), Chang et al. (2008), Chang et al. (2005, 2006), Narayan (2004) and Narayan (2008a,2008b), Diego Romero-Avila (2009)]. Chang et al. (2005), using the data on PRGDP of 26 African countries for the period 1960-2000, employing non-linear logistic unit root tests, found that for a majority of African countries, the series are non-stationary. In another study, Chang et al. (2006), using data on 47 African countries for the period 1980-2004, applying the recently formulated SURADF unit root tests show that for two-thirds of these countries, the null of a unit root hypothesis cannot be rejected. The most recent study, using the Carrion-i-Silvestre panel stationarity unit root tests allowing for multiple breaks and cross-sectional dependence, conducted by Diego Romero-Avila (2009), using the Maddison and Penn World Table Version 6.2 for the period 1950-2001, supports the regime-wise trend stationarity of PRGDP for a panel consisting of 46 African countries. As it will be discussed later in this paper, unit root studies based on panel data, despite enhancing the power of unit root tests do have some shortcomings. The present paper takes the position that the need for studying the time series properties of individual African countries is essential as many of these countries are attempting to solve their economic problems and embarking on new economic initiatives to increase their rate of economic growth by undertaking both monetary and fiscal policies, which warrant information based on individual country unit root tests. In the time-series econometrics literature, the usual procedure to increase the power of unit root tests, in light of shorter univariate time series data, is to use the panel data [see also Breitung and Pesaran (2008) and Baltagi (2005)]. But, in this paper, the focus is on the individual country time-series for several reasons, the main reason being that unlike in the past, consistent individual country time-series data for 27 African countries, are now available , for a relatively long span, 1960-2007 (World Bank, 2009). The other reason for using individual country unit root tests is that when the objective of investigation of the presence of a unit root is to shed some light on the effects of economic policies over time, unit root test results for individual countries will be of tremendous practical significance. Furthermore, a compelling reason for examining the time-series properties of individual countries is the presence of some major theoretical pitfalls of commonly used panel unit root tests leading to misleading inferences, especially when the panel members included in the sample exhibits pronounced variations in economic, political and structural characteristics or heterogeneities [see also Breuer et al. (2002) and Sarno and Taylor (1998)]. It has been demonstrated that in most of the widely used panel unit root tests such as the LLC and

IPS tests, there is a possibility that the panel outcome, where the data generating series of a panel as a whole is stationary is driven often by a small number of stationary panel members [see also Sarno and Taylor (1998), Mark (2001), Breuer et al. (2002), Chortareas and Kapetanios (2004)]. Thus, the existence of a few stationary series in the panel might warrant the rejection of the null hypothesis of the presence of a unit root for the whole panel [see also Breuer et al. (2002)]. The need for separating I (0) from I (1) series and pool-able from non pool-able series to overcome this problem becomes challenging, especially when the panel consists of a large number of countries. Therefore, the main objective of this paper is to extend the literature on applied time-series properties on African countries by employing the recent non-linear univariate unit root test developed by Kapetonios et al. (2003), to empirically determine whether during the period 1960-2007, in the 28 African countries included in the sample, real GDP per capita series in levels are non-stationary or non-linear stationary processes.[1] According to the literature survey conducted by the authors, no such empirical attempts on African countries have been found.

2. Methodology and Data

When the data generating process(dgp), x_t, denoting real GDP per capita, exhibits a non-linear behavior due to the presence of such frictions in the economy as trade barriers, high transaction costs, transportation costs, high regulatory costs, corruption and a low degree of adaptability of resources and frequent policy interventions, the application of traditional linear unit root tests as the ADF [see Dickey and Fuller(1979 and 1981)] and the Phillips-Perron (1988) tests are less powerful and more size distorted. This means that one often accepts a false null hypothesis of the presence of a unit root when in fact the data generating process series may be stationary for central values when it is out of a threshold or an economic regime. In order to tackle this statistical problem, recently, Kapetanios, Shin and Snell (2003) have developed a non-linear unit root test called the KSS test or the NLADF test, which considers the possibility of a smooth transition of a non-linear non-stationary behavior for a given set of values within a threshold and the likelihood of a mean-reverting stationary process when the data generating process is out of the threshold. Specifically, they state the null hypothesis of the presence of a unit root against the alternative of a globally stationary Exponential Smooth Transition Autoregressive (ESTAR) process [see for details, Mourelle and Cuestas (2009), Cuestas (2007), Chortareas et al. (2008), Kapetanios et al. (2003), Van Dijket al. (2001) and Bierens (1997)]. Using their notation, we can specify the dgp model as under:

$$x_t = \beta x_{t-1} + \varphi x_{t-1}(1 - e - \theta X^{-\theta}{}_{t-1}) + \varepsilon_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where the error terms, ε_t, are assumed to be normally distributed. By reparameterising equation (1), we derive the following expression:

$$\Delta x_t = \alpha x_{t-1} + \gamma x_{t-1}\left(1 - e^{-\theta X}{}_{t-1}\right) + \varepsilon_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Furthermore, as Kapetanios et al. (2003) assume in equation (2), if $\alpha = 0$, then in the central regime, x_t is non-stationary. It has been demonstrated by Davies (1977) that the coefficient of $x_{t-1}, \gamma,$ is not identified when a unit root is present. Therefore, using a Taylor's

[1] Benin, Botswana, Burkina Faso, Burundi, Cameron , Central African Republic, Chad, Congo Democratic Republic, Cote d'Ivoire, Gabon, Ghana, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mauritania, Niger, Nigeria, Rwanda, Senegal, Seychelles, Sierra Leone, South Africa, Sudan, Togo and Zambia.

first- order approximation of the ESTAR process, for estimation purpose, one can re-specify equation (2) as:

$$\Delta x_t = \delta x_{t-1}^3 + \mu_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

In order to handle the presence of serial correlation in the error terms, we can incorporate lagged error terms in equation (3) and specify the following estimable model:

$$\Delta x_t = \delta x_{t-1}^3 + \sum_{i=1}^{j} \Delta x_{t-1} + \mu_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

In equation (4), x_t is either the demeaned or de-trended data series and δ is the coefficient of interest for testing the presence of a unit root. The stated null hypothesis is that x_t is a non-stationary data generating process $(\gamma = 0)$ and the alternative hypothesis of a non-linear stationary process $(\gamma < 0)$.

If the null hypothesis is rejected, then the statistical implication is that there exists an asymmetric speed of adjustment towards the equilibrium or the presence of a non-linear mean reverting stationary data generating process. Specifically, Kapetanios et al. (2003) perform the KSS unit root test as the following *t*-test:

$$NLADF = \hat{\delta} / S.e.\left(\hat{\delta}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where $\hat{\delta}$ and S.e. are respectively, the estimated coefficient of $\hat{\delta}$ and the standard error of $\hat{\delta}$. The KSS test statistics, using the demeaned series and de-trended series, are denoted respectively as $NLADF_M$ and $NLADF_T$.

The annual data used for the empirical analysis conducted and reported in this paper for the period 1960-2007 for 27 African countries, are gathered from *Africa Development Indicators 2008-2009*-CD ROM (World Bank, 2009). The selection of countries included in the investigation was dictated by the availability of most recent data for the entire period. Zimbabwe is excluded in this study as this country, besides being a very unstable country politically, has been experiencing over recent years continuous economic, political and other structural changes. The data used for estimation and analysis on per capita real GDP for these countries are in 2000 US dollars. For estimation, the data are expressed in logarithms.

3. Empirical Findings

Table 1 reports the results of the traditional linear unit root tests, the ADF, and the Ng-Perron (2001) MZ_α and MT_t unit root tests. The MZ_α and MT_t unit root tests are the modified versions of the Phillips-Perron (1988) tests. The Phillips-Perron unit root tests are designed to address the frequent incidence of serial correlated and heteroskedastic errors in the data generating process. However, these tests are not very efficient tests because they exhibit less power and more size distortions, especially when the autoregressive coefficient is close to unity and the errors have large moving average (MA) or autoregressive (AR) roots. Moreover, these tests frequently fail to discriminate between a highly persistent stationary data generating process from a non-stationary process. The MZ_α and MT_t unit root tests attempt to overcome some of the shortcomings of the Phillips-Perron (1988) unit root tests [see also Schwert (1989)]. In the

regressions that were run to conduct these tests, a constant and a linear trend were incorporated as the deterministic terms. Considering the traditional ADF test results, it is apparent that for only one country, Togo, the null hypothesis of the presence of a unit root is rejected at the 10% level of significance. The results of the MZ_{α} and MZ_{t} unit root tests indicate that for Cameroon, the null hypothesis is rejected at the 1% level of significance. For Nigeria and Rwanda, the null hypothesis of non-stationarity is rejected at the 10% level of significance. Therefore, for a vast majority of the African countries included in this study, the overwhelming evidence of non-stationarity in levels is supported, indicating that per capita real GDP series in the majority of countries studied is integrated of order one (RGDP~I(1).

Table 1: Linear unit root test results: Level PRGDP series

Country	ADF	MZ_{α}	MZ_{t}
Benin	-2.052(0)	-7.963(0)	-1.944(0)
Botswana	-1.423(8)	-5.355(2)	-1.493(2)
Burkina Faso	-1.805 (0)	-7.387(0)	-1.769(0)
Burundi	-1.193(9)	-1.885(0)	-0.822(0)
Cameroon	-1.480(1)	-215.042(4)*	10.36(4)*
Central African Republic	-2.218 (0)	-6.981(0)	-1.867(0)
Chad	-0.528(9)	-3.746(0)	-1.114(0)
Congo Democratic Republic	-1.801(1)	-8.338(1)	-2.000(1)
Cote d'Ivoire	-2.462(0)	-2.636(1)	-1.086(2)
Gabon	-1.964(0)	-4.84891)	-1.491(1)
Ghana	-0.008(0)	-4.078(1)	-1.189(1)
Kenya	-1.479(0)	-3.109(0)	-1.218(0)
Lesotho	-2.425(2)	-11.300(0)	-2.355(0)
Liberia	-2.282(1)	-9.298(1)	-2.153(0)
Madagascar	-1.586(0)	-6.000(0)	-1.576(0)
Malawi	-2.131(0)	-4.312(0)	-1.456(1)
Mauritania	-1.327(7)	-3.538(1)	-1.330(1)
Niger	-2.161(0)	-8.109(0)	-2.036(0)
Nigeria	-0.494(7)	-14.737(1)*	-2.69(1)*
Rwanda	-2.657(1)	-15.108(0)*	-2.72(0)*
Senegal	-0.313(1)	-5.190(0)	-1.304(0)
Seychelles	-2.228(0)	-8.846(0)	-2.036(0)
Sierra Leone	-1.556(0)	-2.966(0)	-1.185(0)
South Africa	-2.666(1)	-4.917(1)	-1.560(1)
Sudan	-0.006(3)	-7.640(1)	-1.663(1)
Togo	-3.331(0)*	-2.734(0)	-1.108(1)
Zambia	-0.973(0)	-3.439(0)	-1.095(1)

*Significant at the 10% level in rejecting the null-hypothesis. The figures in parentheses are the optimal lags. The MAIC procedure was used to determine the lags for the ADF tests. The 1%, 5% and 10% critical values for the ADF unit root tests are -4.166, -3.509 and -3.184, respectively. The 1%, 5% and 10% critical values for MZ_{α} and MT_{t}, are -23.80,-17.30, 14.20 and -3.42,-2.91 and -2.62,respectively. Deterministic terms include both the constant and time trend.

Table2: Non-Linear Unit root test results: level *PRGDP* series

Country	$NLADF_M$	$NLADF_T$
Benin	-1.619(4)	-1.474(4)
Botswana	-0.677(3)	-1.259(5)
Burkina Faso	-0.850(3)	-4.064(1)*
Burundi	-3.741(3)**	-3.745(3)**
Cameroon	-2.057(3)	-0.926(4)
Central African Republic	-4.960(2)***	-4.280(5)***
Chad	-6.080(2)***	-6.102(2)***
Congo Democratic Republic	-4.651(2)***	-4.408(2)***
Cote d'Ivoire	-2.716(5)	-2.668(5)
Gabon	-1.475(5)	-1.518(5)
Ghana	-5.109(2)***	-5.166(2)***
Kenya	-4.473(2)***	-2.064(5)
Lesotho	-3.455(2)***	-0.971(5)
Liberia	-4.633(1)***	-1.570(5)
Madagascar	-4.957(4)***	-2.001(5)
Malawi	-3.975(1)**	-1.658(5)
Mauritania	1.303(5)	1.258(5)
Niger	-2.023(5)	-0.799(4)
Nigeria	-0.294(5)	-0.057(5)
Rwanda	-1.552(5)	-1.545(5)
Senegal	-0.245(5)	-3.166(1)*
Seychelles	-3.577(2)***	-2.882(2)
Sierra Leone	-3.924(1)**	-1.275(4)
South Africa	-3.015(2)	-3.667(2)**
Sudan	-0.348(5)	-0.262(5)
Togo	-3.254(1)*	-2.595(2)
Zambia	-2.215(5)	-3.439(1)**

The 1%, 5% and 10% critical values for the $NLADF_T$ test are -3.90, -3.4 0 and -3.13, respectively. Deterministic terms include both the constant and time trend. $NLADF_M$ = results based on demeaned data. $NLADF_T$ = results based on de-trended data.

Table 2 presents the results of the KSS non-linear unit root tests. From the results of the non-linear KSS unit root tests, $NLADF_M$, with the demeaned series, we discern that for thirteen countries, about 48 of the total sample of 27African countries, the null hypothesis of non-stationarity is rejected. This finding implies that in Burundi, Chad, Central African Republic, Congo Demographic Republic, Ghana, Kenya, Lesotho, Liberia, Madagascar, Malawi, Seychelles, Sierra Leone and Togo, the per capita series real GDP series are stationary and they exhibit asymmetric or non-linear mean reversion. However, in almost all of these countries where the series on per capita real GDP exhibit upward trends, the unit root tests based on $NLADF_T$ are more relevant. The empirical findings from the KSS unit root test results using de-trended series, $NLADF_T$, show that the null hypothesis of non-stationarity is rejected only in 9 out of 27 countries. In Burkino Faso, Burundi, Cameron, Central African republic, Chad, Ghana, Senegal, South Africa and Togo, the KSS unit root test results, using the detrended series, $NLADF_T$ indicates asymmetric mean reversion and non-linear stationarity. It is quite likely that in these countries, the tests are identifying structural changes by approximating the broken series as non-linear trends [see also Kapetonios et al. (2003) and Bierens 1997)].

Figures 1 through 12 display the plots of GDP per capita for Burkina Faso, Burundi, Chad, Central African Republic, Congo Demographic Republic, Ghana, Nigeria, Rwanda, Senegal, South

Africa, and Zambia where the results were conflicting between the linear and nonlinear unit root tests. An examination of the graphs reveals that the GDP per capita series for these countries fluctuated over the sample period spanning 1972 through 2007. The observed fluctuations could be responsible for the inconsistent results provided by the two different models.

4. Conclusions

This paper extends the literature on applied time series econometrics for developing economies by applying for the first time the recently developed KSS non-linear unit root tests to both the demeaned and de-trended per capita real GDP series of 27 African countries for the period 1960-2007. The paper re-iterates the recent and growing position taken in the literature that while the use of panel data benefits the analysis by enhancing the power of univariate unit root tests, there is the imminent possibility of the time series properties of a minority of panel members influencing the statistical outcome that the panel as a whole is stationary. This shortcoming of the use of panel data highlights the need for conducting the individual country unit root testing if sufficient degrees of freedom are available. The availability of a longer span of data in recently published by the World Bank (2009), Penn Tables (2006) and the Maddison (2009) would render individual country unit root tests and hypothesis somewhat powerful by providing more data observations.

The results from the recently developed nonlinear unit root tests reported in this paper point out that in about one-third of the African countries included in the sample, per capita real GDP series are found to be stationary with asymmetric non-linear mean reversion and therefore in these countries, shocks to the economy in the form of economic policies tend to be temporary. Furthermore, it can be contended that these countries might have experienced structural changes in the form of broken trends in their real per capita output series. For a majority of the countries included in the study, the evidence supports the presence of a unit root in the per capita real GDP series.

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Figure 1: Plot of of GDP Per Capita for Burkina Faso

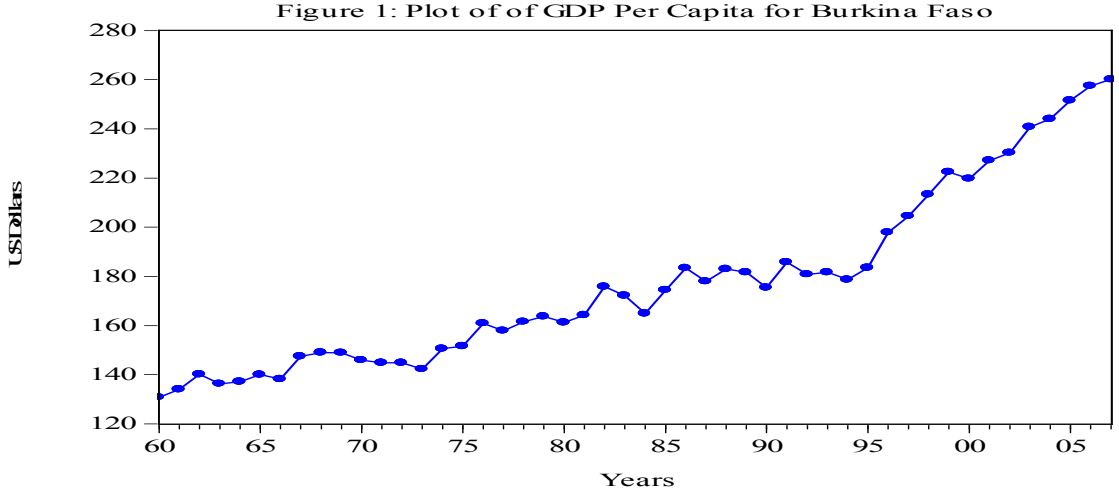

Figure 3: Plot of GDP Per Capita for Cameroon

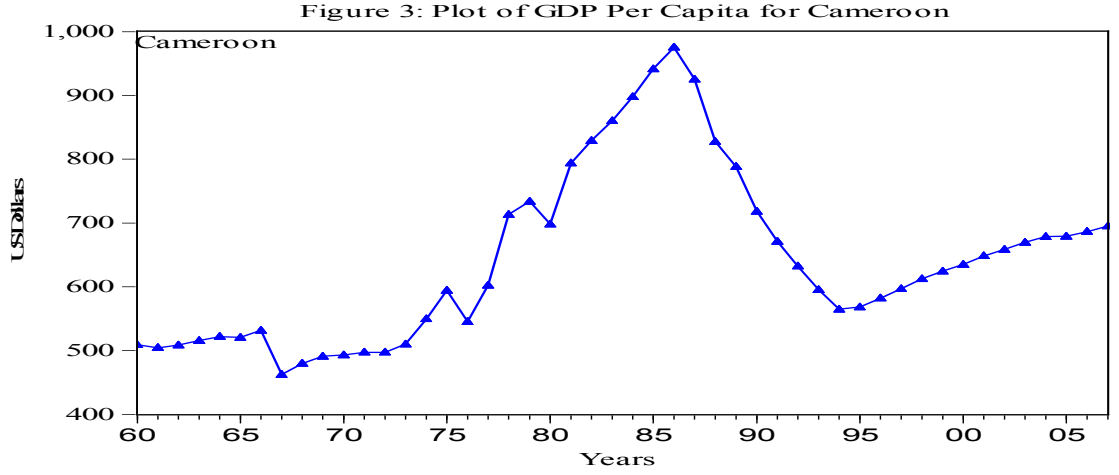

Figure 2: Plot of GDP Per Capita for Burundi

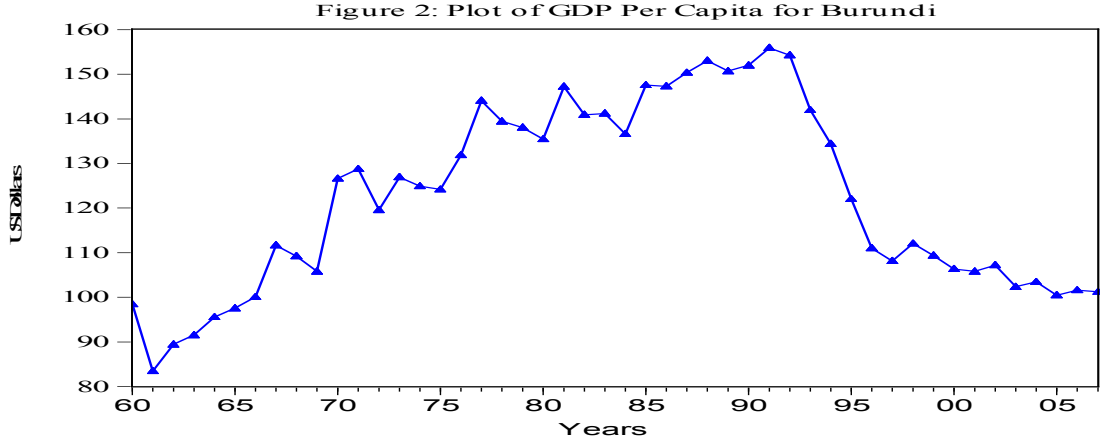

Figure 4: Plot of GDP Per Capita for Central African Republic

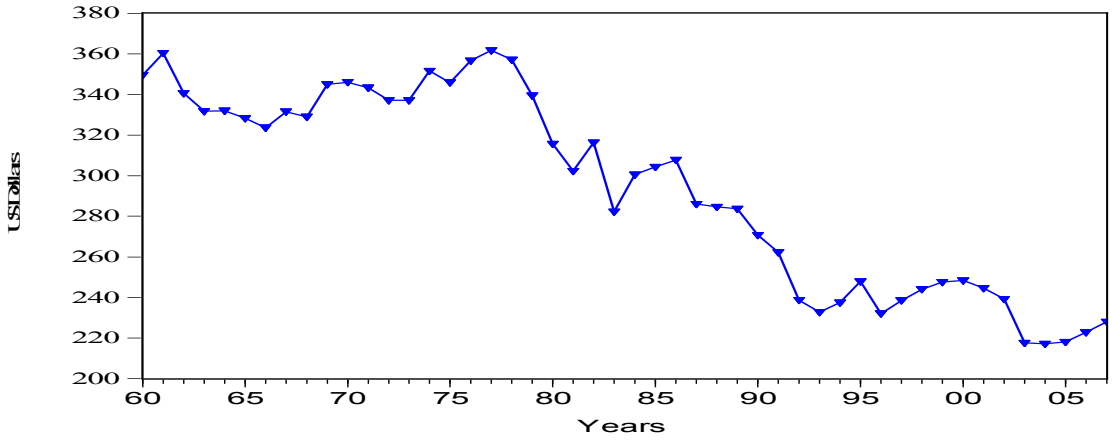

Figure 5: Plot of GDP Per Capita for Chad

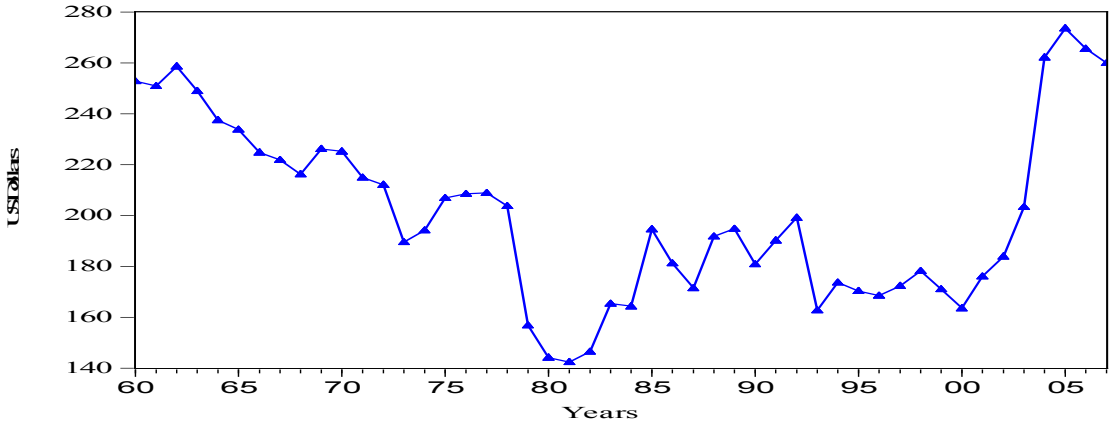

Figure 6: Plot of GDP Per Capita for Congo Democratic Republic

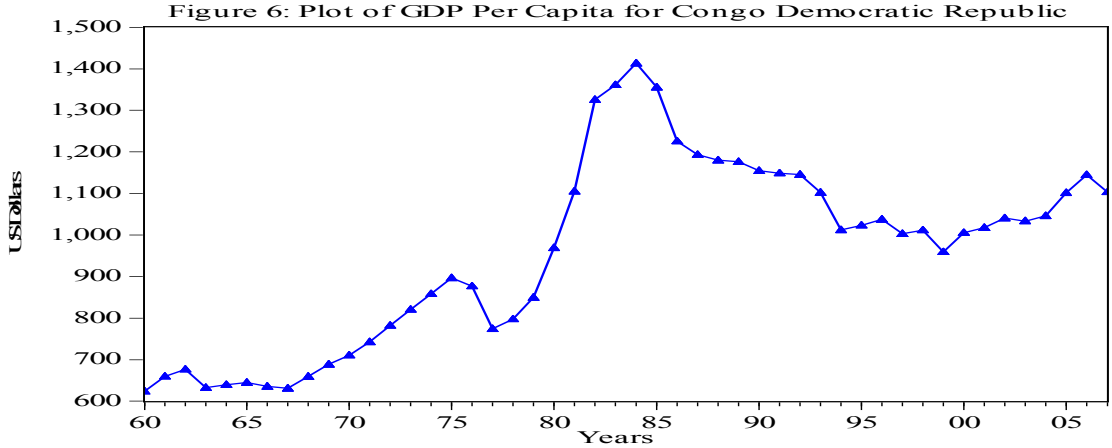

Figure 7: Plot of GDP Per Capita for Ghana

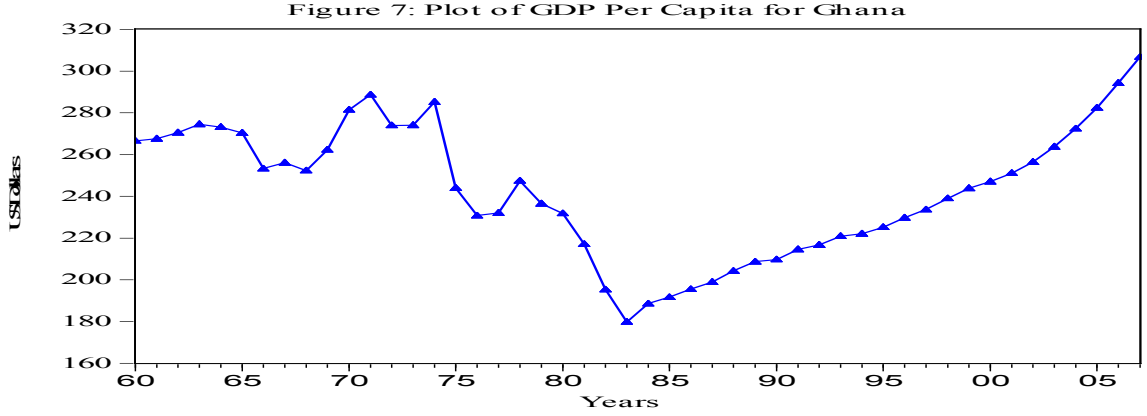

Figure 8: Plot of GDP Per Capita for Nigeria

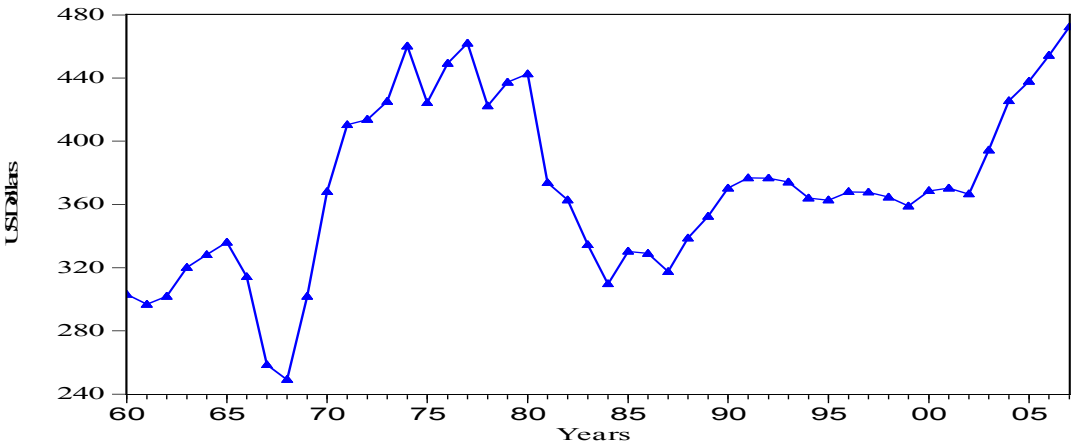

Figure 9: Plot of GDP Per Capita for Rwanda

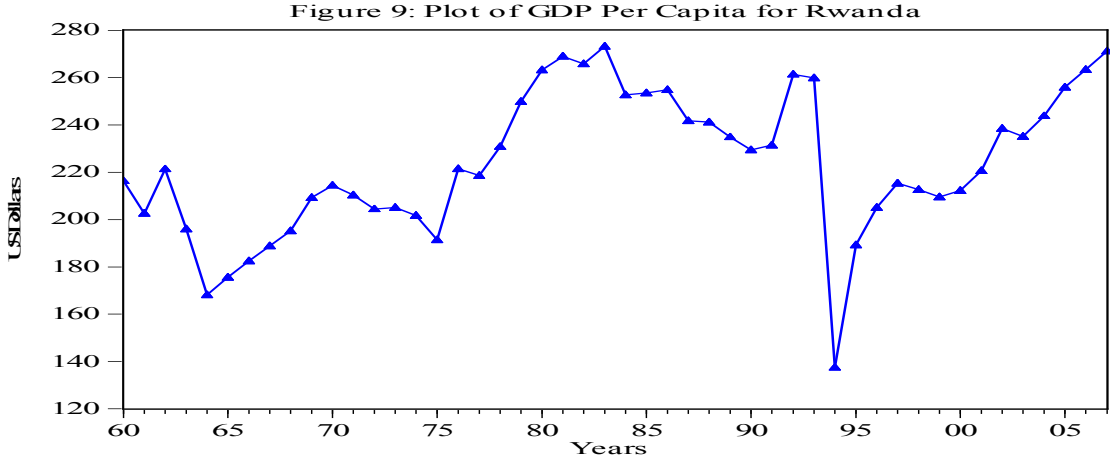

Figure 10: Plot of GDP Per Capita for Senegal

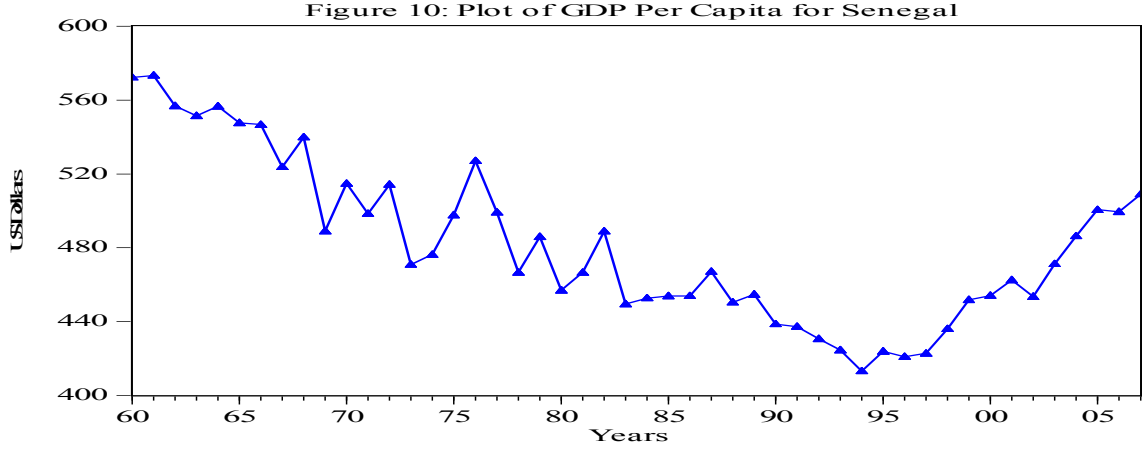

Figure 11: Plot of GDP Per Capita for South Africa

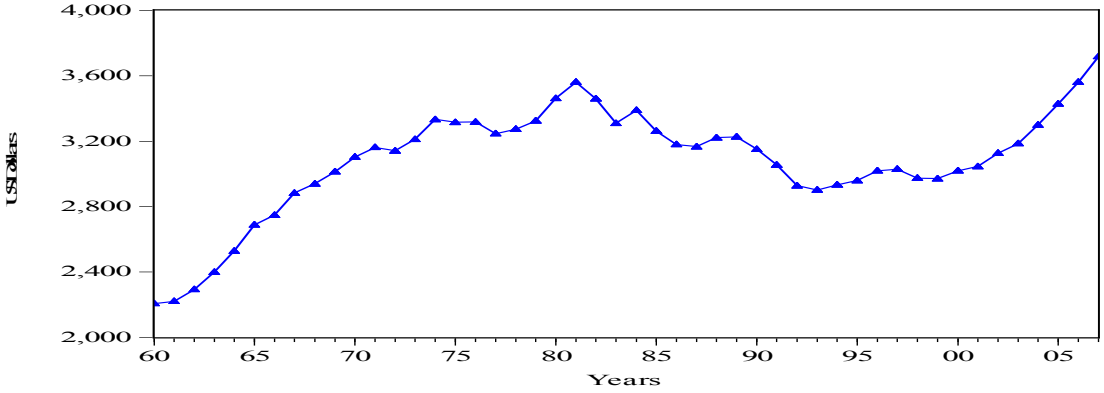

Figure 12: Plot of GDP Per Capita for Zambia