Exchange Rate Volatility in Sudan: Does the Exchange Rate System Matter?

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Abstract

This paper aims to empirically investigate the determinants of exchange rate in Sudan and assess their impact on its volatility. The study gains its importance from the fact raised by the advocates of fixed and managed exchange rate systems that such systems can be the right choice for small economies, where an independent monetary policy is difficult to execute. The paper uses the ARDL model to study the relationship between the dependent and independent variables. To specify the determinant factors of the exchange rate the research employs four tests: Wald test, heteroskedasticity consistence covariance (White) test, HAC consistent covariance (Newey-West) test, and inferential statistics. To determine variables that are responsible for long-run fluctuations, the research applies Vector Error Correction (VEC) mechanism and Wald test to examine short-run causality and determine the speed of adjustment of endogenous variables. The study documents that the determinant factors of the exchange rate in Sudan are the balance of trade, gold purchases, money supply, inflation and foreign reserves. The continuous deterioration and fluctuation in exchange rate throughout the period under study suggest that the exchange rate system followed has no impact on the stability of the exchange rate.

Keywords: Exchange rate, Gold purchases, Money supply, Inflation, Foreign reserves, Exchange rate regimes

1. Introduction

The exchange rate measures the value of one country currency in terms of other currencies. This value is determined differently depending on the exchange rate system being followed. Under a fixed exchange rate system, this value is set by the monetary authorities, whereas in a floating exchange rate system the exchange rate is determined by the relative forces of demand and supply of the currency in the exchange market. The importance of exchange rate has been tremendously discussed in the literature due to its key role in enhancing the competitiveness of a country in international economy and strengthening its inward financial stability. Stability of exchange rate is one of the crucial objectives of all countries, particularly developing ones. It is evident that a stable exchange rate attracts inflows of foreign investment, improves productiveness and trade patterns, fosters exports of goods, restores trade balance and ultimately helps sustainable development of economic stability. In contrast, instability of exchange rate cuts down investment levels, results in misallocation of resources, deters foreign capital inflows, rises inflation rates and worsens the trade balance. Thus exchange rate determination and stability has been of great interest to academics, policymakers, and market practitioners. Though a number of theoretical models have been developed to predict exchange rate, exchange rate determination is still a controversial issue in the literature of international finance. The general consensus in the literature is that exchange rate volatility is a manifestation of fundamental macroeconomic factors volatility and fluctuation. The central focus has been on explaining the behavior of exchange rate with reference to a given set of macroeconomic fundamentals and a number of models have been developed to furnish a proper understanding of the movement of exchange rate. Such factors which include income growth, inflation, interest rate, fiscal and current account balances, foreign exchange reserves, financial and trade openness, and the size and type of capital flows are considered to be country-specific.

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Nevertheless empirical studies have documented diverse viewpoints and conclusions; some of which support these theoretical models and others contradict them. Moreover, which factors are dominant in determining the value of one currency against the other is still an unsolved issue in the literature.

The collapse of the Bretton Woods system in the early 1970s and the evolution of flexible exchange rate regimes have adversely impacted the stability of exchange rates and increased the magnitude of their volatility especially for those of developing economies, and Sudan is not an exception. Since its independence in 1956 a number of exchange rate policies have been implemented by monetary authorities in Sudan; ranging from fixed to floating exchange rate regimes. For instance, during the period 1956-1978 the central bank of Sudan has adopted a fixed exchange rate system, whereby the exchange rate has been pegged at a fixed rate of one Sudanese pound to 2.85 US dollar. Since 1979 the country shifted to a flexible exchange rate system which has resulted in continuous exchange rate devaluations and government interventions. In early nineteen nineties the government announced the economic liberalization policy during which market mechanism is selected as a tool for setting exchange rates. This policy was abolished three years later and replaced by establishing two windows for exchange rate dealings; commercial bank exchange rate dealings in which the exchange rate is devalued to 3 pounds /US$ and a window of the central bank in which the exchange rate is devalued to 2.15 pounds /US$. During the period 2000-2006 and as a result of foreign currency inflows associated with Sudan petroleum exports, the foreign exchange market was unified with a sole exchange rate of 2.6 Sudanese pounds for the dollar. The exchange rate, then, kept on deteriorating at an accelerating rate throughout the period 2006-2017; from 2.6 to 6.9 US dollars, with many interventions and devaluations of currency by the central bank. For instance in 2012 the Sudanese pound was devalued by 91% in one step, from 2.67 to 4.42 pounds for the dollar to minimize the difference between the official and parallel rate. Nevertheless the problem continues and the difference between the parallel and official exchange rates continued to escalate to reach 184 percent of the parallel rate by the end of 2017. This necessitates investigating and analyzing the macroeconomic factors that lie behind this massive volatility in Sudanese exchange rate and exploring whether the exchange rate system followed does have an impact on the degree of exchange rate volatility.

The study uses a more sophisticated method to study the relationship between the exchange rate and its determinants including Autoregressive Distributed Lag (ARDL) model, co-integration analysis, Vector Error Correction (VEC) test and Granger causality test. The rest of this paper is outlined as follows: Section 2 provides a review of the literature that researches the relationship between exchange rate volatility and macroeconomic fundamentals. Section 3 describes the methodology used, Section 4 delineates the empirical results and their discussion and Section 5 presents a summary and concluding remarks.

2. Exchange rate determinants

What determines exchange rate is an unsettled matter in the literature. According to the International Parity theories the inflation differentials and interest differentials between the countries determine their currencies exchange rates. The Balance of Payment Approach argues that the equilibrium exchange rate is determined by the demand and supply of currency flows from current and financial account activities and stresses factors such as international trade, foreign direct investment, portfolio investment, official monetary reserves and exchange rate regimes. In contrast the Asset Market Approach postulates that exchange rates are assets traded in an efficient market and, hence, their values are determined based on expectations about the future. This approach focuses on prospects of economic growth, supply and demand of financial assets, political stability, capital market liquidity, real interest rate and corporate governance. Empirically numerous factors have been cited as determinants of exchange rate. However the relative importance of these factors is subject to much debate. Differentials in inflation, Differentials in interest rate, Money supply, Current account balance, Public debt, GDP growth and Openness of the economy are the most quoted factors. Raza and Afshan (2017), examine the determinants of exchange rate in Pakistan, using time-series data from 1972 to 2013. Their variables include GDP, Inflation, Interest Rate, Money Supply, Terms of Trade and Trade Openness. According to Rajakaruna, (2017), there is negative relationship between exchange rate and official intervention, terms of trade, inflation, call money rates and remittances. The only positive relationship documented is between net foreign purchases and the exchange rate. Cevik et al (2017), show that though the magnitude and statistical significance of the relationship between the exchange rate volatility and macroeconomic variables varies between advanced and emerging market economies, the type of relationship tends to be the same. The analysis reveals a positive relation between exchange rate volatility and inflation and measures of financial development, whereas trade openness has a negative effect on exchange rate volatility. The volatility of productivity growth and terms of trade appear to have an insignificant effect in the case of advanced countries. In addition a number of soft power variables are found to have statistically significant influence on exchange rate volatility.
For instance the index of voice and accountability and life expectancy have dampening effects on exchange rate volatility. Likewise, financial openness, z-score of banks, and the share of agriculture in GDP relative to the service sector lower the volatility of exchange rates. The study by Mpofo (2016), reveals that trade openness significantly reduces the South African currency volatility. The study also finds that volatility of output, commodity prices, money supply and foreign reserves significantly influence exchange rate volatility. Effiong (2014), demonstrates the existence of a unique long-run relationship between the exchange rate and monetary fundamental, namely, money supply, price level, income level and interest rate. In the short run, however, only the interest rate differential is significant and explains most of the variations in the nominal exchange rate in the short-run. Mirchandi (2013) studies the relationship between various macroeconomic variables including interest rate, inflation rate, GDP, current account and foreign direct investment and the exchange rate of Indian Rupee to US Dollar. Using Pearson’s correlation analysis his findings indicates that there is a strong correlation, whether direct or indirect, between the exchange rate and interest rate, inflation rate, foreign direct investment and GDP Growth. His study documents no relationship between current account and the exchange rate.

The empirical results of Proti (2013) study report a negative relationship between exchange rate and total national debt, real interest rate and GDP growth, whereas no significant relation is found between exchange rate movement and inflation and value of imports and exports. Khattak et al (2012), show that both monetary and real factors, namely, money supply, trade balance, foreign exchange reserves, inflation and interest rate have long run relationship with the exchange rate of Pak-rupee. However, the granger causality test results show that the relationship between most of the macroeconomic variables and nominal exchange rate is bi-directional. Abbas, Khan and Rizvi (2011), document that a set of common macroeconomic factors including interest rate differential, inflation, foreign terms of trade, trade restrictions and net capital inflows causes fluctuations in emerging Asian economies. Though there are some differences in the direction and significance of relationship of exchange rate with the variables, exchange rates of all five sample economies seem to have long run relationship with macroeconomic fundamentals. Morana (2009), proclaims that there is an evidence of significant long-term linkages and trade-offs between macroeconomic and exchange rate volatility in the G-7 countries, involving output and inflation volatility in particular, and money growth volatility to a lesser extent. Moreover, although evidence of bidirectional causality has been found, the linkages are much stronger from macroeconomic volatility to exchange rate volatility than the other way around. Chong and Tan (2007), documents the presence of long-run movement between the exchange rates and terms of interest rates, money supplies, consumer price indices, trade balances and composite indices (RCI) three out of the four selected Asian economies countries.

The study also finds that volatility of output, commodity prices, money supply and foreign reserves significantly influence exchange rate volatility. Drine and Rault (2006), affirm that an improvement in terms of trade, an increase of per capita GDP and an increase of capital flows entail a long-run appreciation of the real exchange rate. On the other hand, an increase in domestic investment and degree of openness of the economy entails a real exchange rate depreciation. However their results show the effect of public spending increase to be ambiguous. Elbadawi and Soto (1997), assert that only long-run capital flows and foreign direct investment are cointegrated with the long-term equilibrium exchange rate, while degree of openness is negatively associated exchange rate and results of impact of terms of trade are somewhat ambiguous. The ADRL Test, J.J. co-integration approach and Gregory and Hansen (1996) structural break co-integration approach used confirm the significant long run relationship among the exchange rate and its determinants. Their results indicate the significant negative association of exchange rates with terms of trade, trade openness and economic growth, whereas money supply and inflation rate have a positive and significant effect on exchange rates.

3. Data and Methodology

The study covers the period 2000-2017 and utilizes quarterly based data published by the central bank of Sudan and Central bureau of statistic. IMF website has also been used to help cross-check of data consistency to facilitate robustness of findings. Data employed include statistics on exchange rate premium and money supply, foreign reserves, balance of trade, and gold purchases which represent the macroeconomic factors selected as determinants of the exchange rate in Sudan. The research data amounts to 384 observations. The paper uses the Autoregressive Distributed Lag (ARDL) of Pesaran and Shin (1999) to examine the relationship between the study variables.
This method has the advantage that variables in co-integrating relationship can be either I(0) or I(1) without the need to pre-specify, which are I(0) or I(1). Further ARDL representation does not require symmetry of lag length, each variable can have different number of lag terms. An ARDL model may be written as:

\[ y_t = \alpha + \sum_{i=1}^{p} Y_i y_{t-i} + \sum_{j=1}^{k} \sum_{i=0}^{q_j} x_{j,t-i} B_{j,i} + \epsilon_t \]  

(1)

Some of explanatory variables, \(x_j\) may have no lagged terms in the model \(q_j=0\). These variables are called static or fixed regressors. Explanatory variables with at least one lagged term are called dynamic regressors. To specify an ARDL model, the research determine how many lags of each variable should be included (specify \(P\) and \(q\), …\(q_k\)). Since ARDL model can be estimated via least square regression, standard Akaike, Schwarz and Hannan–Quin information criteria is used for model selection. The calculation of these estimated long-run coefficients is given by:

\[ \hat{\theta}_j = \frac{\sum_{i=1}^{d} \hat{B}_{j,i}}{1 - \sum_{i=1}^{p} \hat{\gamma}_i} \]  

(2)

The co-integrating regression from an ARDL model is obtained by transforming equation (1) into differences and substituting the long-run coefficient from equation (2).

\[ \Delta y_t = \sum_{i=1}^{p-1} \gamma_i^* \Delta y_{t-1} + \sum_{j=1}^{k} \sum_{i=0}^{q_j-1} \Delta x_{j,t-1} \hat{B}_{j,i}^* - \rho E_{t-1} + \varepsilon_t \]  

(3)

Where:

\[ E_{t} = y_t - \alpha - \sum_{j=1}^{p} x_{j,t} \hat{\gamma}_j \]

\[ \phi = 1 - \sum_{i=1}^{p} \hat{\gamma}_i \]

\[ \gamma_i^* = \sum_{m=i+1}^{q_j} \hat{\gamma}_m \]

\[ B_{j,i}^* = \sum_{m=1}^{q_j} \hat{B}_{j,i,m} \]  

(4)

Using Pesaran Shin and Smith (2001) methodology for testing whether the ARDL model contains a level (or long-run) relationship between the independent variable and regressors, equation (3) is transformed into the following representation:

\[ \Delta y_t = \sum_{i=1}^{p-1} \gamma_i^* \Delta y_{t-1} + \sum_{j=1}^{k} \sum_{i=0}^{q_j-1} \Delta x_{j,t-1} \hat{B}_{j,i}^* - \gamma y_{t-1} - \alpha - \sum_{j=1}^{k} x_{j,t-1} \delta_j^* + \varepsilon_t \]  

(5)

The test for the existence of level relationships is then simply a test of:

\[ \rho = 0 \]

\[ \delta_1 = \delta_2 = \cdots = \delta_k = 0 \]  

(6)

The coefficient estimates used in the test may be obtained from regression, using equation (1), or can be estimated directly from a regression using equation (5)

The specified model of the research is a multiple regression, which estimates the regression of Y on X's in which multiple refers to the independent variables as follows:

\[ \text{Premium} = MS + GP + FRS + BOT + INF \]  

(7)
Where:

Premium which is the dependent variable, is the difference between parallel and official exchange rates, MS refers to money supply and includes M1 and quasi money, GP is the gold purchases by the central bank at free market rate, FRS represents foreign reserves built by the central bank, including reserves from export of gold, BOT is the difference between exports and imports, INF is the rate of inflation. The research model satisfies the use of Autoregressive Distributed Lag model (ARDL) for the estimation of the data, by having logFRS and logINF stationary at level I(0) and logPREM, logMS, logGP, logBOT, stationary at first difference I(1).

The research model is specified in line with the hypothesis that none of the xs’ predict y, which can be expressed as:

$$H_0 : B_1 = 0 \text{ since } B = (B_1, B_2 \ldots B_p)$$

$$H_1 : B_1 \neq 0, \text{ implies that even one } B_j \neq 0 \quad (j = 1, 2, \ldots q)$$

Where B1, B2..Bp represents the coefficients of the independent variables. Thus, rejecting the null means that all non-intercept coefficients are not equal to zero, indicating that X's can predict Y.

The study makes use of EViews software which is an ideal package for time series, cross-section, or longitudinal data. The software helps managing data and performing econometric and statistical analysis. Basic regression techniques are used in E-vios for specifying the estimated regression model. This is done by performing diagnostic analysis, and using the specified results in further analysis. E-vios provide tools for evaluating the quality of specification along a number of dimensions. Each test procedure involves the specification of a null hypothesis, which is the hypothesis under test. Output from a test command consists of the sample values of one or more test statistics and their associated probability numbers (p-values). The latter indicate the probability of obtaining a test statistics whose absolute value is greater than or equal to that of the null hypothesis if the null hypothesis is true. Thus, low p-values lead to the rejection of the null hypothesis.

The specification of the estimated research model is carried out by employing three categories of tests, residual diagnostics, stability diagnostics and coefficient diagnostics. In addition it employs ARMA structure analysis to assess the structure of ARMA portion of the estimated research model. To identify the determinant factors of exchange rate the research tests the hypothesis that none of explanatory variables predicts the dependent variable by using four tests: Wald test, heteroskedasticity consistence covariance (White) test, HAC consistent covariance (Newey-West) test and inferential statistics. To test the impact of explanatory variables' fluctuation on exchange rate premium, the study applies long-run elasticity tests to the bounds of the research model. In determining what variables are responsible for long-run fluctuations, the research applies Vector Error Correction (VEC) mechanism. Wald test is employed to examine the long-term and short-run causal effects and determines the speed of adjustment of endogenous variables.

4. Results and Discussion

Descriptive statistics and correlation matrix are employed by the study to provide insight into characteristics of the data in order to enable the best selection of the model. The descriptive statistics presented in Table (1) below shows skewness in the data, which is the departure from asymmetry, having foreign reserves (FRS) and Balance of Trade (BOT) with negative skewness and other variables with positive skewness. Also, the statistics show kurtosis, which indicates that distributions of variables are characterized by peakness and flattail relative to normal distribution. JarqueBera test provides clear evidence to reject the null hypothesis of the normality for unconditional distribution of the quarterly exchange rate changes.
The correlation matrix in Table (2) shows that there is a correlation among the variables in the data of the research. This necessitates testing for perfect collinearity. The results of ADF shown in Table (3) and PP in Table (4) reveal that test statistics values are greater than critical value for logFRS and logINF at level. Thus, they are described as stationary at level I(0). Other variables (logPREM, logMS, logGP, logBOT) have statistics values less than critical value, which means they are described as stationary at first difference I(1). Thus, both tests reject the null hypothesis of the unit root for logFRS and logINF at level, and do not reject the null at level for the other variables.

### Table (2): Correlation

|        | PREM  | MS    | FRS   | GP    | INF   | BOT   |
|--------|-------|-------|-------|-------|-------|-------|
| PREM   | 1.000000 | 0.941961 | 0.669326 | 0.826738 | -0.056721 | -0.813118 |
| MS     | 0.941961 | 1.000000 | 0.706974 | 0.799793 | -0.098448 | -0.762611 |
| INF    | 0.669326 | 0.706974 | 1.000000 | 0.836947 | -0.100400 | -0.528335 |
| GP     | 0.826738 | 0.799793 | 0.836947 | 1.000000 | -0.099312 | -0.605990 |
| FRS    | 0.056721 | -0.098448 | -0.100400 | -0.099312 | 1.000000 | 0.146301 |
| BOT    | -0.813118 | -0.762611 | -0.528335 | -0.605990 | 0.146301 | 1.000000 |

### Table (3): Unit Root Test (ADF) Augmented Dickey-Fuller

| Variables | ADF test critical value | Prob* | ADF test critical value | Test critical value | Prob* |
|-----------|-------------------------|-------|-------------------------|---------------------|-------|
| LogGP     | -2.417102               | -3.462763 | 0.3675                 | -9.311856            | -3.483970 | 0.0000 |
| LogBOT    | 4.023637                | -3.496960 | 1.0000                 | -0.026871            | -3.492149 | 0.9945 |
| LogFRS    | -6.431192               | -3.482763 | 0.0000                 | -7.411243            | -3.486509 | 0.0000 |
| LogINF    | -6.270246               | -3.482763 | 0.0000                 | -8.669799            | -3.487845 | 0.0000 |
| LogPREM   | -2.879798               | -3.482763 | 0.1759                 | -8.301111            | -3.784970 | 0.0000 |
| LogMS     | -2.200878               | -3.482763 | 0.4808                 | -7.822127            | -3.483970 | 0.0000 |

Prob* Macinnon (1996) one-sided p-values
Source: author's summary of the unit root test

### Table (4): Unit Root Test (Phillips-Perron)

| Variables | Adjusted t-statistics | Test critical value | Prob* | Adjusted t-statistics | Test critical value | Prob* |
|-----------|-----------------------|---------------------|-------|-----------------------|---------------------|-------|
| LogGP     | -2.302938             | -3.482763           | 0.4261| -9.608008             | -3.483970           | 0.0000 |
| LogBOT    | 11.421164             | -3.482763           | 1.0000| -5.624072             | -3.483970           | 0.0000 |
| logFRS    | -6.289436             | -3.482763           | 0.0000| -34.236848            | -3.483970           | 0.0000 |
| LogINF    | -6.390005             | -3.482763           | 0.0000| -18.43704             | -3.483970           | 0.0000 |
| LogPREM   | -2.894611             | -3.482763           | 0.1722| -10.97639             | -3.483970           | 0.0000 |
| LogMS     | -2.233128             | -3.482763           | 0.4633| -7.911026             | -3.483970           | 0.0000 |
To check specification of the estimated equation for the research data, residual diagnostics displayed in the Appendix (Specification and diagnostic Tests) reveals that correlograms and Q-statistic show spikes at lags that are insignificant, which indicates insignificant serial correlation. The Histogram and normality test demonstrates that the probability for Jarque-Bera in Figure (1), is (0.10488), which is higher than the level of significance (0.05); indicating that null of normality is not rejected. This suggests that residuals are normally distributed. The stability of the parameters of the model across various sub-samples of the data is tested by estimating Recursive residuals, which are shown in Figure (2). The test advocates instability in the parameters of the estimated equation. However this suggestion is rejected by Cusum test in Figure (3), which shows that cumulative sum of recursive residuals lies inside the area between two critical lines, which is suggestive of coefficient stability.
4.1 Test of hypotheses

The research uses the data collected to reject or "not reject" the hypothesis. Rejecting $H_0 = B_1 = 0$ means that the research rejects the null hypothesis of coefficients excluding intercepts are equal to zero, which means explanatory variables are the exact determinants of the dependent variable.

The estimated model of the research data shown in Table (5) below, which is estimated by Autoregressive Distributed Lag (ARDL) model displayed in Table(6). The F-statistic probability shown in Table (5) rejects both the null hypothesis of the non-intercept coefficient are zero and the null hypotheses that the slope of non-intercept coefficients are zero, indicating that that the determinant factors of exchange rate in Sudan are logMS, logGP, logFRS, logBOT, and logINF.

### Table (5): Estimated Model of the Research Data

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|----------|-------------|------------|-------------|-------|
| C        | 0.258684    | 10.66248   | 0.024261    | 0.9808|
| DLOGMS   | 1.428832    | 2.940055   | 0.485988    | 0.6305|
| DLOGBOT  | 0.099375    | 0.185874   | 0.334636    | 0.5968|
| DLOGGP   | 0.390363    | 0.224061   | 1.742214    | 0.0917|
| LOGFRS   | -0.008627   | 0.129220   | -0.066761   | 0.9472|
| LOGINF   | -0.169477   | 0.245103   | -0.691449   | 0.4946|
| DLOGPREM(-1) | 0.317344 | 0.289159   | 1.097471    | 0.2812|
| DLOGPREM(-2) | 0.248105 | 0.237616   | 1.044143    | 0.3048|
| DLOGPREM(-3) | -0.185241 | 0.237616   | -0.691449   | 0.4946|
| DLOGMS(-1) | -4.280344 | 3.308877   | -1.293594   | 0.2057|
| DLOGMS(-2) | 0.105209 | 2.782565   | 0.037810    | 0.8339|
| DLOGMS(-3) | 1.761023 | 2.643178   | 0.666252    | 0.5103|
| DLOGBOT(-1) | 1.001707 | 0.774856   | 1.292765    | 0.2060|
| DLOGBOT(-2) | 1.070758 | 0.737106   | 1.452653    | 0.1567|
| DLOGBOT(-3) | 0.855806 | 0.751780   | 1.138373    | 0.2640|
| DLOGGP(-1) | 0.070848 | 0.334834   | 0.211590    | 0.8339|
| DLOGGP(-2) | -0.251541 | 0.247034   | -1.018244   | 0.3167|
| DLOGGP(-3) | -0.023918 | 0.213664   | -0.111942   | 0.9116|
| LOGFRS(-1) | 0.611586 | 0.166194   | 3.679945    | 0.0009|
| LOGFRS(-2) | -0.099253 | 0.126346   | -0.785561   | 0.4383|
| LOGFRS(-3) | -0.229998 | 0.105061   | -2.189179   | 0.0365|
| LOGINF(-1) | -0.580448 | 0.383923   | -1.511886   | 0.1410|
| LOGINF(-2) | -0.322356 | 0.252897   | -1.274652   | 0.2122|

Figure (3): Cusum test
Table (6): ARDL estimation x

| Variable         | Coefficient | Std. Error | t-Statistic | Prob.* |
|------------------|-------------|------------|-------------|--------|
| DLOGPREM(-1)     | -0.134419   | 0.166347   | -0.808064   | 0.4244 |
| DLOGPREM(-2)     | -0.093487   | 0.180260   | -0.518624   | 0.6072 |
| DLOGPREM(-3)     | -0.363708   | 0.185199   | -1.963876   | 0.0573 |
| DLOGMS           | 4.611916    | 2.585729   | 1.783604    | 0.0829 |
| DLOGMS(-1)       | -0.603097   | 2.758443   | -0.218637   | 0.8282 |
| DLOGMS(-2)       | 4.197498    | 2.480465   | 1.692222    | 0.0992 |
| DLOGMS(-3)       | 1.649124    | 2.547833   | 0.647266    | 0.5216 |
| DLOGBOT          | -0.029609   | 0.134378   | -0.220339   | 0.8269 |
| DLOGBOT(-1)      | -0.007071   | 0.411193   | -0.017195   | 0.9864 |
| DLOGBOT(-2)      | 0.311034    | 0.505520   | 0.615275    | 0.5422 |
| DLOGBOT(-3)      | 0.360931    | 0.520969   | 0.692807    | 0.4929 |
| DLOGGP           | 0.126000    | 0.243599   | 0.517243    | 0.6082 |
| DLOGGP(-1)       | 0.255990    | 0.239444   | 1.073277    | 0.2903 |
| DLOGGP(-2)       | 0.066441    | 0.233146   | 0.284974    | 0.7773 |
| DLOGGP(-3)       | 0.006645    | 0.227595   | 0.029197    | 0.9769 |
| LOGFRS           | -0.168466   | 0.116509   | -1.445944   | 0.1568 |
| LOGFRS(-1)       | 0.158820    | 0.126810   | 1.252425    | 0.2185 |
| LOGFRS(-2)       | -0.174203   | 0.124664   | -1.397380   | 0.1709 |
| LOGFRS(-3)       | -0.196533   | 0.108591   | -1.809851   | 0.0787 |
| LOGINF           | -0.034762   | 0.251818   | -0.138043   | 0.8910 |
| LOGINF(-1)       | -0.192190   | 0.268283   | -0.716369   | 0.4784 |
| LOGINF(-2)       | 0.184991    | 0.262117   | 0.705758    | 0.4849 |
| LOGINF(-3)       | 0.095794    | 0.240478   | 0.398348    | 0.6927 |
| C                | 2.237085    | 1.455286   | 1.537214    | 0.1330 |

R-squared: 0.366455
Adjusted R-squared: 0.302030
S.E. of regression: 0.642268
Sum squared resid: 12.37524
Log likelihood: -37.77691

*Note: p-values and any subsequent tests do not account for model
The ARDL model demonstrates the presence of co-integration as proved by Wald test, the results of which are shown in Table (7). The calculated value of F-statistic, 3.9, is higher than the upper value of F-statistic in Table (8), which ranges between 2.62 and 3.79 for the five explanatory variables at 0.05 level of significance.

Table (7): Wald Test coefficient restriction

| Test Statistic | Value  | df    | Probability |
|----------------|--------|-------|-------------|
| F-statistic    | 3.925539 | (6, 30) | 0.0052     |
| Chi-square     | 23.55324 | 6     | 0.0006      |

Null Hypothesis: C(25)=C(26)=C(27)=C(28)=C(29)=C(30)=0
Null Hypothesis Summary:

| Normalized Restriction (= 0) | Value   | Std. Err. |
|------------------------------|---------|-----------|
| C(25)                        | -0.977510 | 0.318507  |
| C(26)                        | 0.521971  | 0.346086  |
| C(27)                        | -1.024946 | 0.752530  |
| C(28)                        | 0.881736  | 0.303997  |
| C(29)                        | -0.001084 | 0.000322  |
| C(30)                        | 0.021245  | 0.029159  |

Restrictions are linear in coefficients.

Table (8): Unrestricted intercept and no trend

| k   | 90%   | 95%   | 97.5%  | 99%   | mean  | variance |
|-----|-------|-------|--------|-------|-------|----------|
|     | I(0)  | I(1)  | I(0)   | I(1)  | I(0)  | I(1)     |
| 0   | 6.58  | 6.58  | 8.21   | 8.21  | 9.80  | 9.80     |
| 1   | 4.04  | 4.78  | 4.94   | 5.73  | 5.77  | 6.68     |
| 2   | 3.17  | 4.14  | 3.79   | 4.85  | 4.41  | 5.52     |
| 3   | 2.72  | 3.77  | 3.23   | 4.35  | 3.69  | 4.89     |
| 4   | 2.45  | 3.52  | 2.86   | 4.01  | 3.25  | 4.49     |
| 5   | 2.26  | 3.35  | 2.62   | 3.79  | 2.96  | 4.18     |
| 6   | 2.12  | 3.23  | 2.45   | 3.61  | 2.75  | 3.99     |
| 7   | 2.03  | 3.13  | 2.32   | 3.50  | 2.60  | 3.84     |
| 8   | 1.95  | 3.06  | 2.22   | 3.39  | 2.48  | 3.70     |
| 9   | 1.88  | 2.99  | 2.14   | 3.30  | 2.37  | 3.60     |
| 10  | 1.83  | 2.94  | 2.06   | 3.24  | 2.28  | 3.50     |

To carry out co-integration analysis using Johansen model, the study estimates unrestricted VAR for the log of the dependent and explanatory variables, determines the lag length as selected by AIC and specifies the cointegrating equations using Johansen co-integration model. Johansen co-integration test in Table (9) with one lag, under the assumption of intercept (no trend) in CE and VAR, shows co-integration as revealed by Trace statistics and Max-Eigen values, which are greater than the critical values at 5% level of significance. This shows that there is unique long-run relationship between the dependent and independent variables.
Table (9): Johansen co-integration test

| Hypothesized | Trace Statistic | 0.05 Critical Value | Prob.** |
|---------------|----------------|---------------------|---------|
| No. of CE(s)  | Eigenvalue      |                     |         |
| None *        | 0.592600        | 124.5553            | 95.75366| 0.0001  |
| At most 1     | 0.416917        | 68.88176            | 69.81889| 0.0592  |
| At most 2     | 0.244269        | 35.43738            | 47.85613| 0.4251  |
| At most 3     | 0.193754        | 18.07303            | 29.79707| 0.5607  |
| At most 4     | 0.069938        | 4.72097             | 15.49471| 0.8378  |
| At most 5     | 0.003623        | 0.225064            | 3.841466| 0.6352  |

Trace test indicates 1 co-integrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Co-integration Rank Test (Maximum Eigen value)

| Hypothesized | Max-Eigen Statistic | 0.05 Critical Value | Prob.** |
|---------------|---------------------|---------------------|---------|
| No. of CE(s)  | Eigenvalue          |                     |         |
| None *        | 0.592600            | 55.67351            | 40.07757| 0.0004  |
| At most 1     | 0.416917            | 33.44438            | 33.87687| 0.0562  |
| At most 2     | 0.244269            | 17.36435            | 27.58434| 0.5488  |
| At most 3     | 0.193754            | 13.35273            | 21.13162| 0.4203  |
| At most 4     | 0.069938            | 4.495233            | 14.26460| 0.8037  |
| At most 5     | 0.003623            | 0.225064            | 3.841466| 0.6352  |

Max-Eigen value test indicates 1 co-integrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

4.2 Testing the Impact of Explanatory Variables on Exchange Rate Premium

Both ARDL and Johansen co-integration model agree to the presence of co-integration between the variables in the model. Thus, the study moves further to test the response of the dependent variable to change in either of the independent variables. This is measured by the elasticity of each of the explanatory variable with the dependent variable, as depicted in Table (10). Using the model data and results of elasticity and applying the following formula:

\[ E = -\left(\frac{\theta_1}{\theta_0}\right) \]  

(10)

Where: E is the elasticity or multiplier, \( \theta_1 \) is the coefficient of explanatory variable, \( \theta_0 \) is the coefficient of the dependent variable, the long-run elasticity analysis shows that balance of trade is a major influencing factor in premium. The decline in the balance of payment by one unit leads to decline in the premium by 1.04 units. The second influencing factor is gold purchases; an increase in gold purchases by one unit results in 0.90 unit increase in premium. The factor which ranks third is money supply. The long-run elasticity test shows that one unit increase in money supply results in 0.53 units increase in premium. The forth factor that influences the exchange premium is inflation; as revealed by elasticity test an increase of one unit in inflation leads to increase in premium by 0.02 units. The impact of foreign reserves on exchange premium is negligible; a decline by one unit in foreign reserves leads to decline in premium by 0.001 unit.
Table (10): Elasticity test

|       | $\theta_0$    | $\theta_1$ | Change in $\theta_0$ due to one unit change in $\theta_1$ |
|-------|---------------|------------|-----------------------------------------------------|
| PREM  | -0.977510     | -          | -                                                   |
| MS    | -             | 0.521971   | 0.53                                                |
| BOT   | -             | -1.024946  | -1.04                                               |
| GP    | -             | 0.881736   | 0.90                                                |
| FRS   | -             | -0.001084  | -0.001                                              |
| INF   | -             | 0.021245   | 0.02                                                |

4.3 Testing the speed of adjustment of endogenous variable and significance of long-term causal effect of variables

Vector Error Correction estimates, which are displayed in Table (11) are estimated by one lag and one co-integrating equation. The system of the VEC estimates by variable, provides a short-run model in Table (12). Short-run dynamics of the model shows the speed of adjustment; VECM of 26% to restore equilibrium, which have negative sign and statistically significant at 26%, ensuring that long-run equilibrium can be attained. The size of Error Correction Term (ECT) is small, indicating that the speed of adjustments towards long-run equilibrium is rather slow. Testing the significance of long-term causal effect, the paper uses the probability of t-statistic in the VEC system reported in Table (13).

Table (11): Vector Error Correction Estimates

| Co-integrating Eq. | CointEq1       |
|--------------------|----------------|
| LOGPREM(-1)        | 1.000000       |
| LOGMS(-1)          | -0.881314      |
|                    | (0.28278)      |
|                    | [-3.11665]     |
| LOGBOT(-1)         | -0.796710      |
|                    | (0.43527)      |
|                    | [-1.83039]     |
| LOGGP(-1)          | -0.925223      |
|                    | (0.15194)      |
|                    | [-6.08927]     |
| LOGFRS(-1)         | -1.061901      |
|                    | (0.15336)      |
|                    | [-6.92411]     |
| LOGINF(-1)         | 0.571071       |
|                    | (0.37658)      |
|                    | [1.51648]      |
| C                  | 28.96250       |

Error Correction: | D(LOGPREM) | D(LOGMS) | D(LOGBOT) | D(LOGGP) |
|------------------|------------|----------|-----------|----------|
| CointEq1         | -0.255012  | -0.008237| -0.062888 | -0.006612|
|                  | (0.08252)  | (0.00584)| (0.11975)| (0.06387)|
|                  | [-3.09038] | [-1.41063]| [-0.52514]| [-0.10352]| |
| D(LOGPREM(-1))   | 0.145668   | -0.004537| -0.026745 | 0.133127 |
|                  | (0.14189)  | (0.01004)| (0.20592)| (0.10983)|
Table (12): Vector Error Correction System

| Coefficient | Std. Error | t-Statistic | Prob. |
|-------------|------------|-------------|-------|
| C(1)        | -0.255012  | 0.082518    | -3.090378 | 0.0032 |
| C(2)        | 0.145668   | 0.141891    | 1.026618  | 0.3092 |
| C(3)        | -2.656803  | 2.055515    | -1.292524 | 0.2017 |
| C(4)        | -0.175365  | 0.272795    | -0.642844 | 0.5230 |
| C(5)        | -0.212359  | 0.182281    | -1.165008 | 0.2491 |
| C(6)        | -0.029782  | 0.081856    | -0.363830 | 0.7174 |
| C(7)        | -0.030179  | 0.053166    | -0.151947 | 0.8403 |
| C(8)        | 0.235275   | 0.139381    | 1.688007  | 0.0972 |
R-squared 0.190832  Mean dependent var 0.10086
Adjusted R-squared 0.085940  S.D. dependent var 0.756292
S.E. of regression 0.723064  Akaike info criterion 2.309277
Sum squared resid 28.23239  Schwarz criterion 2.583746
Log likelihood -63.58760  Hannan-Quinn criter. 2.417041
F-statistic 1.819319  Durbin-Watson stat 67
Prob(F-statistic) 0.102300

Table (13): Wald Test (MS variable)

| Test Statistic | Value     | df   | Probability |
|----------------|-----------|------|-------------|
| t-statistic    | -1.292524 | 54   | 0.2017      |
| F-statistic    | 1.670619  | (1, 54) | 0.2017     |
| Chi-square     | 1.670619  | 1    | 0.1962      |

Null Hypothesis: C(3)=0
Null Hypothesis Summary:

Normalized Restriction (= 0)  Value         Std. Err.
C(3)                        -2.656803    2.055515

Restrictions are linear in coefficients.
Wald Test:
Equation: Untitled

| Test Statistic | Value     | df   | Probability |
|----------------|-----------|------|-------------|
| t-statistic    | -1.292524 | 54   | 0.2017      |
| F-statistic    | 1.670619  | (1, 54) | 0.2017     |
| Chi-square     | 1.670619  | 1    | 0.1962      |

Null Hypothesis: C(3)=0
Null Hypothesis Summary:

Normalized Restriction (= 0)  Value         Std. Err.
C(3)                        -2.656803    2.055515

Restrictions are linear in coefficients.

If the probability is less than significance level (0.05), the short-run effect is said to be significant and vice versa. The analysis in the VEC system shows that the short-run effect of all variables is insignificant. Further the short-run causality, which is measured using Wald test shows that all variables; MS, BOT, GP, FRS and INF have no short-run effect. Results are shown in tables 14, 15, 16, 17 and 18 respectively. Thus both VEC system analysis and Wald test agree that all determinant factors of exchange rate are responsible for long-run fluctuations.
Table (14): Wald Test (BOT variable)

| Test Statistic | Value    | df | Probability |
|----------------|----------|----|-------------|
| t-statistic    | -0.642844| 54 | 0.5230      |
| F-statistic    | 0.413248 | (1, 54) | 0.5230 |
| Chi-square     | 0.413248 | 1  | 0.5203      |

Null Hypothesis: $C(4)=0$
Null Hypothesis Summary:

| Normalized Restriction (= 0) | Value  | Std. Err. |
|-----------------------------|--------|-----------|
| $C(4)$                      | -0.175365 | 0.272795 |

Restrictions are linear in coefficients.

Table (15): Wald Test (GP variable)

| Test Statistic | Value    | df | Probability |
|----------------|----------|----|-------------|
| t-statistic    | -1.165008| 54 | 0.2491      |
| F-statistic    | 1.357244 | (1, 54) | 0.2491 |
| Chi-square     | 1.357244 | 1  | 0.2440      |

Null Hypothesis: $C(5)=0$
Null Hypothesis Summary:

| Normalized Restriction (= 0) | Value  | Std. Err. |
|-----------------------------|--------|-----------|
| $C(5)$                      | -0.212359 | 0.182281 |

Restrictions are linear in coefficients.

Table (16): Wald Test (FRS variable)

| Test Statistic | Value    | df | Probability |
|----------------|----------|----|-------------|
| t-statistic    | -0.363830| 54 | 0.7174      |
| F-statistic    | 0.132372 | (1, 54) | 0.7174 |
| Chi-square     | 0.132372 | 1  | 0.7160      |

Null Hypothesis: $C(6)=0$
Null Hypothesis Summary:

| Normalized Restriction (= 0) | Value  | Std. Err. |
|-----------------------------|--------|-----------|
| $C(6)$                      | -0.029782 | 0.081857 |

Restrictions are linear in coefficients.
Table (17): Wald Test (INF variable)

| Test Statistic | Value   | df     | Probability |
|----------------|---------|--------|-------------|
| t-statistic    | -0.202501 | 54    | 0.8403      |
| F-statistic    | 0.041007  | (1, 54)| 0.8403      |
| Chi-square     | 0.041007  | 1     | 0.8395      |

Null Hypothesis: C(7)=0
Null Hypothesis Summary:

Normalised Restriction (= 0) Value Std. Err.
C(7) -0.030179 0.149031

Restrictions are linear in coefficients.

Table (18): Premium as a Dependent Variable

| Variable          | Coefficient | Std. Error | t-Statistic | Prob.  |
|-------------------|-------------|------------|-------------|--------|
| LOGGP             | 0.238639    | 0.134544   | 1.773692    | 0.0815 |
| LOGMS             | -0.282195   | 0.087229   | -3.235097   | 0.0020 |
| LOGPREM(-1)       | 0.608593    | 0.107731   | 5.649214    | 0.0000 |
| PREM(-1)          | -0.441969   | 0.267009   | -1.655258   | 0.1034 |
| GP(-1)            | 0.000145    | 0.000202   | 0.717851    | 0.4758 |
| MS(-1)            | 3.94E-05    | 1.36E-05   | 2.895767    | 0.0054 |

R-squared          | 0.905979    | Mean dependent var | 1.949565 |
Adjusted R-squared | 0.897732    | S.D. dependent var  | 2.163677 |
S.E. of regression | 0.691931    | Akaike info criterion | 2.191731 |
Sum squared resid  | 27.28979    | Schwarz criterion   | 2.395839 |
Log likelihood     | -63.3953    | Hannan-Quinn criter. | 2.272008 |
Durbin-Watson stat | 1.834554    |                     |          |

Based on causality relationships estimated, the research specify Granger causality test in the form of Vector Error Correction (VEC) framework for the following equations:

LogINF c logPREM logGP logMS (12)

LogPREM c logGP logMS (13)

The above two equations are estimated by ARDL model and subjected to specification tests as applied to the research model. The analysis revealed that LogPREM in equation (13) is caused by logGP and logMS, with a predicting power of 90% as shown in Table (18). The short-run model derived by VEC system, which is depicted in Table (19), reveals that logGP has significant effect on logPREM. Employing Wald test, with Chi-square (0.05) lower than the significance level at 5%, explains that logGP has significant short-run effect on logPREM. Using short-run elasticity test, one unit change in logGP leads to a positive change in premium by 1.75. Other explanatory variables, logMS and LogINF have insignificant impact.
The research findings coincide with the theoretical and empirical literature. However what is unique with this study is the considerable impact of gold purchases on premium fluctuations which exceeds that of money supply. This can be justified on the basis that the exchange rate used by the Sudanese central bank for gold purchases is higher than the rate prevailing in the market. This in turn pushes up the exchange rate. The negligible impact of reserves on premium is another point to note. This is attributed to the country’s low reserves position.

5. Conclusions

VEC and Wald tests show that all explanatory variables possess long-term causal effect on premium. This finding agrees with the existence of long-run relationship between variables confirmed by ARDL and agreed upon Johansen Joselius models. The statistical analysis demonstrates that the determinant factors of exchange rate in Sudan are balance of trade, gold purchases, money supply, inflation and foreign reserves. Further, the results reveal that explanatory variables explain and account for about 80% of variation in premium. Testing the impact of fluctuations of explanatory variables on exchange rate, the paper applies long-run elasticity tests, which shows that fluctuations in determinant factors influence exchange rate stability in varying degrees. Short-run dynamics of the model shows that the speed of adjustment to restore equilibrium in the long run is slow. The determinant variables that cause short-run volatility are gold purchases and money supply. However the impact of money supply on short volatility in premium is through its impact on inflation volatility, which in turn leads to fluctuation in exchange rate premium.

The continuous deterioration and fluctuation in exchange rate throughout the period under study suggest that the exchange rate system followed has no impact on the stability of the exchange rate. The numerous interventions by the central bank and the swings between different monetary and fiscal policies, which aims among other objectives to stabilize the exchange rate, failed completely. Alleviating exchange rate variability requires managing exchange rate determinant factors through the central bank interference. For instance, improving the balance of trade through implementing policies that enhance productivity, controlling government expenditure, encourage savings and minimize trade barriers could have a favorable impact on the exchange rate. Likewise, gold purchases done by the central bank of Sudan should be made at the prevailing market exchange rate and not a higher one. The expansionary monetary policy followed by the central bank since 2014, which targeted money supply growth by more than 16%, heightened inflation and led to a high and fluctuating exchange rate for the Sudanese pound. Thus coordination of fiscal and monetary policies could pave the way to mitigating the exchange rate instability in Sudan. In addition exchange rate stability can be maintained through effective application of inflation targeted policy rather, as it evident from the study that inflation management is crucial for exchange rate stability in Sudan.

### Table (19): VEC system (short-term model)

|          | Coefficient | Std. Error | t-Statistic | Prob. |
|----------|-------------|------------|-------------|-------|
| C(1)     | -0.407859   | 0.127696   | -3.193983   | 0.0023|
| C(2)     | 0.190896    | 0.147381   | 1.295250    | 0.2005|
| C(3)     | -0.335719   | 0.177245   | -1.894092   | 0.0633|
| C(4)     | -1.248059   | 1.889235   | -0.660616   | 0.5115|
| C(5)     | 0.168305    | 0.133051   | 1.264962    | 0.2110|

R-squared 0.170465  Mean dependent var 0.100806
Adjusted R-squared 0.112252  S.D. dependent var 0.756292
S.E. of regression 0.712581  Akaike info criterion 2.237362
Sum squared resid 28.94301  Schwarz criterion 2.408905
Log likelihood -64.35821  Hannan-Quinn criter. 2.304714
F-statistic 2.928307  Durbin-Watson stat 2.024749
Prob(F-statistic) 0.028481

The research findings coincide with the theoretical and empirical literature. However what is unique with this study is the considerable impact of gold purchases on premium fluctuations which exceeds that of money supply. This can be justified on the basis that the exchange rate used by the Sudanese central bank for gold purchases is higher than the rate prevailing in the market. This in turn pushes up the exchange rate. The negligible impact of reserves on premium is another point to note. This is attributed to the country’s low reserves position.
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Appendix

Specification and diagnostic Tests

Correlograms and Q-statistic

| Autocorrelation | Partial Correlation | AC     | PAC     | Q-Stat  | Prob* |
|-----------------|---------------------|--------|---------|---------|-------|
| *.              | *.                  | 1      | 0.083   | 0.083   | 0.438 | 0.508 |
| *.              | *.                  | 2      | -0.085  | -0.093  | 0.9045 | 0.636 |
| *.              | *.                  | 3      | -0.110  | -0.096  | 1.6907 | 0.639 |
| *.              | *.                  | 4      | -0.080  | -0.072  | 2.1118 | 0.715 |
| *.              | *.                  | 5      | -0.134  | -0.144  | 3.3285 | 0.649 |
| *.              | *.                  | 6      | -0.175  | -0.188  | 5.4417 | 0.489 |
| *.              | *.                  | 7      | -0.069  | -0.100  | 5.7787 | 0.566 |
| *.              | *.                  | 8      | 0.029   | -0.044  | 5.8402 | 0.665 |
| *.              | *.                  | 9      | 0.040   | -0.049  | 5.9568 | 0.744 |
| *.              | *.                  | 10     | 0.190   | 0.130   | 8.6286 | 0.568 |
| *.              | *.                  | 11     | -0.062  | -0.151  | 8.9187 | 0.629 |
| **             | **                  | 12     | -0.243  | -0.292  | 13.511 | 0.333 |
| *.              | *.                  | 13     | 0.077   | 0.087   | 13.985 | 0.375 |
| *.              | *.                  | 14     | -0.068  | -0.176  | 14.354 | 0.424 |
| **             | **                  | 15     | -0.167  | -0.254  | 16.673 | 0.339 |
| *.              | *.                  | 16     | -0.013  | -0.031  | 16.687 | 0.406 |
| *.              | *.                  | 17     | 0.123   | -0.053  | 17.986 | 0.390 |
| *.              | *.                  | 18     | 0.124   | -0.108  | 19.351 | 0.371 |
| *.              | *.                  | 19     | -0.062  | -0.197  | 19.704 | 0.413 |
| *.              | *.                  | 20     | 0.115   | -0.005  | 20.943 | 0.401 |
| *.              | *.                  | 21     | -0.007  | -0.189  | 20.947 | 0.462 |
### Correlograms of Squared Residuals

| Autocorrelation | Partial Correlation | AC  | PAC  | Q-Stat | Prob  |
|-----------------|---------------------|-----|------|--------|-------|
| .               | .                   | 22  | -0.047 | -0.097 | 21.166 | 0.510 |
| *.              | .                   | 23  | 0.121  | 0.036  | 22.643 | 0.482 |
| .               | *                   | 24  | 0.002  | -0.151 | 22.644 | 0.541 |
| .               | *                   | 25  | 0.050  | 0.123  | 22.906 | 0.583 |
| .               | .                   | 26  | 0.054  | -0.017 | 23.223 | 0.620 |
| .               | .                   | 27  | 0.059  | -0.055 | 23.622 | 0.651 |
| *.              | .                   | 28  | -0.100 | -0.058 | 24.773 | 0.640 |

### Heteroskedasticity-Consistent Covariance (White) x

| Variable        | Coefficient | Std. Error | t-Statistic | Prob.   |
|-----------------|-------------|------------|-------------|---------|
| C               | 0.258684    | 8.593480   | 0.030102    | 0.9762  |
| DLOGMS          | 1.428832    | 3.263159   | 0.437868    | 0.6646  |
| DLOGBOT         | 0.099375    | 0.116926   | 0.849891    | 0.4021  |
| DLOGGP          | 0.390363    | 0.223490   | 1.746667    | 0.0909  |
| LOGFRS          | -0.008627   | 0.102148   | -0.084455   | 0.9333  |
| LOGINF          | -0.169477   | 0.251141   | -0.674827   | 0.5050  |
| DLOGPREM(-1)    | 0.317344    | 0.282111   | 1.124892    | 0.2696  |
| DLOGPREM(-2)    | 0.248105    | 0.282173   | 0.879267    | 0.3862  |
| DLOGPREM(-3)    | -0.185241   | 0.211964   | -0.873926   | 0.3891  |
## HAC Consistent Covariance (Newey-West) x

| Variable       | Coefficient | Std. Error | t-Statistic | Prob.  |
|----------------|-------------|------------|-------------|--------|
| C              | 0.258684    | 9.063887   | 0.028540    | 0.9774 |
| DLOGMS         | 1.428832    | 3.454854   | 0.413572    | 0.6821 |
| DLOGBOT        | 0.099375    | 0.124972   | 0.795177    | 0.4328 |
| DLOGGP         | 0.390363    | 0.210714   | 1.852569    | 0.0738 |
| LOGFRS         | -0.008627   | 0.099973   | -0.086292   | 0.9318 |
| LOGINF         | -0.169477   | 0.264165   | -0.641556   | 0.5260 |
| DLOGPREM(-1)   | 0.317344    | 0.323472   | 0.981055    | 0.3344 |
| DLOGPREM(-2)   | 0.248105    | 0.316657   | 0.783513    | 0.4395 |
| DLOGPREM(-3)   | -0.185241   | 0.178973   | -1.035023   | 0.3089 |
| DLOGMS(-1)     | -4.280344   | 4.445217   | -0.962910   | 0.3433 |
| DLOGMS(-2)     | 0.105209    | 2.910622   | 0.036147    | 0.9714 |
| DLOGMS(-3)     | 1.761023    | 2.068172   | 0.851488    | 0.4012 |
| DLOGBOT(-1)    | 1.001707    | 0.601945   | 1.664116    | 0.1065 |
| DLOGBOT(-2)    | 1.070758    | 0.496494   | 2.156638    | 0.0392 |
| DLOGBOT(-3)    | 0.855806    | 0.537490   | 1.592226    | 0.1218 |
| DLOGGP(-1)     | 0.070848    | 0.287871   | 0.246109    | 0.8073 |
| DLOGGP(-2)     | -0.251541   | 0.214981   | -1.170064   | 0.2512 |
DLOGGP(-3)  -0.023918  0.194238  -0.123138  0.9028
LOGFRS(-1)  0.611586  0.177923  3.437359  0.0017
LOGFRS(-2)  -0.099253  0.111679  0.888730  0.3812
LOGFRS(-3)  -0.229998  0.065215  -3.526763  0.0014
LOGINF(-1)  0.611586  0.177923  3.437359  0.0017
LOGINF(-2)  -0.099253  0.111679  0.888730  0.3812
LOGINF(-3)  -0.229998  0.065215  -3.526763  0.0014
LOGPREM(-1) -0.977510  0.416285  -2.348179  0.0257
LOGMS(-1)   0.521971  0.285824  1.826198  0.0778
LOGBOT(-1)  -1.024946  0.613880  -1.669618  0.1054
FRS(-1)     -0.001084  0.000296  -3.655514  0.0010
INF(-1)     0.021245  0.028159  0.754479  0.4564
LOGGP(-1)   0.881736  0.418722  2.105781  0.0437

R-squared 0.645100  Mean dependent var 0.104166
Adjusted R Squared 0.302030  S.D. dependent var 0.768772
S.E. of regression 0.642268  Akaike info criterion 2.259230
Sum squared resid 12.37524  Schwarz criterion 3.306403
Log likelihood -37.77691  Hannan-Quinn crit. 2.668837
F-statistic 1.880374  Durbin-Watson stat 1.802638
Prob(F-statistic) 0.045371  Wald F-statistic 36.79385
Prob(Wald F-statistic) 0.000000

Wald Test single restriction

| Test         | Statistic | Value | df   | Probability |
|--------------|-----------|-------|------|-------------|
| t-statistic  | -1.751960 | 30    | 0.0900 |
| F-statistic  | 3.069363  | (1, 30) | 0.0900 |
| Chi-square   | 3.069363  | 1     | 0.0798 |

Null Hypothesis: C(25)+C(26)+C(27)+C(28)+C(29)+C(30)=1
Null Hypothesis Summary:

| Normalized Restriction (= 0) | Value | Std. Err. |
|-----------------------------|-------|-----------|
| -1 + C(25) + C(26) + C(27) + C(28) + C(29) + C(30) | -1.578587 | 0.901041 |

Restrictions are linear in coefficients.
| Variable            | Coefficient | Std. Error | t-Statistic | Prob.  |
|---------------------|-------------|------------|-------------|--------|
| C                   | -3.494411   | 13.96439   | -0.250237   | 0.8042 |
| DLOGMS              | 1.517059    | 3.001718   | 0.505397    | 0.6172 |
| DLOGBOT             | 0.074410    | 0.735837   | 0.101123    | 0.9202 |
| DLOGGP              | 0.306628    | 0.227794   | 1.346079    | 0.1891 |
| LOGFRS              | 0.058423    | 0.171327   | 0.341001    | 0.7356 |
| LOGINF              | -0.126894   | 0.267067   | -0.475139   | 0.6384 |
| DLOGPREM(-1)        | 0.397180    | 0.345771   | 1.148679    | 0.2604 |
| DLOGPREM(-2)        | 0.297755    | 0.250296   | 0.264611    | 0.7932 |
| DLOGPREM(-3)        | 0.813191    | 3.233980   | 0.251452    | 0.8033 |
| DLOGMS(-1)          | -5.088901   | 4.261502   | -1.194156   | 0.2424 |
| DLOGMS(-2)          | -0.923262   | 3.489125   | -0.264611   | 0.7932 |
| DLOGMS(-3)          | 0.581319    | 3.233980   | 0.251452    | 0.8033 |
| DLOGBOT(-1)         | 0.844793    | 1.255219   | 0.673024    | 0.5064 |
| DLOGBOT(-2)         | 0.837169    | 1.748154   | 0.478887    | 0.6357 |
| DLOGBOT(-3)         | 0.632727    | 1.330980   | 0.475385    | 0.6382 |
| DLOGGP(-1)          | -0.159077   | 0.352933   | -0.450730   | 0.6557 |
| DLOGGP(-2)          | -0.254977   | 0.274644   | -0.928393   | 0.3611 |
| DLOGGP(-3)          | -0.018155   | 0.266624   | -0.068093   | 0.9462 |
| LOGFRS(-1)          | 0.553195    | 0.164766   | 3.357468    | 0.0023 |
| LOGFRS(-2)          | -0.050308   | 0.214770   | -0.234244   | 0.8165 |
| LOGFRS(-3)          | -0.210809   | 0.200416   | -1.051858   | 0.3019 |
| LOGINF(-1)          | -0.668274   | 0.423208   | -1.579067   | 0.1256 |
| LOGINF(-2)          | -0.440533   | 0.339371   | -1.298087   | 0.2048 |
| LOGINF(-3)          | 0.039130    | 0.252134   | 0.155196    | 0.8778 |
| LOGPREM(-1)         | -1.005437   | 0.353831   | -2.841576   | 0.0083 |
| LOGMS(-1)           | 0.657207    | 0.391836   | 1.677249    | 0.1046 |
| LOGBOT(-1)          | -0.822706   | 1.027415   | -0.800753   | 0.4300 |
| LOGGP(-1)           | 0.910345    | 0.267806   | 3.399270    | 0.0020 |
| FRS(-1)             | -0.000936   | 0.000342   | -2.733821   | 0.0107 |
| INF(-1)             | 0.023661    | 0.038936   | 0.607690    | 0.5483 |
| AR(3)               | -0.371152   | 0.265221   | -1.399404   | 0.1727 |
| SIGMASQ             | 0.197197    | 0.057127   | 3.451919    | 0.0018 |

| R-squared          | 0.660684    | Mean dependent var | 0.104166 |
| Adjusted R-squared | 0.285013    | S.D. dependent var | 0.768772 |
| S.E. of regression  | 0.650050    | Akaike info criterion | 2.288402 |
| Sum squared resid   | 11.83182    | Schwarz criterion | 3.405386 |
| Log likelihood      | -36.65207   | Hannan-Quinn criter. | 2.725316 |
| F-statistic         | 1.758678    | Durbin-Watson stat | 1.874547 |
| Prob(F-statistic)   | 0.067436    |                     |          |

Inverted AR Roots .36+.62i  .36-.62i  -.72
### Granger causality

| Null Hypothesis                                      | Obs | F-Statistic | Prob. |
|-------------------------------------------------------|-----|-------------|-------|
| LOGMS does not Granger Cause LOGPREM                  | 63  | 6.35845     | 0.0144|
| LOGPREM does not Granger Cause LOGMS                  |     | 1.31798     | 0.2555|
| LOGINF does not Granger Cause LOGPREM                 | 63  | 1.19319     | 0.2791|
| LOGPREM does not Granger Cause LOGINF                 |     | 14.4115     | 0.0003|
| LOGGP does not Granger Cause LOGPREM                  | 63  | 4.64376     | 0.0352|
| LOGPREM does not Granger Cause LOGGP                  |     | 7.22066     | 0.0093|
| LOGFRS does not Granger Cause LOGPREM                 | 63  | 2.47393     | 0.1210|
| LOGPREM does not Granger Cause LOGFRS                 |     | 6.4E-05     | 0.9936|
| LOGBOT does not Granger Cause LOGPREM                 | 63  | 0.46675     | 0.4971|
| LOGPREM does not Granger Cause LOGBOT                 |     | 0.18659     | 0.6673|
| LOGINF does not Granger Cause LOGMS                   | 63  | 0.44973     | 0.5050|
| LOGMS does not Granger Cause LOGINF                   |     | 23.3864     | 1.E-05|
| LOGGP does not Granger Cause LOGMS                    | 63  | 0.09736     | 0.7561|
| LOGMS does not Granger Cause LOGGP                    |     | 4.01797     | 0.0495|
| LOGFRS does not Granger Cause LOGMS                   | 63  | 0.03422     | 0.8539|
| LOGMS does not Granger Cause LOGFRS                   |     | 0.47148     | 0.4950|
| LOGBOT does not Granger Cause LOGMS                   | 63  | 0.02831     | 0.8669|
| LOGMS does not Granger Cause LOGBOT                   |     | 0.26268     | 0.6102|
| LOGGP does not Granger Cause LOGINF                   | 63  | 20.3895     | 3.E-05|
| LOGINF does not Granger Cause LOGGP                   |     | 0.21196     | 0.6469|
| LOGFRS does not Granger Cause LOGINF                  | 63  | 0.06941     | 0.7931|
| LOGINF does not Granger Cause LOGFRS                  |     | 0.85314     | 0.3594|
| LOGBOT does not Granger Cause LOGINF                  | 63  | 0.83112     | 0.3656|
| LOGINF does not Granger Cause LOGBOT                  |     | 0.53885     | 0.4658|
| LOGFRS does not Granger Cause LOGGP                   | 63  | 1.10922     | 0.2965|
| LOGGP does not Granger Cause LOGFRS                   |     | 0.00535     | 0.9419|
| LOGBOT does not Granger Cause LOGGP                   | 63  | 0.07964     | 0.7788|
| LOGGP does not Granger Cause LOGBOT                   |     | 0.00866     | 0.9261|
| LOGBOT does not Granger Cause LOGFRS                  | 63  | 0.72346     | 0.3984|
| LOGFRS does not Granger Cause LOGBOT                  |     | 0.22757     | 0.6351|