MODELLING EXCHANGE RATE OF USD TO SRI LANKAN RUPEES WITH OIL PRICES, GOLD PRICES, SILVER PRICES AND RETURN OF ALL SHARE PRICE INDEX OF SRI LANKA

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Declaration

The work described in this dissertation was carried out by me in association with my supervisors and the Department of Mathematics, University of Moratuwa, Sri Lanka under the guidance of coordinator and has not been submitted elsewhere.

Signature: Date: 23-11-2022

The above candidate has carried out research for the Masters thesis under our supervision.

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Abstract

This report contains the analysis of secondary values of US dollar foreign exchange rate (LKR per USD), Gold price (LKR per Troy ounce), Oil price (LKR per barrel), Silver price (LKR per Metric Ton), and Stock return (All Share Price Index) in Sri Lanka. The purpose of this study is to find the relationship among these variables and forecast the US dollar foreign exchange rate in Sri Lanka. This study has used the EViews8 data analysis package to develop time series models to identify the significance of the relationship between exchange rate and other factors using monthly data from October 2000 to December 2019. Log transformed first differenced series were used in Autoregressive Conditional Heteroskedasticity/ Generalized Autoregressive Conditional Heteroskedasticity modeling. The best model fits for the exchange rate was an exponential GARCH model with EGARCH (2,2). All variables were significant at the 5% level of significance and free from the serial correlation/ heteroskedasticity. The model is sufficient but residuals are not normal. Finally, USD forecasting was done for January to December 2019 using the best fitted model. The mean average percentage error value (5.27%) is in between the highly accurate range (0%-10%).

Key Words: US dollar, ARCH, GARCH, EGARCH, conditional heteroskedasticity

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LIST OF ABBREVIATIONS

Abbreviation	Description
ACF	Auto Correlation Functions
ADF	Augmented Dickey and Fuller
APGARCH	A power of Generalized Autoregressive Conditional Heteroskedasticity
ARCH	Autoregressive Conditional Heteroskedasticity
ARMA	Autoregressive Moving-average
ASPI	All Share Price Index
CCGARCH	Conditional Correlation Generalized Autoregressive Conditional Heteroskedasticity
EGARCH	Exponential Generalized Autoregressive Conditional Heteroskedasticity
GARCH	Generalized Autoregressive Conditional Heteroskedasticity
GARCH-M	Generalized Autoregressive Conditional Heteroskedasticity in Mean
GED	Genaralized Error Distribution
MAPE	Mean Absolute Percentage Error
PACF	Partial Auto Correlation Functions
SVAR	Structural Vector Autoregressive
TGARCH	Threshold Generalized Autoregressive Conditional Heteroskedasticity
USD	United States Dollar
VAR	Vector Autoregressive
VECM	Vector Error Correction Model

Chapter 1

INTRODUCTION

1.1 Background of the study

Volatilities of oil and gold prices are affecting the stock market index. Sellers and buyers meet each other in a stock market to bonds and trade stocks. Investors come and buy the stocks, after a few times they sell it at a higher price in the stock market. Gold, oil, silver, USD (United States Dollar), and stock prices are vital factors in the whole global economy (Phuong, 2017).

The relation between the price of the USD and the prices of other assets (gold, oil, silver, and stocks) is considered for many reasons. Is there a relationship between these five assets? What is the best model to forecast exchange rate? How does the USD affect on the other four markets? All of these problems demand attention. These five factors have not been taken into account collectively in earlier studies on the topic.

Phuong's study appraises the price changes of the variables of the real figures and financial factors. Then find great significant evidence in the relationship between oil, gold, silver, USD, and stock prices. It can help others to obtain correct decisions (Phuong, 2017).

Past studies covered the relation of the exchange rate, gold, and oil (Hammoudeh et al., 2008; Malliaris, 2013). Azar studied stocks and their relationship to the dollar, however, failed to connect gold and oil (Azar, 2013). The studies by Azar and Cengiz covered the relationship between the dollar and stocks, gold, and oil (Cengiz et al., 2011; Azar, 2015). Inci and Lee examined the link between exchange rate changes with eight developed nations and stock returns (Inci & Lee, 2011). Mehmet found the link between gold, silver, and oil (Mehmet, 2017). Lee et all neglected the stock market and the dollar (Lee et al., 2012). Still other researchers dwelled uniquely on dollar and gold (Tully & Lucey, 2007), or stocks and oil (Abyankar et al., 2013), gold or oil and the dollar (Zagaglia & Marzo, 2013). This study covered the five assets simultaneously.

The exchange rate is perfectly positively related to the returns on oil, stocks, gold, and silver. All relationship is statistically significant (Azar, 2015). The exchange rate makes depreciation, because the imports are expensive but exports are cheaper. Therefore, imports decrease and exports increase. Cash flows for importing firms soar and aggregate output becomes higher, increasing equity prices. One further procedure operates in obstruction. Higher equity prices raise possession. The demand for money increases and it is affects the pressure on interest rates which then goes up. Then higher interest rates are affects the dollar and capital inflows appreciation.

1.2 Exchange rate of USD

A lot of countries use currencies as a medium of exchange (the Dollar in the United States and the Rupee in Sri Lanka etc.). This is more widely used in the foreign exchange markets. That means, if the exchange rate of the USD for the Sri Lankan rupee is Rs. 280, then a person has to pay 280 Sri Lankan rupees in exchange for one USD.

The importance of the exchange rate differs from country to country. The exchange rate and imports are very important for small open economies.

The inflation and interest rate has a negative relationship with the exchange rate. The exchange rate and net foreign purchases has a positive relationship. According to the results of the VARM (vector auto regression model), above variables cause the most fluctuations in the USD (Rajakaruna, 2011).

1.3 Significance of the study

Insufficient quantitative studies are reported in Sri Lanka. Therefore, it is difficult for the investors to understand the relation of the exchange rate with oil prices, gold prices, silver prices and the ASPI in the Sri Lankan market. But in the developed countries, there are lots of studies that explain the relationship of the various factors.

1.4 Objectives of the study

Key objective:

- Model the relationship between the exchange rate with oil prices, gold prices, silver prices, and return of ASPI.

Specific objectives:

- Study the variation of the exchange rate with individual factors, gold prices, oil prices, silver prices, and the return of ASPI.
- Fit suitable statistical models including time series and conditional heteroskedastic models.
- Forecast exchange rate using the best fitted models.

1.5 Data set of the study

To establish the quantitative relationship between relevant variables monthly prices of exchange rate and other factors were collected from the different secondary sources in previous studies.

For this study, secondary data of the exchange rate, gold price, crude oil price, silver price, and all share price index are employed starting from October 2000 to December 2018. The sample size was 218 monthly observations per variable. 2019 monthly data of each variable were used for model validation.

Crude Oil Price data were obtained from Bloomberg and other data (silver prices, gold prices, ASPI, and the exchange rate) are retrieved from the website of the Central Bank of Sri Lanka.

1.6 Outline of the thesis

Chapter 1 gives brief introduction about the background of the study, significance of the study, objectives of the study, and data set of the study.

Chapter 2 explains the theoretical background of the study and describes other researches that were carried out in this area.

Chapter 3 gives a brief introduction to descriptive analysis and five financial time series models.

Chapter 4 interprets the results generated from EViews8 software.

Chapter 5 explains the empirical results based on Descriptive and Time Series Analysis.

Chapter 6 includes the discussion and the conclusion of the study as well as the suggestions for the future improvements.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

The key objective of this study is to model the relationship between the exchange rate in Sri Lanka with the gold price, silver price, oil price, and ASPI. The research problems have been included in the preceding section by detecting the existing knowledge gaps.

2.2 Analyses on time series modeling

Abyankar et al. (2013) examined the relationship between stock market and the oil price shocks in Japan using a structural vector autoregressive (SVAR) model. Their sample data started from January 1988 to December 2009. They found that oil price shocks were positively correlated with the stock market.

Malliaris (2013) examined the relationships between gold, euro, and the oil price in Chicago. Sample data started from January 4, 2000 to December 31, 2007. They first employed a time series analysis and then followed neural network methodologies. They used Augmented Dickey and Fuller (ADF) tests of stationarity and tests of cointegration.

Nararuk (2014) found the relationship between the stock market index (Stock Exchange of Thailand (SET)) and the monetary variables (consumer price index, Forex, narrow money and repurchase rate). They used multivariate cointegration (vector error correction model (VECM)), causality analysis and test for the source of volatility. The period covered was from January 1999 to December 2012.

Mehmet (2017) examined the variables (platinum, silver, palladium, gasoline, and crude oil prices) with gold price in Turkey. In the analyses, they used monthly data from July 1990 to February 2014. According to the VAR and VECM analysis gold prices had a short term correlation with crude oil prices, gasoline, and silver prices did not have long term correlations with gold prices, but crude oil and gold prices showed a long term correlation with gasoline prices.

2.3 Analyses on ARCH/ GARCH modeling

Tully and Lucey (2007) investigated the effects of few macroeconomic variables on gold prices in Ireland using APGARCH (A power of GARCH) model. This study examined future price and cash price of gold and economic variables from 1984 to 2003. They fitted Autoregressive Conditional Heteroskedasticity (ARCH) and Genarelized ARCH (GARCH) models were nested within the APGARCH model. Researchers provided the APGARCH model as the best fit for the data.

Hammoudeh et al. (2008) examined the relationship of interest rate and crude oil with volatility behavior of copper, silver, and gold in New York. This study used GARCH models with data from January 2, 1990 to May 1, 2006. They concluded that the relation of past oil shocks on copper, silver, and gold is different. That means the past oil shocks affect the conditional volatility of gold market in the CCGARCH (Conditional Correlation GARCH/ EGARCH) model.

Cengiz et al. (2011) determined the relationship between gold price and oil price, exchange rate, inflation rate, interest rate data in USA using the MGARCH model. This study included monthly data from June, 1992 to March, 2010. Models used for modeling heteroskedasticity were the ARCH model and GARCH models. Finally, they found a positive correlation between oil prices and gold prices and also the highest negative correlation between the exchange rate and gold prices.

Lee et al. (2012) examined the relationship between West Texas Intermediate crude oil and gold prices using the threshold cointegration test and TECM-GARCH with

GED (Genaralized Error Distribution). They used sample data from May 1, 1994 to November 20, 2008.

Azar (2013) used the US stock prices, Standard & Poor's 500 (S&P 500) stock index in Lebanon, the eleven foreign exchange rates and USD as the variables. The samples were monthly data from January 1, 1973 to April 1, 2013. The sample size was 484 observations for each variable. The first difference of the natural logs of the eleven foreign currencies and the S&P 500 index were analyzed using Granger-causality tests and GARCH (1,1) model. These log returns revealed no relationship between the exchange rates and stock prices, but there was a relationship between US stock prices and three foreign exchange rates.

Zagaglia and Marzo (2013) used daily data from October 13, 2004 to March 5, 2010 to find the relation between the USD and the euro, the British pound with exchange rates. They considered the pattern of volatility between gold prices and the dollar. This research used the statistical coefficient of generalized autoregressive conditional heteroskedasticity (GARCH) models to get conclusions on the hedging properties of gold for the USD.

Azar (2015) at Haigazian University, Beirut in Lebanon studied the relationship between the USD and other factors (US stocks, gold, and oil). The samples were monthly data from January 1985 to November 2014. The sample size was 359 observations per variable and used the first difference of the natural logarithms of all variables. The null hypothesis of a normal distribution for the residuals is rejected by the Jarque-Bera test.

Chapter 3

METHODOLOGY

3.1 Time series analysis procedure

Analysis of time series is helpful not only for economists and businessmen. Time series analyses are helpful in the analysis of the past behavior of a variable, forecasting, evaluation of current achievement and making comparative studies.

The time series should be stationary to build up time series model with the Box-Jenkins approach. Moreover, if it starts to move less or more constantly at a fixed level the series is stationary. Futhermore a series which shows a steady thriving, overall movement or a series that progress back and forth from one fixed level to another level cannot be modeled without being converted to a stationary series. Finally, fit the selected model and check whether the errors are normally distributed and the variance is constant, using histogram of standardized residual and plot of residuals. EViews8 data analysis software was used to analyze the secondary data output (NCSS Statistical Software, 2016).

3.2 Descriptive analysis

3.2.1 Test of stationarity

The data should be stationary is a common assumption in many time series techniques. That means, the mean, variance, and autocorrelation structure do not change over the time period. Stationarity of five series of data will be investigated using the Augmented Dickey and Fuller (ADF) test (National Bureau of Standards (NIST), 2012).

3.2.2 Summary statistics

Summary statistic is the process of quantitatively describing or summarizing features and analyzing collection of information.

Descriptive statistics (Measures of variability or dispersion (Maximum, Minimum, Standard Deviation, Skewness), Measures of central tendency (Mean, Median) and Jarque-Bera values) of five stationary series will be used.

3.3 ARMA model

Main assumption of ARMA model is stationarity of time series. After the series is stabilized, then considered the ACFs (Auto Correlation Functions) and PACFs (Partial Auto Correlation Functions). Then the orders of AR and MA terms in the ARMA model were identified.

Using ACF and PACF plots together to define the AR process, expect that the ACF should show a geometric or will gradually decrease and simultaneously the PACF should show a sharp drop after p significant lags. Define a MA process, expect the opposite from the ACF and PACF plots. In the absence of a gradual decreasing pattern in both the ACF and PACF plots, modeling should be done using the ARMA method (Adeleye, 2018).

3.4 Financial time series analysis

Liberally used models for modeling heteroskedasticity are Engle (1982)'s Autoregressive Conditional Heteroskedasticity (ARCH) model and Bollerslev (1986)'s Generalized ARCH (GARCH) models. Other models such as GARCH in mean (GARCH-M), Exponential GARCH (E-GARCH), Threshold ARCH (T-ARCH) are derivated afterwards (Adeleye, 2018).

3.4.1 ARCH model

Heteroskedasticity suggests that the series exhibits uneven variance, and the use of AR terms demonstrates that heteroskedasticity seen over several time periods may be autocorrelated. ARCH just indicates that the series under consideration has a time-varying variance that is dependent on the lag effect.

ARCH is designed to model and forecast conditional variances. Conditional variance can also depend on more than one lagged realization. The ARCH (*p*) model simultaneously examines the mean and variance of a variable.

The representation of the ARCH (*p*) mean is:

$$Y_t = c + \epsilon_t \ ; \qquad \epsilon_t \sim iid\ N\ (0, \sigma^2{}_t) \qquad ----(1)$$

$$\epsilon_t = \sigma_{t|t-p}\, e_t \ ; \qquad e_t \sim N(0, \sigma^2) \qquad ----(2)$$

The representation of the ARCH (*p*) conditional variance is:

$$\sigma^2{}_{t|t-p} = \alpha_0 + \sum_{i=1}^{p} \alpha_i \epsilon^2{}_{t-i} \qquad ----(3)$$

Note: $\alpha_0 > 0,\ 0 \leq \alpha_1 < 1$ but the ARCH (*p*) model frequently yields negative coefficients of the lagged periods of the squared error (Adeleye, 2018).

3.4.2 GARCH model

The main difference of the GARCH model from the ARCH model is that the GARCH (*p*,*q*) process introduces the lagged conditional variance. Zero mean, constant unconditional variance and non-constant conditional variance are the characteristics of a GARCH model.

GARCH (*p*,*q*) model where *p* = lagged terms of the conditional variance (σ) and
q = lagged terms of the squared error (ϵ^2).

The representation of the GARCH(p,q) conditional variance is:

$$\sigma^2{}_{t|t-p} = \alpha_0 + \sum_{j=1}^{p} \beta_j \sigma^2{}_{t-j} + \sum_{i=1}^{q} \alpha_i \epsilon^2{}_{t-i} \qquad ----(4)$$

Note: For stationarity, $\alpha_1 + \beta_1 < 1$. If $\alpha_1 + \beta_1 \geq 1$, an "integrated GARCH" process or IGARCH has occurred (Adeleye, 2018).

3.4.3 GARCH-M model

The return of security may depend on its volatility in finance. If, the standard deviation or conditional variance is introduced into the mean equation, fit the GARCH-in-Mean (GARCH-M) model.

Premium is a positive function of the risk. If the risk is captured by the conditional variance or volatility, then the conditional variance may enter the conditional mean function. These models capture the risk using the standard deviation of the series instead of its variance (Adeleye, 2018).

The representation of the GARCH-M (p,q) conditional variance is:

$$\sigma^2{}_{t|t-p} = \varphi + \sum_{j=1}^{p} \beta_j \sigma^2{}_{t-j} + \sum_{i=1}^{q} \alpha_i \epsilon^2{}_{t-i} \qquad ----(5)$$

3.4.4 TGARCH model

Other volatility model is the threshold GARCH model. It is commonly used to handle leverage effects. Threshold GARCH was introduced independently by Zakoïan (1990) and Glosten, Jaganathan, and Runkle (1993). The main reason for fitting the TGARCH model is that it can capture asymmetries in terms of negative and positive shocks.

A standard ARCH and GARCH model treats 'good news' and 'bad news' symmetrically. That is, their impact on asset volatility σ_t is the same. This implies that only the absolute value of the innovation matters and not its sign.

The generalized specification for the conditional variance is given by:

$$\sigma^2{}_{t|t-p} = \varphi + \sum_{j=1}^{p} \beta_j \sigma^2{}_{t-j} + \sum_{i=1}^{q} \alpha_i \epsilon^2{}_{t-i} + \sum_{k=1}^{q} \gamma_k \epsilon^2{}_{t-k} I_{t-k} \quad ----(6)$$

Where, $I_t = 1$ (bad news) if $\epsilon_t < 0$ and $I_t = 0$ otherwise.

Note: good news, $\epsilon_{t-i} > 0$ and bad news, $\epsilon_{t-i} < 0$, have different effects on the conditional variance; bad news has an impact of $\alpha_i + \gamma_i$, while good news has an impact of α_i . If $\gamma_i \neq 0$, the news impact is asymmetric. If $\gamma_i > 0$, bad news increases volatility and say that there is a leverage effect for the *i*-th order (Adeleye, 2018).

3.4.5 EGARCH model

This model has the equation which is on log variance instead of variance itself. The main advantage of this model is that it automatically satisfies the positivity of the variance. The Exponential GARCH (EGARCH) model was proposed by Nelson (1991) which can be used to capture the policies, information, news, incidents and events on the financial market.

The specification for the conditional variance is:

$$\log(\sigma^2{}_t) = \varphi + \sum_{i=1}^{q} \alpha_i \left|\frac{\epsilon_{t-i}}{\sigma_{t-i}}\right| + \sum_{j=1}^{p} \beta_j \log\left(\sigma^2{}_{t-j}\right) + \sum_{k=1}^{q} \gamma_k \frac{\epsilon_{t-k}}{\sigma_{t-k}} \quad ----(7)$$

Note: The leverage effect is exponential, because the left-hand side is the *log* of the conditional variance. The presence of leverage effects can be tested by the hypothesis that $\gamma_i < 0$. The impact is asymmetric if $\gamma_i \neq 0$ (Adeleye, 2018).

3.5 Model fitting and model diagnostics

3.5.1 Model fitting procedure

GARCH models were fitted using EViews8 software. Statistical results depend on the available data. From the literature, the preferred model(s) should have:

1. Least number of parameters
2. Significant coefficients
3. High adjusted R-squared
4. High log likelihood ratio
5. Lowest Schwartz Information Criterion
6. Residuals are normal
7. No heteroskedasticity: Lagrange Multiplier test for ARCH (ARCH-LM), White or Breusch-Godfrey (BG) tests (Adeleye, 2018).

8. No autocorrelation: Correlogram

The common method of testing autocorrelation is the Durbin-Watson test. Serial correlation is similar to the statistical concepts of autocorrelation or lagged correlation (Abdullah & Fredrik, 2013).

3.5.2 Prediction accuracy

Finally measure the prediction accuracy of the forecasting method in statistics using the mean absolute percentage error (MAPE). It expresses the accuracy as a ratio defined by the formula:

$$MAPE = \frac{1}{n} \sum_{t=1}^{n} \left| \frac{A_t - F_t}{A_t} \right| \times 100\% \qquad ----(8)$$

Note: A_t and F_t represents the actual and forecast value.

3.5.3 GARCH model diagnostics

After estimating the parameters, the adequacy of the model can be assessed by detecting whether the model assumptions are satisfied. Ljung-Box test for residuals and squared residuals can be used to test the validity of mean and volatility equations and kurtosis, skewness, QQ plot of residuals can be used to test the validity of assumptions.

Chapter 4

DESCRIPTIVE ANALYSIS

4.1 Visualizations

Figure 4.1 represents variations of Exchange Rate (ER), Oil Price (OP), Gold Price (GP), Silver Price (SP), and All Share Price Index (ASPI) from October 2000 to December 2019 monthly data.

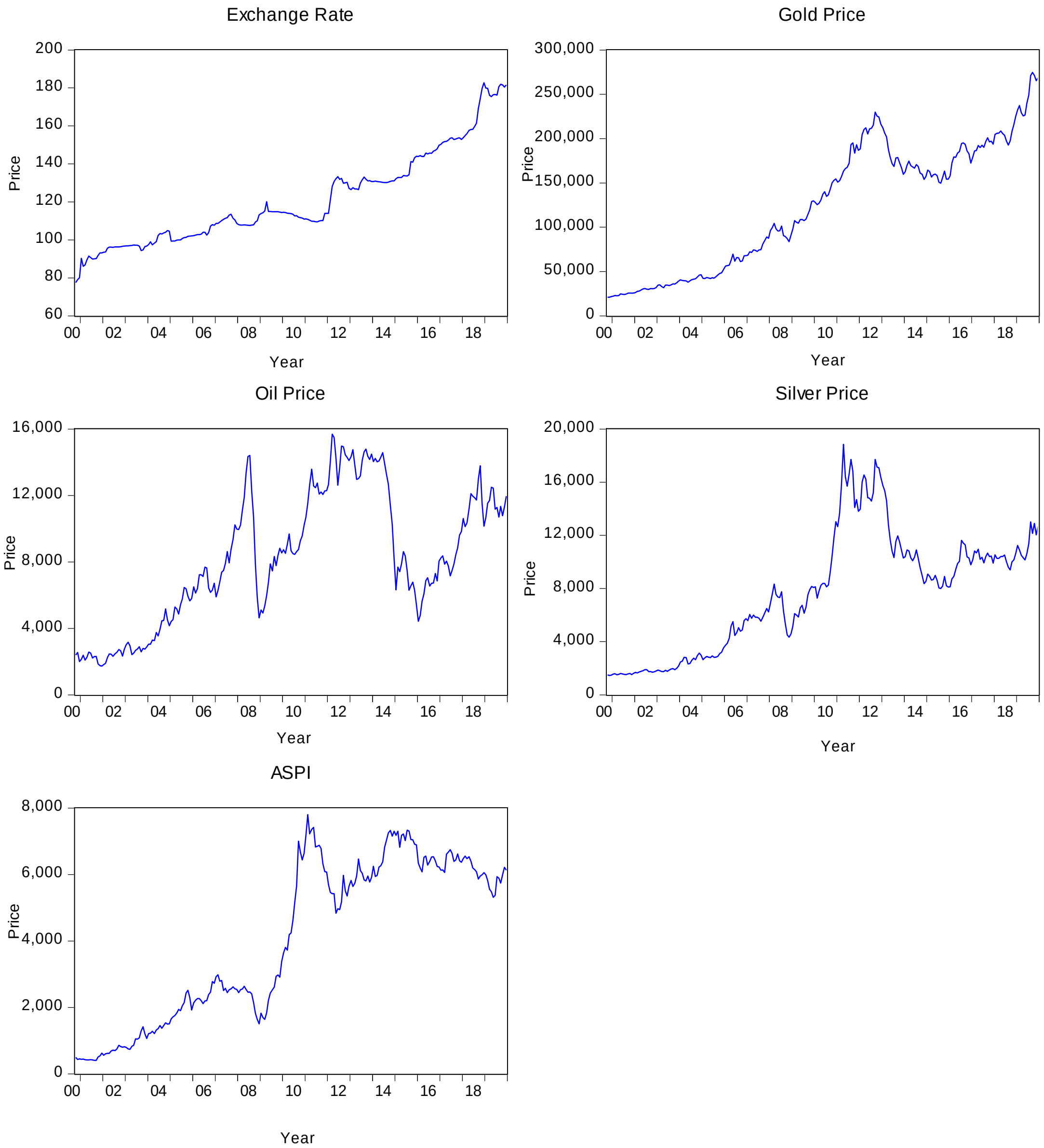

Figure 4.1: Line Graphs of Original Series from 2000 to 2019

Figure 4.2 shows how ER, GP, OP, SP, and ASPI varied from January 2015 to December 2019 monthly data.

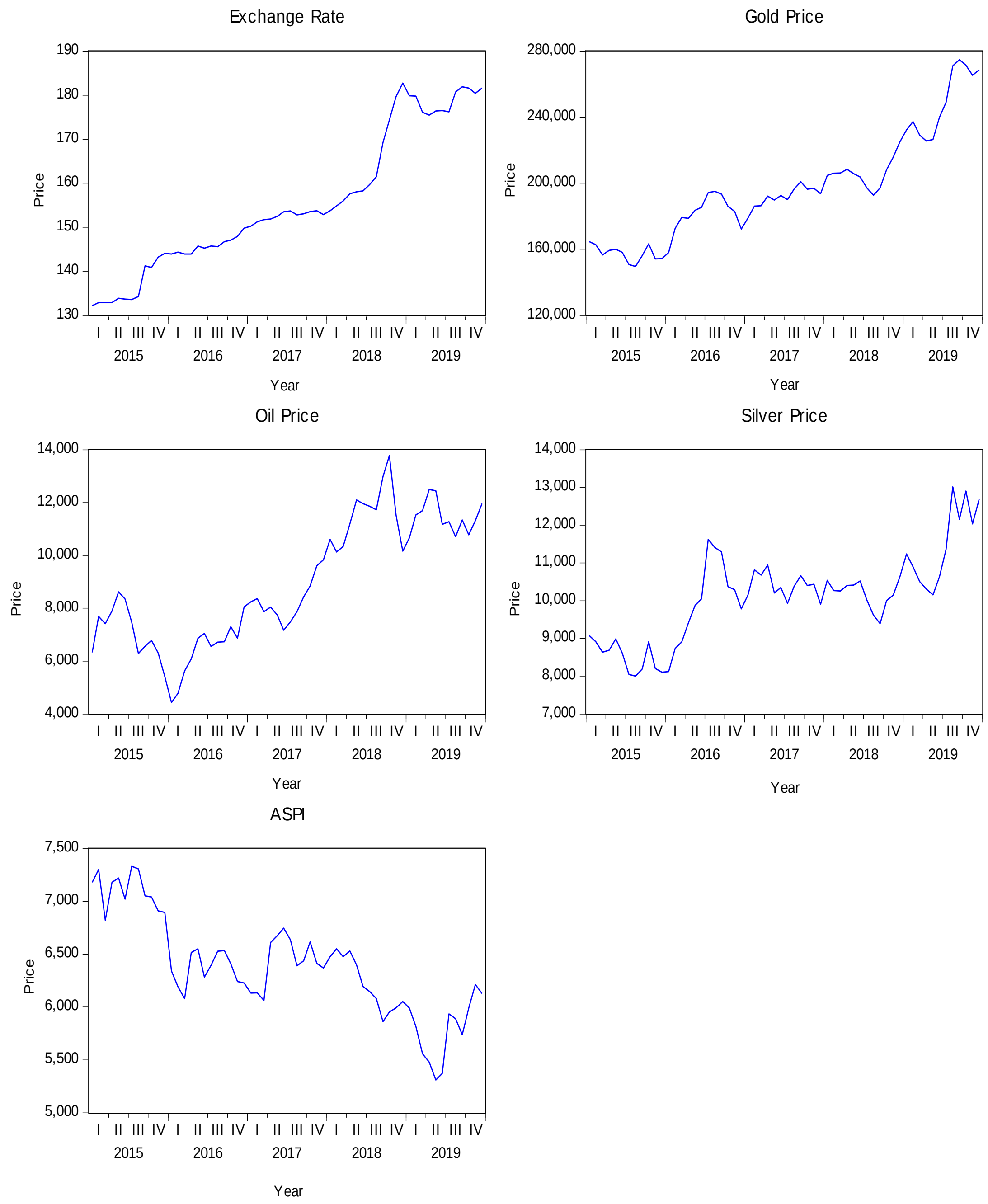

Figure 4.2: Line Graphs of Original Series for Last Five Years

Line graphs of ER, GP, OP, SP, and ASPI from January 2018 to December 2019 monthly data are shown in Figure 4.3.

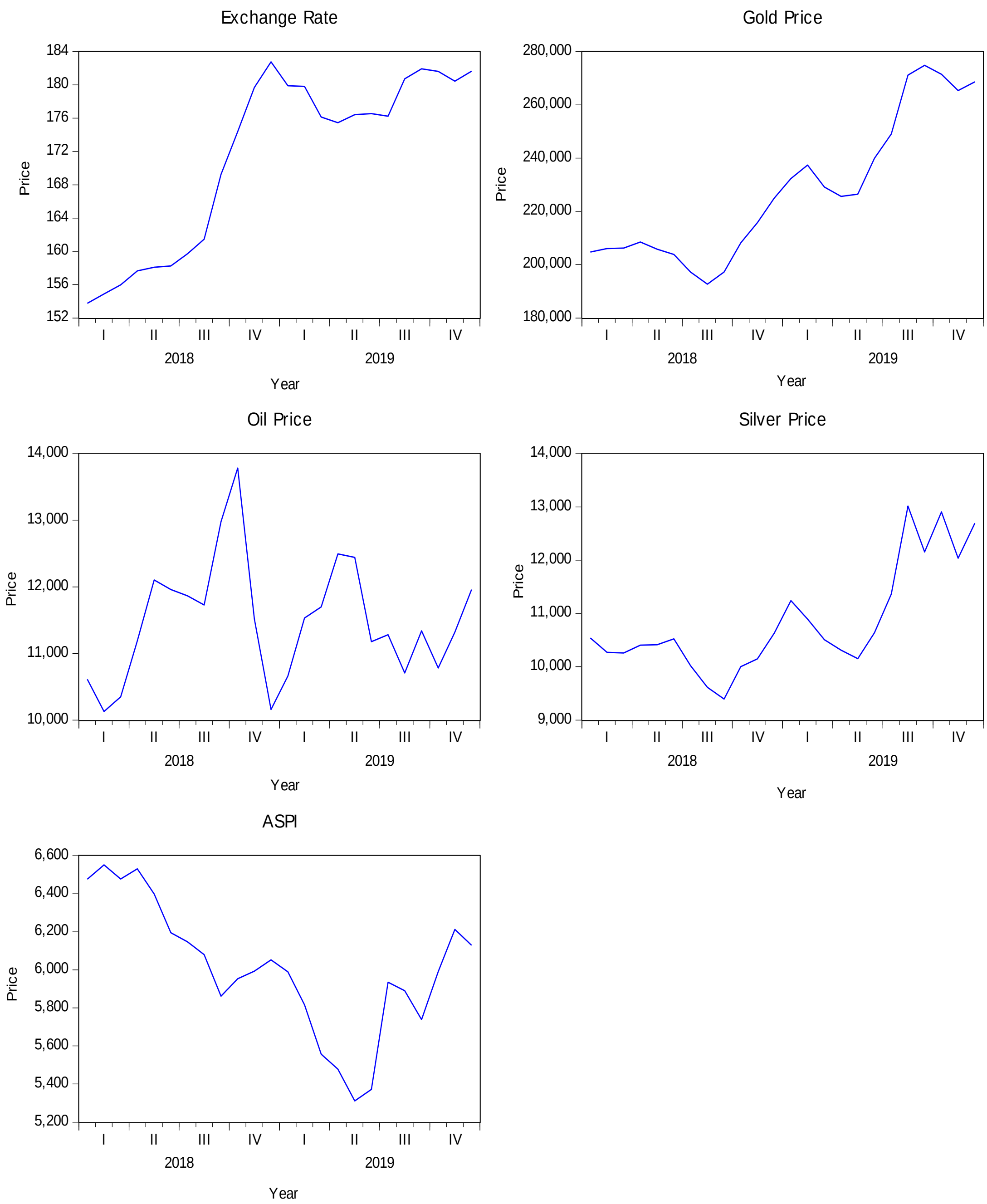

Figure 4.3: Line Graphs of Original Series for Last Two Years

The time series plots in Figure 4.1 showed an upward trend and seasonal cycles. Exchange Rate (ER) and Gold Price (GP) had small fluctuations, but they still showed an upward trend until the end of 2019. Silver Price (SP) and All Share Price Index (ASPI) started to increase gradually from 2009 to 2011 and afterwards fluctuated slowly.

Figure 4.2 describes the variation of the original series for the last five years. ER, GP, OP, and SP series have an upward trend and ASPI has a downward trend. All series fluctuated slowly. The maximum value of exchange rate and oil price were reported at the end of 2018. Minimum values of variables were shown at the end of 2015 except ASPI.

The line graphs in Figure 4.3 showed upward/downward trends and seasonal cycles. ER and GP had small fluctuations. The Sri Lankan stock market was unstable in that period. The Easter attack in Sri Lanka might have been the reason for it. Variations are not clearly seen in Figure 4.1 but can be more clearly seen in Figures 4.2 and 4.3.

4.1.1 Exchange Rate

According to Figure 4.1 Exchange Rate has an upward trend and small fluctuations in the 2009 to 2011 period. When considering the last five years, ER has gradually increased but high peaks at the end of 2018 can be seen in Figures 4.2 and 4.3. Then values have decreased up-to March of 2019.

4.1.2 Gold Price

GP has an upward trend and it has gradually increased slowly with small fluctuations throughout the period which is clearly shown in Figure 4.2.

4.1.3 Silver Price

SP has fluctuated highly in the 2011 to 2013 period. Figure 4.2 shows no trend but shows few fluctuations. Figure 4.3 shows that the high fluctuations occurred at the end of 2019.

4.1.4 Oil Price

OP showed that the seasonal cycles clearly in Figure 4.1 and a sharp decline in 2008 and 2014, which led to high fluctuations. According to Figure 4.2, the price has decreased at the end of 2015 and 2018. But normally OP has gradually increased with small fluctuations. Price changes in 2018 and 2019 can be seen in Figure 4.3.

4.1.5 All Share Price Index

According to Figure 4.2, ASPI values have gradually decreased throughout the period with small fluctuations. Figure 4.3 shows that the values started to gradually decrease from 2019, February to June and increased slowly afterwards.

Table 4.1: Annual Variations in the Mean and Standard Deviation of Original Series

Year	ER		GP		SP		OP		ASPI	
	Mean	Std.	Mean	Std.	Mean	Std.	Mean	Std.	Mean	Std.
2000	78.9	1.2	21137.9	428.5	1481.3	15.6	2316.4	282.1	458.6	31.3
2001	90.2	2.1	24225.7	1317.8	1562.5	38.3	2177.8	276.5	455.3	66.0
2002	95.8	1.0	29666.0	295.2	1760.4	73.9	2391.2	295.2	711.9	98.1
2003	96.5	0.9	35077.0	1929.3	1882.6	122.0	2784.8	213.8	1009.8	221.6
2004	101.4	2.9	41434.8	2629.5	2696.7	253.3	3888.3	677.8	1368.8	119.6
2005	100.6	1.0	44728.2	3209.7	2938.9	236.4	5474.3	658.8	2011.5	282.3
2006	104.2	2.1	62855.0	4566.9	4812.8	642.9	6794.3	561.6	2327.6	219.2
2007	110.6	1.6	77095.2	6834.9	5923.9	282.0	8050.4	1387.2	2652.5	177.3
2008	108.5	1.6	94393.3	6107.6	6488.8	1427.1	10550.8	3118.3	2261.2	390.2
2009	115.1	1.5	111818.4	9758.9	6731.5	978.3	7110.6	1432.7	2415.6	578.2
2010	112.9	1.2	138368.8	10040.1	9098.4	1765.0	9000.4	561.1	5147.7	1280.4
2011	110.7	1.5	173472.5	16325.3	15564.6	1830.5	12261.2	695.6	6899.1	536.5
2012	128.4	5.5	212923.8	11023.1	15871.6	1180.7	14268.2	962.1	5366.1	336.4
2013	129.4	2.4	181912.5	16627.0	12287.0	1926.8	14052.0	660.5	5920.2	217.1
2014	130.6	0.3	165231.1	6220.8	9960.1	895.7	12915.2	1985.3	6658.5	539.6
2015	136.3	4.5	157510.5	4796.5	8530.6	399.2	7091.6	963.2	7104.7	173.9
2016	145.8	1.8	181834.1	10707.2	9990.1	1097.2	6420.5	1036.3	6358.0	156.0
2017	152.5	1.1	191737.0	5966.8	10405.2	328.5	8292.8	803.5	6435.4	231.1
2018	163.8	10.0	205947.1	8547.7	10184.8	377.0	11530.9	1129.4	6226.4	247.5
2019	178.8	2.5	249278.5	19678.5	11492.6	1036.9	11449.0	614.4	5784.9	295.8

Table 4.1 shows how the original series varied annually with mean and standard deviation. All variables have gradually increased. A statistics known as a standard deviation quantifies a dataset's dispersion from its mean. The standard deviation will be higher if the data points are further widespread.

Exchange rate and Gold Price have the highest mean in 2019. According to Table 4.1, Gold Price data points are more spread out.

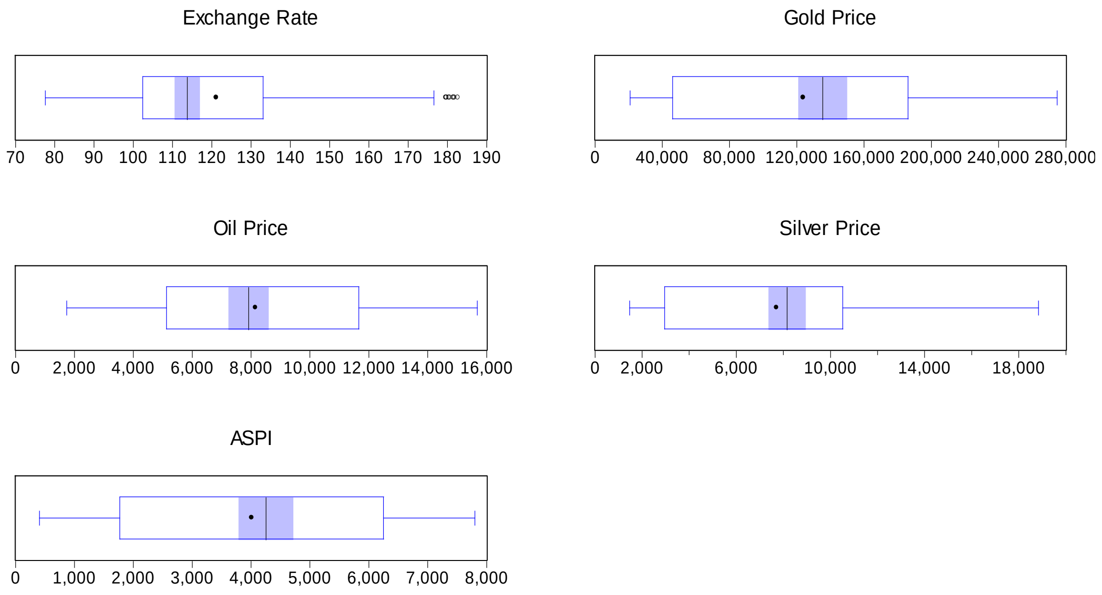

Figure 4.4: Box Plots of Original Series

The descriptive analysis of the statistics in Figure 4.4 describes a positive skewness on the exchange rate, oil price, and all share price index. An assessment of the asymmetry in the data distribution is known as the skewness. The short line represents the median and a black dot represents the mean value in the Box plot. Box plot helps to identify outliers. Outlier is an observation that is numerically distinct from the rest of the data. The exchange rate has some outliers. More than 177 LKR per USD values are considered as the outliers. Outliers are presented in 2018, September to 2019 December.

Furthermore, kurtosis values were smaller than 3 for each series. Usually, kurtosis value over 3 shows early symptoms of no heteroskedasticity. If the data distribution is not normal, the Jarque-Bera test gives a probability value which is < 0.05. According to the J-Bera statistic in Table 4.1 and Figure 4.4, none of the series has a normal distribution.

Chapter 5

ADVANCED STATISTICAL ANALYSIS

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5.1 Test of stationarity

The fundamental stationarity detection techniques include plotting data or functions of the data and evaluating visually whether they exhibit the property of stationarity (or non-stationarity) of data.

As a preliminary step, one needs to test whether the data used have a stationary or stable deployment. Then, data are generated to check the first difference of the original series (Kwiatkowski, 1992).

The time series plot (Figure 4.1) in section 4 discusses trends, seasonal and cyclic patterns observed. Logarithm transformations and differencing can be used to stabilize the variance and mean of a time series by removing trend and seasonality.

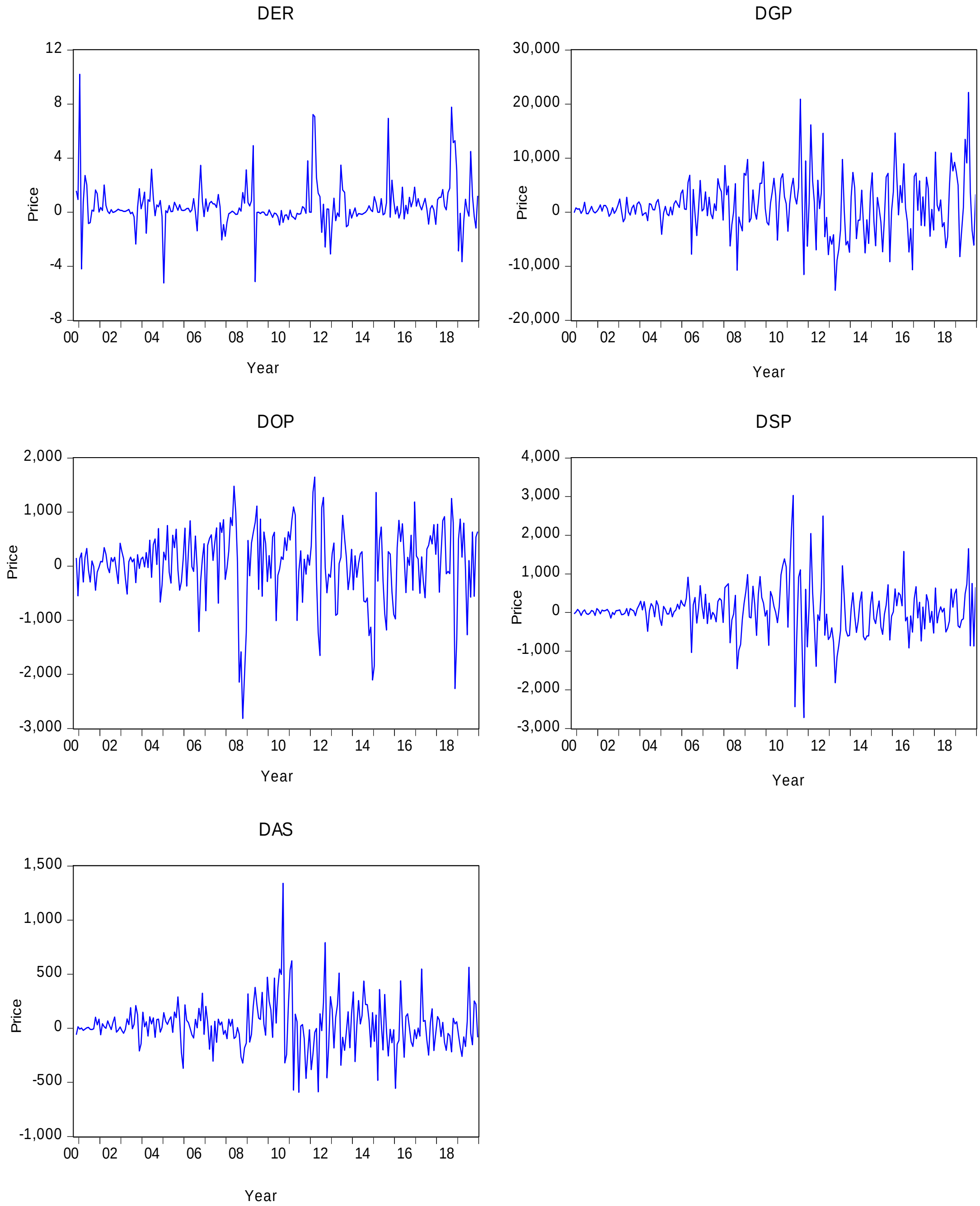

Figure 5.1: Line Graphs of the First Difference of Original Series from 2000 to 2019

Figure 5.1 shows that the first difference of the original series has a problem of variance non-stationarity. Therefore, the series needs to take the logarithm transformation to become variance stationarity. Then the original series was converted to the logarithm transformed series.

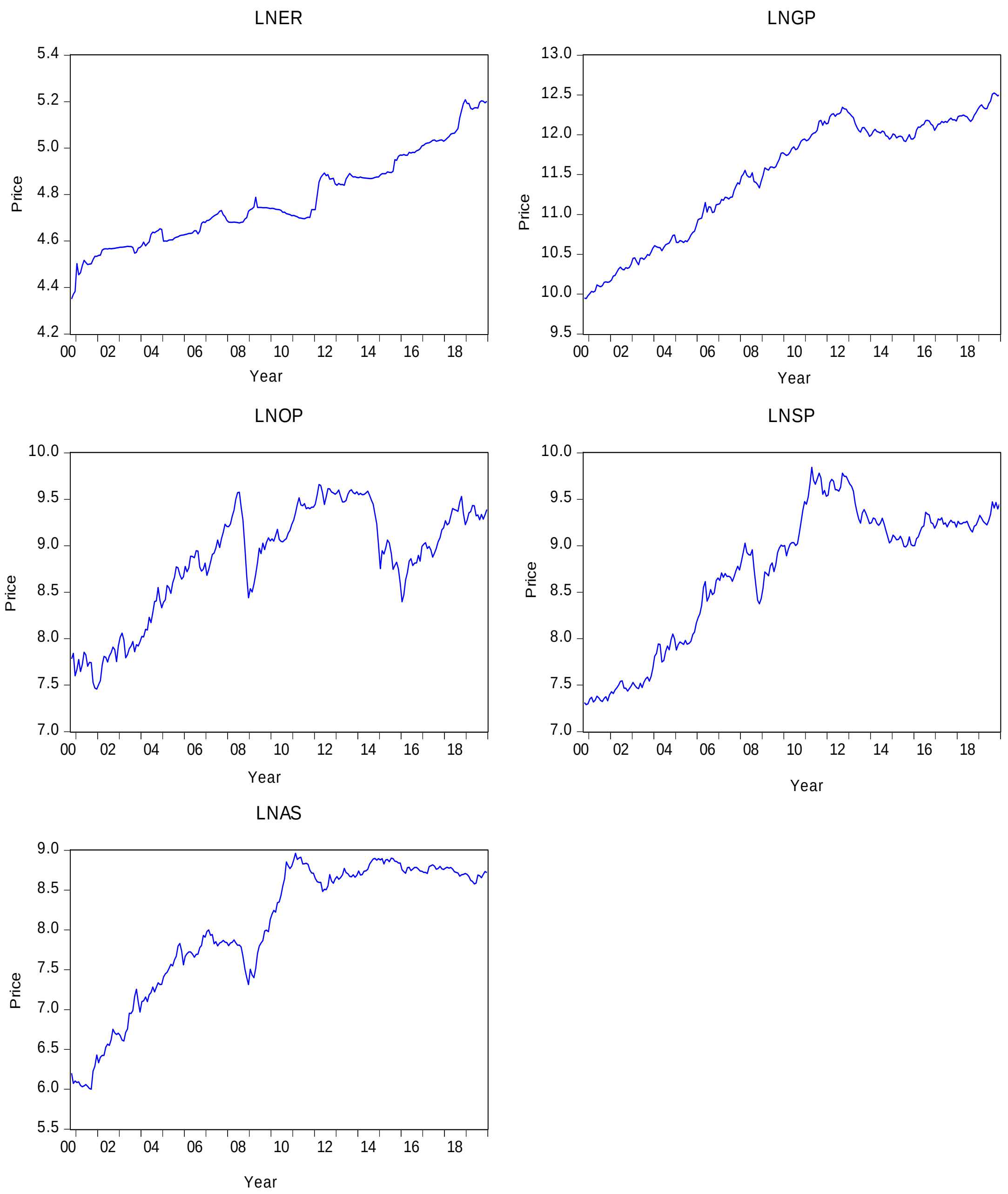

Figure 5.2: Line Graphs of Logarithm Transformation of Original Series from 2000 to 2019

As shown above (Figure 5.2) the logarithm transformation still have upward and seasonal cycles, which implies level non-stationarity. Then the first differenced logarithm transformed series was considered.

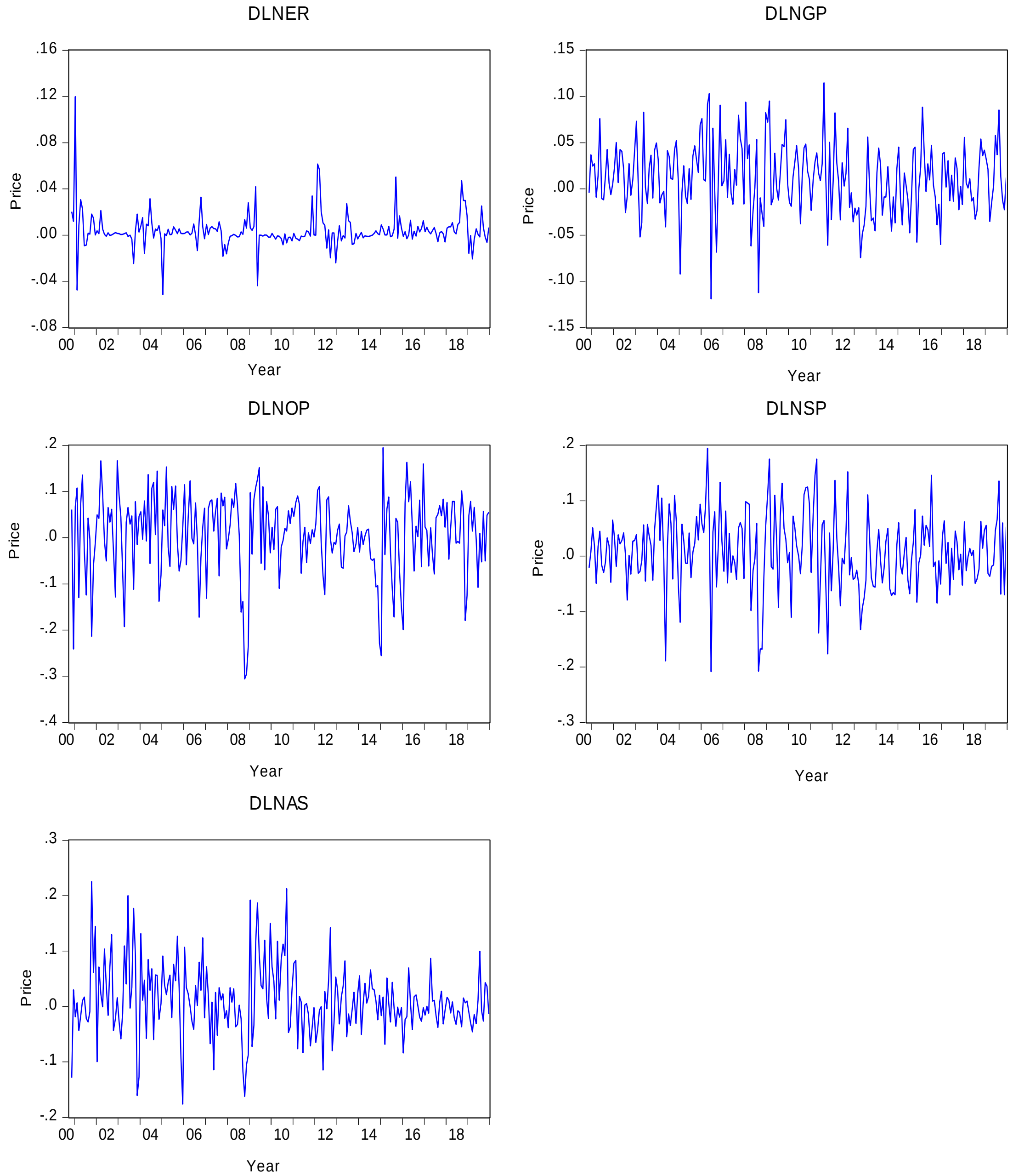

Figure 5.3: Line Graphs of the First Difference of Logarithm Transformation from 2000 to 2019

Now variances are stationary. Therefore, the first difference of the logarithm transformation series is stationary. There are no trends or cycles since the mean, variance, and autocorrelation remain constant throughout time and across the series.

Table 5.1: Unit Root Test for Original Series

Variables	**Level I (0)**		**First Difference I (1)**	
	ADF t-Statistic	**P Value**	**ADF t-Statistic**	**P Value**
Gold Price	-0.4266	0.9010	-11.9682**	0.0000
Exchange Rate	1.4973	0.9993	-12.0482**	0.0000
Oil Price	-2.1281	0.2339	-9.7878**	0.0000
Silver Price	-1.5486	0.5072	-11.9716**	0.0000
ASPI	-1.1278	0.7049	-13.4876**	0.0000
** denotes rejection at the 5% significance level				

All variables are stationary at first difference and converted into stationary form before addressing the objectives. After that, the OLS (Ordinary Least Square) model was constructed to determine the factors which influence on exchange rate. This table confirms that the differencing should be used to make the series stationary.

Table 5.2: Summary of Unit Root Test for First Differenced Logarithm Transformed Series

Variables	ADF Test	
	Without Trend	With Trend
DLNGP	0.0000	0.0000
DLNER	0.0000	0.0000
DLNOP	0.0000	0.0000
DLNSP	0.0000	0.0000
DLNASPI	0.0000	0.0000

Augmented Dickey-Fuller (ADF) was used and the reported results of both with and without a trend to show the stability of the series are presented in Table 5.2. The null hypotheses for ADF is the existence of a unit root I (1), otherwise reject the null hypothesis (Abyankar & Wang, 2013). According to Table 5.2, series is stationary at the 5% significance level.

5.2 Volatility

The volatilities of the variables are the same as in Figure 5.3. DLNGP and DLNOP series have sharp peaks and deeps throughout the period. DLNAS has a peak in 2001 and decreasing volatility after 2012. Peaks in this series are followed by deeps, and it was particularly volatile in 2003, 2005 and 2008. DLNSP has more volatility in-between 2003 and 2012. DLNER has a peak in 2000. This series is more volatile in 2004, 2008, 2011 and 2015.

5.3 The best ARMA models

Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) plots of the series are needed to find the order of AR and/or MA terms. This includes a suggestion for the model that would match the time series data the best. When comparing two models, the one with the lower Akaike Information Criterion (AIC) is usually the better model.

Sample: 2000M10 2019M12
Included observations: 230

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.220	0.220	11.268	0.001
		2	0.021	-0.029	11.367	0.003
		3	-0.015	-0.014	11.423	0.010
		4	-0.063	-0.059	12.358	0.015
		5	-0.023	0.004	12.486	0.029
		6	-0.135	-0.138	16.813	0.010
		7	-0.010	0.052	16.835	0.018
		8	-0.129	-0.155	20.843	0.008
		9	-0.087	-0.028	22.676	0.007
		10	0.117	0.134	25.975	0.004
		11	0.089	0.035	27.889	0.003
		12	0.061	-0.001	28.794	0.004

Sample: 2000M10 2019M12
Included observations: 230

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.199	0.199	9.1843	0.002
		2	-0.089	-0.133	11.019	0.004
		3	-0.067	-0.022	12.074	0.007
		4	0.077	0.090	13.470	0.009
		5	-0.058	-0.112	14.266	0.014
		6	-0.032	0.021	14.511	0.024
		7	0.123	0.131	18.129	0.011
		8	-0.067	-0.161	19.208	0.014
		9	-0.088	0.002	21.094	0.012
		10	-0.024	-0.002	21.233	0.020
		11	0.093	0.042	23.336	0.016
		12	-0.066	-0.073	24.389	0.018

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.220	0.220	11.268	0.001
		2	0.021	-0.029	11.367	0.003
		3	-0.015	-0.014	11.423	0.010
		4	-0.063	-0.059	12.358	0.015
		5	-0.023	0.004	12.486	0.029
		6	-0.135	-0.138	16.813	0.010
		7	-0.010	0.052	16.835	0.018
		8	-0.129	-0.155	20.843	0.008
		9	-0.087	-0.028	22.676	0.007
		10	0.117	0.134	25.975	0.004
		11	0.089	0.035	27.889	0.003
		12	0.061	-0.001	28.794	0.004

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.132	0.132	4.0877	0.043
		2	-0.110	-0.129	6.8964	0.032
		3	-0.021	0.013	7.0003	0.072
		4	0.043	0.031	7.4358	0.115
		5	-0.029	-0.043	7.6383	0.177
		6	0.027	0.048	7.8097	0.252
		7	0.039	0.021	8.1731	0.318
		8	-0.041	-0.046	8.5844	0.379
		9	0.009	0.035	8.6038	0.475
		10	0.037	0.017	8.9421	0.538
		11	0.147	0.148	14.236	0.220
		12	-0.026	-0.062	14.406	0.276

Sample: 2000M10 2019M12
Included observations: 230

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.115	0.115	3.0591	0.080
		2	0.015	0.002	3.1141	0.211
		3	0.037	0.035	3.4345	0.329
		4	0.191	0.186	12.058	0.017
		5	0.060	0.019	12.916	0.024
		6	-0.043	-0.057	13.350	0.038
		7	-0.013	-0.013	13.388	0.063
		8	0.039	0.006	13.749	0.089
		9	0.091	0.078	15.751	0.072
		10	-0.032	-0.034	16.006	0.099
		11	-0.055	-0.045	16.737	0.116
		12	0.100	0.104	19.163	0.085

Figure 5.4: Correlograms of ER, GP, OP, SP, ASPI (Zero level)

Figure 5.4 shows that AR (1) and MA (1) approximating the intervals and the other lags are inside the intervals of all parameters, which mean the data are stationary at zero level. In this case, AR (1) and MA (1) terms are orders of the correlogram model. It is used as an experimental method to check which model is the best. Subsequently, estimated parameters are necessary to define the best model.

Table 5.3: The Best ARMA Models

Description	Best ARMA Model	Minimum Sum of Squared Residuals	Minimum AIC
DLNER	ARMA (2,2)	0.0430	-5.7096
DLNGP	ARMA (1,2)	0.3211	-3.7056
DLNOP	ARMA (6,1)	1.5038	-2.0917
DLNSP	ARMA (7,1)	0.9278	-2.5698
DLNASPI	ARMA (2,2)	0.8945	-2.6210
DLNER (all)	ARMA (2,2)	0.0330	-5.8674

Table 5.3 shows the best ARMA models on the variables selected with the lowest values of Akaike Information Criterion (AIC) and Minimum Sum Squared Residual. ARMA (2,2) on DLNER, ARMA (1,2) on DLNGP, ARMA (6,1) on DLNOP, ARMA (7,1) on DLNSP, and ARMA (2,2) on DLNAS are identified as best fitted models.

Parameter estimation, residual Q statistic probabilities and squared residual probabilities of the above models are included in Appendix. According to Figure 1, the probabilities of coefficients are less than the value of 0.05. It means that the effect of AR and MA terms is significant. Results confirm that models are the suitable. The values of the Durbin-Watson test lie in the range of acceptance region (1.5 to 2.5).

5.3.1 Model assumptions

To test whether the errors are normally distributed, histogram of standardized residuals was compared with the standard normal distribution using the chi-squared goodness of fit test.

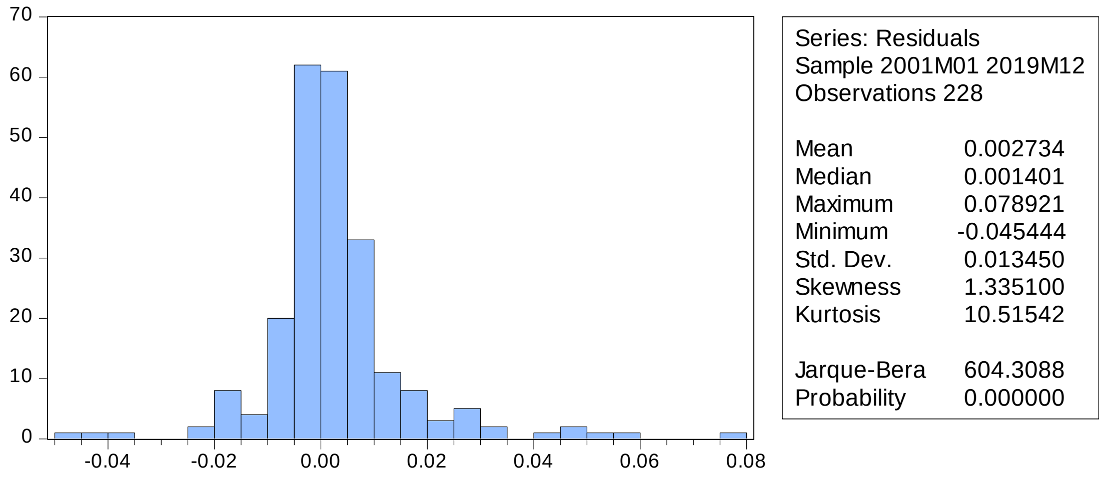

Figure 5.5: Histogram of Residuals ARIMA-X Model of ER

Figure 5.5 shows that the histogram of ARIMA-X (2,2). Its probability is 0.0000 which is less than the value of 0.05, it shows that the residuals are not normal and the model is sufficient. Other separate histograms of residuals are also not normal.

The plots of residuals were inspected to see if the variance is constant. Sample ACF and PACF of the residuals were calculated in order to determine if the residuals are white noise.

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	0.086	0.086	1.7204	
		2	0.026	0.018	1.8743	
		3	0.114	0.111	4.8793	0.027
		4	0.043	0.024	5.3119	0.070
		5	-0.050	-0.061	5.8987	0.117
		6	-0.108	-0.115	8.6361	0.071
		7	-0.103	-0.095	11.158	0.048
		8	-0.067	-0.040	12.234	0.057
		9	-0.110	-0.073	15.105	0.035
		10	-0.048	-0.006	15.660	0.048
		11	-0.030	-0.015	15.883	0.069
		12	-0.039	-0.032	16.251	0.093
		13	-0.093	-0.106	18.369	0.073
		14	0.014	0.004	18.415	0.104
		15	0.041	0.021	18.830	0.128

Figure 5.6: Correlogram of Residuals ARIMA-X Model of ER

Figure 5.6, shows that the residuals of the ARIMA-X (2,2) model of the exchange rate, are within the interval and the probability of more lags is greater than 5%. This implies that residuals of other separate models (Appendix – Figure 2) confirm the constant variance.

5.4 The best ARCH/GARCH models

Figure 5.2 shows the gap between the top and bottom point is very high. This indicates the heteroskedasticity. A good model has randomly distributed residuals. The existence of heteroskedasticity can be appraised from the probability value on the trial and error of ARMA <0.05 which means that the ARMA (2,2) on the DLNER, ARMA (6,1) on the DLNOP, and ARMA (2,2) on the DLNASPI are contained ARCH effects. ARMA (1,2) on the DLNGP, ARMA (7,1) on the DLNSP have not contained ARCH effects. This result confirms that Figure 2 of the Measures of residuals in Appendix.

Now determine the existence of heteroskedasticity in stock index data, then check the models of ARCH / GARCH to determine the best model.

Here, C=Coefficient	A1=ARCH 1
A2=ARCH 2	G1=GARCH 1
G2=GARCH 2	AIC=Akaike Information Criterion
SC=Schwarz Criterion	ARS=Adjusted R-Square

Table 5.4: Testing ARCH/GARCH for DLNER

Coefficient	ARCH (2)	GARCH (1,2)	GARCH-M (1,2)	TARCH (1,2)	EGARCH (2,2)
C	0.0000	0.0000	0.0000	0.0000	0.0000
A1	0.0060	0.0001	0.0003	0.0000	0.0018
A2	0.0007				0.0079
G1		0.0000	0.0000	0.0000	0.0000
G2		0.0000	0.0011	0.0000	0.0000
AIC	-5.9283	-5.9594	-5.9644	-6.0107	-6.0784
SC	-5.8505	-5.8660	-5.8554	-5.9016	-5.9538
ARS	-0.1344	-0.0520	-0.0483	-0.0191	-0.0556

According to Kharisya (2015), the optimal ARCH / GARCH model may be identified by looking at the values of AIC, SC, SSR, and ARS (Adjusted R-Square), which are all the lowest. In Table 5.4, it can be found that the best model of DLNER is EGARCH (2,2) with five parameters. EGARCH (1,1) has three parameters, but the highest AIC value is presented here compared to other models.

Table 5.5: Testing ARCH/GARCH for DLNGP

Coefficient	ARCH (2)	GARCH (1,2)	GARCH-M (1,2)	TARCH (2,1)	EGARCH (1,1)
C	0.0000	0.0124	0.0219	0.1438	0.1210
A1	0.7731	0.1355	0.1584	0.4282	0.0003
A2	0.0786			0.0472	
G1		0.0000	0.0000	0.0000	0.0000
G2		0.0002	0.0016		
AIC	-3.6778	-3.6982	-3.6913	-3.7045	-3.7401
SC	-3.5999	-3.6048	-3.5823	-3.5955	-3.6467
ARS	0.0097	0.0092	0.0079	0.0088	0.0088

Table 5.5 shows that the best model of ARCH / GARCH on the DLNGP is EGARCH (1,1) with three parameters which has the minimum AIC and SC.

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Table 5.6: Testing ARCH/GARCH for DLNOP

Coefficient	ARCH (1)	GARCH (1,1)	GARCH-M (2,2)	TGARCH (1,2)	EGARCH (1,1)
C	0.0000	0.0730	0.0377	0.0230	0.0191
A1	0.0016	0.0049	0.0002	0.3876	0.0173
A2			0.0154		
G1		0.0000	0.0001	0.5732	0.0000
G2			0.0000	0.0159	
AIC	-2.1174	-2.1237	-2.1357	-2.1271	-2.1331
SC	-2.0551	-2.0458	-2.0111	-2.0180	-2.0397
ARS	0.0365	0.0440	0.0412	0.0397	0.0467

Table 5.6 shows that the best model of DLNOP is the GARCH (1,1) with three parameters which has no negative ARCH/GARCH terms. That means the model has satisfied the stability condition.

Table 5.7: Testing ARCH/GARCH for DLNSP

Coefficient	ARCH (2)	GARCH (1,1)	GARCH-M (1,1)	TGARCH (1,1)	EGARCH (1,1)
C	0.0000	0.2428	0.2394	0.2219	0.0000
A1	0.2881	0.0469	0.0517	0.0178	0.0000
A2	0.0493				
G1		0.0000	0.0000	0.0000	0.0000
G2					
AIC	-2.5703	-2.6238	-2.6147	-2.6565	-2.7078
SC	-2.4925	-2.5459	-2.5213	-2.5631	-2.6144
ARS	0.0414	0.0368	0.0317	0.0400	0.0420

From Table 5.7, it can be deduced that the best ARCH / GARCH model on the DLNSP is EGARCH (1, 1) with three parameters which shows the lowest values of AIC and SC.

Table 5.8: Testing ARCH/GARCH for DLNAS

Coefficient	ARCH (2)	GARCH (2,1)	GARCH-M (1,1)	TGARCH (2,1)	EGARCH (2,1)
C	0.0000	0.0161	0.0137	0.0162	0.0172
A1	0.0577	0.2794	0.0227	0.8848	0.1808
A2	0.0585	0.0598		0.0151	0.1438
G1		0.0004	0.0000	0.0001	0.0000
G2					
AIC	-2.6699	-2.7231	-2.7240	-2.7201	-2.7147
SC	-2.5920	-2.6296	-2.6305	-2.6111	-2.6057
ARS	0.0064	0.0034	0.0152	0.0034	0.0038

From Table 5.8, it can be deduced that the best ARCH / GARCH model on the DLNAS is GARCH-M (1, 1) with three parameters which shows the lowest values of AIC and SC.

Table 5.9: Testing ARCH/GARCH for DLNER (considering independent variables)

Coefficient	ARCH (2)	GARCH (1,2)	GARCH-M (1,2)	TGARCH (1,2)	EGARCH (2,2)
C	0.0000	0.0000	0.0000	0.0000	0.0000
A1	0.0151	0.0032	0.0004	0.0010	0.0000
A2	0.0001				0.0091
G1		0.0014	0.0001	0.1112	0.0000
G2		0.0000	0.0000	0.0000	0.0000
AIC	-5.9421	-6.0193	-6.0261	-6.0264	-6.0751
SC	-5.8019	-5.8635	-5.8548	-5.8551	-5.8882
ARS	-0.1157	-0.0145	-0.0056	0.0234	-0.0007
Calculate MAPE values					
MAPE	-	6.19%	12.4%	7.71%	5.27%

From Table 5.9, it can be deduced that the best ARCH / GARCH model on the DLNER is EGARCH (2, 2), which shows the lowest values of AIC and SC. In addition, EGARCH (2,2) has the lowest MAPE value. The dependent variable is DLNER and independent variables are DLNGP, DLNSP, DLNOP, and DLNAS.

5.5 EGARCH (2,2) model

Table 5.10 represents the EGARCH (2,2) model with the mean equation and conditional variance equation for DLNER with four independent variables.

Table 5.10: The Best Fitted Model

EGARCH (2,2)			
Mean equation		Conditional variance equation	
Constant	0.0025 (0.0000)	Constant	-9.4230 (0.0000)
DLNGP	0.1061 (0.0000)	ARCH (1)	1.1638 (0.0000)
DLNSP	-0.0623 (0.0000)	ARCH (2)	0.4930 (0.0091)
DLNOP	0.0167 (0.0000)	Exp. term	-0.1260 (0.0811)
DLNAS	-0.0140 (0.0178)	GARCH (1)	-0.3693 (0.0000)
DLNER (-1)	0.0283 (0.6535)	GARCH (2)	0.4576 (0.0000)
R-squared	0.9207	Akaike inf. Cri.	-6.0751
Adjusted R^2	0.9192	Schwarz criterion	-5.9996
Durbin-Wat. Statistic	1.9593	Log likelihood	671.1566

Considering the EGARCH (2,2) model, all coefficients on the log returns of variables are statistically significant in the conditional variance equation and mean equation. The coefficient of the asymmetric term is negative (-0.1260) and statistically significant at the 10% level. The exponential term is, $e^{-0.126058}$.

If there is no serial correlation, the Durbin-Watson (DW) statistic will be around 2 ('EViews User's Guide', 1994). DW statistic is 1.9593, which means that the model is free from the serial correlation. Therefore EGARCH (2,2) on DLNER is a good model.

The estimation mean equation is:

$$\begin{aligned} Dln(Exchange\ Rate) &= 0.0025 + 0.1061 * Dln(Gold\ Price) - 0.0623 \\ &* Dln(Silver\ Price) + 0.0167 * Dln(Oil\ Price) - 0.0140 \\ &* Dln(All\ Share\ Price\ Index) + 0.0283 \\ &* Dln(Exchange\ Rate - 1) \qquad ----(9) \end{aligned}$$

The estimation conditional variance equation is:

$$\log(\sigma^2{}_t) = -9.4230 + 1.1638 * \left|\frac{\epsilon_{t-1}}{\sigma_{t-1}}\right| + 0.4930 * \left|\frac{\epsilon_{t-2}}{\sigma_{t-2}}\right| - 0.3693 * \log(\sigma^2{}_{t-1}) + 0.4576 * \log(\sigma^2{}_{t-2}) - 0.1260 * \frac{\epsilon_{t-1}}{\sigma_{t-1}} \qquad ----(10)$$

5.5.1 Diagnostic checks

In Figure 5.7, as per the correlogram of residual of model EGARCH (2,2), the probability of each lag is greater than 5% and all the lags are within the intervals. It means that the model is sufficient and also EGARCH (2,2) is the most suitable to forecast the exchange rate.

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	0.117	0.117	3.0130	0.083
		2	0.098	0.085	5.1276	0.077
		3	0.122	0.103	8.4113	0.038
		4	0.071	0.041	9.5296	0.049
		5	0.021	-0.009	9.6254	0.087
		6	-0.113	-0.140	12.518	0.051
		7	-0.058	-0.050	13.279	0.066
		8	-0.013	0.014	13.315	0.101
		9	-0.069	-0.033	14.402	0.109
		10	-0.071	-0.035	15.546	0.113
		11	-0.063	-0.038	16.462	0.125
		12	-0.020	-0.005	16.552	0.167

Figure 5.7: Residual Q Statistic Probabilities of EGARCH (2,2)

In Figure 5.8, as per the correlogram of squared residual of model EGARCH (2,2), the probability of each lag is greater than 5% and all the lags are within the interval. It means that the model is sufficient.

	AC	PAC	Q-Stat	Prob*
1	-0.045	-0.045	0.4390	0.508
2	-0.024	-0.026	0.5687	0.752
3	0.026	0.024	0.7181	0.869
4	-0.007	-0.005	0.7293	0.948
5	-0.014	-0.013	0.7704	0.979
6	0.001	-0.001	0.7705	0.993
7	0.015	0.014	0.8193	0.997
8	-0.042	-0.041	1.2263	0.996
9	0.045	0.042	1.6831	0.996
10	0.035	0.036	1.9632	0.997
11	-0.044	-0.037	2.4031	0.997
12	-0.049	-0.054	2.9702	0.996

Figure 5.8: Squared Residual Probabilities of EGARCH (2,2)

EGARCH (2,2) is the most suitable to forecast the exchange rate. The Q statistic and the standard correlogram show the model as sufficient to forecast ER. Finally, EGARCH (2,2) is the best fitted model for forecasting the exchange rate. EGARCH (2,2) was used for conducting forecast analysis.

5.5.2 Model assumptions

There are four parameters used in the model. All coefficients are significant at the 5% level. EGARCH (2,2) has a high log likelihood ratio and the lowest Schwartz Information Criterion (SIC). Table 5.10 describes that the model is free from the serial correlation using the Durbin-Watson test.

Table 5.11: Heteroskedasticity Test: ARCH

	DLNER	DLNGP	DLNOP	DLNSP	DLNAS	DLNER (all)
F-statistics	0.0881	0.0001	0.0981	0.0011	0.0586	0.4280
Obs*R-squared	0.0889	0.0001	0.0990	0.0011	0.0591	0.4311
Prob. F (1.214)	0.7668	0.9910	0.7544	0.9735	0.8089	0.5136
Prob. Chi-squa.	0.7655	0.9909	0.7530	0.9733	0.8078	0.5114

Table 5.11 shows that the probabilities of F statistics are 0.7668, 0.9910, 0.7544, 0.9735, and 0.8089 (Exchange rate, Gold price, Oil price, Silver price and ASPI). This means that the individual fitted models are free from heteroskedasticity. As a result, it can be concluded that the initial difference in the series of logarithm transformations exhibits a large heteroskedastic volatility movement. Thus EGARCH (2,2) on DLNER, EGARCH (1,1) on DLNGP, GARCH (1,1) on DLNOP, EGARCH (1,1) on DLNSP, and GARCH-M (1,1) on DLNAS are good models. Finally, it is found that the best fitted model for DLNER by considering independent variables. The probability of F statistics is 0.5136, which means that the EGARCH (2,2) on DLNER is free from heteroskedasticity. Therefore EGARCH (2,2) on DLNER is a good model.

Figure 5.9 shows that the histogram of EGARCH (2,2). Its probability is 0.0000 which is less than the value of 0.05, it shows that the residuals are not normal and the model is sufficient.

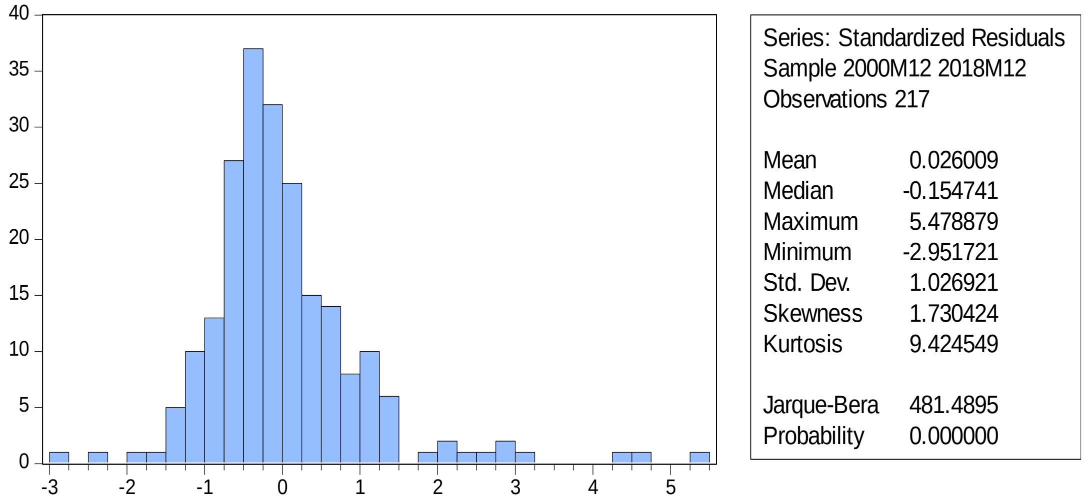

Figure 5.9: Histogram (EGARCH (2,2))

5.5.3 Forecasting

Figure 5.10 shows actual and forecast values of EGARCH (2,2) model for transformed series.

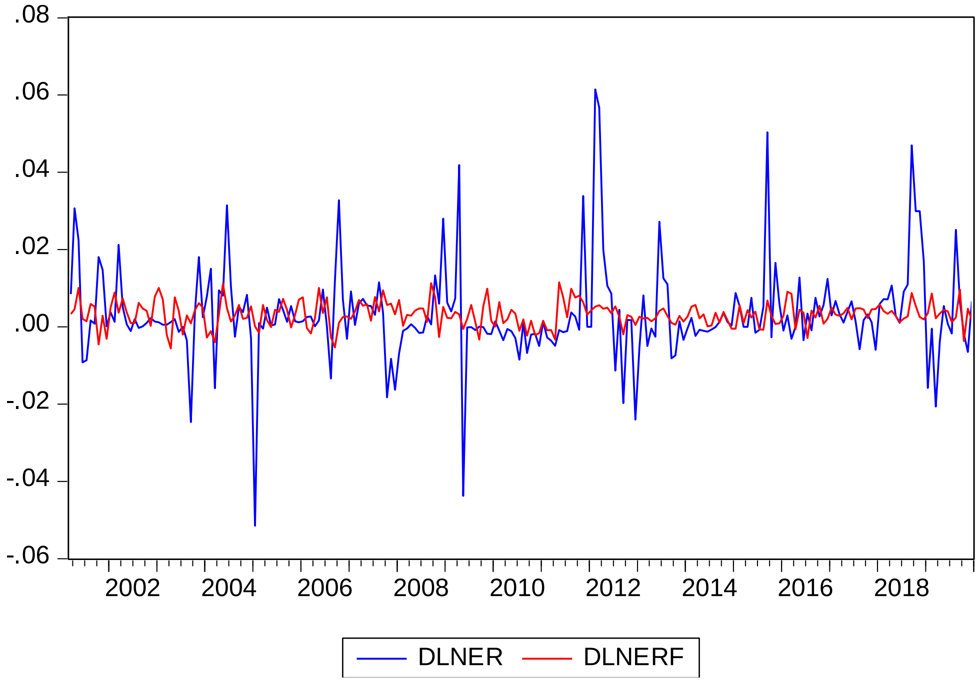

Figure 5.10: Actual and Fitted Values for DLNER from 2000 to 2019

Figure 5.10 doesn't give a clear idea about the model for DLNER. DLNER has high fluctuations but fitted DLNER has slow fluctuation. However, Exchange Rate (ER) is the dependent variable. Therefore, fitted DLNER values are converted to the fitted ER values using Excel.

Figure 5.11 shows actual and forecast values of the EGARCH (2,2) model for the original series, showing that when the actual and forecasted values of the exchange rate move upwards.

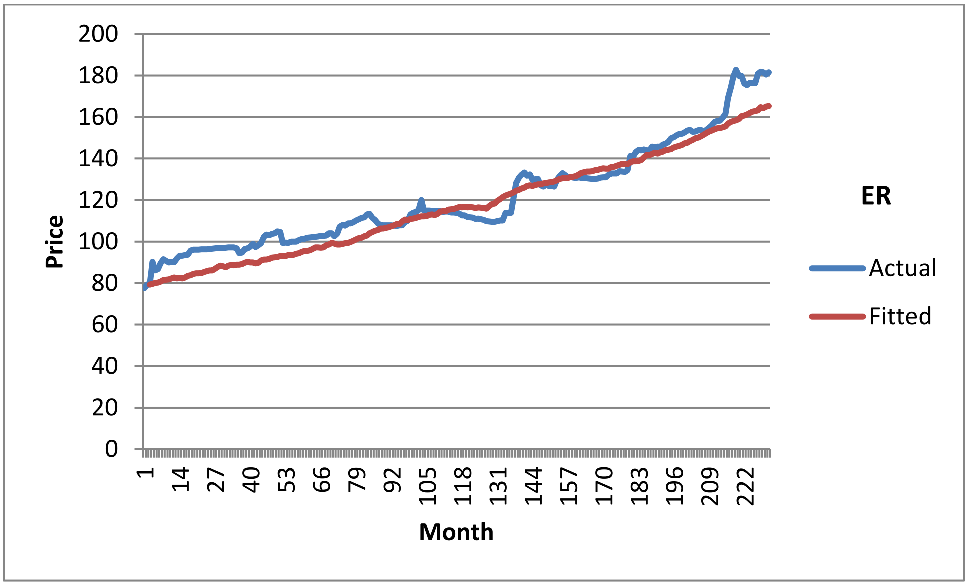

Figure 5.11: Actual and Fitted Values for ER

Forecast data shows that the mean absolute percentage error (MAPE) value on the correspondent exchange rate for 2019, is 9.09% for the whole period, which is 5.27%. MAPE value is <10 (9.09 and 5.27<10), which means the EGARCH (2,2) model is a highly accurate forecasting method. Therefore EGARCH (2,2) is the best model.

The objective of the study was to develop and evaluate ARCH/ GARCH model for exchange rate prediction. Thus, it is imperative to exhibit its applicability. Table

5.12 shows that the comparison of actual and forecast values for January to December 2019 and it clearly shows that the actual values and the forecast values are closer to each other. It is concluded that EGARCH (2,2) is the best model to forecast the exchange rate of the Sri Lankan economy.

Table 5.12: Actual and Forecasted Exchange Rates

Month	Actual	Forecasted	% Error
January	179.8	158.9	11
February	179.7	160.3	10
March	176.1	160.7	8
April	175.4	161.2	8
May	176.4	161.9	8
June	176.5	162.6	7
July	176.2	162.8	7
August	180.7	163.2	9
September	181.9	164.8	9
October	181.6	164.2	9
November	180.4	164.9	8
December	181.6	165.2	8

Chapter 6

DISCUSSION AND CONCLUSION

This research analyzed the factors that would affect the exchange rate in Sri Lanka. Four independent variables have been employed such as gold price, oil price, silver price, and all share price index to test whether there is a significant relationship with the exchange rate. The relationships among economic factors are important for making business decisions and investments.

6.1 Conclusions of the study

According to this study, the exchange rate is positively affected by stock market prices, gold price and oil price and negatively affected by silver price. Exchange rate is a vital factor in the economy because it may have direct impacts on factors or work as a connection between variables.

The first difference of logarithm transformation series is stationary. Because, the series are not displays systematic patterns. Then all variables were converted into stationary form before model fitting. The ARMA (2,2) on the DLNER, ARMA (6,1) on the DLNOP, and ARMA (2,2) on the DLNASPI are with ARCH effects but ARMA (1,2) on the DLNGP, ARMA (7,1) on the DLNSP are not with ARCH effects. Since fitted ARMA models contained ARCH effects, conditional heteroskedastic models are fitted.

Thus EGARCH (1,1) on DLNGP, GARCH (1,1) on DLNOP, EGARCH (1,1) on DLNSP, and GARCH-M (1,1) on DLNAS are found to be good models. Finally, it can be deduced that the best model is ARCH/ GARCH on DLNER is EGARCH (2,2). The best fitted model is tested for feasibility and the model is free from heteroskedasticity. From the obtained statistics, it is evident that the residuals are non-normally distributed.

6.2 Limitations of the study

This study contains a number of limitations, some of which are connected to the lengthy period of time that daily and weekly data were available. This study has considered only four dependent variables even though many important factors conclude the exchange rate. Therefore, the results are somewhat impractical in the real world.

This study is heavily dependent on the data from secondary sources and there may be small differences from the values due to many reasons such as Tsunami, Easter attack, Flood etc.

The results from this study are applicable only in the Sri Lankan market.

6.3 Suggestions for future study

Future studies are encouraged to incorporate other factors that have a substantial impact on the US currency despite the factors that this study suggests effect the exchange rate (inflation rate, interest rate, money supply, and jewellery demand, etc.).

Multivariate GARCH models (MGARCH) are likely one of the most vital areas for future research.

Furthermore, this study is only focusing on Sri Lanka. Future studies are encouraged to include developed, developing, and emerging countries.

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Appendix

Dependent Variable: DLNER
Method: Least Squares
Date: 07/30/21 Time: 11:06
Sample (adjusted): 2001M01 2019M12
Included observations: 228 after adjustments
Convergence achieved after 18 iterations
MA Backcast: 2000M11 2000M12

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.003032	0.000735	4.123547	0.0001
AR(2)	0.631739	0.102668	6.153219	0.0000
MA(2)	-0.713638	0.103929	-6.866562	0.0000

R-squared	0.153484	Mean dependent var	0.003593
Adjusted R-squared	0.145959	S.D. dependent var	0.014975
S.E. of regression	0.013839	Akaike info criterion	-5.709602
Sum squared resid	0.043091	Schwarz criterion	-5.664479
Log likelihood	653.8946	Hannan-Quinn criter.	-5.691396
F-statistic	20.39761	Durbin-Watson stat	1.624107
Prob(F-statistic)	0.000000		

Inverted AR Roots	.79	-.79
Inverted MA Roots	.84	-.84

Dependent Variable: DLNGP
Method: Least Squares
Date: 07/30/21 Time: 11:19
Sample (adjusted): 2000M12 2019M12
Included observations: 229 after adjustments
Convergence achieved after 6 iterations
MA Backcast: 2000M10 2000M11

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.011166	0.002578	4.330403	0.0000
AR(1)	0.149048	0.066480	2.242012	0.0259
MA(2)	-0.120218	0.066863	-1.797964	0.0735

R-squared	0.032724	Mean dependent var	0.011162
Adjusted R-squared	0.024164	S.D. dependent var	0.038157
S.E. of regression	0.037693	Akaike info criterion	-3.705648
Sum squared resid	0.321100	Schwarz criterion	-3.660665
Log likelihood	427.2967	Hannan-Quinn criter.	-3.687501
F-statistic	3.822907	Durbin-Watson stat	1.992460
Prob(F-statistic)	0.023292		

Inverted AR Roots	.15	
Inverted MA Roots	.35	-.35

Dependent Variable: DLNOP
Method: Least Squares
Date: 07/30/21 Time: 11:25
Sample (adjusted): 2001M05 2019M12
Included observations: 224 after adjustments
Convergence achieved after 6 iterations
MA Backcast: 2001M04

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.007488	0.006101	1.227437	0.2210
AR(6)	-0.155478	0.064410	-2.413879	0.0166
MA(1)	0.264414	0.064784	4.081440	0.0001

R-squared	0.087039	Mean dependent var	0.007452
Adjusted R-squared	0.078777	S.D. dependent var	0.086999
S.E. of regression	0.083502	Akaike info criterion	-2.114583
Sum squared resid	1.540951	Schwarz criterion	-2.068892
Log likelihood	239.8333	Hannan-Quinn criter.	-2.096140
F-statistic	10.53469	Durbin-Watson stat	1.978634
Prob(F-statistic)	0.000043		

Inverted AR Roots	.64-.37i	.64+.37i	.00+.73i	-.00-.73i
	-.64-.37i	-.64+.37i		
Inverted MA Roots	-.26			

Dependent Variable: DLNSP
Method: Least Squares
Date: 07/30/21 Time: 11:30
Sample (adjusted): 2001M06 2019M12
Included observations: 223 after adjustments
Convergence achieved after 6 iterations
MA Backcast: 2001M05

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.009490	0.006677	1.421284	0.1567
AR(7)	0.163556	0.068014	2.404761	0.0170
MA(1)	0.254838	0.065594	3.885087	0.0001

R-squared	0.073188	Mean dependent var	0.009269
Adjusted R-squared	0.064762	S.D. dependent var	0.068771
S.E. of regression	0.066507	Akaike info criterion	-2.569652
Sum squared resid	0.973105	Schwarz criterion	-2.523815
Log likelihood	289.5162	Hannan-Quinn criter.	-2.551148
F-statistic	8.686405	Durbin-Watson stat	1.999459
Prob(F-statistic)	0.000234		

Inverted AR Roots	.77	.48+.60i	.48-.60i	-.17-.75i
	-.17+.75i	-.70-.33i	-.70+.33i	
Inverted MA Roots	-.25			

Dependent Variable: DLNAS
Method: Least Squares
Date: 07/30/21 Time: 11:34
Sample (adjusted): 2001M01 2019M12
Included observations: 228 after adjustments
Convergence achieved after 10 iterations
MA Backcast: 2000M11 2000M12

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.012082	0.005093	2.372403	0.0185
AR(2)	0.689290	0.236354	2.916352	0.0039
MA(2)	-0.632687	0.254866	-2.482435	0.0138

R-squared	0.009044	Mean dependent var	0.011478
Adjusted R-squared	0.000235	S.D. dependent var	0.063763
S.E. of regression	0.063755	Akaike info criterion	-2.654461
Sum squared resid	0.914564	Schwarz criterion	-2.609338
Log likelihood	305.6085	Hannan-Quinn criter.	-2.636255
F-statistic	1.026692	Durbin-Watson stat	1.777943
Prob(F-statistic)	0.359862		

Inverted AR Roots	.83	-.83
Inverted MA Roots	.80	-.80

Dependent Variable: DLNER
Method: Least Squares
Date: 07/30/21 Time: 11:44
Sample (adjusted): 2001M01 2019M12
Included observations: 228 after adjustments
Convergence achieved after 13 iterations
MA Backcast: 2000M11 2000M12

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DLNGP	0.043288	0.023369	1.852370	0.0653
DLNAS	-0.046181	0.013689	-3.373484	0.0009
C	0.003120	0.000672	4.640450	0.0000
AR(2)	0.608244	0.101102	6.016141	0.0000
MA(2)	-0.742508	0.095048	-7.811912	0.0000

R-squared	0.200633	Mean dependent var	0.003593
Adjusted R-squared	0.186294	S.D. dependent var	0.014975
S.E. of regression	0.013508	Akaike info criterion	-5.749367
Sum squared resid	0.040691	Schwarz criterion	-5.674162
Log likelihood	660.4278	Hannan-Quinn criter.	-5.719024
F-statistic	13.99267	Durbin-Watson stat	1.658741
Prob(F-statistic)	0.000000		

Inverted AR Roots	.78	-.78
Inverted MA Roots	.86	-.86

***Figure 1*: Parameter Estimation Tables of the Best ARMA Models**

Lag	AC	PAC	Q-Stat	Prob
1	0.025	0.025	0.1422	
2	0.083	0.082	1.7382	
3	-0.042	-0.047	2.1579	0.142
4	-0.054	-0.060	2.8553	0.240
5	0.018	0.028	2.9306	0.402
6	-0.158	-0.153	8.8256	0.066
7	0.035	0.036	9.1172	0.104
8	-0.123	-0.104	12.710	0.048
9	-0.078	-0.092	14.160	0.048
10	0.110	0.126	17.063	0.029
11	0.059	0.067	17.920	0.036
12	0.061	-0.007	18.817	0.043

Lag	AC	PAC	Q-Stat	Prob
1	-0.003	-0.003	0.0015	
2	-0.040	-0.040	0.3737	
3	-0.092	-0.092	2.2932	0.130
4	0.100	0.099	4.6018	0.100
5	-0.047	-0.055	5.1069	0.164
6	-0.035	-0.036	5.3952	0.249
7	-0.008	0.007	5.4085	0.368
8	-0.112	-0.137	8.3263	0.215
9	-0.042	-0.039	8.7420	0.272
10	-0.035	-0.042	9.0269	0.340
11	0.086	0.056	10.772	0.292
12	-0.069	-0.059	11.900	0.292

Lag	AC	PAC	Q-Stat	Prob
1	0.122	0.122	3.4384	
2	0.085	0.071	5.1204	
3	0.115	0.099	8.2223	0.004
4	0.093	0.065	10.242	0.006
5	-0.038	-0.072	10.590	0.014
6	-0.046	-0.058	11.080	0.026
7	-0.089	-0.092	12.979	0.024
8	-0.046	-0.017	13.473	0.036
9	-0.087	-0.051	15.281	0.033
10	-0.027	0.017	15.454	0.051
11	-0.070	-0.045	16.652	0.054
12	-0.062	-0.044	17.600	0.062

Lag	AC	PAC	Q-Stat	Prob
1	0.003	0.003	0.0015	
2	-0.006	-0.006	0.0103	
3	-0.015	-0.015	0.0661	0.797
4	0.054	0.054	0.7550	0.686
5	-0.037	-0.038	1.0766	0.783
6	0.031	0.031	1.2978	0.862
7	0.041	0.043	1.7073	0.888
8	-0.047	-0.052	2.2381	0.897
9	0.033	0.039	2.4930	0.928
10	0.006	0.002	2.5025	0.962
11	0.149	0.147	7.8696	0.547
12	-0.036	-0.030	8.1828	0.611

Lag	AC	PAC	Q-Stat	Prob
1	0.110	0.110	2.7722	
2	-0.059	-0.071	3.5693	
3	0.025	0.040	3.7120	0.054
4	0.153	0.144	9.2011	0.010
5	0.055	0.025	9.9084	0.019
6	-0.083	-0.078	11.548	0.021
7	-0.012	0.003	11.585	0.041
8	0.014	-0.018	11.629	0.071
9	0.109	0.105	14.490	0.043
10	-0.058	-0.064	15.289	0.054
11	-0.021	0.013	15.394	0.081
12	0.102	0.092	17.914	0.056

Lag	AC	PAC	Q-Stat	Prob*
1	0.103	0.103	2.4653	
2	0.102	0.092	4.8666	
3	0.097	0.080	7.0759	0.008
4	0.087	0.064	8.8582	0.012
5	-0.040	-0.071	9.2378	0.026
6	-0.056	-0.069	9.9705	0.041
7	-0.112	-0.109	12.960	0.024
8	-0.064	-0.033	13.924	0.030
9	-0.098	-0.054	16.216	0.023
10	-0.016	0.033	16.281	0.039
11	-0.066	-0.034	17.348	0.044
12	-0.063	-0.051	18.308	0.050

***Figure 2*: Measures of Residual Q Statistic Probabilities of the Best ARMA Models**

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.366	0.366	30.360	0.000
		2	0.253	0.137	44.922	0.000
		3	0.036	-0.110	45.225	0.000
		4	0.034	0.023	45.497	0.000
		5	0.118	0.145	48.718	0.000
		6	-0.023	-0.134	48.845	0.000
		7	0.009	0.003	48.863	0.000
		8	-0.049	-0.003	49.421	0.000
		9	0.001	0.014	49.421	0.000
		10	-0.000	-0.014	49.421	0.000
		11	0.046	0.073	49.922	0.000
		12	0.018	-0.025	50.004	0.000

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.105	0.105	2.5603	0.110
		2	0.148	0.138	7.6610	0.022
		3	0.072	0.046	8.8823	0.031
		4	0.146	0.119	13.865	0.008
		5	0.032	-0.006	14.110	0.015
		6	0.057	0.018	14.880	0.021
		7	0.082	0.062	16.484	0.021
		8	-0.053	-0.096	17.160	0.028
		9	-0.070	-0.086	18.333	0.031
		10	-0.010	0.005	18.357	0.049
		11	0.044	0.055	18.836	0.064
		12	-0.094	-0.083	21.012	0.050

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.283	0.283	18.442	0.000
		2	0.034	-0.049	18.718	0.000
		3	0.056	0.065	19.449	0.000
		4	0.001	-0.035	19.450	0.001
		5	-0.016	-0.006	19.513	0.002
		6	0.000	0.005	19.513	0.003
		7	-0.010	-0.012	19.538	0.007
		8	-0.047	-0.043	20.061	0.010
		9	-0.005	0.022	20.067	0.018
		10	-0.008	-0.015	20.083	0.028
		11	-0.038	-0.029	20.431	0.040
		12	-0.051	-0.038	21.070	0.049

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.099	0.099	2.1964	0.138
		2	0.167	0.159	8.5420	0.014
		3	-0.016	-0.047	8.6022	0.035
		4	0.099	0.081	10.834	0.028
		5	0.137	0.137	15.144	0.010
		6	0.097	0.047	17.333	0.008
		7	0.060	0.014	18.171	0.011
		8	0.005	-0.019	18.177	0.020
		9	0.040	0.017	18.548	0.029
		10	-0.052	-0.084	19.193	0.038
		11	0.021	-0.003	19.294	0.056
		12	-0.036	-0.028	19.597	0.075

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.180	0.180	7.5213	0.006
		2	0.156	0.128	13.181	0.001
		3	0.187	0.146	21.302	0.000
		4	0.146	0.083	26.274	0.000
		5	0.071	-0.002	27.454	0.000
		6	0.015	-0.050	27.506	0.000
		7	0.121	0.090	30.959	0.000
		8	0.018	-0.028	31.036	0.000
		9	0.014	-0.006	31.086	0.000
		10	-0.071	-0.105	32.316	0.000
		11	0.085	0.100	34.068	0.000
		12	-0.031	-0.046	34.305	0.001

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.313	0.313	22.631	0.000
		2	0.036	-0.068	22.936	0.000
		3	0.040	0.055	23.315	0.000
		4	-0.009	-0.041	23.333	0.000
		5	-0.025	-0.009	23.475	0.000
		6	-0.001	0.009	23.475	0.001
		7	-0.019	-0.024	23.563	0.001
		8	-0.028	-0.015	23.752	0.003
		9	0.025	0.041	23.899	0.004
		10	-0.017	-0.042	23.966	0.008
		11	-0.027	-0.005	24.137	0.012
		12	-0.047	-0.047	24.678	0.016

***Figure 3*: Measures of Squared Residual Probabilities of the Best ARMA Models**

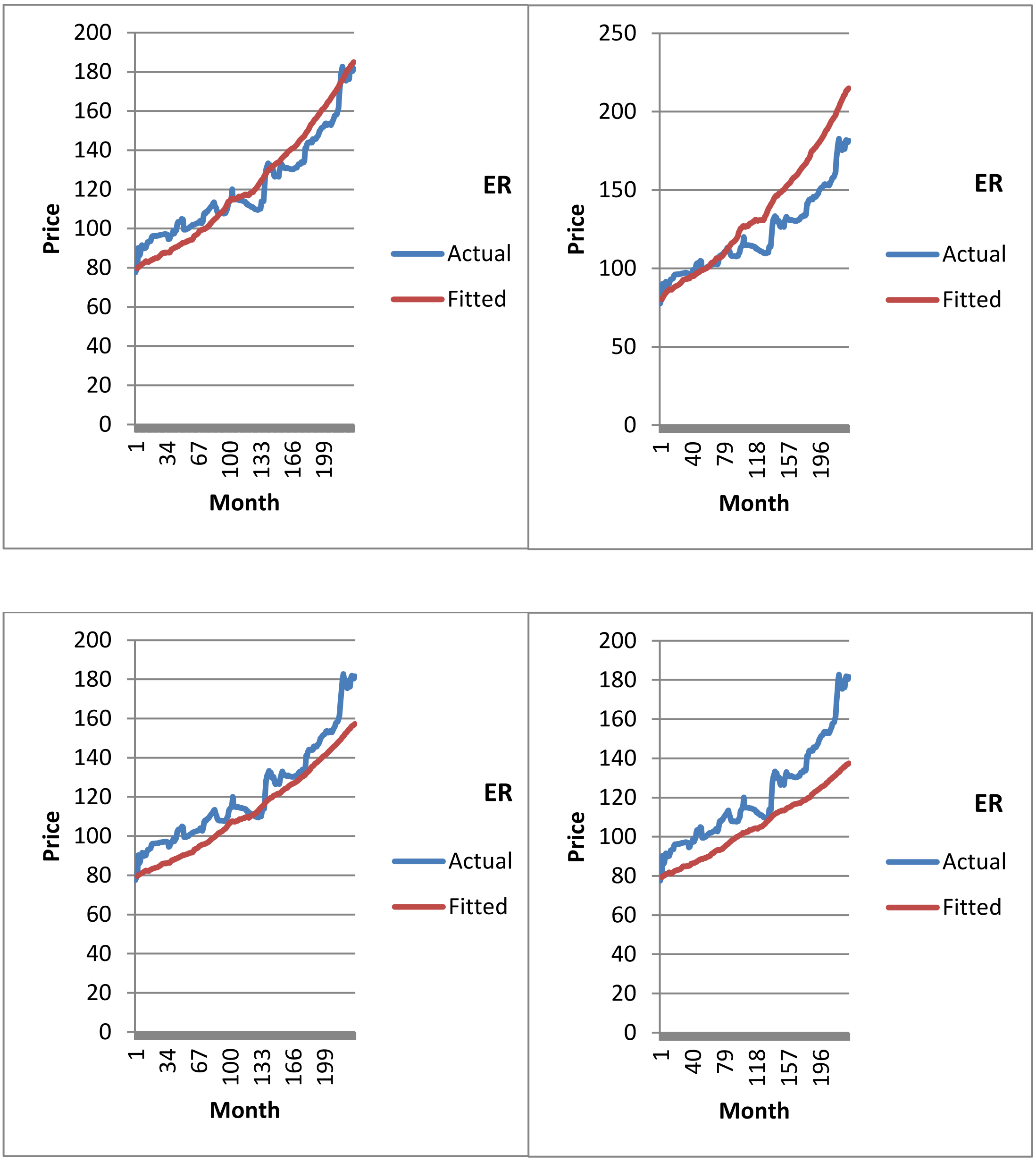

***Figure 4*: Plots with Actual and Fitted Values of ARCH/ GARCH Models for exchange rate from 2000 to 2019**

(GARCH (1,2)/ GARCH-M (1,2)/ TGARCH (1,2)/ EGARCH (1,1))