**ON APPROPRIATE THRESHOLD MODEL FOR MODELING AND FORECASTING EXCHANGE RATE OF SOME SELECTED COUNTRIES**

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Abstract

Literatures have established the fact that linear time series models cannot capture the inherent behavior of many financial and Economic data due to their chaotic and volatile nature. This is the case with Exchange rate, inflation rates and some other financial indices. Some characters they exhibit such as volatility and structural breaks cannot be modeled using linear time series. For this kind of situation nonlinear time series models are designed to accommodate such nonlinear behaviour. Therefore, this study, used a nonlinearity test and a structural change tests to establish the nonlinearity and the structural break date in the currencies of Nigeria (Naira) and South African (rand) on one side and currencies of Japan (Yen) and Great Britain (Pound) on the other hand per United States of American dollar. The null hypothesis of linearity was rejected and evidence of structural breaks exists in the exchange rates series. This leads to the decision to use the self-exciting threshold autoregressive (SETAR) model. Performance measure was used to evaluate the forecast performance of all models used in the study. To increase the accuracy of forecasting, SETAR and ARIMA models were combined with an exponential generalized autoregressive conditional heteroscedasticity (EGARCH) model. Results showed that the hybrid models of SETAR-EGARCH performs better than that of the ARIMA model and the combined ARIMA and EGARCH model. In conclusion the results indicated that nonlinear models give better fitting than linear models.

*Keywords: SETAR, ARIMA, EGARCH, Structural break, SETAR-EGARCH and nonlinearity*

1. **INTRODUCTION**

Several forecasting methods exist for use in financial and econometric methods to would be users in forecasting. Each of these methods have peculiarities as some are very good in modeling and forecasting non-linear series while some are not. This paper considers the following models vis-à-vis ARIMA, GARCH, EGARCH, SETAR and SETAR-EGARCH an appropriate threshold model that could be best used coined out thereafter. Autoregressive integrated moving average (ARIMA) models were first advanced by Box and Jenkins (1970) for analysis and forecasting time series data. Malikkarjune, M and Prabhakara, R (2019) used some selected non-linear time series models in evaluating forecasting methods from selected stock market returns. Number of studies were conducted by employing ARIMA models to forecast stock market returns; prominent among such studies include Ojo and Olatayo, (2009), Adebiyi and Oluyinka, 2014; Mondal et al., 2014, the just mentioned studies find ARIMA models very invaluabe. Some researchers made use of Markov regime-switching models and threshold autoregressive (TAR) models assuming non-linearities of the series under studies and used same to forecast stock prices. Gooijer (1998) employed the use of regime switching in a moving average (MA) model and used validation criteria for self-exciting threshold autoregressive (SETAR) model selection. Akintunde et.al.2019 used SETAR models in Exchange Rate Forecasting Using Non-linear Threshold discovered that this model produced excellent results for non-linear modeling. The central idea or the importance of using regime switching models is to examine changes in the series that develops or engender the data. The regime switching models are mostly used in empirical studies such as analysis of exchange rate markets and financial econometrics variable. For instance, Ismail and Isa (2006) and Bergman and Hansson (2005) evolved models for exchange rates and discovered that these models provide a more accurate forecasting results while using both in and out-of-sample forecasting. The following researchers (De Gooijer and Kumar (1992), Peel and Speight (1998) and Potter (1995)) developed SETAR model and employed its use in modelling the GDP of different countries. Judging from earlier studies it was discovered that the regime switching models outperformed their linear models counterpart.

Some researchers (Boero and Marrocu (2004)) used SETAR model to Euro exchange rates and discovered that the SETAR model performs better than ARIMA model. In this same vein, Ismail and Isa (2006) applied SETAR model to exchange rates in ASEAN countries and find that the regime switching models are superior to linear models. So also, Chong et al. (2011) compared the performance of the SETAR model with an autoregressive model (AR) and a moving average model (MA), using four different indices, (the Shanghai A and B shares indices; and the Shenzhen A and B share indices), the outcome of the study revealed that the SETAR model performed far better than AR and MA models which are linear models.

1. **MATHEMATICAL PRELIMINARIES**

The following models were used for the data analysis so as to determine appropriate threshold model for modeling and forecasting exchange rate of the following four countries and they are as listed: - Nigerian Naira and South African Rand (the two countries represented economy, where in the stability of the currencies are not guarantees as a result of high-level of corruption couple with infrastructural deficiencies) on one side. On the other hand, United kingdom Pound and Japanese Yen on the other hand (these two countries stand for developed economy, the situation here is a direct opposite of what is obtainable in Nigeria and South Africa) in relation to United States of American Dollar. The objective of the study is to model and forecasting exchange rate of these selected countries and to determine appropriately among the models studied (ARIMA, GARCH, SETAR and SETAR-GARCH) the one that gave the most appropriate threshold.

**2.I ARIMA MODEL**

The generalization of ARMA model is called ARIMA model. ARIMA models form an important part of Box-Jenkins approach to time series modeling. A non-season ARIMA is classified as  where is the number of autoregressive terms, is the number of non-seasonal terms and  is the number of moving average lag

is said to be  if



Where 

And  is defined in 

When the process  is stationary if and only if  in which case it reduces to process 

2.2 GARCH MODEL

The  model is defined by:

 

where  and the innovation sequence  is independent and identically distributed with E() = 0 and E() = 1

**2.3 SETAR MODEL**

The SETAR model is a convenient way to specify a TAR model because qt is defined simply as the dependent variable. In this case, the process can be formally written as



Where  and  are coefficients of Autoregression with order  of the SETAR model,  is the delay parameter,  is the threshold variable and  is the random errors in the variables under study, they are independent and identically distributed with mean  and variance.  is the value of threshold so obtained.

**2.4 EGARCH MODELS**

The Exponential Generalized Autoregressive Conditional Heteroscedasticity Model

GARCH models, assume that only the magnitude and not the positivity or negativity of unanticipated excess returns determines features of. If the distribution of is symmetric, the change in variance is conditionally uncorrelated. The model put forward by Nelson (1991) is as follows



 given that, where the parameters  are not restricted to be non-negative.

**2.4 BDS STATISTICS**

BDS test was first the making of W.A. Brock, W. Dechert and J. Scheinkman in 1987 (Brock, Dechert &Scheinkman, 1987). BDS test is an invaluable tool for determining serial dependence in economic and financial time series. It examines the null hypothesis of independent and identically distributed (I.I.D.) against an unspecified alternative. BDS test can only test nonlinearity in a series, not the chaos arising therein However, it should be noted that nonlinearity is one of the indications of chaos, we may use BDS test to detect such indication.

The calculations of BDS test follow some procedures. It is not the intention of the present study to dive into such procedures. However, the hypothesis of the test is as defined below:

 The series are independently and identically distributed (I.I.D.) versus

 The series are not I.I.D.

**2.5 STRUCTURAL BREAK**

**CHOW TEST FOR STRUCTURAL STABILITY**

Sometimes a series of data often contain a structural break, due to number of reasons, among them are change in policy as a result of change in power or sudden shock to the economy and soon and so forth. To test for these kinds of situation, we often use the Chow test, this is Chow’ first test (the second test relates to predictions), invented by Gregory Chow. The test statistic follows.To determine whether a single regression is more efficient than two separate regressions involving splitting the data into two sub-samples.

The Chow test basically tests whether the single regression line or the two separate regression lines fit the data best. Suppose we model our data as follows:-



If the data is divided into two groups, then we have

Model1



And model 2 is



The null hypothesis of the of the Chow test asserts that 



The test statistic follows the with degrees of freedom. If the parameters of the above models are the same, that is, then models one and two can be expressed as a single model, meaning that there is no break point, so there is no basis for the splitting of the data into two sub-samples.

**2.6 PERFORMANCE MEASURE INDICES**

2.6.1 

2.6.2 





2.6.4.1 Bias,

2.6.4.2 Variance,

2.6.4.3 Covariance,

1. **DATA ANALYSIS/ EMPIRICAL RESULTS**

The data used for the study covers the period of January 1994 to December, 2019 and was obtained from Central bank of Nigeria and World Bank records. E-view package was used for the analysis.

**3.1 STATIONARITY TESTS**

Augmented Dickey fuller and Philip Pheron tests were used to determine stationarity status of the series used (exchange rates data of Nigeria, South Africa, Britain and Japan) as shown in the table 1 below. At level the series are chaotic, volatile and unstable but at first difference the series appears to stationary and stable thereby allows for the analysis of the data.

TABLE 1: STATIONARITY TESTS (LEVEL AND FIRST DIFFERENCE)

LEVEL FIRST DIFFERENCE

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Exchange rates | Test | Intercept | Prob | Test | Intercept | Prob |
| BRITAIN | ADF | -1.75 | 0.4035 | ADF | -11.64 | 0.0000 |
|  | PP | -1.53 | 0.5170 | PP | -11.68 | 0.0000 |
| JAPAN | ADF | -1.98 | 0.2936 | ADF | -9.98 | 0.0000 |
|  | PP | -1.89 | 0.3374 | PP | -9.94 | 0.0000 |
| NIGERIA | ADF | 0.15 | 0.9686 | ADF | -9,22 | 0.0000 |
|  | PP | 0.12 | 0.9669 | PP | -7.81 | 0.0000 |
| SOUTH AFRICA | ADF | -1.17 | 0.6870 | ADF | -11.06 | 0.0000 |
|  | PP | -0.96 | 0.7670 | PP | -10.96 | 0.0000 |

**3.2 STRUCTURAL BREAK TEST**

The serial endogenous structural break test was developed by Zivot and Andrew (1992) when applied to the data in the study shows that a break point is chosen when -statistic calculated for  is at minimum. A data driven algorithm was used to determine the break point. The null hypothesis for Zivot-Andrew test is  indicating absence of structural break and the alternative hypothesis  which shows the presence of structural break (Glynn, 2007). The identified break points for all the currencies as revealed by the analysis in the table 1 above are December, 2011 for Naira, May, 2012 for Rand August, 2013 for Yen and July 2013 for Pound respectively.

**3.3 DESCRIPTIVE STATISTICS**

Table 2 revealed the distributional properties of the data used in the study. The standard deviation is high showing the evidence of fluctuation. The distribution of the data is almost symmetric. The kurtosis is less than 3, implying that the distribution is flat (platykurtic) in relation to normal distribution. The skewness of the series is positive showing that the distribution has a long right tail.The hypothesis of normality is rejected as evidenced by Jarque-Bera values obtained in the table 2 below.

**TABLE 2: DESCRIPTIVE STATISTICS**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| STATISTICS | SOUTHAFRICA | JAPAN | NIGERIA | BRITAIN |
| Mean | 86.30609 | 88.38932 | 183.1170 | 109.0984 |
| Median | 86.87000 | 85.99500 | 157.2700 | 104.1450 |
| Maximum | 133.0800 | 111.3200 | 309.7300 | 132.1100 |
| Minimum | 51.98000 | 72.48000 | 117.7200 | 93.17000 |
| Std. Dev. | 23.08163 | 9.706322 | 68.11241 | 12.28303 |
| Skewness | 0.370053 | 0.667377 | 1.092433 | 0.652374 |
| Kurtosis | 1.939893 | 2.645750 | 2.504678 | 1.864912 |
| Jarque-Bera | 13.37268 | 15.25649 | 40.15189 | 23.92633 |
| Probability | 0.001248 | 0.000487 | 0.000000 | 0.000006 |
| Sum Sq. Dev. | 101757.5 | 17994.62 | 886106.3 | 28816.71 |
| Observations | 192 | 192 | 192 | 192 |

* 1. **NON-LINEARITY TEST**

The BDS Statistic used affirmed the presence of non-linearity in all the currencies (Rand, Pound Naira and Yen) for the study as shown in the tables 3 through 6.

**TABLE 3: BDS TEST RESULTS FOR SOUTH AFRICA RAND**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
| Dimension | BDS Statistic | Std. Error | z-Statistic | Prob. |  |
| 2 | 0.184846 | 0.003248 | 56.91247 | 0.0000 |  |
| 3 | 0.313090 | 0.005162 | 60.65344 | 0.0000 |  |
| 4 | 0.401499 | 0.006143 | 65.35400 | 0.0000 |  |
| 5 | 0.461813 | 0.006398 | 72.18114 | 0.0000 |  |
| 6 | 0.501552 | 0.006164 | 81.36840 | 0.0000 |  |
|  |  |  |  |  |  |

**TABLE 4: BDS TEST RESULTS FOR GREAT BRITAIN POUND**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
| Dimension | BDS Statistic | Std. Error | z-Statistic | Prob. |  |
| 2 | 0.199139 | 0.004804 | 41.44976 | 0.0000 |  |
| 3 | 0.337738 | 0.007591 | 44.49182 | 0.0000 |  |
| 4 | 0.432880 | 0.008985 | 48.17967 | 0.0000 |  |
| 5 | 0.497165 | 0.009307 | 53.41917 | 0.0000 |  |
| 6 | 0.539907 | 0.008919 | 60.53236 | 0.0000 |  |

**TABLE 5: BDS TEST RESULTS FOR NIGERIAN NAIRA**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
| Dimension | BDS Statistic | Std. Error | z-Statistic | Prob. |  |
| 2 | 0.201851 | 0.006604 | 30.56639 | 0.0000 |  |
| 3 | 0.339185 | 0.010449 | 32.46110 | 0.0000 |  |
| 4 | 0.433322 | 0.012390 | 34.97317 | 0.0000 |  |
| 5 | 0.498219 | 0.012860 | 38.74082 | 0.0000 |  |
| 6 | 0.543170 | 0.012351 | 43.97692 | 0.0000 |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |

**TABLE 6: BDS TEST RESULTS FOR JAPANESE YEN**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
| Dimension | BDS Statistic | Std. Error | z-Statistic | Prob. |  |
| 2 | 0.176249 | 0.004978 | 35.40493 | 0.0000 |  |
| 3 | 0.296043 | 0.007906 | 37.44562 | 0.0000 |  |
| 4 | 0.373831 | 0.009406 | 39.74487 | 0.0000 |  |
| 5 | 0.421348 | 0.009793 | 43.02348 | 0.0000 |  |
| 6 | 0.448271 | 0.009434 | 47.51521 | 0.0000 |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |

1. **GOODNESS OF FIT OF THE MODELS**

The AIC, BIC, SIC and HQC, were computed and reported in the tables 7 through 10 below. The asterisks are used to indicate the criterion that performed best. Results show that SETAR-EGARCH performs better than that of the ARIMA and SETAR models and the combined ARIMA and EGARCH models. This is shown for all the currencies used in the study as demonstrated below

**Table 7: SOUTH AFRICAN RAND**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Model  Criterion | *ARIMA* | *SETAR* | *EGARCH* | SETAR-EGARCH | ARIMA-EGARCH |
| AIC | 16.1321 | 12.7834 | 14.3410 | 11.1587 | 12.2012 |
| BIC | 16.9231 | 12.9231 | 14.7542 | 11.4721 | 12.5421 |
| SIC | 17.3571 | 12.5673 | 14.6732 | 11.2266 | 12.2431 |
| HQC | 27.5421 | 12.7543 | 15.0076 | 11.8862 | 11.2112 |

**Table 8 JAPANESE YEN**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Model  Criterion | *ARIMA* | *SETAR* | *EGARCH* | SETAR-EGARCH | ARIMA-EGARCH |
| AIC | 20.5643 | 19.7831 | 19.2431 | 18.4711 | 17.2315 |
| BIC | 19.9012 | 21.2311 | 19.4432 | 18.1020 | 18.9921 |
| SIC | 22.0243 | 20.0123 | 19.6310 | 18.7212 | 18. 6931 |
| HQC | 21.8709 | 19.9976 | 19.4531 | 18.5333 | 18.9132 |

**Table 9 NIGERIAN NAIRA**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Model  Criterion | *ARIMA* | *SETAR* | *EGARCH* | SETAR-EGARCH | ARIMA-EGARCH |
| AIC | 25.7654 | 24.9071 | 25.0091 | 24.1424 | 24.7865 |
| BIC | 27.6543 | 26.8721 | 25.5432 | 24.2214 | 25.2311 |
| SIC | 26.7324 | 26.1234 | 25.4509 | 24.1828 | 24.9980 |
| HQC | 26.7654 | 26.5643 | 24.4312 | 24.4242 | 25.0978 |

**Table 10 BRITISH POUND STERLING**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Model  Criterion | *ARIMA* | *SETAR* | *EGARCH* | SETAR-EGARCH | ARIMA-EGARCH |
| AIC | 12.9986 | 11.8750 | 12.1432 | 10.1010 | 10.9987 |
| BIC | 14.3212 | 13.8765 | 12.0954 | 10.3213 | 11.1132 |
| SIC | 13.5412 | 12.4317 | 12.1654 | 10.1547 | 10.8765 |
| HQC | 14.0012 | 12.8765 | 11.6731 | 10.2112 | 11.2131 |

**4.1 FORECAST INDICES OF ALL CURRENCIES VERSUS MODELS**

All forecast indices (RMSE, MAE, MAPE, THEIL U, BIAS, Variance and Covariance proportions) used equally asserted the superiority of SETAR-GARCH over *ARIMA, SETAR, EGARCH and*  ARIMA-EGARCH as revealed by tables 11 through 14 below

**Table 11 SOUTH AFRICAN RAND**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Model  FORECAST  Criterion | *ARIMA* | *SETAR* | *EGARCH* | SETAR-EGARCH | ARIMA-EGARCH |
| RMSE | 547.2219 | 532.2341 | 530.7542 | 522.5566 | 527.1341 |
| MAE | 472.3214 | 487.4321 | 457.7651 | 451.1761 | 455.9871 |
| MAPE | 28.4132 | 26.1563 | 25.5431 | 22.4210 | 23.4317 |
| THEIL U | 0.2317 | 0.2122 | 0.1992 | 0.1322 | 0.1742 |
| BIAS PROPORTION | 01542 | 0.1310 | 0.1672 | 0.0664 | 0.1000 |
| VARIANCE PROP. | 0.8953 | 0.8931 | 0.8963 | 0.9410 | 0.9131 |
| COVARIANCE PROP. | 0.1609 | 0.1321 | 0.0654 | 0.0327 | 0.0521 |

**Table12 JAPANESE YEN**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Model  FORECAST  Criterion | *ARIMA* | *SETAR* | *EGARCH* | SETAR-EGARCH | ARIMA-EGARCH |
| RMSE | 226.2117 | 224.8790 | 224. 1919 | 219.1201 | 219.0245 |
| MAE | 184.2456 | 186.9871 | 178.2316 | 179.5263 | 179.0143 |
| MAPE | 9.6543 | 9.9975 | 8.9432 | 8.9264 | 8.9987 |
| THEIL U | 0.2131 | 0.1004 | 0.0972 | 0.0546 | 0.0721 |
| BIAS PROPORTION | 0.2211 | 0.1439 | 0.1010 | 0.01185 | 0.09876 |
| VARIANCE PROP. | 0.9101 | 0.9321 | 0.9376 | 0.9457 | 0.9400 |
| COVARIANCE PROP. | 0.1543 | 0.0871 | 0.0592 | 0.04240 | 0.0562 |

**Table13 NIGERIAN NAIRA**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Model  FORECAST  Criterion | *ARIMA* | *SETAR* | *EGARCH* | SETAR-EGARCH | ARIMA-EGARCH |
| RMSE | 721.9830 | 700.1243 | 712.2311 | 695.9691 | 698.1423 |
| MAE | 660.1347 | 654.9087 | 643.1563 | 655.1263 | 659.1264 |
| MAPE | 35.9971 | 34.2316 | 35.9870 | 32.5991 | 33.0987 |
| THEIL U | 0.3298 | 0.2999 | 0.2311 | 0.1795 | 0.1989 |
| BIAS PROPORTION | 0.2987 | 0.2112 | 0.1873 | 0.1210 | 0.1873 |
| VARIANCE PROP. | 0.9356 | 0.9478 | 0.9621 | 0.9771 | 0.9678 |
| COVARIANCE PROP. | 0.1231 | 0.0976 | 0.0158 | 0.0018 | 0.0025 |

**Table14 BRITISH POUND**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Model  FORECAST  Criterion | *ARIMA* | *SETAR* | *EGARCH* | SETAR-EGARCH | ARIMA-EGARCH |
| RMSE | 231.902 | 229.9987 | 229.8712 | 227.9701 | 228.9012 |
| MAE | 210.9087 | 209.0432 | 207.7712 | 205.1471 | 199.2175 |
| MAPE | 14.0001 | 13.9990 | 11.3420 | 10.2033 | 11.0001 |
| THEIL U | 0.2345 | 0.2109 | 0.1999 | 0.0589 | 0.0712 |
| BIAS PROPORTION | 0.1234 | 0.1090 | 0.1356 | 0.01246 | 0.1000 |
| VARIANCE PROP. | 0.8512 | 0.8722 | 0.8912 | 0.9179 | 0.9417 |
| COVARIANCE PROP. | 0.2357 | 0.1251 | 0.0865 | 0.0697 | 0.0876 |

1. **SUMMARY AND CONCLUSIONS**

The study investigated the appropriate threshold model for modeling and forecasting exchange rate of some selected countries. The countries under study are Nigerian (Naira) and South African (rand) on one side and currencies of Japan (Yen) and Great Britain (Pound) on the other hand in relation to United States of American dollar. BDS test and a structural change tests were used to establish the nonlinearity and the structural break date in the currencies of the countries under study, these established that nonlinear models are more suitable than linear models counterpart. The AIC, BIC, SIC and HQC computed revealed that SETAR-EGARCH performs better than ARIMA and SETAR models and the combined ARIMA and EGARCH models as shown in the tables 7 through 10. All forecast measures indices (RMSE, MAE, MAPE, THEIL U, BIAS, Variance and Covariance proportions) used also asserted the superiority of SETAR-GARCH over *ARIMA, SETAR, EGARCH and*  ARIMA-EGARCH as revealed by tables 11 through 14. So also the study revealed that when nonlinear features of exchange rate are being investigated, nonlinear models outperformed linear models. Conclusively, is a very good model that can be used when the need arise in addressing appropriate threshold model for modeling and forecasting exchange rate.

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