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RESEARCH ARTICLE

USING GARCH MODELS TO FORECAST EXCHANGE RATE IN SUDAN DURING THE PERIOD (2008 - 2017)

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Abstract

The study aimed to adopting GARCH models to forecast exchange rate in Sudan during the period (2008-2017) through using monthly data on USD and SDG exchange rate. the Problem of the study was represented in that to what extent GARCH models can be adopted to interpret the behavior and trend and then forecast the SDG exchange rate in future?
The study used the descriptive analytical and econometric methods and GARCH model. The study hypothesized that GARCH models are highly capable of forecasting exchange rate and other financial variables. The study came up with findings the most of which: GARCH models are capable of forecasting exchange rate accurately and GARCH (1,1) model the best which is selected for this purpose. The study recommended to develop the proposed model for long-term forecasting.

عنوان البحث

إستخدام نماذج GARCH للتنبؤ بسعر الصرف في السودان خلال الفترة (2008-2017)

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المستخلص

هدفت الدراسة إلى اعتماد نماذج قارش للتنبؤ بسعر الصرف في السودان خلال الفترة (2008–2017) من خلال استخدام البيانات الشهرية لسعر صرف الدولار الأمريكي والجنيه السوداني، تمثلت مشكلة الدراسة في إلى أي مدى يمكن اعتماد نماذج قارش لتفسير السلوك والاتجاه ثم التنبؤ بسعر صرف الجنيه السوداني في المستقبل، استخدمت الدراسة المنهج الوصفي التحليلي ونموذج قارش لتفسير الظاهرة، افترضت الدراسة أن نماذج قارش قادرة للغاية على التنبؤ بسعر الصرف والمتغيرات المالية الأخرى، توصلت الدراسة إلى نتائج أهمها: نماذج قارش قادرة على التنبؤ بدقة بسعر الصرف ونموذج قارش (1،1) الأفضل الذي تم اختياره لهذا الغرض، أوصت الدراسة بتطوير النموذج المقترح للتنبؤ على المدى الطويل.

Introduction:

Exchange rate is considered one of the major economic and financial variables in countries' economies. because of its economic importance, its behavior and trend should be analyzed as accurately as possible to serve the real interpretation of national economy position under large fluctuations in Sudanese economy since 2012, which directly influenced macroeconomic indicators - including exchange rate - which was largely falling year by year due to the erosion of foreign exchange reserves in the coffers of central bank. Accordingly, this study discusses an attempt to apply GARCH models on exchange rate of USD and SDG in Sudan through monthly data on exchange rate of the two currencies during the period (2008-2017) in order to interpret and forecast the SDG exchange rate behavior in the future.

Problem of the study:

There are many statistical and economic models, including traditional and modern models that are used to analyze time series and forecast economic variables behavior, but they were not accurate in the process of interpretation, solving measurement problems and forecasting particularly when it comes to financial variables. So, thus it is difficult to adopt those models in this field. As GARCH models one of the most methods used to model financial variables behavior, the problem of study can be stated in the following question:

To what extent GARCH models can be adopted to interpret the behavior and trend and then forecast the average of SDG exchange rate in the future?

Hypotheses of the study:

1. GARCH models can accurately solve measurement problems.
2. Values forecasted by using GARCH models are very close to actual values.

Importance of the study:

(a) Scientific importance:

It rises from that those models are considered modern methodologies of analyzing and forecasting the financial economic variables behavior. This means that there is lack of research on the filled, and most studies investigate exchange rate in Sudan did not used GARCH models.

(b) Practical importance:

It is highlighted in concluding an econometric model used to forecast the monthly average of exchange rate in Sudan for the coming period supporting the process of proper planning, accurate budgeting, and controlling the external trade rate.

Objectives of the study:

a) To identify GARCH models and generative models.

b) To verify the effectiveness of modern systems for time series analysis and forecasting the behavior and trend of financial economic variables, including exchange rate.

c) To formulate an econometric model to forecast exchange rate in Sudan and develop it to benefit the country's economic planning process.

Methodology of the study:

The study uses the analytical descriptive and econometric methods, and GARCH methodology as the major approach of this study.

Sources of the data:

This study is based on secondary data from several sources, including references, researches and various publications related to the issue, and data from Central Statistical Organization.

Limitations of the study:

a) Spatial limits: Republic of Sudan.

b) Time limits: (2008-2017).

Examples of previous studies:

1- Hanan Khalfawi (2015) study:

The study aimed at providing a model for the change in DZD nominal exchange rate using ARCH models. It also aimed at using modern models in time series analysis instead of classical models. This study adopted the descriptive approach to highlight the theoretical framework of exchange rate variable, the theoretical framework of ARCH models, as well as the common econometric models. The most important finding is that; ARCH model (1) was sufficient to represent the nominal exchange rate in Algeria isolated from major foreign currencies. The most important recommendation is to give sufficient attention to econometric and predictive models relating to different economic phenomena.

2- Amina Darbal (2014) study:

The study aimed at trying to identify classic and modern models, as well as studying the behavior of the DFM index and preparing a quantitative model by which to predict the DFM index in order to make the appropriate decisions and descriptive approach. The study used the analytical method, The study assumed several assumptions, the most important of which were the inefficiency of the ARIMA models in forecasting the returns of the Dubai Stock Exchange index, but rather assumed the efficiency and superiority of the ARCH models in them. This area, the most important The findings of the study are that the models of artificial neural networks (ANN) have greater predictability than the conditional self-regression models (ARCH), and their preference over other models.

3. K.Pilbeam (2014) study:

The study examined different GARCH models for the purpose of forecasting fluctuations in the foreign exchange market using different currencies: the dollar, the euro, the pound sterling and the Japanese yen. The study compared different samples of the GARCH analog and asymmetric models, Indicated that three models of the GARCH family were preferable to other models. The study recommended using the proposed models for their full efficiency in predicting future currency fluctuations.

Theoretical framework of the study:

First: Exchange Rate

1 - Definition of exchange rate:

"The price of a currency in another currency, or the exchange rate of two currencies of one currency is considered a commodity while the other currency represents a price for that commodity" (Adel Hashish, 2003, p. 176).

The exchange rate is the number of units to be paid from a particular currency, to obtain one unit of another currency. There are several different tariff rates for the purpose of the exchange, or according to the time range (deferred, urgent, ...), According to the conditions and requirements of supply and demand in the foreign exchange market for currencies, and of these definitions include:

1. Foreign exchange spot:

It means the prices of selling and buying foreign currencies that occur daily with Islamic banks and other commercial banks and exchange companies, or prices announced for instant cash transfers through customer accounts. The determination of the current exchange rate depends on the conditions of supply and demand for foreign currencies, which in turn is affected by changes in interest rates.

2. Forward exchange rate:

These foreign exchange rates are determined by the forward exchange market, where transactions are made for transactions ranging from one to six months. The forward exchange rate is defined as: the present value of the future exchange rate in a period of between 30 - 180 days).

3. Future exchange rate:

These are the prices that are set for currency exchange in a contract period of more than six months. This is often related to the foreign exchange rates of transactions related to the exchange of goods and services for long-term financing of investment projects necessary for economic development, These prices are also related to long-term capital movements in global money and money markets, as well as long-term public or government investments in these markets, such as basic infrastructure, service and productive projects of a collective nature or social capital.

4. Outright Exchange rates:

It is called urgent exchange rates. These are transactions that happen on a time basis in the future not exceeding a week. These transfer rates represent the largest relative weight of transactions occurring in the markets. As for the future delivery of currencies in kind Represents only a very small percentage of total future contracts" (Hamdi, 1996, pp. 19-21).

2 -Explanatory theories of the exchange rate:

1. Price elasticity of demand:

This theory considers that the exchange rate affects the balance between the value of exports and the imports of the country concerned. If a trade deficit occurs, this will lead to a reduction in the local currency exchange rate against foreign currencies under the flexible exchange rate system, External and import prices are high for residents, resulting in higher exports and lower imports until the balance of trade balance is achieved. The rate of exchange rate adjustment depends on the extent of the export and import response, known as the exchange rate elasticity.

2. Purchasing Power Parity theory:

The theory assumes that the equilibrium of the exchange rate between two currencies can happen when there is a balance in the purchasing power of domestic prices, for example if US $ 1 can be equivalent to SDG8; Purchasing Power Parity can be made in the case that these two amounts can be purchased The same amount of goods in the two countries (America and Sudan), because the theory assumes that local money depends on the level of prices prevailing domestically, if prices have increased the decline in purchasing power and vice versa, but what is taken on this theory that it did not concern the manner of identification Exchange rates that will affect the achievement of the balance N, plus they ignore transportation costs and deportation that affect the cost of goods, and thus prevent the purchasing power parity between the inside and outside.

3. Cash exchange rate model:

This theory attempts to develop a monetary model of the exchange rate according to the relative relationship between the different currencies. The monetary model under the assumption of price elasticity is one of the models explained for the reasons of fluctuations in exchange rates. In this model, the exchange rate is one of the macroeconomic variables that affect and is affected by inflation , Level of production, growth rate, budget deficit and balance of payments.

4. Portfolio model:

The portfolio model (the entrance of portfolio balance to exchange rate or to balance of payments) is an alternative to the exchange rate of the exchange rate. There is an inverse relationship between the real exchange rate and the current account. At the same time, the demand for money affects both real (deposits do not achieve interest such as current deposits) in the place of interest-bearing assets (such as treasury bills and time deposits). The demand for money is linked directly to the interest rate , Thus changing the exchange rate accordingly For factors that determine cash flows and capital (Haidar et al., 2005, pp. 8-9).

Second: GARCH Models:

1. Time series definition:

Time Series: The time series is defined as "a sequence of observed values of a random phenomenon linked to time or (ordered by place)". Examples include monthly sales volume of a commodity, volume of daily production of oil in a field, and other variables. The purpose of the study and analysis of time series is as follows:

1. Understanding and random modeling phenomenon seen.
2. Predicting the future values of the observed phenomenon.
3. Control the random phenomenon if possible (Adnan Berry, 2002, p. 10).

2. GARCH Models Definition:

The OLS method assumed constant variation of random error limit, but this is not applied on financial economic variables because they are usually affected by a non-constant variation of error limit, so the technique came to modelize the Conditional Heteroskedasticity, it took (CH) from the name of the model (Auto Regressive) and became (ARCH), which means Autoregressive Conditional Heteroskedasticity which was first used in (1982) by the English researcher (Robert F. Engel) in a research on estimating inflation variation in United Kingdom. Such models led to a significant shift in Applied Econometrics, and this modeling evolved into what became known as (Generalized ARCH) model. These models then evolved to include a large number of derivative models known as (GARCH Family Models). General formula for GARCH (p, q) models is written as follows:

$$\sigma_t^2 = \lambda_0 + \lambda_1 u_{t-1}^2 + \lambda_2 \sigma_{t-1}^2 + \cdots + \lambda_p u_{t-p}^2 + \lambda_q \sigma_{t-q}^2 \qquad \rightarrow (1)$$

$$y_t = \alpha + \beta x_t \qquad (2)$$

Equation (1) is called conditional variation equation, and equation (2) represents the average equation, whereas:

α and λ_0 $\equiv$ Constants

β and λ_1 $\equiv$ Slope of estimated parameters for mean and conditional variation equations, respectively

σ_t^2 ≡ Variation in current period. σ_{t-1}^2 ≡ Conditional variation in previous period

y_t ≡ Present value of series. x_t ≡ Average value of series

$\lambda_p u_{t-p}^2$ ≡ Part of ARCH. $\lambda_q \sigma_{t-q}^2$ ≡ Part of GARCH

3. Stages of (ARCH/GARCH)

This methodology consists of five main steps arranged as follows:

First: Time Series Stationary Test

ARCH / GARCH models require that the investigated time series to be stationary. Time series stationary means the data of one variable reflects inconstancy of all existing data (Tariq Alrasheed and Samia Mahmoud, 2010, p.10).

that means there is (Unit Root) problem in time series which means average and variation of the variable are not independent of time, i.e. time is the direct cause of the (Unit Root) problem. Consequently, the time series is inconstant, and at this stage a Augmented Dickey–Fuller (ADF) test is adopted, based on the formula:

$H_o : \alpha_1 = 0 H_1 : \alpha_1 \neq 0$

(T) Test statistic of ADF table is compared as follows:

$$t = \frac{\alpha 1}{S.E(\alpha 1)}$$

If the calculated value of test is greater than the tabular value of (ADF) test at significant level (5%), we refuse null hypothesis, so the series does not suffer from the (Unit Root) problem, the series is stationary, and vice versa.

The test consists of three main equations:

$$\Delta X_t = \alpha_1 X_{t-1} + \sum_{j=1}^{P} \beta_j \Delta X_{t-j} + e_t \rightarrow 1$$

$$\Delta X_t = \alpha_0 + \alpha_1 X_{t-1} + \sum_{j=1}^{P} \beta_j \Delta X_{t-j} + e_t \rightarrow 2$$

$$\Delta X_t = \alpha_0 + \alpha_1 X_{t-1} + \sum_{j=1}^{P} \beta_j \Delta X_{t-j} + \delta_t + e_t \rightarrow$$

Whereas:

α and β ≡ Coefficients of (A.D.F) test.

X_t ≡ Random Context. Δ ≡ Coefficient of difference

Whereas:

$$\Delta X_t = X_t - X_{t-1}$$

Thus, the required differences are calculated by subtracting each difference from the preceding difference.

e_t ≡ Context of the white noise: "It is a series of random variables predicted by the mathematical zero and not linked each to other, i.e. its common variations null and have the same variation" (Naqar, Alawwad, 2011, p. 130).

Second: ARCH / GARCH model identification phase:

Identification: means determining grade values of (ARCH / GARCH) models, i.e. determining Auto-regression values in the case of ARCH (p) model, and determining error rank and conditional variation in the case of GARCH (p, q) model, in general; Identification tools are represented in (ARCH / GARCH) models in three:
- Auto Correlation Function (ACF)
- Partial Auto Correlation Function (PACF)
- Correlation between the coefficient of each function and the gap length (Correlogram) (Abdelqader Attia, 2005, p. 729).

There are several tests adopted to determine the values and degree of errors auto-correlation, the most important are:

Portmanteau Test:

(Box-Pierce) test and (Ljung-Box) test represent Portmanteau test

This test is based on the concept of errors auto- correlation (a measure of correlation between observations that happened at different times in an investigated series), (Box-Pierce) test statistic is written as follows:

$$Q = T\sum_{s=1}^{p} \widehat{P_s}^2$$

It allows us to test (P_S=0) for all S values which represents the null hypothesis, whereas:

$$Q \to X_p^2$$

Q follows the distribution of Chi-square at freedom degree P.

To improve this statistic the statistic (Ljung-Box) comes according to the following:

$$Q^* = T(T+2)\sum_{s=1}^{p}\frac{\widehat{P_s}^2}{T-S}$$

It has the same Q distribution, as well as the auto-correlation function, we find the partial auto-correlation function, which allows to measure the relationship between the value in the time t and the value in time t-k considering all values achieved during this interval. Partial auto-correlation between y_t and y_{t-k} is the coefficient of y_{t-k} resulting from the following equation:

$$y_t = +\beta_0 + \beta_1 y_{t-1} + \beta_2 y_{t-2} + \cdots + \beta_k y_{t-k} + \mathcal{E}_t$$

Through the above equation we can examine and diagnose time series behavior in the conditional variation equation (GARCH) as it represents the equation of auto-correlation and partial auto-correlation (Amina Derbal, op. Cit., P. 32).

Third: Model estimation stage:

At this stage, values of ARCH / GARCH model parameters are estimated using the (Maximum Likelihood Method), which can be achieved according to the following:

$$L\left(\frac{y_t}{\theta}\right) = -\frac{N}{2}Log(2\pi) - \frac{1}{2}\sum_{t=1}^{N} Log\sigma_t^2 - \frac{1}{2}\sum_{t=1}^{N} r_t^2 / \sigma_t^2$$

Whereas: 0 ≡ Vector parameters to be estimated $(\beta_j, \alpha_i, \alpha_0, \mu)$

Model selection criteria:

There are several criteria that can be resorted to in selecting the appropriate model, the most important of which are:

- Akaike *information* criterion (AIC):

In 1974, Akaike introduced a criterion of information known as (AIC). When reconciling time series models time series models with (h) parameters for investigated time series data, to assess to what extent those models are appropriate to the data according to (AIC) criterion for each model to select the model that gives the lowest value for the criterion, and therefore it would be useful when compared with the (AIC) values of other models that are reconciled for the same set of data, according to the following formula:

$AIC = nL\text{n}(\sigma_e^2) + 2h \quad \rightarrow 1$

Whereas:

$n \equiv$ sample size. $\sigma_e^2 \equiv$ residual variation estimation of reconciled model, symbolized by (MSE) and calculated according to:

$$\sigma_e^2 = \frac{1}{n-h}\sum_{t=1}^{n}(y_t - \hat{y}_t)^2 \quad \rightarrow 2$$

Whereas: $h \equiv$ model grade

Fourth: Diagnostic examination stage of proposed model:

This stage is one of the most important stages of econometric modeling, through which identified; the quality of proposed model the conformity to specifications set by the researcher in terms of model representation of the investigated phenomenon, and to what extent the model is able to explain the phenomenon, and is predictable. Therefore, we will be satisfied with the residual tests and the model's predictability test.

Ljung – Box Test:

The test aims to ensure that there is no residual auto-correlation, and the generated context is completely random (Osman Naggar, op. Cit., P. 134).

The test is based on the following two hypotheses:

Null hypothesis: There is no auto-correlation between the residuals.

Alternative hypothesis: There is an auto-correlation between residuals (there is at least a non-zero coefficient).

$$H_0: r_1(e_t) = r_2(e_t) = \cdots = r_k(e_t) = 0$$
$$H_1: r_1(e_t) \neq r_2(e_t) \neq \cdots \neq r_k(e_t) \neq 0$$

Whereas: $r_k(e_t)$ represents the coefficient of auto-correlation of residuals at lag period (k).

The test statistic is calculated according to the following:

$$Q = N(N+2)\sum_{k=1}^{k}\frac{rk^2}{N-k}$$

Whereas:

N ≡ Sample size and Q ≡ Test value.

Null hypothesis is accepted in the following case:

$$Q < \chi^2_{0.05}(k - (p + q)$$

It follows the Chi- square test.

With regard to testing the model predictability, there are several tests, the most important are:

1- Thail's Inequality Coefficient

$$T = \sqrt{\frac{\sum(d_f - d_a)^2}{\sum d_a^2}}$$

Whereas:
T ≡ Thail’s test statistic. d_f ≡ Change in expected value of dependent variable.
da ≡ Actual change in value of dependent variable.
Test results are as follows:
1. If T equal zero, the model's predictability is very high.
2. If T equal one, the value change in dependent variable is constant over time.
3. If T is greater than one, model's predictability is very low. Generally, T value should be between zero and one, and whenever it approaches zero, it demonstrates model's predictability of the future behavior of dependent variable.

2- **Mean Square Error (M.S.E)**

It is the simplest, most famous and important way to detect model predictability, whereas it calculates Mean Square Error (M.S.E) for estimated models according to the following equation:

$$M.S.E = \frac{\sum(y_f - y_a)^2}{n-k}$$

Whereas:
y_f ≡ expected value of dependent variable. n ≡ sample size (number of observations)
y_a ≡ actual value of dependent variable. k ≡ number of model’s estimated parameters
The smaller value of (M.S.E), the better model predictability and vice versa
(Attiyah, op. Cit., PP. 741-747)
Fifth: Forecasting stage using proposed model
Forecasting can be made for these models according to the following formula:

$$\sigma_h^2(e) = \alpha_0 + \sum_{i=1}^{p} \alpha_1\, \sigma_h^2(e - 1) + \sum_{j=1}^{q} \beta_1\, \sigma_h^2(e - 1)e > 1$$

The forecasting method is often used by the sample, and then a number of observations are forecasted. It is preferable to use the square root of mean error square; it is calculated by the following:

$$RMSE = \sqrt{\frac{1}{T}\sum_{t=1}^{T}(r_t^2 - \sigma_t^{\wedge 2})^2}$$

$\sigma_t^{\wedge 2}$ ≡ Estimated conditional variation obtained from reconciled models GARCH
r_t^2 ≡ Consistent estimated for $(\sigma_t^{\wedge 2})$

Fourth: Exchange Rate Features in Sudan 2008/2016:

We briefly review the main features and effects of exchange rate on macroeconomic indicators, and their impact on exchange rate.

Table (1) Exchange Rate and Macroeconomic Variables

Year	Exchange rate	Inflation rate	GDP rate	Money supply rate
2008	3.1085	14.3	7.8	16.42
2009	3.2387	11.2	5.9	23.3
2010	3.0508	13.0	5.2	18.22
2011	3.7140	18.1	3.47	25.12
2012	4.5615	35.1	2.21	40.13
2013	6.3120	37.1	3.30	43.52
2014	7.6123	36.9	3.10	38.20
2015	6.6867	16.9	4.9	20.5
2016	7.0609	17.8	3.1	19.3

Source: Central Bank of Sudan Annual Reports.

Figure (1) Graphical representation of exchange rate series 2008/2016.

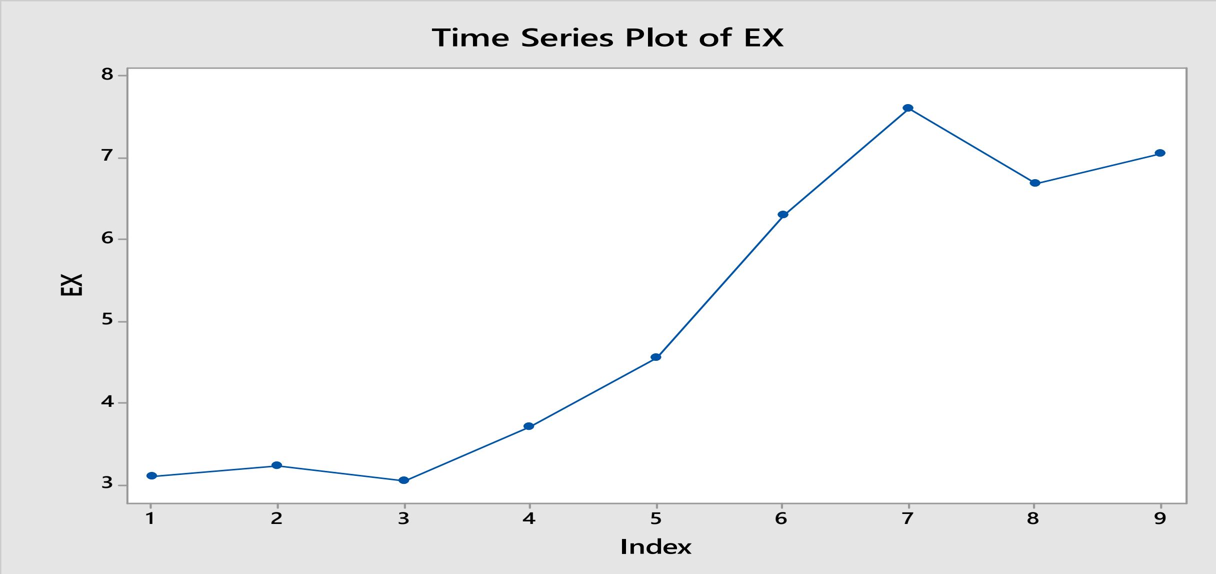

Figure (2) Exchange Rate and Major Economic Indicators

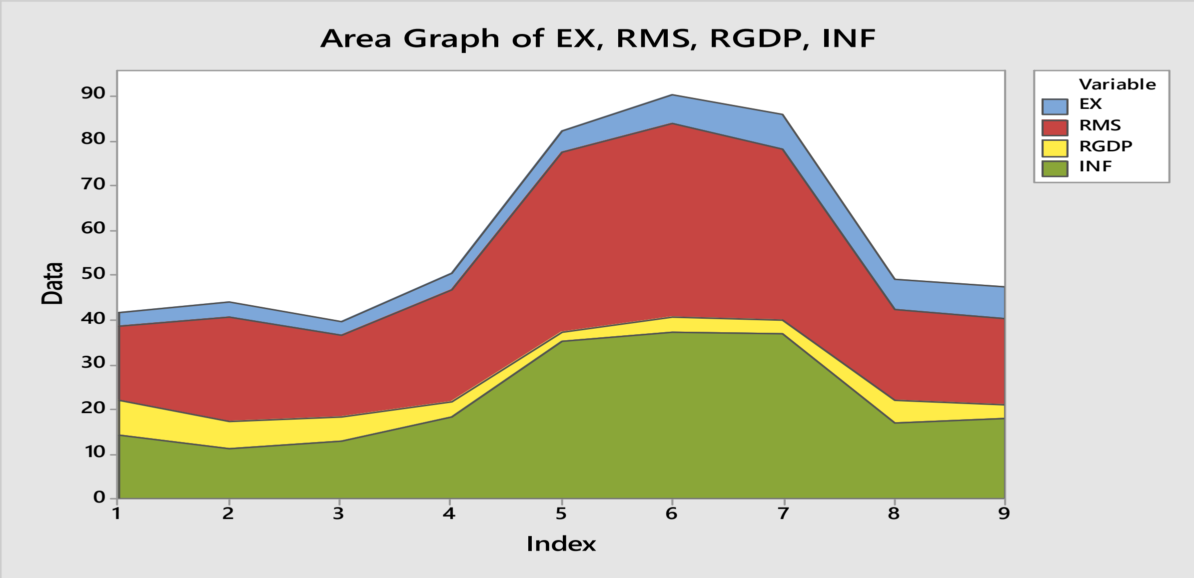

Table and figure above, show that there is fluctuation in exchange rate during that period, the average exchange rate during that period reached (5.038) with a standard deviation of (1.869). Also we note clearly that since 2012 exchange rate deteriorated, the average exchange rate reached (4.5615) because the growth rate of money supply increased from (25.12) in 2011 to (40.13) in 2012, followed by an increase in inflation rates from (18.1) in 2011 to (35.1) in 2012 by an increase of 194%. The growth rate of GDP declined from (3.47) in 2011 to (2.21) in 2012 by a decrease of 63.7%, that was due to South Sudan secession in 2011, which led to a decline in oil export proceeds. In addition, agricultural and industrial sectors were neglected during that time leading to a decline in GDP growth rate in the country, from 2013 to 2016. The fluctuation and turbulence of those macro variables due to their close interdependence - as shown in the above Table and Figure - also the recent global financial crisis had repercussions on the national economy, in addition to the United States embargo imposed on the country since 1996, the public debt of about 47 billion dollars, the recurrent wars in south and west of the country during that period led to the displacement of large number of farmers to urban areas which directly contributed to the decline in agricultural production the backbone of country's economy. Therefore, we find a clear variation in economic indicators during that period, the average inflation rate during 2008-2016 reached (22.27) with a standard deviation of (10.82), the average rate of money supply growth reached (27.22) with a standard deviation of (10.47), while the average GDP growth rate was (4.33) with a standard deviation of (1.77). We note that there was convergence between the average growth of money supply and the average inflation rate, which means they are closely and directly correlated, so they affect and are directly affected by exchange rate they are all monetary phenomena in Sudan. We also note the convergence between the average exchange rate and the average growth rate of GDP, which means the exchange rate, is affected and affects the rate of growth of GDP as they are closely correlated. So, we can say that those macroeconomic variables are clearly correlated each with other - as previously mentioned – therefore, we find that they are all directly affected by exchange rate and also affect it, and this is indicated by the critical theory explaining the exchange rate behavior, about which we talked in theoretical framework of this study.

Applied aspect:

1. Time series description of exchange rate:

The lowest value of series (2.8126) was in May 2010, the highest value of series (7.8988) was in August 2017, the overall average of series (5.2824) with a standard deviation of (1.8912), the convolution coefficient of series (-0.0047) and Kurtosis coefficient (1.2708). This means that the series data does not follow the normal distribution.

The probability value of distribution is (0.0006) less than (0.05) so, the null hypothesis: “time series is distributed normally”, is rejected. Time series do not follow the normal distribution are very common in the case of financial variables, because the series often has the effect of uneven variation that causes imbalances in series average due that to it is influenced by preceding time lags. However, GARCH models use other types of error distributions to estimate models non- normally distributed.

2. Series stationary test:

The null hypothesis: "Series is unstable", is tested.

Table (2) Augmented Dicky-Fuller (ADF) Test Results

Calculated value	Tabular value at 5%	Probability value
-0.725	-2.885	0.8354

Source: E-Views Output Results

The test shows that the series suffers from (Unit Root) problem, because the calculated value of test is smaller than the tabular value at level 5%. We therefore accept the null hypothesis: "Series is unstable". In order to make the series stable, we take the first difference of series according to the following table:

Table (3) Augmented Dicky-Fuller (ADF) Test Results for first difference of series

Calculated value	Tabular value at 5%	Probability value
-10.086	-2.885	0.000

Source: E-Views Output Results

From the Table (3), it is clear that the series became stationary in the first difference, we find that the calculated value of the test (- 10.086) is greater than the tabular value (- 2.885) at the level 5%. Therefore, we reject the null hypothesis and accept the alternative hypothesis: "Series is stationary", because the probability value of test (0.000) is less than (0.05), the following Figure shows this.

3. Variation variability test:

This is done by the adopting ARCH test and testing null hypothesis: "There is variation variability in the series".

Table (4) ARCH results for the original series

F - statistics	Pro.F - statistics	Obs*R^2	Pro.Chi^2
686.649	0.000	101.675	0.000

Source: E-Views Output Results

According to the test results, the probability value of Chi-square is (0.000) less than the probability value (0.05). This leads to the acceptance of null hypothesis, and therefore we acknowledge the problem of variation variability.

4. Estimation of model:

Several models are reconciled; the most important two are ones in the following table:

Table (5) Selected Models Results

Model	ARCH(1,0)	Prop	EGARCH(1,1)	Prop
Cons	0.0004	0.000	-0.0037	0.138
Resid1	0.445	0.009	-	-
Resid2	-	-	-	-
Varia1	-	-	-3.494	0.037
Varia2	-	-	0.731	0.0002
Varia3	-	-	0.956	0.009
AIC	-4.318	-	-4.31	-

Source: E-Views Output Results

According to the data in the Table above, it is clear that the estimated model EGARCH (1,1) is superior to the model ARCH (1), as it recorded the lowest value of the standard **Akaike** Information criterion (AIC), which was (-4.312) compared to (-4.318) The ARCH model (1), the estimated parameters in both models are all significant, as all their probability values are less than the level of significance (0.05), so we adopt the best model in the case of its higher ability to forecast the future.

5. Testing the model's predictability:

GARCH models use a sample-based prediction method. Often, 25% of the data are tested to determine the model's predictability, so the forecast sample will be from January 2015 to December 2016 for each model. Approximately, 25% of the series has 108 observations.

5. Testing model's predictability:

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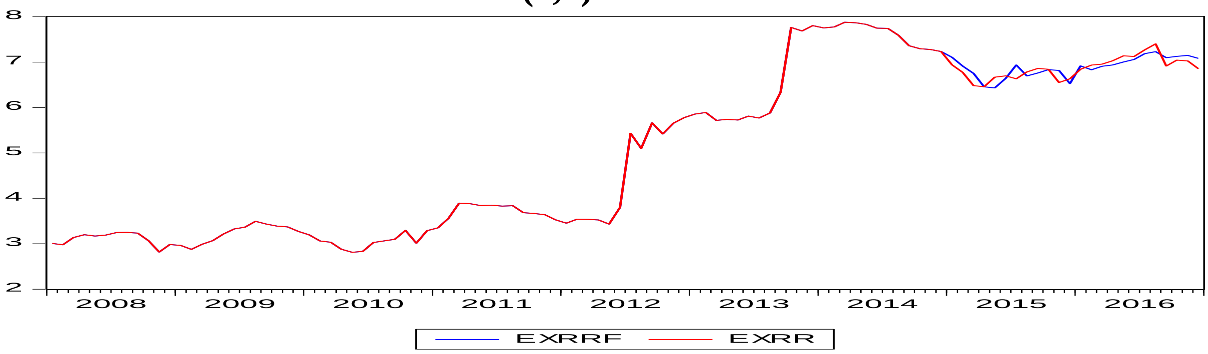
Table (6) Models' Predictability

Model	Thail.coff	RMSE	MAE	MAPE
ARCH(1)	0.0112	0.155	0.129	1.899
EGARCH(1,1)	0.0111	0.153	0.130	1.908

Source: E-Views Output Results.

According to the above results, it is clear that the two models are highly predictable, whereas the values of both Thile coefficient and square root of mean square error (0.0112 and 0.0111) and (0.155 and 0.135) in the two models respectively, but it is preferred to use the model EGARCH (1, 1) because it has two ends, while ARCH model (1) contains only one end, it does not include the conditional variation equation. The residual tests are the determinant in this matter, as the best model must be free of the problem of variation variability and free of the problem of serial correlation of residuals, the following figure shows the relationship between the actual values and the estimated values of the model EGARCH (1,1).

Figure (3) Real and estimated exchange rate series according to EGARCH model (1,1)



According to the above figure, the real values approximate to the estimated values of EGARCH model (1,1). That supports the model's predictability.

Table (7) ARCH test results for EGARCH (1,1) model residuals

F – statistics	Pro.F - statistics	Obs*R^2	Pro.Chi^2
0.4872	0.4876	0.4942	0.4820

Table (8) ARCH test results for ARCH (1) model residuals

F – statistics	Pro.F - statistics	Obs*R^2	Pro.Chi^2
0.4390	0.4645	0.5465	0.4597

The two models seem to be completely free of the variation **variability** problem, as the probability value of the ARCH test was (0.4820) and (0.4597) in both models. This means the null hypothesis: "There is variation variability problem" is rejected.

The tests of sequential independence of residuals are completely free of the problem of the auto-correlation of all gaps at different time levels along the series with the estimated model residuals. This means that the EGARCH (1,1) model passed all tests for good models, so it can be adopted to interpret and analyze the problem of conditional variation and to forecast the monthly average exchange rate in the coming period.

The forecasted values using EGARCH (1,1) for the period from January 2017 to December 2017 are shown in the following table:

Table (9) Expected exchange rate values from January to December 2017, SDG / USD

January	February	March	April	May	June
7.5266	7.52.6	7.5147	7.5087	7.5027	7.4967
July	August	September	October	November	December
7.4907	7.4848	7.4788	7.4728	7.4669	7.4609

Results

1. Time series data of monthly average exchange rate were not stable at the level due to the presence of (Unit Root), so first differences of the series were taken to make it stable.
2. GARCH models have a very high ability to explain the behavior of economic and financial variables. This was clear by addressing the problems of variation heterogeneity and the sequential correlation of residuals, particularly in exchange rate data.
3. The GARCH models are predictable to forecast the future accurately, and this was clear through the model EGARCH (1,1), which was selected as the best model to represent and forecast the average exchange rate in Sudan.
4. It is clear through the descriptive analysis of the annual exchange rate data; there is a strong relationship between the exchange rate and the rate of growth of GDP without other financial variables.

Recommendations

1. GARCH models to be adopted when it comes to financial economic variables, because they give more accurate representation than other methodologies that ignore the problem of variation variability.
2. The proposed EGARCH (1,1) model should be developed to be used to forecast medium and long-term periods, in order to benefit from it in correct economic planning and budgeting.
3. The causal relationship between the exchange rate and the growth rate of GDP should be searched for.
4. Accurate statistical data of economic and financial variables should be provided daily, weekly and monthly credibly and be available to all researchers, enabling them to conduct research that will describe the behavior and forecast the economic process accurately.

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