Standard Scientific Research and Essays Vol 3(5): 105-109, May 2015 (ISSN: 2310-7502)
http://www.standresjournals.org/journals/SSRE

Research Article

Detection of non-linearity in the time series using BDS statistics

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Accepted 20 May 2015

Abstract

The need to determine the status of the series is a very important issue that must be addressed before embarking on the statistical analysis of such series; this paper therefore, examines the status of the commercial bank savings in Nigeria. From the analysis we discovered that at level the series was not stationary as shown in figure1, however at the first difference (figure 2) the series was stationary, so also the unit root test applied shows that at level the series was not stationary (table1) but at first difference it was stationary (table 2) and this actually paved way for the application of Brock- Dechert-Scheinkman (table 3) test which actually revealed that this series could be best estimated by the use of non-linear model as the null hypothesis of linearity of the series was out rightly rejected and the alternative was accepted. The importance of this result lies on the fact that it guides against model misspecification as using linear model to estimate the parameter of the non-linear model will result in model judgmental error.

Keywords: Stationary, Unit root, BDS test, linear model, non-linear model, bank savings

INTRODUCTION

Commercial banking in Nigeria witnessed an era of impressive profitability, characterised by high competition, huge deposits and varied investment opportunities, in an effort to make quick profits, the commercial banks relied essentially on self liquidating loans and diversified their portfolio into less risky investments with safe margin. They are the most important savings, mobilization and financial resource allocation institutions. Consequently, these roles make them an important phenomenon in economic growth and development, in performing these roles; banks need to have the potential, scope and prospects for mobilising financial resources and allocating them to productive investments. Therefore, no matter the sources of income or the economic policies of the country, commercial banks would be interest in giving out loans and advances to their numerous customers bearing in mind the three principles guiding their operations which are profitability, liquidity and solvency.

The current trend in Nigeria banking and finance sector, suggest that the days of cheap profits are now over and only banks with well conceptualised lending and credit administration policies and procedures can survive the emerging competition. The best evidence that a bank is viable is if it is able to sustain consistent growth of high-quality earnings. It does not follow, however, that the bank will continue to be viable in a changing, regulatory, economic, or competitive environment.

Barltrop (1992) opined that it is desirable for a bank to maintain earnings growth at a pace that yields a level of dividends satisfactorily to shareholders, while also reinforcing its capital so that it can maintain an acceptable capital to asset ratio. Abe (1985) posited that deposits are the major source of funding for every licenced bank. A bank depends on a hand-core funding base generated from current, savings and term deposit accounts. To a large extent, the deposit base forms the bedrock of bank's loan and advances from which it derives its income. Nwadibia (1992) asserts that fixed assets represent the land and building and other fixed assets which are owned by the bank.

The BDS Test

There are so many ways of establishing the status of a given series among them are Hinich portmanteau test (1986), C brook test (1986), H and C- test (1986), BDS test and so many other ways. The attention of this paper is on Brock-Dechert-Scheinkman test (hereafter denoted as the BDS test) was first devised by W.A. Brock, W. Dechert and J. Scheinkman (Brock et al., 1987, 1996) and can be used as a general test of model misspecification. Since the BDS test has reasonable power against the GARCH models, it has been utilized as a diagnostic tool to determine the adequacy of GARCH models for detecting non-linear of the series (Guglielmo et al., 2005). In this case, the standardized residuals from the fitted GARCH models are subjected to the BDS test under the null hypothesis of sufficient linear components of the series. If the BDS test rejects the null hypothesis using appropriate critical values derived from simulation, then the fitted GARCH model is assumed to be an adequate characterization of the data. The BDS test statistic is calculated as follows. First, the $'m'$- histories' of the data $x_t^m = \left(x_t, x_{t+1}, ..., x_{t-m+1}\right)$ are calculated for $t = 1, 2, ..., T-m$ for some integer embedding dimension $m \geq 2$. The correlation integral is then computed, which counts the proportion of points in m-dimensional hyperspace that are within a distance $\in$ of each other.

$$C_m T(\in) = \frac{2}{(T-m+1)(T-m)} \sum_{t<s} I \in \left(x_t^m x_s^m\right),$$

Where $I_\in$ is an indicator function that equals one if $\left\| x_t^m - x_s^m \right\| < \in$ and zero otherwise, and $\|.\|$ denotes the sup. norm. BDS show that under the null hypothesis that the observed x_t are iid, then $C_{m,T}(\in) - C_1(\in)^m$ with probability one as the sample size tends to infinity and $\in$ tends to zero. The BDS test statistic, which has a limiting standard normal distribution, then, follows as:

$$W_{m,T}(\in) = \frac{T^{\frac{1}{2}}\left[C_{m,T}(\in) - C_{1,T}(\in)^m\right]}{\sigma_{m,T(\in)}}$$

where

$$\sigma_{m,T(\in)} = 2\left[k^m + 2\left\{\sum_{j=1}^{m-1} k^{m-j} C_{1,T}(\in)^{2j}\right\} - (m-1)^2 C_{1,T}(\in)^{2m} - m^2 K C_{1,T}(\in)^{2m-2}\right]^{\frac{1}{2}}$$

and $K(\in)$ is estimated by

$$K(\in) = \frac{6\sum_{t<s<r} h \in \left(x_t^m, x_r^m, x_s^m\right)}{\left[(T-m+1)(T-m)(T-m-1)\right]}$$

and

$$h \in (i,j,k) = \left[I \in (i,j) I \in (j,k) + I \in (i,k) I \in (k,j) + I \in (j,i) I \in (i,k)\right] / 3$$

Two parameters are to be chosen by the user: the value of $\in$ (the radius of the hyper-sphere which determines whether two points are 'close' or not), and m (the value of the embedding dimension). Brock et al. (1991) recommend that $\in$ is set to between half and three halves the standard deviation of the actual data and m is set in line with the number of observations available (e.g. $m \leq 5 \, for T \leq 200$ etc.). In this study, all combinations of $\frac{\in}{\sigma} = 1 \text{ and } 1.5$ (where σ

is the standard deviation of the sample data), and m =2 and 5 are used.

BDS test is a two-tailed test, we should reject the null hypothesis if the BDS test statistic is greater than or less than the critical values (e.g. if α=0.05, the critical value = $\pm$1.96).

A level of significance (α) 5% are usually taken in the hypothesis testing. The series (savings) were analyzed using E-view and the hypothesis was set as follows:

H_0: The series are linearly dependent

H_1: The series are not linearly dependent

DATA/ DATA ANALYSIS

The data for the paper was extracted from annual report of central bank of Nigeria covering the period from 1961 to 2011. The data covers a period of fifty years. The data was analyzed using Econometric view software (E-view).

Stationary condition of the series

The line graph of the series (figures 1) show that the series was non-stationary, as a result of the evident of volatility which do not fluctuate around a constant mean. Consequently we looked at the first differences of the series (figures 2) since it has no persistent trend and its values fluctuate around a constant mean of zero.

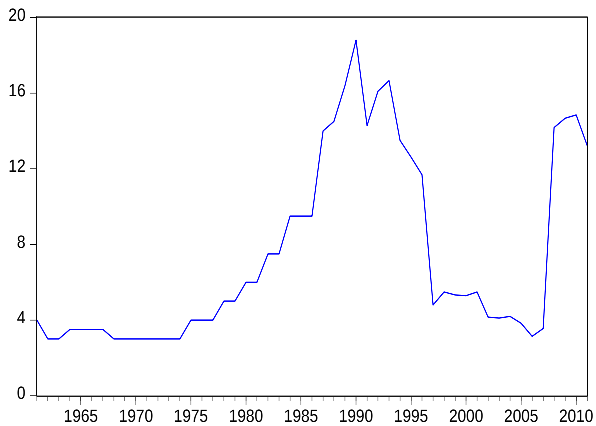

Figure 1. Savings

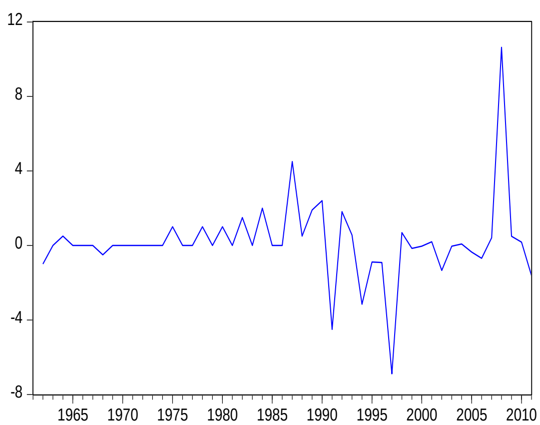

Figure 2. difference in savings

The stationary condition of the series can be formally verified by using unit root test (URT) for the leveled and first differences of the series. We test for a unit root using the augmented Dickey-Fuller (ADF) statistic. At level all the series are not stationary but at first difference all series are stationary as shown in tables (2a) and (2b) below.

Table 2a. Series at level
Null Hypothesis: SAVINGS has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.460837	0.5450
Test critical values:	1% level	-3.568308	
	5% level	-2.921175	
	10% level	-2.598551	

*MacKinnon (1996) one-sided p-values.
Augmented Dickey-Fuller Test Equation
Dependent Variable: D(SAVINGS)
Included observations: 50 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
SAVINGS(-1)	-0.094021	0.064361	-1.460837	0.1506
C	0.869101	0.561982	1.546494	0.1286

R-squared	0.042567	Mean dependent var	0.184400
Adjusted R-squared	0.022620	S.D. dependent var	2.217706
S.E. of regression	2.192480	Akaike info criterion	4.447122
Sum squared resid	230.7345	Schwarz criterion	4.523603
Log likelihood	-109.1780	Hannan-Quinn criter.	4.476246
F-statistic	2.134046	Durbin-Watson stat	1.884090
Prob(F-statistic)	0.150575		

Table 2b. Series at first difference
Null Hypothesis: D(SAVINGS) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic based on SIC, MAXLAG=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.829776	0.0000
Test critical values:	1% level	-3.571310	
	5% level	-2.922449	
	10% level	-2.599224	

*MacKinnon (1996) one-sided p-values.
Augmented Dickey-Fuller Test Equation
Dependent Variable: D(SAVINGS,2)
Method: Least Squares
Included observations: 49 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(SAVINGS(-1))	-1.000258	0.146455	-6.829776	0.0000
C	0.208629	0.324150	0.643618	0.5230
R-squared	0.498109	Mean dependent var		-0.012857
Adjusted R-squared	0.487431	S.D. dependent var		3.153429
S.E. of regression	2.257665	Akaike info criterion		4.506499
Sum squared resid	239.5614	Schwarz criterion		4.583716
Log likelihood	-108.4092	F-statistic		46.64584
Durbin-Watson stat	1.987809	Prob(F-statistic)		0.000000

Table 3. BDS Test for Savings Included observations: 51

Dimension	BDS Statistic	Std. Error	z-Statistic	Prob.	
2	0.144246	0.009741	14.80755	0.0000	
3	0.221633	0.015731	14.08868	0.0000	
4	0.257688	0.019034	13.53808	0.0000	
5	0.267745	0.020160	13.28090	0.0000	
6	0.291196	0.019759	14.73715	0.0000	
Raw epsilon		8.697418			
Pairs within epsilon		1847.000	V-Statistic	0.710111	
Triples within epsilon		71459.00	V-Statistic	0.538699	
Dimension	C(m,n)	c(m,n)	C(1,n-(m-1))	c(1,n-(m-1))	c(1,n-(m-1))^k
2	796.0000	0.649796	871.0000	0.711020	0.505550
3	711.0000	0.604592	854.0000	0.726190	0.382958
4	631.0000	0.559397	836.0000	0.741135	0.301709
5	556.0000	0.514339	817.0000	0.755782	0.246594
6	491.0000	0.474396	780.0000	0.753623	0.183200

This table shows that test statistics is far bigger than the critical values, thus we reject the null hypothesis that the series are linearly dependent. The results actually suggested that the savings in Nigeria economy are non linearly dependent which is a pointer to the chaotic behavior of financial time series data.

CONCLUSION AND RECOMMENDATIONS

The paper examines the status of the series, from where we discovered from the graph and from the Unit root test that the series was not stationary at level and that at first difference it was stationary. The BDS test applied for the analysis of the series shows that the linearity of the series was rejected and from this we concluded that for the would be researcher that may want to analyze and estimate the parameter of any given time series must necessarily test for the status of the series so as not to run into error of misspecification of the model, as the results that would be obtained using wrong models will lead to wrong forecasting which will lead to wrong policy formulation.

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