Nonlinear Econometric Approaches in Testing PPP of SADC Economies towards Monetary Union

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Abstract

The theory of purchasing power parity implies that real exchange rate series should be stationary. However, conventional unit root tests on the Southern African Development community (SADC) real exchange rates confirm the existence of a unit root. Such deficiencies in the investigation of the dynamics of real exchange rates in the region calls for nonlinear methods like the method used in this study to be pursued, which may better explain the dynamics of real exchange rates in SADC. In this paper two nonlinearity tests are employed: the nonparametric test developed by Brock, Dechert, and Scheinkman - known as the BDS test and the Fourier stationarity test. The BDS test detects the independent and identically distribute (iid) assumption of the time series used in the analysis while the Fourier approximation mimics a wide variety of breaks and other types of nonlinearities. Both tests confirm the non-linear nature of real exchange series in SADC. The result from the Fourier stationarity test further provides strong evidence of an OCA among the 11 SADC countries included in the study.

1 Introduction

The goal of the regional integration agenda in southern Africa is to create a fully integrated internationally competitive region to ensure economic growth and poverty reduction. The region faces a number of challenges achieving this goal but opportunities are all plentiful and the region is well positioned to take

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advantage of them (AfDB, 2011). The success of the integration process depends on stable economies in terms of inflation rates, interest rates, exchange rates, and levels of employment, among other factors (UNECA, 2010). Member states, particularly policy makers should consider regional integration as part of their broader strategic development objectives. To meet such objectives analysis of the applicability of Optimum Currency Area (OCA) theory among the economies envisaging monetary union has been a crucial step in the literature. OCA theory, an approach for analysing monetary unions, dates back to 1961 with Mundell's seminal article setting out the theoretical foundations (Mundell, 1961). Following Mundell's works, McKinnon (1963), Kenen (1969) and other economists made great contributions to the refinements of the theory.

This study employs two nonlinearity tests, namely the nonparametric test developed by Brock, Dechert, and Scheinkman known as the BDS test and the Fourier stationarity test. The investigation of non-linearity and asymmetries in macroeconomic behaviour constitutes an increasingly popular area of empirical research. The vast majority of studies are based on linear tests for mean-reversion in real exchange rates such as the Engle-Granger and Johansen cointegration tests. As is common with many macroeconomic variables, the data generation process of SADC real exchange rates is a stationary non-linear process. The implicit assumption of linearity of real exchange rates has made the majority of existing empirical literature on long-run PPP behaviour inconclusive and/or inconsistent. Given this gap the study seeks to answer the question of whether nonlinearities are present in SADC real exchange rates. To prove the question empirically we employ the concepts and methodologies of flexible Fourier stationarity tests proposed by Becker et al., (2006). Su et al. (2012) employ a similar methodology for the analysis of real exchange rate dynamics in 20 selected African countries for the fact that such series are of low frequency and often exhibit structural breaks. In such cases, flexible Fourier tests are more suitable (Enders and Lee, 2009; Pascalu, 2010). The objective of this paper is to assess the validity of purchasing power parity theory for SADC member states as an optimal currency area (OCA) criterion towards monetary integration in the SADC region.

The present empirical study contributes significantly to this field of research by using the flexible Fourier stationary test, proposed by Becker et al. (2006), to test the validity of long-run PPP in a sample of SADC economies. To the best of our knowledge, this study is the first of its kind to utilize the flexible Fourier stationary test and BDS test to test the long-run PPP in the SADC economies. The BDS test detects the independent and identically distributed (iid) assumption of the time series used in the analysis, while the Fourier approximation mimics a wide variety of breaks and other types of nonlinearities. The investigation of nonlinearities and asymmetries in macroeconomic behaviour constitutes an increasingly popular area of empirical research (Holmes, 2004). A prior study by Mokoena et al., (2009) using SADC real exchange rates argued that non-linear approaches to exchange rate adjustments are likely to provide a firmer basis for inference and stronger support for the PPP in the long term in the region. These findings provide firm ground for our analysis and hence we expect PPP will be valid for most of member countries of SADC. This paper may provide more sound results than has hitherto been the case with linear estimations of PPP in SADC. We also trust that this paper will make an important contribution to OCA literature and the policy debate on monetary union in SADC.

The remainder of this paper is organized as follows. Section 2 presents the data and methodology. Section3 first presents the empirical results and discussions. The last section concludes the paper.

2 Data and Methodology

2.1 Data

This analysis covers a sample of 11 SADC member countries. Four member states of SADC namely the DRC, Lesotho, Namibia, and Zimbabwe are not included in this study given the data limitations. Mokoena et al. (2009) also excluded these countries for similar reasons. Monthly data for the period January 1995 to August 2012 is used in this study. All data relating to consumer price indices (CPI) (based on 2005=100) and nominal exchange rates relative to the US dollar are taken from the IMF International Financial Statistics. Each of the consumer price index and nominal exchange rate series was transformed into natural logarithms before the econometric analysis.

In logarithmic form, the real exchange rate ($y_{i,t}$) is calculated as follows:

$$y_{i,t} = s_{i,t} + p^*_{us,t} - p_{i,t} \tag{1}$$

where $y_{i,t}$ is the logarithm of the real exchange rate against the US dollar, $s_{i,t}$ is the logarithm of the nominal exchange rate against the US dollar, and $p^*_{us,t}$ and $p_{i,t}$ respectively, are the logarithms of consumer price indices in the US and country 'i'.

As shown in Table1, Zambia has the highest mean real exchange rate followed by Madagascar and Tanzania, whereas Botswana has the lowest followed by Seychelles and South Africa. All the countries' exchange rates are symmetrically distributed around the mean since the measures of *skewness* for each country is close to zero. The Jarque-Bera test however, reveals that the (log) real exchange rate series of SADC countries are not *normally* distributed. This normality test is significant for all countries in the sample at a 1 percent level of significance, except for Madagascar which is significant at the 5 percent level. See graphical illustration of the logarithm of real exchange rate and fitted nonlinearities for the SADC countries included in this study in AppendixA1. In addition to graphical illustrations we also carried out a nonparametric nonlinearity test known as the BDS test named after Brock, Dechert, and Scheinkman (1987).

2.2 BDS Test

The motivation for the BDS test lies with *iid* assumption in time series data. To detect this assumption non-parametric test like BDS are more appropriate than parametric tests. It is generally believed that a non-parametric model provides a more robust approach to statistical inference because it is more likely to approximately capture the true underlying structure (Delegado and Robinson,1992; Yatchew,1998; Epstein and Scheider,2003). Following Franch and Coutreras (2002), let Y_t be a univariate real exchange rate series is iid from some distribution. Also, define

$$P_A = \Pr(|Y_t - Y_s| < \varepsilon) \tag{2}$$

as the probability that two points are within a distance 'ε'of each other. Further we can define:

$$P_B = \Pr(|Y_t - Y_s| < \varepsilon, |Y_{t-1} - Y_{s-1}| < \varepsilon) \tag{3}$$

Equation 3 holds true as the probability of a history of the two observations being within ε of each other. Under independence of Y_t, the two events contained in the event B are independent and therefore $P_B = P_A^2$.One can estimate P_A and P_B and also $P_B - P_A^2$ which has an expected value of zero under the null hypothesis. To estimate the probability that two m length vectors are within ε, define:

$$c_{m,n}(\varepsilon) = \frac{2}{(n-m+1)(n-m)} \sum_{s=m}^{n} \sum_{t=s+1}^{n} \prod_{j=0}^{m-1} I_\varepsilon(Y_{s-j}, Y_{t-j}) \tag{4}$$

where

$$I_\varepsilon(Y_{s-j}, Y_{t-j}) = \begin{cases} 1 & \text{if } |Y_{t-1} - Y_{s-1}| < \varepsilon \\ 0 & \text{otherwise} \end{cases} \tag{5}$$

Here n is the sample size and m is the so-called embedding dimension. Under the null of independent and identical distribution (iid),

$$E(C_{m,n}(\varepsilon)) = (E(C_{1,n}(\varepsilon)))^m \tag{6}$$

Brock et al. (1996) show that, given an embedding dimension, m, and a value of the radius,ε, the BDS statistic is given as:

$$w_{m,n}(\varepsilon) = \sqrt{n-m+1}\,\frac{c_{m,n}(\varepsilon) - c_{1,n-m+1}^{m}(\varepsilon)}{\sigma_{m,n}(\varepsilon)} \tag{7}$$

It is asymptotically distributed as N (0, 1). This formula uses the square root of the consistent estimator

$$\sigma_{m,n}^2(\varepsilon) = 4\left[k^m + 2\sum_{j=1}^{m-1} k^{m-j} c^{2j} + (m-1)^2 c^{2m} - m^2 k c^{2m-2}\right] \tag{8}$$

where

$$\begin{matrix} c = c_{1,n}(\varepsilon) \\ k = k_n(\varepsilon) \end{matrix} = \frac{6}{n(n-1)(n-2)} \sum_{t=1}^{n} \sum_{s=t+1}^{n} \sum_{r=s+1}^{n} h_\varepsilon(Y_t, Y_s, Y_r) \tag{9}$$

$$h_\varepsilon(i,j,k) = \frac{1}{3}\left[I_\varepsilon(i,j)I_\varepsilon(j,k) + I_\varepsilon(i,k)I_\varepsilon(k,j) + I_\varepsilon(j,i)I_\varepsilon(i,k)\right] \tag{10}$$

The consistent estimators $c_{1,n}$ and $k_n(\varepsilon)$ are in the class of U-statistics and, as is pointed out by Kanzler (1999), they are the most efficient estimators of c and k, respectively. (See BDS test result in Table 3).

2.3 Methodology for Stationary test with a Fourier function

Motivations for Fourier Unit Root Test

There have been methodological problems in attempts to test the validity of the PPP hypothesis and hence its contribution in reinforcing OCA theory among regional economic integrations towards monetary union. First, one has to know the exact number and location of the breaks. These are not usually known and therefore need to be estimated. This in turn introduces an undesirable pre-selection bias (see Maddala and Kim, 1998). Second, current available tests account only for one to two breaks. Third, the use of dummies suggests sharp and sudden changes in the trend or level. However, for low frequency data it is more likely that structural changes take the form of large swings which cannot be captured well using only dummies. Breaks should therefore be approximated as smooth and gradual processes (see Leybourne et al., 1998). These arguments motivate the use of a recently developed set of unit root and stationarity tests that avoid this problem. Both Becker et al. (2004, 2006) and Enders and Lee (2009) develop tests which model any structural break of an unknown form as a smooth process via means of Flexible Fourier transformations. Several authors, including Gallant (1981), Becker et al. (2004) and Enders and Lee (2009), and Pascalau (2010), show that a Fourier approximation can often capture the behaviour of an unknown function even if the function itself is not periodic.

Marcela et al. (2003) and Narayan (2005, 2006) provide evidence that, when structural breaks are included for individual countries, the real exchange rate is stationary, implying support for purchasing power parity. Chang et al., 2012 applied a flexible Fourier stationary test to test the validity of long-run PPP in a sample of East Asian countries over the period January 1986 to October 2009. The empirical results from this study indicate that PPP does not hold for most of the East Asian countries, with the exception of Indonesia and Japan.

This procedure allows us to study the non-linear mean-reverting behaviour of PPP without having to specify the kind of nonlinear adjustment process. Enders and Lee (2004, 2009) develop their unit root test using the LM principle. As indicated by Pascalau (2010), the LM has increased power over the DF approach. Following Enders and Lee (2004, 2009), we consider the following Data Generating Process (DGP):

$$y_t = \alpha_0 + \theta_t + \gamma_1 \sin(2\pi kt/T) + \gamma_2 \cos(2\pi kt/T) + \varepsilon_t \tag{11}$$

$$\varepsilon_t = \beta\varepsilon_{t-1} + u_t \tag{12}$$

$$\triangle\, y_t = \delta_0 + \delta_1 \sin(2\pi kt/T) + \delta_2 \cos(2\pi kt/T) + v_t \tag{13}$$

Where $k(1 \leq k \leq 5)$ is the number of frequencies of the Fourier function, 't' is a trend term, 'T' is the number of usable observations in the regression analysis and $[\delta_1 \sin(2\pi kt/T) + \delta_2 \cos(2\pi kt/T)]$ captures structural change in the series $\{y_t\}$.

The unit root test allows for an unknown number of endogenous structural breaks with the functional forms.

There is non-linearity and unknown breaks if the hypothesis $\delta_1 = \delta_2 = 0$ is rejected using F-statistics F (k) of *Table 3* in Enders and Lee (2004). The 'k' in F (k) is the $k_{\min}$ obtained from regression (4), which gives the minimum residual sum of squares (RSS) for different frequencies. The rejection of the above hypothesis is indicative of the presence of structural breaks. If θ =0 (using the τ_{DF} statistics from Table 3 in Enders and Lee 2004), there is a unit root. However, if θ is significantly different from zero, we reject the unit root taking into account nonlinearity and possible structural breaks and therefore the series $\{y_t\}$ is stationary (i.e. exhibit stochastic convergence (Nyong, 2013)). Further details on the methodological aspects of this paper can be found in Enders and Lee (2004, 2009). See Fourier unit root test result on Table 4.

3 Results and Discussion

Univariate unit root tests show that the real exchange rate data of the SADC economies included in this study have a unit root and is non-stationary. The results are not reported here but are available upon request. Mokoena et al. (2009) also reported the same result.As we discussed in Section 2, a panel of 11 SADC countries was used in this study with monthly data from 1995 to 2012.The BDS test detects the (iid) assumption of the time series used in the analysis, while the Fourier approximation mimics a wide variety of breaks and other types of nonlinearities. If the real exchange rate is found stationary by using the unit root test with structural break(s), the effects of shocks such as real and monetary shocks that cause deviations around a mean value or deterministic trend are only temporary. Then, PPP is valid in the long run with reference to OCA theory.

Table 2 provides the BDS statistics for all eleven exchange rate series of SADC countries included in the study. The results strongly suggest that the real exchange rate series of all the SADC countries included in this study reject the iid null hypothesis at the 1 percent level significance.

The Fourier unit root test results are reported in Table 1 with the time paths of SADC countries included in this study. As reported in Appendix A1 the time paths of all the real exchange rates clearly observe structural shifts in the trend. Given these findings the Fourier approximations appear reasonable to use in detecting unit roots in SADC countries.

The third column in Table 3 shows the sum of square of residuals (SSRs). The F-test for SSRs for all the SADC countries included in the study is significant at 1 percent level of F-test result. This result indicates that a single frequency works best for all of the SADC countries in the study. As shown in the fifth column of Table 3 the statistical values are all significant at a 1 percent level of significance. This condition implies that both the sine and cosine terms in equation (12) in the methodology section should be included in the estimated model. Thus, the hypothesis $\delta_1 = \delta_2 = 0$ is rejected using F-statistics F (k) of *Table 3* in Enders and Lee (2004).

The last column in Table 4 reports the results of unit root tests with a nonlinear function based on the estimated frequencies. All the T-statistic values for the 11 SADC member countries are significant at a 1 percent significance level. The Fourier function employed by Enders and Lee (2004, 2009) in this study provides some evidence favouring the long-run validity of PPP for the SADC member countries included in this study. The logarithm of real exchange rate is nonlinear stationary, implying that deviations from the real exchange rate are mean reverting towards the PPP equilibrium. These findings are in line with the findings by Chi-Wei Su et al., 2013, which strongly support PPP equilibrium for 19 African countries. As mentioned by Chi-Wei Su (2013), trade barriers, as well as interventions in the exchange markets, could be behind this nonlinear behaviour.

4 Conclusions

An in-depth investigation of the non-linear behaviour of macroeconomic fundamentals like real exchange rates of SADC countries is crucial for the analysis of an OCA in the region. Such studies are critical not only as a contribution to the literature on OCA theory in SADC, but also contributes empirical evidence for policymakers. The goal of the regional integration agenda in southern Africa is to create a fully integrated internationally competitive region to ensure economic growth and poverty reduction. However, the region needs to conform to OCA criteria before the counties in the region fully embark on monetary union. Given the long run dynamics of real exchange rates for the 11 member countries of SADC using the Fourier estimation method our findings come out in support of the region being an OCA based on the PPP theory. As suggested by Chang et al., 2009 these 11 SADC countries can use PPP to predict an exchange rate that determines whether a currency is over- or under-valued and experiencing differences between domestic and foreign inflation rates.

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Table 1: Descriptive Statistics and Normality Test of SADC (Log) Real Exchange Rate

Country	Country Code	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera
Angola	AGO	4.460	4.479	5.627	1.966	0.551	-0.867	5.800	95.768***
Botswana	BWA	1.714	1.696	2.129	1.493	0.143	0.743	2.945	19.527***
Madagascar	MDG	7.438	7.453	7.894	7.171	0.152	0.114	2.155	6.767**
Malawi	MWI	4.629	4.680	5.107	4.083	0.215	-0.910	3.432	30.886***
Mauritius	MUS	3.300	3.335	3.492	3.093	0.111	-0.262	1.833	14.453***
Mozambique	MOZ	3.118	3.104	3.457	2.874	0.146	0.559	2.463	13.603***
South Africa	ZAF	1.909	1.884	2.528	1.592	0.193	0.975	3.992	42.273***
Seychelles	SYC	1.798	1.733	2.263	1.558	0.158	1.054	3.212	39.619***
Swaziland	SWZ	1.949	1.911	2.580	1.581	0.207	0.832	3.416	25.979***
Tanzania	TZA	6.911	6.937	7.161	6.635	0.118	-0.470	2.462	10.357***
Zambia	ZMB	8.476	8.601	9.066	7.904	0.316	-0.284	1.481	23.240***

Source: own computation from sample data (1995m1-2012m8)
Note: ** and*** indicate significance at the 5% and 1% levels, respectively.

Table 2: The BDS test results for the monthly exchange rate time series (Fraction of pairs)[1]

	BDS Statistics of SADC Real Exchange Rates – country codes as local currency/USD H_o = iid is rejected in all cases										
	Country Codes[2]										
m	ANG	BWA	MDG	MWI	MUS	MOZ	ZAF	SYC	SWZ	TZA	ZMB
2	0.169	0.1796	0.1650	0.1779	0.181	0.175	0.176	0.181	0.175	0.174	0.181
3	0.2857	0.3015	0.2745	0.2957	0.303	0.290	0.295	0.302	0.294	0.291	0.304
4	0.3610	0.3827	0.3446	0.3711	0.385	0.364	0.373	0.381	0.375	0.366	0.387
5	0.4114	0.4342	0.3869	0.4177	0.437	0.408	0.423	0.431	0.425	0.411	0.440
6	0.443	0.465	0.4103	0.4444	0.470	0.432	0.452	0.461	0.456	0.435	0.475
c_1,n(ε)	0.7701	0.208	0.243	0.298	0.181	0.217	0.262	0.240	0.293	0.179	0.562
k_1(ε)	3824810	3821906	3831102	3823116	3817066	3814646	3830134	3825536	3821180	3818034	3806902
V-Statistic	0.7033	0.7027	0.7045	0.7030	0.7019	0.701	0.7042	0.7034	0.702	0.702	0.700
	P***<0.001, m=embedding dimension, Included observations (n): 2332										

Source: own computation from sample data (1995m1-2012m8)

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[1] There are other methods as well on the basis of how we select epsilon(e) like;
Fraction of pairs: e is calculated so as to ensure a certain fraction of the total number of pairs of points in the sample lie within of each other.
Fixed value: is fixed at a raw value specified in the units as the data series. Standard deviations: is calculated as a multiple of the standard deviation of the series.
Fraction of range: is calculated as a fraction of the range (the difference between the maximum and minimum value) of the series.
The default is to specify as a fraction of pairs, since this method is most invariant to different distributions of the underlying series.

[2] See Table 1 for the full names of the countries.

Table 3: Stationary Test with a Nonlinear Fourier Unit Root Test

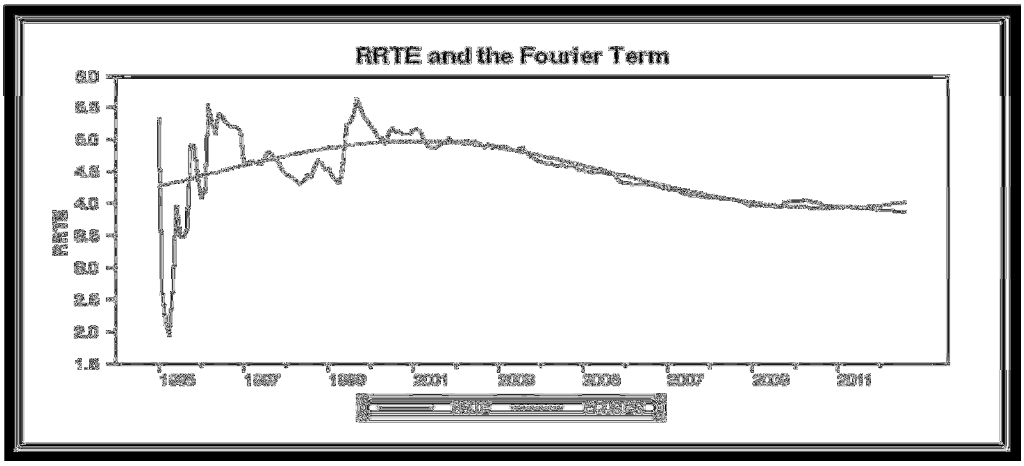
Country Code	Obs. (T)	SSRs	$\hat{k}$ *Frequency*	$F_{\mu}(\hat{k})$	$\tau_{\mu}(\hat{k})$
AGO	200	1.295	1	220.18***	-7.033***
BWA	203	0.146	1	446.14***	-2.731***
MDG	210	0.227	1	418.91***	-3.841***
MWI	199	0.311	1	360.60***	-2.731***
MUS	204	0.052	1	554.05***	-1.298***
MOZ	199	0.131	1	446.58***	-3.529***
ZAF	203	0.248	1	392.53***	-3.004***
SYC	200	0.195	1	409.52***	-2.461***
SWZ	203	0.311	1	369.82***	-2.653***
TZA	199	0.058	1	525.94***	-3.085***
ZMB	203	0.349	1	357.99***	-0.410***

Source: own computation from sample data (1995m1-2012m8)

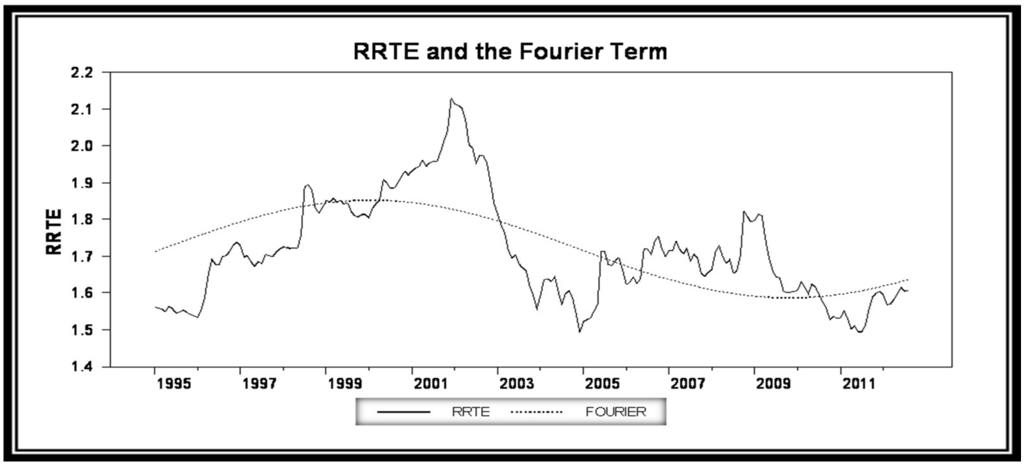
Appendices

Appendix A1: Graphical Illustration of the (Log) Real Exchange Rate & Fitted Nonlinearities of 11 SADC Countries

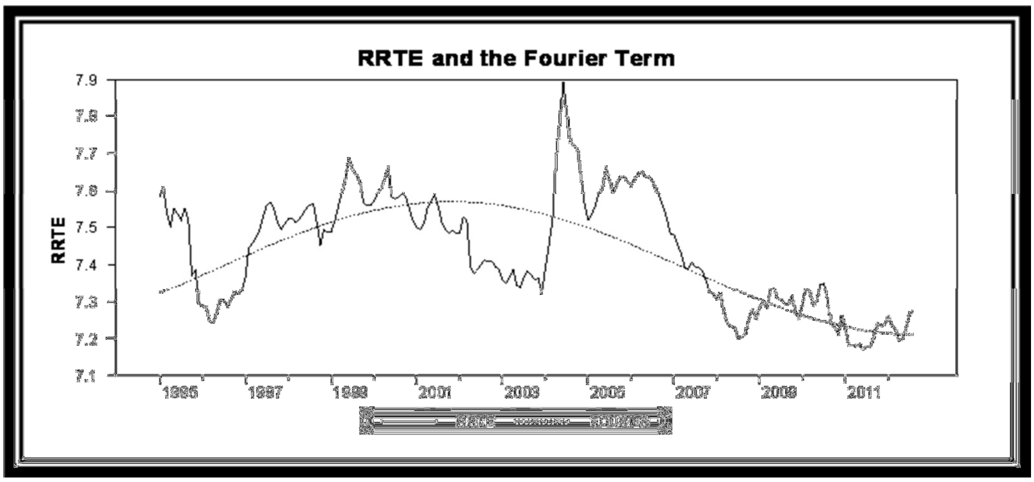
1. Angola:



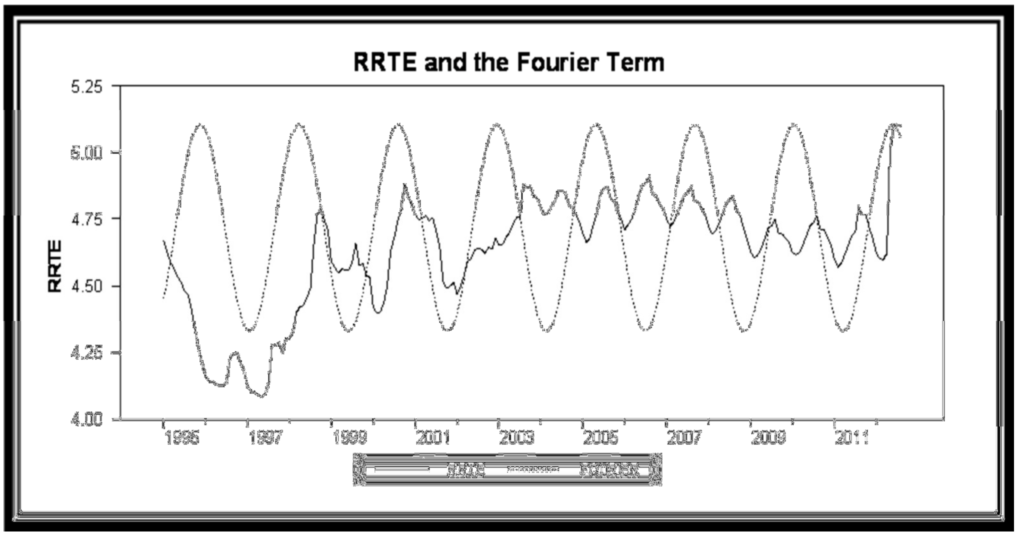
2. Botswana:



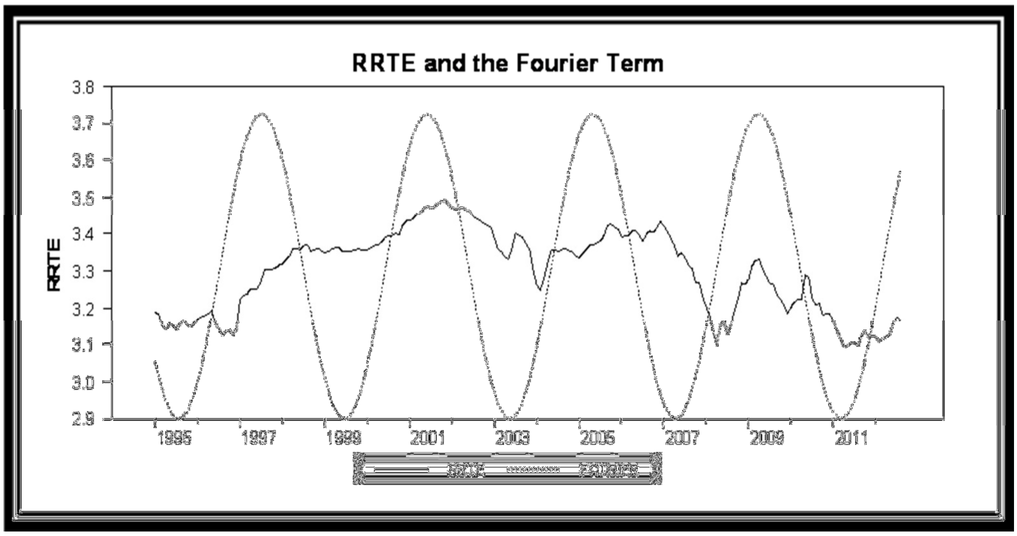
3. Madagascar:



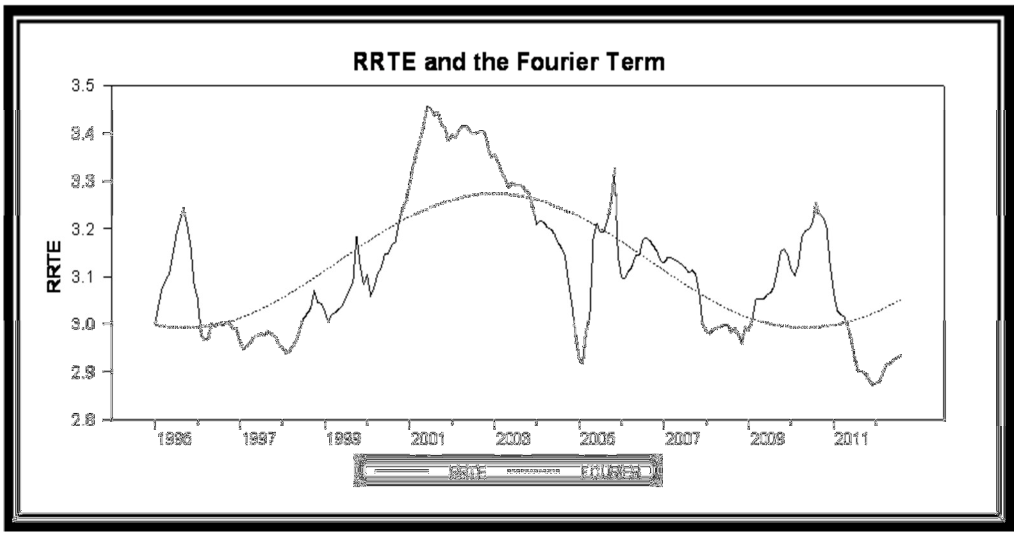
4. Malawi:



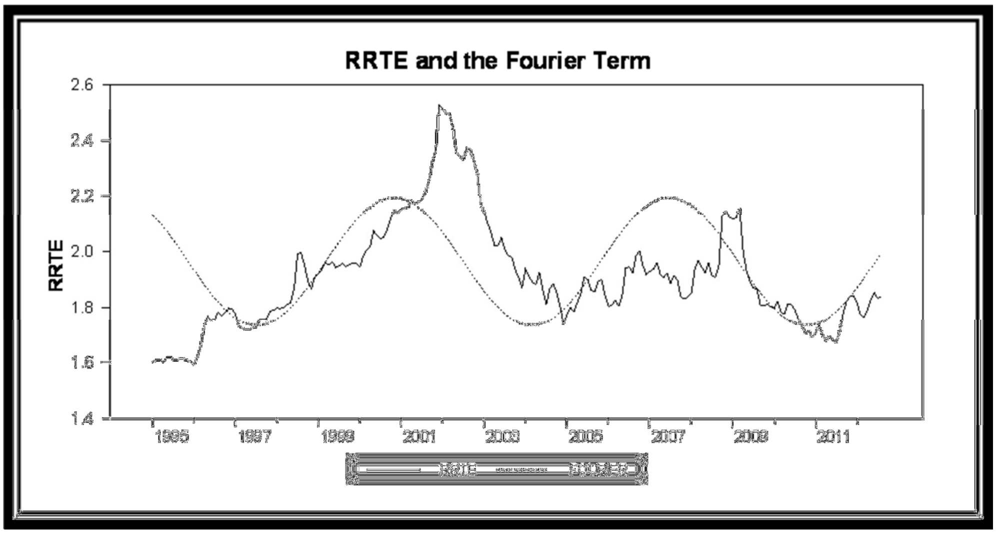
5. Mauritius:



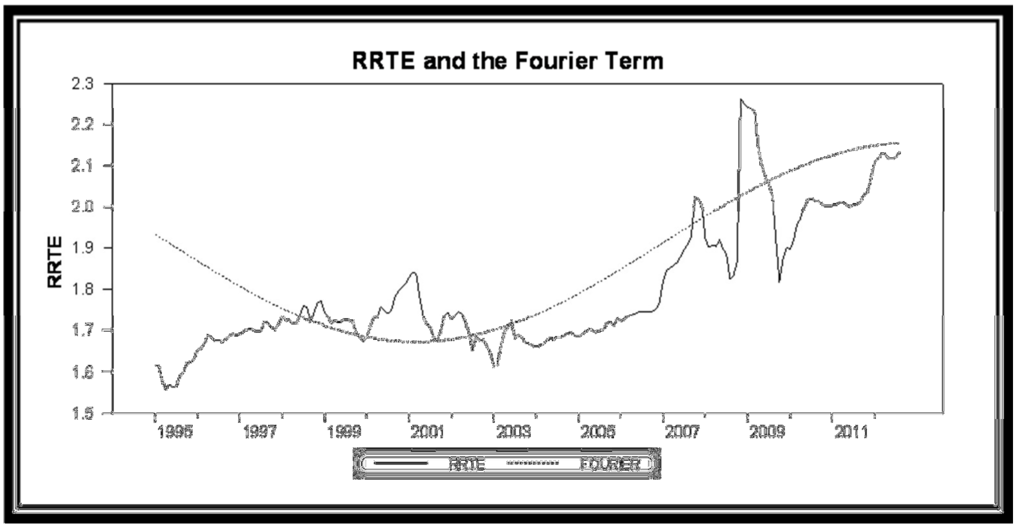
6. Mozambique



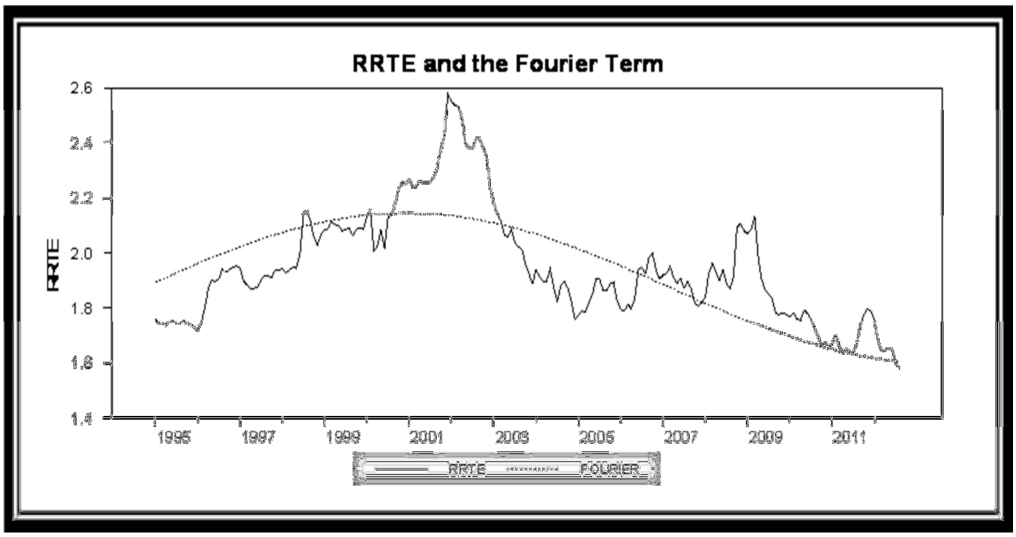
7. South Africa:



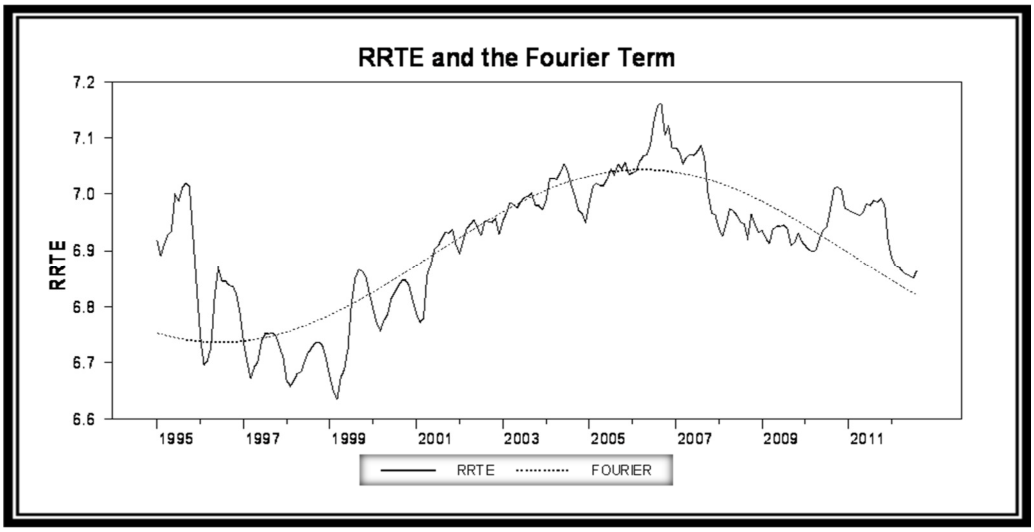
8. Seychelles:



9. Swaziland:



10. Tanzania:



11. Zambia