The Monetary Model of Exchange Rate in the Sudan: An ARDL Bounds Testing Approach

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Abstract:

This study aims at examining the bound test of monetary model of exchange rate in the Sudan using an Autoregressive Distributed Lag (ARDL) approach. Quarterly readings of Exchange Rate, income, inflation rate and money demand in the Sudan covered the period from 2003:Q1 – 2016:Q2 has been used in the analysis of this study. The ARDL approach was applied to the data, the empirical results conclude that ARDL(2,0,1,0) model was selected as a an appropriate model to fit the data. Furthermore the cointegration and long run form as well as bounds test conclude that there is long run relationship between the variables, inflation rate shows a significant long run relationship in the monetary exchange rate model however, income as well as money demand are not. Moreover the diagnostic checking revealed that the monetary exchange rate model has no serial correlation, no ARCH effects and stable therefore ARDL approach is highly recommended in examining the long run relationship among exchange rate determinations.

Key Words: Exchange Rate, ADF Test, ARDL Approach, Bound Test

المستخلص:

تهدف هذه الدراسة لإختبار النموذج النقدي لسعر الصرف في السودان ، باستخدام طريقة نماذج فترات الإبطاء الموزعة ، استخدمت في هذه الدراسة بيانات ربع سنوية لاسعار صرف الجنية السوداني مقابل الدولار الامريكي ، الدخل ، معامل التضخم و الطلب على النقود للفترة من 2003:Q1 – 2016:Q2. تم تطبيق طريقة نماذج فترات الابطاء الموزعة على بيانات الدراسة ، أسفرت نتائج التحليل عن اختيار نموذج فترات الابطاء الموزعة ARDL(2,0,1,0) كأفضل نموذج لتمثيل البيانات . اشارت نتائج التكامل المشترك و اختبار الحدود عن وجود علاقة طويلة الاجل بين المتغيرات حيث توجد علاقة طويلة الاجل بين سعر الصرف و معامل التضخم . كما أشارت نتائج الفحص التشخيصي للنموذج الى عدم وجود ترابط ذاتي في حدود خطأ النموذج المقدر ، ثبات تباين حدود الخطأ للنموذج المقدر الى ثبات النموذج المقدر .

Introduction:

In order to determine the short run and long run relationships between variables, Johanson Cointegration and VECM framework have been widely used in the literature. However, Pesaran et al. (2001) point out critical flaws with this approach. Therefore, ARDL model is used to determine the relationship between variables. The ARDL framework has been promoted by Pesaran and Shin (1995, 1999), Pesaran, et al. (1996), and Pesaran (1997). The ARDL framework provides consistent and robust parameter estimates for both the short run and long run. Furthermore, the ARDL method does not require pretesting of the variables. It means, this method can be used irrespective of the order of integration of variables. ARDL approach can use it when all variables are purely I(0), or I(1) or a mixture of both. In order to obtain robust results, the ARDL approach utilized to establish the existence of long-run and short-run relationships. ARDL is extremely useful because it allows us to describe the existence of an equilibrium/relationship in terms of long-run and short-run dynamics without losing long-run information.

Nowadays the exchange rate becomes one of the most heavily and interesting research areas in the discipline. Exchange rate movements are perhaps the most important factors affecting sales and profit forecasts, changes in exchange rates have a significant impact on the world's political and economic stability and the welfare of individual countries. In testing the theory of long-run equilibrium, the concepts and tests of co-integration are suitable. Since the application involves a multivariate relation, it is necessary to employ maximum likelihood-based tests that allow for more than one co-integrating vector. The monetary approach was tested by implementing Johansen's (1988) maximum likelihood procedure. Unlike the co-integration technique of Engle and Granger (1987), this procedure allows for the

existence of more than one co-integrating vector, a possibility that can occur in a multivariate framework. MacDonald and Taylor (1994a), argued that modelling and forecasting the exchange rate is a hazardous occupation.

The Problem:

There have been growing efforts among economists to re-examine exchange rate behavior especially in its long-run stability. Modeling of exchange rate movements is one of the most importance issues of research to be dealt with. Due to an enormous significance of the exchange rate in any economy, there is a need to study exchange rate behavior of foreign exchange markets in detail. Monetary approach developed in 1970's is one of the most important tools to demonstrate the variations in the exchange rate. This study is will look for the answers of the following questions:

How about short and long run stability of exchange rate?

What should be equilibrium exchange rate?

What are the determinants of exchange rate?

The Objective:

The main objectives of this study are:

Estimate the monetary exchange rate mode using the ARDL approach.

Investigate the monetary model of exchange rate long-run relationship.

Carry out the monetary exchange rate model determinations.

Literature review:

The ARDL approach remains one of the most important tools employed to explain the nature in exchange rates. Nowadays, with better-quality statistical tools along with a more exact specification of the model, the long-term

validity of the monetary approach to exchange rate determination has been established.

Dara Long and Sovannroeun Samreth (2008) examine the validity of short-run and long run monetary models of exchange rate for the Philippines, using Autoregressive Distributed Lag (ARDL) approach. They found a short-run and long-run relationship among variables in the monetary exchange rate model, they conclude that the estimation of the monetary model of exchange rate, assumed to be satisfied beforehand, might suffer from a number of deficiency. That is, it is not proper to estimate the exchange rate model before the monetary restrictions are confirmed.

Civcir (2003), examined the validity of the monetary model of exchange rate determination as an explanation of the Turkish Lira-United States dollar relationship. The result suggested is in favor of the monetary model. The equilibrium relationships are used to construct an equilibrium measure of the lira. Results indicate that a sensible estimate about the equilibrium value of the lira/US dollar exchange rate can be obtained.

Morley (2007) examined the relationship between equities and the exchange rate through the frame work of the monetary model of exchange rates; he found that in the short-run, as well as the long run, stock prices have a significant effect on the exchange rate.

Uz and Ketenci (2008) expanded the study of the monetary approach to exchange rates by looking at four monetary variables monetary differential, output differential, interest differential, and price differential. The authors examined these relationships for 10 new EU members (Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, the Slovak Republic, Slovenia, and Turkey). They found that nominal exchange rates are co-integrated with these monetary variables when using panel data.

ARDL approach:

An ARDL is a regression equation containing logs of both dependent and independent variables. It is usually denoted with the notation ARDL($p, q_1, q_2, \dots, q_k$) where p is a number of lags of the dependent variable, q_1 to q_k are the number of lags of the independent variables. The autoregressive distributed lag (ARDL) model is firstly introduced by Pesaran and Shin (1999) and extended by Pesaran et al. (2001). It deals with single cointegration, it does not require all variables to be I(1) as the Johansen framework and it is still applicable if we have I(0) and I(1) variables in the data. An ARDL model may be written as follows:

$$y_t = \alpha + \sum_{i=1}^{p} \gamma_i y_{t-i} + \sum_{j=1}^{k} \sum_{i=0}^{q_j} \beta_{j,i} x_{j,\ t-i} + \varepsilon_t$$

Long run Relationships:

Since An ARDL model estimates the dynamic relationships between the dependent and independent variables, it is possible to transform the model into a long run representation, showing the long run response of the dependent variable to a change in the independent variables. The estimated long run coefficients can be calculates by the following formula:

$$\theta_j = \frac{\sum_{i=1}^{q_j} \hat{\beta}_{j,i}}{1 - \sum_{i=1}^{p} \gamma_i}$$

Bounds Testing Procedure:

It is essential to test the existence of long run relationship before estimating long run coefficients and error correction models. For the purpose, Ordinary Least Squares (OLS) method is employed to locate the value of F or Wald Statistic for the joint significance of the parameters of lagged variables i.e.

$$H_0: \beta_1 = \beta_2 = \cdots = \beta_k = 0$$
$$H_1: \beta_1 \neq \beta_2 \neq \cdots \neq \beta_k \neq 0$$

The null hypothesis shows that the parameters of the lagged variables are simultaneously equal to zero which indicating no long run relationship (No cointegration) whereas the alternative hypothesis explains that at least one of the parameters of the lagged variables is not equal to zero suggesting long run relationship (cointegration). The null hypothesis is tested against the alternative hypothesis using F-statistic. The F statistic has a non-standard distribution which depends upon whether the variables included in the ARDL model are integrated of order I(0) or I(1) or a mixture of I(0) and I(1). The computed F statistic is compared with critical values proposed by Pesaran et al. (1996). If the computed F statistic is greater than the upper bound critical value, the null hypothesis of no long run relationship is rejected. If F-statistic is less than the lower bound critical values, the null hypothesis is accepted implying that there is no a long run relationship or cointegration. If the F-statistic lies between the lower and upper bound critical values, the test is inconclusive for the given level of significance.

Model Specification:

The exchange rate model assumes that the desired level of exchange rate depends on the other macroeconomic variables which can be written as:

$$EXR = f(incm, INF, m_2)$$

The exchange rate function employed in this paper is takes the form:

$$EXR_t = \beta_0 + \beta_1 incm_t + \beta_2 INF_t + \beta_3 m_2 + \varepsilon_t$$

where EXR stands for exchange rate, incm for the income, INF for inflation rate and m_2 for money demand.

The ARDL model specifications of the functional relationship between exchange rate and other macroeconomic variables such as income, inflation rate and money demand can be expressed as follows:

$$\Delta EXR_t = \beta_0 + \sum_{i=1}^{n} \beta_{1i} \Delta EXR_{t-i} + \sum_{i=1}^{n} \beta_{2i} \Delta incm_{t-i} + \sum_{i=1}^{n} \beta_{3i} \Delta INF_{t-i} \sum_{i=1}^{n} \beta_{4i} \Delta m_{2_{t-i}} + \alpha_1 EXR_{t-1} + \alpha_2 incm_{t-1} + \alpha_3 INF_{t-1} + \alpha_4 m_{2_{t-1}} + \varepsilon_t$$

The ARDL approach to co-integration Pesaran et al (2001) involves estimating the conditional error correction version of the ARDL model for the exchange rate and difference between the income and inflation rate and money demand is written as follows:

$$\Delta EXR_t = \beta_0 + \sum_{i=1}^{n} \beta_{1i} \Delta EXR_{t-i} + \sum_{i=1}^{n} \beta_{2i} \Delta incm_{t-i} + \sum_{i=1}^{n} \beta_{3i} \Delta INF_{t-i} \sum_{i=1}^{n} \beta_{4i} \Delta m_{2_{t-i}} + \lambda ECM_{t-1} + \varepsilon_t$$

Empirical Results:

This section provides the empirical analysis results of the application of an ARDL approach to the data under consideration through correlation test, ADF test, ARDL model estimation and diagnostic checking of the monetary model of exchange rate in the Sudan.

The Data:

The data will be used in the analysis of this paper are quarterly readings of Exchange Rate, net income, inflation rate and money demand for the Sudan for the period 2003:Q1 – 2016:Q2 the data are obtained from Central Bureau of Statistics and Bank of Sudan.

Correlation Coefficients:

Table (1) below reports the correlation coefficients between a dependent variable exchange rate and income, inflation rate and money demand as an independent variables:

Table (1) Correlation Coefficients between the model variables:

Exchange Rate	*Income*	*Inflation Rate*	*Money Demand*
Correlation	0.333	0.625*	0.77*
Sig	0.14	0.00	0.00
N	54	54	54

The correlation test results show indicates that the correlation among exchange rate and income is not significant whereas a significant correlation among exchange rate and inflation rate as well as money demand is present.

ADF test results:

This section involves the application of the ADF of unit root test for testing whether exchange rate , income, inflation rate and demand for money series levels and first differences in the Sudan for the period 2003:Q1 – 2016: Q2 are stationary or not. The ADF test results were carried out in the table (1) below:

Table (2) ADF test results of EXR, INCM, INF, and M2 in the Sudan for the period (1970 - 2015):

Variables	*Level*		*First Difference*	
	Intercept	*Trend and Intercept*	*Intercept*	*Trend and Intercept*
EXR	*-0.7583*	*-2.0755*	*-3.2769**	*-3.3293*
INCM	*-1.9880*	*-2.3825*	*-8.0371**	*-7.9783**
INF	*-1.7174*	*-1.7685*	*-6.0727**	*-5.3854**
M2	*-0.1575*	*-5.6043**	*-7.3492**	*-5.103**

** means rejection of the null hypothesis (the series has a unit root) at 5% significance level*

The ADF test with trend and intercept results in table (2) above shown that exchange rate, income, inflation rate and demand for money series levels in the Sudan are nonstationary however, the first difference of these series are stationary i.e. all variables are I(1).

Figure (1) bellow shows the short run parameter estimates of exchange rate as a dependent variable on income, inflation rate and money demand in the Sudan as independent variables.

Dependent Variable: EXR
Method: Least Squares
Sample: 2003Q1 2016Q2
Included observations: 54

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.514343	0.290277	5.216886	0.0000
INCM	-0.001095	0.000498	-2.197061	0.0327
INF	0.047015	0.016936	2.775993	0.0077
M2	4.56E-08	7.17E-09	6.354356	0.0000

R-squared	0.663391	Mean dependent var	3.629750
Adjusted R-squared	0.643195	S.D. dependent var	2.036035
S.E. of regression	1.216188	Akaike info criterion	3.300507
Sum squared resid	73.95566	Schwarz criterion	3.447839
Log likelihood	-85.11369	Hannan-Quinn criter.	3.357327
F-statistic	32.84682	Durbin-Watson stat	0.772498
Prob(F-statistic)	0.000000		

Figure (1) the parameters estimation of linear regression equation.

It can be seen that all parameters in the model are significant. The estimated equation of exchange rate regression model can be written as:

EXR = 1.51 - 0.00109*INCM + 0.0470*INF + 4.55760607091e-08*M2

An ARDL model Estimation:

The applications of the ADF test on exchange rate, income, inflation rate and money demand data for the Sudan revealed that the all variables under consideration are I(0). Hence an ARDL model was applied to the data. Figure (2) bellow shows the ARDL(2, 0, 1, 0) model parameter estimation of exchange rate on income, inflation rate and money demand in the Sudan.

ARDL Models, Dependent Variable: EXR
Dynamic regressors (1 lag, automatic): INCM INF M2
Selected Model: ARDL(2, 0, 1, 0)

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
EXR(-1)	0.622503	0.138705	4.487976	0.0000
EXR(-2)	0.260483	0.131769	1.976812	0.0511
INCM	-3.21E-05	0.000170	-0.188504	0.8513
INF	0.006967	0.009818	0.709664	0.4815
INF(-1)	0.019877	0.011188	1.776596	0.0322
M2	1.37E-09	3.11E-09	0.439036	0.6627
C	-0.039935	0.147446	-0.270847	0.0178
@ TREND	0.002843	0.010807	0.263046	0.7937

R-squared	0.966779	Mean dependent var	3.668867
Adjusted R-squared	0.963168	S.D. dependent var	2.065400
S.E. of	0.396382	Akaike info	1.095300

regression	4	criterion	00
Sum squared resid	7.22753	Schwarz criterion	1.3204 44
Log likelihood	-22.4778	Hannan-Quinn criter.	1.1816 15
Durbin-Watson stat	1.76637 0		

*Note: p-values and any subsequent tests do not account for model selection

Figure (2) An ARDL(2, 0, 1, 0) model the parameters estimation.

Figure (2) illustrate the parameter estimates of an ARDL(2,0,1,0) model as well as other related statistics, model estimation results conclude that, exchange rate lag 1, 2 and inflation rate lag 1 are parameters are statistically significant while income as well as money demand are not significant. The estimated equation of an ARDL(2,0,1,0) model is written as:

$$EXR_t = 0.04 + 0.62\mathrm{EXR}_{t-1} + 0.26\mathrm{EXR}_{t-2} + 0.2INf_{t-1} + \varepsilon_t$$

The result findings also conclude that there is a positive significant relationship among exchange rate and its 1, 2 lags, inflation rate and it lag and also demand for money whereas there is a negative and non significant relationship among exchange rate and income.

The Cointegration equation:

Since the ADF test concluded that all variables in the model are I (1), figure (3) bellows illustrate the cointegrating of exchange rate monetary model:

ARDL Cointegrating And Long Run Form
Dependent Variable: EXR
Selected Model: ARDL(2, 0, 1, 0) Sample: 2003Q1 2016Q2 Included observations: 52

Cointegrating Form

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(EXR(-1))	-0.260483	0.131769	-1.976812	0.0541
D(INCM)	-0.000032	0.000170	-0.188504	0.8513
D(INF)	0.006967	0.009818	0.709664	0.4815
D(M2)	0.000000	0.000000	0.439036	0.6627
CointEq(-1)	-0.117014	0.037120	-3.152337	0.0028

Cointeq = EXR - (-0.0003*INCM + 0.2294*INF + 0.0000*M2)

Figure (3) ARDL Cointegration and Long Run Form:

It can be seen that the cointegration coefficient is negative and statistically significant; this result indicates there is a long run relationships between exchange rate and income, inflation rate and money demand variables, which means 12% percent of the disequilibrium (the speed of adjustment) in the exchange rate is adjusted toward equilibrium quarterly.

Long Run Form:

The long run coefficients of the monetary exchange rate model are shown in figure (4) below, it can be seen that the income and money demand variables has not long run relationships in the monetary exchange rate model whereas inflation rate has a significant long run relationship.

Long Run Coefficients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
INCM	-0.000274	0.001434	-0.191265	0.8492
INF	0.229415	0.061921	3.704973	0.0006
M2	0.000000	0.000000	0.473771	0.6379

Figure (4) ARDL Cointegration and Long Run Form:

The long run equation is written as follows:

Cointeq = EXR - (-0.0003*INCM + 0.2294*INF + 0.0000*M2)

ARDL Bound Test:

Pesaran, shin and smith(2001) described a methodology for testing whether the ARDL model contain long run relationships between the dependent and independent variables, the ARDL bound test result is shown below:

ARDL Bounds Test
Date: 10/13/16 Time: 01:12
Sample: 2003Q3 2016Q2
Included observations: 52
Null Hypothesis: No long-run relationships exist

Test Statistic	Value	K
F-statistic	5.928319	3

Critical Value Bounds

Significance	I0 Bound	I1 Bound
10%	2.01	3.1
5%	2.45	3.63
2.5%	2.87	4.16
1%	3.42	4.84

Figure (5) ARDL Bound Test:

Figure (5) demonstrate the ARDL(2,0,1,0) bound test, it can be seen that F-Statistic = 5.9283 which is more than 5% upper bound value 3.63, this result indicated to reject the null hypothesis that there is no long run relationship exist, which means that there is a long run relationship a among exchange rate as a dependent variable and income, inflation rate and money demand as an independent variables.

To check whether an ARDL (2,0,1,0) model has a serial correlation or not, the LM test has been conducted below:

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	2.573112	Prob. F(2,44)	0.0877
Obs*R-squared	5.439849	Prob. Chi-Square(2)	0.0659

Figure (6) Breusch-Godfrey Serial Correlation LM Test:

A closer look to figure (6) it can be seen that (Obs*R^2) = 5.439849 with probability value 0.0659 which is greater than 5% significance level, this result means accept the null hypothesis that there is no serial correlation. Therefore the estimated ARDL(2,0,1,0) model has no serial correlation.

Heteroskedasticity Test: ARCH

Heteroskedasticity Test: ARCH

F-statistic	0.279092	Prob. F(1,49)	0.5997
Obs*R-squared	0.288838	Prob. Chi-Square(1)	0.5910

Figure (7) Heteroskedasticity Test: ARCH

The ARCH test effect revealed that the ARDL(2,0,1,0) model has no ARCH effect.

Stability Test:

To check whether this ARDL(2,0,1,0) model is stable or not, the statistical Ramsey test was carried out, figure (8) below shows the empirical results:

Ramsey RESET Test
Equation: UNTITLED
Specification: EXR EXR(-1) EXR(-2) INCM INF INF(-1) M2
Omitted Variables: Squares of fitted values

	Value	Df	Probability
t-statistic	0.610328	45	0.5447
F-statistic	0.372500	(1, 45)	0.5447

It can be seen that F-Statistic = 0.3725 with probability value 0.5447 which is greater than 5% significance level, which means the monetary exchange rate model is stable.

Conclusion:

This study has examined the monetary exchange rate model in the Sudan using an Autoregressive Distributed Lag (ARDL) approach. Quarterly readings of Exchange Rate, net income, inflation rate and money demand for the Sudan for the period 2003:Q1 – 2016:Q2. The correlation coefficient test shown that there is a significant correlation between exchange rate and inflation rate as well as money demand, while there is no correlation between exchange rate and income. The augmented dickey fuller of unit root (ADF) test with trend and intercept applied to the data, the empirical results conclude that all variables under consideration series levels are nonstationary however, the first difference of those series are stationary. According to AIC, SBC and HQ of lag order selection statistics criteria the ARDL(2,0,1,0) model was chosen as an appropriate to represents the monetary exchange rate model. The

bound test results concluded that there is a long run relationship, which implies that about 12 percent of the disequilibrium in the exchange rate is adjusted toward equilibrium quarterly. Inflation rate has a significant long run relationship while income and money demand are hasn't. Breusch-Godfrey Serial Correlation LM Test results revealed that there is no serial correlation; the ARCH test effect indicated that there are no ARCH effect, Ramsey statistical test confirmed that the ARDL(2,0,1,0) model is stable. The findings also concluded that there is a negative and significant relationship between exchange rate and income, while there is positive and significant relationship between exchange rate and inflation rate and money demand in short run. In the long run the empirical findings demonstrates that there are a negative not significant relation between exchange rate and income, positive significant relationship among exchange rate and inflation rate and positive not significant relationship among exchange rate and money demand. The findings also revealed that exchange rate lag1,2 and inflation rate lag1 determine the monetary exchange rate mode. Therefore the study recommends that market participants in the foreign exchange market may monitor and forecast future of exchange rate movements using the inflation rate.

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