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Exchange Rate Determination: An Application of a Monetary Model for the Sudan for the Period (1982-2018)

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Abstract

The purpose of this study is to construct and estimate an econometric model for the nominal exchange rate in the Sudan for the short and long run. The study has used the flexible-price monetary model for the years 1982-2018. The results of the co-integration test for the autoregressive-distributed lag approach have confirmed the significant long-run relationship among considered variables. The estimations of the long run have indicated a significant negative association of exchange rates with the real gross domestic product (*GDP)*. However, money supply and consumer prices index have a positive and significant effect on exchange rates. Signs of the estimated coefficients of the error correction model agreed with the theoretical model, which supports the monetary model. The coefficient on error-correction term (ECM_{t-1}), is negatively signed and significant at 1% level of significance confirming the existence of long-run relationship. This has shown that about 46 % of any disequilibrium has been corrected for every year in the economy. Based on the findings, the study recommended that, to stabilize the exchange rate, policy makers should adopt suitable macroeconomic policies that aim at increasing real *GDP*. In addition, the monetary authority should control money supply to reduce inflation and to achieve exchange rate stability.

Keywords: Exchange rate, monetary model, co integration, ARDL, short-run and Long run

تحديد سعر الصرف: تطبيق النموذج النقدي على السودان للفترة (1982–2018)

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المستخلص

الهدف من هذه الدراسة هو بناء وتقدير نموذج اقتصادي قياسي لسعر الصرف الاسمي في السودان للمدى القصير والطويل. تستخدم الدراسة النموذج النقدي في ظل مرونة السعر للفترة 1982-2018. نتائج اختبار التكامل المشترك لنموذج الانحدار الذاتي للإبطاء الموزع تؤكد العلاقة طويلة المدى بين متغيرات النموذج. تشير تقديرات المدى الطويل إلى وجود علاقة سالبة بين سعر الصرف الاسمي والناتج المحلي الإجمالي الحقيقي، ووجود علاقة موجبة بين سعر الصرف الاسمي وكل من عرض النقود والرقم القياسي لاسعار المستهلك. تتفق دلالات المعاملات المقدرة لنموذج تصحيح الخطأ مع النموذج النظري الذي يدعم النموذج النقدي. وان اشارة معامل تصحيح الخطأ (ECM_{t-1}) سالبة، ومقبول عند مستوى معنوية 1% مما يؤكد وجود علاقة طويلة المدى. هذا يدل على أن حوالي 46 % من الاختلال يتم تصحيحه سنوياً في الاقتصاد. وبناءً على النتائج، أوصت الدراسة بأنه لتحقيق استقرار سعر الصرف، يجب على صانعي السياسات تبني سياسات اقتصادية كلية ملائمة تهدف إلى زيادة الناتج المحلي الإجمالي الحقيقي. بالإضافة إلى ذلك، يجب على السلطة النقدية أن تتحكم في عرض النقود لتقليل التضخم وتحقيق استقرار سعر الصرف.

كلمات مفتاحية: سعر الصرف، النموذج النقدي، التكامل، الانحدار الذاتي للإبطاء الموزع، المدى القصير والمدى الطويل.

Introduction

Exchange rate is one of the determinants used in assessing the performance of an economy. A very strong exchange rate is a reflection of a strong and viable economy. On the other hand, a very weak currency is a reflection of a very weak performance of an economy.

Concerning Sudan economy Table (1) gives a summary of selected macroeconomic indicators. The performance of Sudan economy has revealed a general downward trend at the beginning of the 1980s. This has been reflected in a -3.1 % rate of real *GDP* growth in the period 1982-1985, the inflation rate was high (36.5%) with a series of devaluations, and both the current account and government budgets were firmly in deficits.

Many factors have been blamed for this steady deterioration of the economy. The internal causes include unstable economic policies, ill-conceived plans, poor maintenance of capital stock, inadequate and inconsistent implementation of economic policies and declining national saving. In addition, numerous political, social and natural problems accentuated the economic situation. In addition to, the war in South of Sudan had continued to drain resources and halted development efforts. Among the external factors are the deterioration in the term of trade, the high protectionist barriers erected by the industrial countries, sharp increase in prices of capital goods and other imports, and the sluggish demand for local primary products by industrial countries because of the recession these countries were facing during 1980s. However, as Table (1) indicates, rate of real *GDP* growth (4.5%) showed recovery signs during the period 1986-1990 (Bior, 2000). The growth rate in money supply during this period reached 39% compared with the targeted rate of 30%.

Since early 1990s, Sudan has adopted economic policy packages toward economic liberalization and resource mobilization. Instead of improving, macroeconomic performance was deteriorating over the sub-period 1990-1995 (UNDP, 2006). Poor implementation of reforms and continued expenditure pressures resulted in a growing monetization of the fiscal assets, depreciating domestic currency and raising inflation during this sub-period (IMF, 2012). Over the sub-period 1996-2000, the government further committed itself to the liberalization package of 1992. Coinciding with the substantial inflow of foreign direct investment related to the commercial exploitation of oil, the policy stance contributed to enabling a macroeconomic environment (UNDP, 2006). The economy responded positively to these liberalization reforms. Most economic indicators showed significant improvement, e.g. *GDP* growth increased to about 10.4 %, inflation fell from more than 105.9 % during the period 1990-1995 to 43.7 % during the period 1996-2000 and the exchange rates (official, parallel, and black-market rates)

were unified into one rate. It was worth mentioning that the period witnessed the exportation of oil in August 1999. The growth rate in money supply during the period 1996-2000 reached 38.2%.

Table 1: Selected Macroeconomic Indicators for the Sudan (1982-2018)

Item	1982-85	1986-90	1991-95	1996-00	2001-05	2006-10	2011-15	2016-18
Real GDP growth	-3.1	4.5	5.1	10.4	4.1	5.7	4.4	4.9
Budget def. /surp. to GDP	-3.7	-10.6	-5.2	-1.1	-1.1	-2.9	-2.6	-2.2
Current acc. to GDP	-3.1	-1.6	-6.9	-7.2	-5.5	-7.1	-6.9	-10.1
Money supply (M2) growth	39.2	39.8	89.9	38.2	32.5	20.6	21.8	69.7
CPI Inflation	36.5	48.5	105.9	43.7	8.6	9.9	28.6	37.8
Official rate of exchange (SDG per US$1.00)	0.002	0.01	0.3	2.1	2.5	2.2	4.6	13.1
Parallel rate of exchange (SDG per US$1.00)	0.003	0.01	0.4	2.2	2.5	2.2	6.8	25.4

Source: Author's calculations based on the data obtained from Central Bank of Sudan, Central Bureau of Statistics, and Ministry of Finance and National Economy.

During the period 2000-2010, Sudan's macroeconomic performance was broadly satisfactory. Real growth averaged to 5% and fiscal and external deficits remained modest at about 2 % and 6 % of *GDP*, respectively. The inflation rate was declined to the single digits ranged between 8% and 9%, the exchange rate was unified and stable, and the money supply growth rate was decreased to reasonable levels. The economic stability has led to confidence from the external parts that enhanced the relations and economic cooperation with the regional and international financial institutions, these improvements due to economic reforms that accompanied with favourable weather conditions that led to improvement in agriculture sector in addition, to investment in oil and oil-related industries and services.

The period 2011-2018 has seen regression in Sudan's economic transformation. The secession of South Sudan 2011 has contributed to creating severe macroeconomic imbalances and deteriorating considerably the economic conditions in Sudan. Real *GDP* growth averaged to 4.7%, the falling oil revenue also contributed to a slight deterioration in the fiscal deficit average 2.4% of *GDP*. Similarly, the current account deficit averaged 8.5 % of *GDP*, inflation has risen rapidly to around 28.6 to 37.8 % and the exchange rate of the dollar against the local currency on the curb market depreciated further during this period. The growth rate in money

supply during the period 2016-2018, reached 69.7% compared with the targeted rate of 17% (Central bank of Sudan, 2018), this attributed to the direct government borrowing from the central bank, increasing of central bank purchases of securities, and the expansionary impact of the purchase and allocation of proceeds of gold exploration.

Statement of the problem:

What determines exchange rate is an unsettled matter in the literature since there are diverse theories and models. The problem of this study is to identify the main determinants and answering the related questions of the nominal exchange rate in the Sudan over the period 1982 to 2018.

Importance of the study:

The importance of the study is due to the fact that the exchange rate affects many variables in economy. It affects foreign demand for domestic goods, decisions to save and invest and economic growth. Information on the extent to which exchange rate diverges from its equilibrium rate serves as a guide to policy makers to ensure that it does not send wrong signals to economic agents. Wrong signals can results in inefficient allocation of resources and could cause a reduction in the country's welfare.

Objectives of the Study

The objectives of this study are to:

- Construct an econometric model for the nominal exchange rate in the Sudan that will provide not only short-run but also long run forecasts.
- Estimate the parameters of the model for the nominal exchange rate model for the Sudan;
- Derive the policy implications form the analysis.

Hypotheses of the Study

The main hypotheses to be tested are:

- There is an inverse relationship between the nominal exchange rate and real gross domestic product in the Sudan.
- There is a direct relationship between the nominal exchange rate and real money supply in the Sudan.

- There is a direct relationship between the nominal exchange rate and consumer price index in the Sudan.

The plan of the study is as follows: Section 2 reviews the previous studies related to exchange rate determination in Sudan. Section 3 discusses the theoretical base for exchange rate modelling. Section 4, presents model specification and methodology. Section 5 presents the estimation results and empirical analysis. Finally, Section 6 draws the conclusion and policy implications.

Previous Studies

In Sudan, there have been several attempts to analyse the determinants of exchange rate. Elhussein and Ahmed (2019) empirically investigated the determinants of exchange rate in the Sudan and assessed their impact on its volatility. The study gained its importance from the fact raised by the advocates of fixed and managed exchange rate systems that such systems could be the right choice for small economies, where an independent monetary policy was difficult to execute. The paper used the *ARDL* model to study the relationship between the dependent and independent variables. The study documented that the determinant factors of the exchange rate in the Sudan were 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 suggested that the exchange rate system followed had no impact on the stability of the exchange rate.

Mustafa (2019) measured, estimated of the real effective exchange rate in the Sudan during (1975-2017) and analysed of trend of its relation with the explanatory variables. The independents variables included; degree of openness, relative productivity differentials, capital inflows in terms of loans and grants, government expenditure, terms of trade, inflation rate and the dummy variable referred to the civil war up to separating of South Sudan. Annual data were collected from annual reports of Central Bank of Sudan and was used to apply the Ordinary Least of Square Method. The empirical results showed that set of explanatory variables except capital inflows in terms of loans and grants has a significant influence on real effective exchange rate but with different directions. The study recommended that, the government should follow a policy of encouraging exports and attract foreign direct investment to increase capital inflows. In addition, the Central Bank of Sudan should adopt contractibility monetary policy to control inflation.

Ebaidalla (2017) identified the factors that influenced the parallel exchange rate premium in the Sudan during the period 1979–2014. In addition, the impact of parallel exchange rate premium on economic performance was examined focusing on three key macroeconomic indicators namely; economic growth, inflation and exports. The empirical results showed that the parallel exchange rate premium was significantly affected by policy variables such as, real exchange rate, trade openness and money supply. The results also revealed that *GDP* growth, expected rate of devaluation, and foreign aid had a significant effect on the parallel exchange premium. Moreover, the results demonstrated that parallel premium had a detrimental impact on both economic growth and export performance. Expectedly, the results showed a positive and significant association between premium and inflation rate. Accordingly, the paper concluded with some policy implications that aimed to narrow the spread between the black and official exchange rate as an important way out to constrain inflationary pressures, improve export competitiveness, and boost economic growth.

Theoretical base for exchange rate modelling

Several researchers and economists have determined exchange rates according to diverse theories and models. The theories usually considered included the purchasing power parity, the monetary model, current balance model and portfolio balance model.

The Purchasing Power Parity (*PPP*)

In 1918, Gustav Cassel, the Swedish Economist, popularized the purchasing power parity as an ease to setting relative gold parties. The *PPP* approach has been widely used in empirical literature as a method of determining exchange rates. There are two main forms of purchasing power parity theory; absolute purchasing power parity; and, relative purchasing power parity (Shapiro, 2014). As a theory of exchange rate determination, the simplest and strongest form of absolute *PPP* is based on an international multi-good version of law of one price. Absolute *PPP* predicts that the exchange rare should adjust to equate the prices of national baskets of goods and services between two countries because of market forces driven by arbitrage. Under absolute *PPP*, the exchange rate (e) is simply equal the ratio of the domestic price (P) to the foreign price (P^*) of a given aggregate bundle of commodities, but this implies that the real exchange rate is constant.

$$e = \frac{P}{P^*} \quad (1)$$

The relative version of purchasing power parity implies that the exchange rate between two countries should eventually be adjusted to account for differences in their inflation rates. That is, countries that follow monetary policies with different inflation-rate objectives should expect to see this difference manifest itself in an exchange rate movement.

$$e = b\ \frac{P}{P^*}\ (2)$$

Where b is some constant, which reflects barriers to the operation of absolute *PPP* (e.g. transport costs, information costs, etc.).

The monetary approach

The monetary approach to exchange rate has developed into two main types of models; the flexible-price monetary model due to Frankel (1976) and Bilson (1978); and, the sticky-price monetary model of Dornbusch (1976) and with its modification as the real interest differential model of Frankel (1979)

Flexible-price monetary model

The early, flexible-price monetary model has relied on the twin assumption of continuous Purchasing Power Parity (*PPP*) and the existence of stable money demand functions for the domestic and foreign economies. The flexible-price monetary model is, implicitly, a market-clearing general equilibrium model in which continuous *PPP* among national price levels is assumed. The model has set out the formal model along the following lines.

- Goods prices are perfectly flexible and thus that purchasing power parity holds instantaneously:

$$e = p - p^*\ (3)$$

Where, e is the log of the spot exchange rate, defined as the price of foreign currency in terms of domestic currency and p and p^* are the logs of the domestic and foreign price levels, respectively.

- We assume conventional money demand functions at home and abroad,

$$m = p + \beta_1 y - \beta_2 i\ (4)$$

$$m^* = p^* + \beta_1 y^* - \beta_2 i^*\ (5)$$

Where, m and m^* are the logs of the domestic and foreign money supplies, respectively; y and y^* are the logs of domestic and foreign real income; and i and i^* are the domestic and foreign

interest rates. For simplicity, we assume that the elasticity with respect to income β_1 and the semi elasticity with respect to the interest rate β_2 are equal across countries. Combining equations (3), (4) and (5), we have one representation of the flexible price monetary equation:

$$e = (m - m^*) - \beta_1(y - y^*) + \beta_2(i - i^*) \quad (6)$$

- The monetary approach, if it is to maintain that bond supplies do not affect interest or exchange rates as money supplies do, must assume that domestic and foreign bonds are perfect substitutes and thus that uncovered interest parity holds,

$$\Delta e^e = i - i^* \quad (7)$$

Where Δe^e is the expected depreciation of domestic currency.

- The market will be aware of the purchasing power parity condition (3), and so we will have:

$$\Delta e^e = \pi - \pi^* \quad (8)$$

Where π and π^* are the expected inflation rates, at home and abroad, respectively.

- Substituting (7) and (8) into (6) , we get an alternative representation of the flexible price monetary equation:

$$e = (m - m^*) - \beta_1(y - y^*) + \beta_2(\pi - \pi^*) \quad (9)$$

The theoretical expectations equilibrium exchange rate can be shown to be completely determined by trends in relative money supply growth, relative *GDP* growth, and relative inflation rate differentials. According to the monetary model, a relative increase in domestic monetary growth, a relative decrease in domestic *GDP* growth, and a relative rise in domestic inflation rates will exert downward pressure on a domestic currency's value.

Sticky-price monetary model

Another version of the monetary model is the sticky price monetary model first developed in Dornbusch (1976). In the model *PPP* does not, hold in the short-run but is considered to be a long-term phenomenon. The model consists of the uncovered interest parity, the money demand, money market equilibrium, a relation for the inflation rate, and a function generating the expected changes of the exchange rate.

Dornbusch sets out the formal model along the following lines:

- It is assumed that the country is a small, open economy. This allows us to assume that it faces a given world interest rate(i^*).
- Perfect capital mobility and the assumption that domestic and foreign assets are perfect substitutes for each other ensure that uncovered interest parity holds continuously (equation 7).
- Expectations are found according to the following equation:

$$\Delta e^e = \phi(\bar{e} - e) \quad (10)$$

Where ϕ is the coefficient of adjustment ($\phi > 0$), e is the logarithm of the current exchange rate and $\bar{e}$ is the logarithm of the long-run exchange rate.

Expectations are thus formed regressively. If the current exchange rate is above its long-run rate, then it will fall towards its long-run rate and vice versa if the current exchange rate is below its long-run level.

- Money market equilibrium requires that real money demand equals real money supply at home and abroad (equations 4 and 5)
- The long-run exchange rate is determined by monetary factors and real factors. If domestic prices increase at a faster rate than foreign prices, then the exchange rate will depreciate to maintain a constant real exchange rate. In this sense, the model embraces *PPP* and money is assumed to be neutral in the long run. However, the long-run exchange rate is also determined by real factors (e.g. real income), which may warrant a change in the real exchange rate.
- Goods market equilibrium requires the aggregate demand equals aggregate supply. The demand for domestic output is a function of the real exchange rate, the domestic interest rate and real domestic income. In its log-linear version, aggregate demand is given by:

$$d = \alpha(e + p^* - p) + \beta_1 y - \beta_2 i \quad (11)$$

Where *d* is the logarithm of the demand for domestic output.

Aggregate supply is fixed at its full employment level, y. If the aggregate demand is greater than aggregate supply then prices will rise, and vice versa, if aggregate demand is less than aggregate supply. This is reflected in the price adjustment equation:

$$\dot{p} = \delta[\alpha(e + p^* - p) + \beta_1 y - \beta_2 i] \quad (12)$$

Where $\dot{p}$ is the change in the price level.

Following same procedures as outlined under the flexible-price monetary model, the econometrically estimable sticky price monetary model is derived as:

$$e = (m - m^*) - \beta_1(y - y^*) + \beta_2[(i - \pi) - (i^* - \pi^*)] \quad (13)$$

This equation is identical to the flexible-price monetary model expect for the third explanatory variable, the interest differential. In this model, a deviation of the actual exchange rate from *PPP* in the short-run is explained by interest differential.

Current balance model

The current account model of exchange rate determination views the exchange rate as the price of foreign exchange, which equates the demand for and supply of foreign exchange arising from the purchase of imports or the sale of exports. More specifically, the demand for foreign exchange arises from the desire to purchase goods or services from abroad. The supply of foreign exchange comes from the export of goods and services produced domestically (Dornbusch and Fischer, 1980). If the current account is in disequilibrium, this will be associated with disequilibrium in the market for foreign exchange. The exchange rate, that is the domestic price of foreign exchange, would therefore change in order to restore equilibrium at a zero current account. For example, let us assume that the current account is in deficit. This implies that the demand for imports exceeds the demand for exports, leading to an excess demand for foreign exchange. This causes the price of foreign exchange rate to depreciate. If the current account is in surplus then the current account model says that the exchange rate will be appreciate.

Portfolio-balance model

The portfolio balance model to exchange rate determination is largely attributed to Branson (1977) and Dornbusch (1976). The distinguishing feature of portfolio-balance model of exchange rate determination is that they place much more emphasis on the influence of asset markets. In particular, both the money and bond market are key components of these theory. The model posits that, exchange rates are determined by the supply of and demand for all financial assets. The monetary model is actually a subset of the broader portfolio-balance model in that the monetary model narrowly focuses on the supply of and demand for money as the key determinant of exchange-rate movements. The portfolio-balance model broadens the menu of assets that can determine the path that exchange rates take. In addition to relative changes in money supply and demand, the portfolio-balance model focuses on relative changes in bond supply and demand (domestic as well as foreign) as key determinants of exchange-rate movements.

Model specification and methodology

From the above discussions in the previous section, the model in this study is determined by considering the flexible-price monetary model due to Frankel (1976) and Bilson (1978).

$$LEXCH = \beta_0 + \beta_2 LRGDP + \beta_3 LRM_2 + \beta_4 LCPI + \mu \quad (14)$$

Where, $LEXCH$ is the logarithm of nominal exchange rate, $LRGDP$ is the logarithm of real gross domestic product, LRM_2 is the logarithm of real money supply (M_2), $LCPI$ is the logarithm consumer price index and μ is the error term.

According to theoretical and empirical evidence, the coefficient of real gross domestic product is expected to be negative ($\beta_2 < 0$). The signs of real money supply and consumer price index are expected to be positive ($\beta_3, \beta_4 > 0$).

Unit Root Analyses

The augmented Dickey–Fuller (ADF) unit root test has been used to examine the stationary properties for a long-run relationship of time-series variables (see Dickey & Fuller, 1979).

Co-integration Analyses

In order to find the long run and short run relationship between the variables, the econometrics technique which is Autoregressive Distributive lag Model (*ARDL*) has been used, as it is applicable, variables having stationary at level or at the first difference i.e. I(0) and I(1). According to Pesaran *et al*. (2001), the *ARDL* approach has required the following three steps. In the first step, the existence of any long-run relationship among the variables of interest is determined using an *F*-test (bound test for cointegration). The second step of the analysis is to determine the Lag Length for the *ARDL* Model. To select the appropriate model of the long run, it is necessary to determine the optimum lag length (*k*) by using proper model order selection criteria. Selection of the order of the *ARDL* model for the computation of the long-run coefficients is based on Akaike in-formation lag length selection criteria up to two lags. The third step of the analysis is to estimate the coefficients of the long-run relationship and determine their values, followed by the estimation of the short-run elasticity of the variables with the error correction representation of the *ARDL* model. By applying the *ECM* version of *ARDL*, the speed of adjustment to equilibrium will be determined.

This study has covered the period 1982 to 2018. Data on official and parallel exchange rate and money supply were compiled from the Central Bank of Sudan database, Annual

Reports and the data on consumer price index, real *GDP* and *GDP* deflator were collected from the Central Bureau of Statistics. Nominal exchange rate calculated as the average of official and parallel exchange rate while real money supply calculated as a ratio of nominal money supply to *GDP* deflator.

Estimation results and empirical analysis

To check the stationary properties, the augmented Dickey-Fuller unit root test has been used. The null hypothesis is a unit root whereas the alternative hypothesis is stationary in levels. The results of the *ADF*-tests for all variables used in the behavioral equations are reported in table (2) and table (3). The first column shows the list of all variables that are tested. The second column shows whether the equation that has been estimated for the testing purpose has involved a constant and a trend, or a constant only, or neither a constant nor trend. The third column shows the number of lags that have been used for each model. The fourth column is the *ADF t*-statistic, called τ_τ for a constant and trend, τ_μ for only constant, and τ for neither constant nor trend. The last column is the *F*-test ϕ_1 (ϕ_2), testing whether the constant and trend (constant) is significant under the null hypothesis of no unit root.

From results in Table (2), it is clear that most of the variables are non-stationary in level form. The results of the stationary tests in first difference form are presented in Table (3) and this reveals that most of the variables that have been used in the estimation of the individual behavioral equations are found to be integrated of the first order.

Table 2: Statistical Properties of the Variables in the Model-ADF tests for the Order of Integration of Variables in Levels, 1982-2018.

Series	Model	Lags	τ_τ, $\tau_{\mu,\tau}$	ϕ_1, ϕ_2
LEXCH	Intercept and trend	1	-1.903766	4.835985*
	Intercept	1	-1.440656	6.088811**
	None	1	-1.537884	
LRGDP	Intercept and trend	0	-3.523467*	7.034664**
	Intercept	1	0.702004	0.354002
	None	1	4.419114	
LRM_2	Intercept and trend	1	-1.246008	3.675712
	Intercept	1	0.087685	3.423229
	None	1	1.136193	
LCPI	Intercept and trend	2	-3.021002	22.09999***
	Intercept	1	-1.373022	20.91346***
	None	1	0.949076	

Source: Author's estimation using the econometric software *E-Views 9.*

Note: Length of lags selected based on Akaike Information Criterion (*AIC*).

- *** (**) [*] indicate significant at the 1 (5) [10] % level.
- At a 1 (5) [10] % significance level the MacKinnon critical values are -4.262735 (-3.552973) [-3.209642] when a constant and trend are included, -3.646342 (-2.954021) [-2.615817] when only a constant is included and -2.636901 (-1.951332) [-1.610747] when neither is included.
- b- At a 1 (5) [10] % significance level, the Dickey-Fuller critical values are 8.21 (5.68) [4.67] when a constant and trend are included, 7.88 (5.18) [4.12] when only a constant is included.

Table 3: Statistical Properties of the Variables in the Model-ADF tests for the Order of Integration of Variables in First Differenced Form, 1982-2018.

Series	Model	Lags	τ_τ, $\tau_{\mu,\tau}$	ϕ_1, ϕ_2
LEXCH	Intercept and trend	0	-3.256558*	5.353219*
	Intercept	0	-3.231435**	10.44217***
	None	0	-2.306797**	
LRGDP	Intercept and trend	0	-6.362529***	20.24687***
	Intercept	0	-6.252300***	39.09126***
	None	3	-0.689428	
LRM_2	Intercept and trend	3	-3.612484**	4.101568
	Intercept	0	-3.425402**	11.73338***
	None	0	-3.192987***	
LCPI	Intercept and trend	0	-1.783014	1.635865
	Intercept	0	-1.738676	3.022996
	None	0	-0.842564	

Source: Author's estimation using the econometric software *E-Views 9.*

Note: Length of lags selected based on Akaike Information Criterion (*AIC*).

- *** (**) [*] indicate significant at the 1 (5) [10] % level.
- At a 1 (5) [10] % significance level the MacKinnon critical values are -4.262735 (-3.552973) [-3.209642] when a constant and trend are included, -3.646342 (-2.954021) [-2.615817] when only a constant is included and -2.639210 (-1.951687) [-1.610579] when neither is included.
- b- At a 1 (5) [10] % significance level, the Dickey-Fuller critical values are 8.21 (5.68) [4.67] when a constant and trend are included, 7.88 (5.18) [4.12] when only a constant is included.

Estimation Results

In the first step the bound test approach for exchange rate equation has shown that, there exists long run relationship between variables. The calculated value of the *F*-statistics is 8.30, which is greater than upper bound critical value at the 1% level of significance, thus null hypothesis of no co-integration relationship rejected. *ARDL* (1, 0, 0, 0) selected based on Akaike information criterion with maximum lag length of two.

Long run Estimates

The estimation result of the long-run equation of exchange rate has been given below. Exchange rate has negatively and significantly cointegrated with the real *GDP*, while it has positively and significantly cointegrated with the real money supply and consumer price index.

$$LEXCH = -5.76 - 4.42\,LRGDP + 1.25\,LRM_2 + 1.43\,LCPI \quad (15)$$
$$(-3.27)\ (-2.67) \qquad (1.92) \qquad (7.26)$$

$$R^{-2} = 0.99 \qquad S.E. = 0.22 \qquad DW = 1.62$$

(The numbers in parentheses are the t-statistics)

The above long-run equation is plotted in figure (1) and it is indicative of stability by visual inspection.

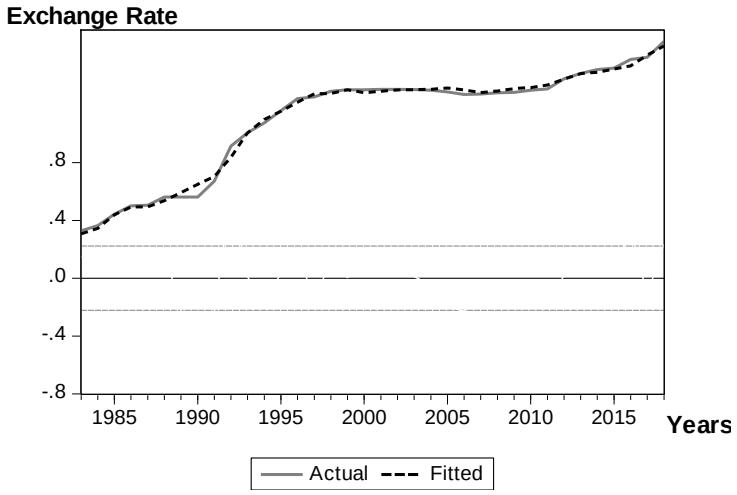

Figure 1: Exchange rate cointegration equation

Source: Author's construction based on the results of estimating equation (15) using *E-Views 9.*

Short-run Estimates

The result of the estimation of short-run error correction model for exchange rate has shown that the coefficients of all variables have the sign that confirms to the exchange rate theory along with their statistical significance.

$$\Delta LEXCH = -2.04\Delta LRGDP + 0.5\,\Delta LRM_2 + 0.66\Delta LCPI - 0.46ECM_{t-1} \quad (16)$$
$$(-5.69) \qquad (3.33) \qquad (5.70) \qquad (-3.58)$$

$$R^{-2} = 0.99 \qquad S.E. = 0.22 \qquad DW = 1.62$$

(The numbers in parentheses are the t-statistics)

The error-correction term (ECM_{t-1}), is correctly signed and significant at one % level of significance confirming the existence of long-run relationship. This shows that about 46 % of any disequilibrium corrected for every year in the economy.

Conclusion and policy implications

This study has constructed a flexible-price monetary model based on Frankel (1976) and Bilson (1978) for the Sudan exchange rate. The unit root test reveals that all the series are non-stationary in level form but stationary after taking the first differences indicating that the series integrated of the first order. The results of the co-integration test for the autoregressive-distributed lag approach have confirmed the significant long-run relationship among considered variables. Results indicate that exchange rate is determined by real gross domestic product, real money supply and consumer price index. Based on the findings, the study recommended that to stabilize the exchange rate, policy makers should adopt suitable macroeconomic policies that aim at increasing real *GDP*. In addition, the monetary authority should control money supply to reduce inflation and stable exchange rate.

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