The current research article analyzes the impact of changes in real exchange rate upon external trade balance of Sudan during the period 1978-2017. It employs Autoregressive Distributed Lag (ARDL) approach, impulse response functions and Granger causality test. The empirical findings indicate that exchange rate devaluations have no impact on the merchandize trade balance, thus evidence in favor of the J-curve pattern was not found. Granger causality test runs one-way from trade ratio to real exchange rate and not the other way. Thus, the results can be considered as an additional contribution to evidence stated in literature that focused a vibrant range of economies. These findings are appropriate for policy making in Sudan as well as in various developing countries since the focal point is major trade balance deficit.

Key words: Exchange rate, trade balance, J-curve hypothesis, Bound test, ARDL approach.

INTRODUCTION

The theoretical linkage that exists between trade balance and real exchange rate movements is provided by J-curve, as per Marshall Lerner Condition (MLC). This infers that whenever the exchange rate changes, it only increases the trade balance when the absolute amount of demand for exports and long-term imports of price elasticity is greater than one.

Conversely, trade in goods has been shown to be non-elastic in nature for a short period of time, as changing consumption patterns and commercial contracts take time to change (Bahmani-Oskooee and Ratha, 2004). As a result, the MLC was not initially achieved, and the condition got violated. This phenomenon i.e., currency devaluation has the potentials to create a ruckus in the trade balance for a short span of time. This dynamic and robust relationship that exists between trade balance and real exchange rate is otherwise called as J-curve effect. The current study
focuses on the perspective of J-curve phenomenon, which denotes the short-term backlog in the trade balance. This is then followed by a stepwise fashioned long-term improvement in the trade balance after the country’s currency got significantly depreciated. As per the conclusion of researchers (Junz and Rhomberg (1975), Magee (1973), Bahmani-Oskooee (1985), and Meade (1988)) when the exchange rates are adjusted immediately, the consumers and producers may experience a time lag in adopting to the adjusted prices to relative prices. So, this kind of depreciation or devaluation further diminishes the foreign trade balance for a short span of time. This in turn extends the time required for the expected recovery effect on foreign trade balance. In time, the foreign trade balance travels in the path similar to the alphabet ‘J’, based on which the effect is termed as J-curve effect (Krugman and Obstfeld 2003).

To be precise, the J-curve scenario forecasts the beginning-level deterioration of the trade balance after currency depreciation, which is normal, prior to the occurrence of improvement. The trade balance response is hypothesized in the shape of alphabet J. J-curve hypothesis is developed on the basis of lagged adjustment process. This is an important argument since it infers that the beginning level impact of depreciation goes negative and the positive effects of depreciation are experienced when time passes (Carter and Pickö 1989). The exchange rate is mostly utilized as a tool to ensure the regulation of trade and capital flow in a number of developing economics. This pattern results in maintaining the balance of payments deficit, thanks to the structural gap which is present between the volume of exports and imports. Such economics react in an inflexible manner in case of a demand arise, for exports and imports. Further, most of the times, the growth rate of imports is higher compared to the exports, resulting in high trade imbalances (Bhattarai & Armah 2005).

As Ali (1985) stated, the IMF's original argument for devaluation of the Sudanese pound that a few domestic and external economic developments that had affected budget processes, credit expansion and cost-benefit relations over the past few years had resulted in structural imbalances in the Sudanese economy; these clearly indicates severe budget and balance of payments imbalances. In addition to taking steps to eliminate the causes of imbalances, it has become necessary to devalue the Sudanese pound in accordance with the IMF's vision to accelerate the growth rate by rationalizing the allocation of resources to make the most of Sudan's current and potential comparative advantage, particularly in agriculture and agro-industries.

An analysis conducted by IMF lists the possible influence of devaluation upon the balance of payments; moderate improvement is only experienced in trade balance as a result of the proposed devaluation for a short span of time. However, this gets increased with adjustments made in the cropping pattern, cultivation of new lands and high production of commodities by Sudan which brings higher elasticity of demand. For a short period of time, rigid demand of imports is likely to be experienced since the imports already got reduced to only essential products, thanks to quantitative restrictions. However, the devaluation would make it possible to relax gradually these restrictions and allow the level of imports to be determined to a large extent by market forces, this substitution of the price mechanism for administrative allocation of foreign exchange would result in a more efficient use of the country’s scarce foreign exchange. Furthermore, the rise in the cost of imports would encourage projects and production techniques which use less imports and would also stimulate production of import substitutes. By strengthening confidence in the Sudanese, the devaluation is also likely to encourage foreign investments. In addition, the greater availability of foreign exchange due to export growth and increased inflow of foreign capital would permit larger imports of agrarian as well as industrial-manufactured products and thus permit a better utilization of existing capacity (Ali, 1985). The note was obviously following the J-curve approach. It may
be considered unusual if a country suffers a continuous deficit over say 30 years, without any single period of surplus, it would even be more unusual if this persistent deficit was increasing at a constant proportional rate. Sudan’s trade performance on merchandise is characterized by persistent trade deficits as shown in Figure 1. Sudan experiences fluctuations in its exchange rates which pose a significant impact on its economy. This phenomenon is reflected in the balance of trade too. Sudan has been recording a persistence trade deficit since 1970s, and the Sudanese pound has been repeatedly devalued.

**Figure 1: Sudan’s merchandise trade flows, 1978-2017**

![Graph showing Sudan's merchandise trade flows from 1978 to 2017]

Source: Central Bank of Sudan, Statistical Reports, Various issues.

Sudan underwent financial liberalization exercise as per the Economic Recovery Program (ERP) and Structural Adjustment Programs (SAPs) proposed by the International Monetary Fund after 1978. This led to shifting from fixed to floating exchange rate regime. After this shift, the whole economy of the country has been heavily influenced by exchange rate fluctuations which is now considered as a vital macroeconomic variable. In the past 30 years, the economy of Sudan is characterized by successive and persistent trade imbalances in addition to extreme level of exchange rate depreciation. These devastating developments led the researchers to better understand the impact of exchange rates on external trade in Sudan.

Though numerous studies have focused the economies of developing countries, the impact of real exchange rate upon the external trade of Sudan is still an unexplored area of research with questionable background. The growth in Southeast Asian region can be better understood with the correct exchange rate since it is a crucial factor economic growth. In case of African and Latin American countries and its economies, the volatile exchange rates have always confined the development and even pulled back the economic growth of the countries (Bhattarai & Armah, 2005).

Therefore, it is interesting to investigate whether devaluation of Sudanese pound could solve the structural imbalances in Sudan’s external trade and how we can improve the performance of external trade balance. Stucka (2004) mentioned two approaches to increase the trade balance in which the first approach i.e., Internal is to rely on supply side polices. These policies are inclusive of coercing labor productivity or wages by tax limitations, keeping inflation under control, relaxed labor market conditions etc. Some of these measures enhances the GDP, which in turn exert a
positive impact upon exports. In the second approach i.e., external one, the currency is devalued or depreciated. This drastically alters the relative price of imports and exports. J-Curve hypothesis mentions that when the currency gets depreciated, it negatively impacts the trade balance in short term, though the long-term effect may be positive.

J-curve is touted to be a mixed evidence. There are two groups of empirical research found in which the first one corresponds to J-curve in two-country framework i.e., domestic and the rest-of-world, Felminghan (1988). Being a phenomenon with aggregative approach, J-curve seems to be appropriate one. But currencies tend to depreciate or else appreciate simultaneously in alignment with other counterparts. By considering this phenomenon, the second research group focused on the trade balance between two partners (Bahmani-Oskooee and Brooks (1999), and Onafowora (2003).

The focus of the current research article is to estimate both short as well as long-run impact of exchange rate changes on external trade balance of Sudan. To be specific, the research article attempts to find answers for the question i.e., is there any proof available for the J-curve effects of real exchange rate on external trade balance of Sudan.

In addition to examine causality relationships among the variables were determined. The period that is explored covers 1978-2017. 1978 is chosen as first year because it’s the first year of devaluation, followed by a series of devaluations in which any devaluation paved the way for devaluation, and 2017 was the final year up to when the data was available for almost all the considered variables.

The first section introduces the manuscript theme while the rest of the manuscript is organized as follows; In the second section, a brief literature review of relevant works, both theoretical and empirical studies on J-curve hypothesis are presented. Section 3 presents the methodology and data sources. Section 4 discusses the results while the final section i.e., fifth section arrives at the conclusion for the manuscript and offers some policy implications.

LITERATURE REVIEW

Theoretical considerations

The currency devaluation can only be taken under consideration if the exchange rate is kept under control by the government. Devaluation can be defined as an official reduction in currency’s par value by few percentages in alignment with other currencies or is an attempt at ‘unification’ by narrowing the differences between the official and the parallel rates (Ahmed, 2001 and Ogbonna, 1982).

When the balance of trade changes due to the changes in the quantity of imports and exports at unchanged prices, this can be called the quantity effect. On the other hand, when the balance of trade undergoes changes due to alterations in prices, at unchanged volumes, this can be considered as the price effect. The method of calculating quantity and price components in the balance of trade, involves the partial equilibrium analysis of holding one variable constant while a change in the other is analyzed. This is not to imply, however, that volume and price are always independent variable (Mehta and Moore, 1982).
Price and volume effect are the two counteractive effects produced by devaluation. In terms of output, the price effect worsens the current account balance since the devaluation turns the import an expensive one while the exports are made cheaper. Further, the contribution of volume effect is the improvement in current account. This is because when the exports become cheap, it results in the increased volume of exports. Likewise, when the import highly becomes cost-incurring, it results in the reduction of volume of imports. J-curve decodes this scenario by considering time factor in the manifestation of these effects. With regards to responses, the price effect is a quasi-immediate one as soon as the devaluation occurs. When it comes to volume effect, its manifestation is a time-consuming process. This is decided by the country’s production capacity to react, with the implementation of novel measures to aggravate the production. The export activities get triggered with an assumption that the domestic goods set to be cheaper in international market while on the other hand, foreign goods become relatively costly. This phenomenon is known as volume effect i.e., when there is an increase in the volume of exports, then the volume of imports gets reduced.

Thus, when we observe that the current account balance of a country declines after the devaluation of its currency, and a few months after the country’s current account balance start to increase, we conclude that we are in the presence of a J-curve effect. Therefore, a real devaluation in the beginning results to a decline in the balance of trade in the short run, then after some few months when the economy starts to adjust itself, the positive impact of the volume effect starts to manifest itself. But it should be noted that this mainly depends on the elasticity of demand of export goods and services in the country in question. Thus, the sustainable adjustment in the competitive nature of a country depends on the ability of that country to absorb and control inflation that will occur on the prices of imported goods as a result of devaluation in the short run, and in the long run the country should be able to boost production in other to generate a positive balance of trade (Pegou et al. 2012). After the currency is devaluated by the government of a country, there is a decline observed in the country’s current account balance which start to increase after few months. This phenomenon is understood to be J-curve effect. So, during the initial times, the devaluation may reduce the balance of trade for a short period of time. However, as soon as the economy is back to form in a few months’ time, one could experience in the positive impact of volume effect getting manifested by itself.

According to J-curve hypothesis, once the domestic currency got devaluated, the economy experiences small elasticities for a short period due to which the Marshall-Lerner condition cannot be met. This further increases the deficit in balance of trade. Researchers also tried to determine the empirical validity of J-curve hypothesis. A general conclusion arrived by these studies (Rosenswieg and Koch 1988, Moffett 1989, Rose and Yellen 1989) is that the standard J-curve pattern seems to have no fit with the actual data in a reasonable fashion. However, an alternative explanation was proposed by few researchers (Greenwood 1984; Razin 1984; McKinnon and Ohno 1986) in modern theory of trade balance determination. In modern theory frameworks, intertemporal shocks are cited as the main reason behind external trade imbalances. This further shits the time distributions of both production as well as consumption. Such disturbing events create a negative impact upon both trade balance as well as exchange rate. The modern theory implies that the perspectives underlying exchange rate, in terms of standard J-curve hypothesis, sound too exaggerating especially when it is cited as the reason behind trade balance size changes. If at all, the real exchange rate alters only at the beginning, to accommodate the existing trade imbalance. This in turn triggers further changes in the trade balance.
The standard theory lists out some of the instances during when a J-curve pattern may be applied. These instances include specific expected responses for price and volume components of trade balance to a reduction in exchange rate. To be specific, the declining points in the J-curve is due to price or direct effect of the currency depreciation whereas the volume or indirect effect of the depreciation results in rising part of the J-curve. There are two major propositions which can explain the modern theory of trade-balance determination. The first is that the exogenous factors influence the movements in real exchange rate as well as trade balance. Thus an alteration in one variable can only partially explain the change in other variable. The second proposition is the bidirectional relationship between the variables (Mahdavi and Sohrabian 1993)

**Empirical Studies**

There is a long history of empirical studies conducted regarding Marshall-Lerner condition. Magee (1973) endorsed the short-run effect and J-curve phenomenon based on the fact that once the currency is devalued, there occurs short-run devaluation and long-run improvement which looks like the alphabet ‘J’. Further, various research studies conducted earlier to investigate this phenomenon with the help of wide range of techniques and different model specifications. According to Magee’s theoretical arguments, in spite of the improved trade balance in long-run after devaluation, there is an altogether different response occurs in short-run. Further, the short-run trade balance experiences a decline in the beginning which gets improved after time pass by (Magee, 1973).

Magee (1973) arguments were further supplemented with five possible lags by Junz and Rhomberg (1973). Recognition lag is one of the five lags which arise when the buyers and sellers take time to understand the ongoing changes in competition conditions. Since the information getting disseminated changes on the basis of language and distance, the international trade may experience longer delay in time. Further, the delivery lag is also expected to occur next to decision lag, with the establishment of new business networks and placement of new orders. In addition to the above, procurement of new materials/equipment i.e., replacement lag as well as production lag too were cited as other delay types (Junz and Rhomberg, 1973).

The J-curve is decomposed into three unique periods by Moffett (1989) such as currency contract period, pass-through period and quantity response period. In the foremost one, the trade contracts are performed on the basis of pre-depreciation relative prices. In the second period, the prices are adjusted as per the new exchange rate. The adjustment occurs in the final period for the import and export quantities to new prices. But various factors confine the simultaneous effect of exchange rate change on foreign trade balance such as foreign trade policy, country’s exchange rate system reaction of economic actors to price changes, composition of foreign trade and finally the treaties among stakeholders which may prohibit the emergence of expected increase in foreign trade balance in short-term (Lal and lowinger, 2002).

Numerous studies were conducted to decode the long-run impact of currency devaluation upon trade balance improvement and the occurrence of J-curve pattern. These studies can be broadly classified into two categories such as studies that used aggregated data and studies that used binary data. Researchers deployed different models in both the categories in addition to different definitions and measurements for conceptual variables. All the studies meet at a focal point with similar assumption regarding the impact of exchange rate changes on trade balance i.e., if
consumption increased the trade balance, then the estimate is hurtled (Bahmani-Oskooee and Fariditavana, 2015).

Some studies have tested the phenomenon for many developed and developing countries, their findings are mixed, but still more in a favor than not of the proposition that currency depreciation improves trade balance, and that J-curve effect takes place (Petrovic and Gligoric, 2010). However, African nations have not received much attention on this regard. Notable studies in Africa include Few researchers validated this pattern using data from developed and developing countries. With mixed findings, most of studies did not support the claim that currency depreciation improves trade balance and J-curve effect occurs (Petrovic and Gligoric, 2010). There is only a negligible amount of attention focused on African nations in this perspective. Some of the important African studies are Kulkarni & Clarki (2009), Adeniyi, Omosakin and Oyinlola (2011), Bahmani-Oskooee and Hosny (2012), Ziramba and Chifamba (2014) and Riti (2012). In the study conducted by Ziramba et al (2014), the researchers assessed the behavior of trade balance patterns in South Africa after real effective exchange rate got depreciated. The study made use of the aggregate data for the period 1975 to 2011. The study results found no empirical evidence that supports J-curve phenomenon for the scenarios considered. In the study conducted by Bahmani-Oskooee and Gelan (2012), J-curve hypothesis was experimented for nine African countries such as South Africa, Nigeria, Kenya, Burundi, Egypt, Mauritius, Sierra Leone, Tanzania and Morocco. The study found no substantial claim for J-curve.

ESTIMATED MODEL AND METHODOLOGY

Estimated Model:

The current study considers foreign income, domestic income and real exchange rate as the main determinants of trade balance.

\[(TB)_t = \beta_0 + \beta_1 Y_t + \beta_2 Y^*_t + \beta_3 (RER)_t + \mu_t\]  

Where;

TB= trade balance defines as the ratio of exports to imports(X/M)

Y= domestic income of Sudan proxy by its GDP.

Y* = foreign income proxy by the GDP of Sudan’s major trading partners.

X and M= imports and exports refer to the merchandise components in US dollar.

Real exchange rate (RER) = capturing domestic and foreign price-level changes, with an increase in the exchange rate (units of domestic to foreign), representing a depreciation.

The data of export and import in US dollars are collected from Central Bank of Sudan. The GDP data in constant prices for base year 1990. The source of this data was collected from Central Bureau of Statistics, Khartoum, Sudan. Sudan trading partners include Saudi Arabia, China, Japan, Germany and United Kingdom to represent the rest of the world, for the base year 1990. The trading partners’ GDP multiplied by their official nominal exchange rate to converted to US dollars.
The relationship between a nominal exchange rate $E$ and a real exchange rate, $RE,$ can be expressed algebraically by:

$$RE = \frac{E P^*}{P}$$

where $P^*$ : represents relevant index of foreign price proxy by the consumer price index of Sudan’s major trading partners, namely Saudi Arabia, China, Japan, Germany and United Kingdom for the base year 1990. These countries are chosen because they constitute a greater share of Sudan’s foreign trade. It is set in index form to make it unit-free. The source of data of Sudan’s major trading partners is various issues published by Direction of Trade Statistics. The source of their GDP as far as their consumer price index are concerned, is fetched from various publications of International Financial Statistics, published by IMF. Central Bank of Sudan was the source of official exchange rate data.

The constant term is denoted by $\beta_0$ in this equation (1). Further, the constant terms $\beta_1, \beta_2, \beta_3,$ indicate long-term coefficient for each variable whereas the error term is shown by $\mu_t$.

Under normal condition, with regards to expected signs, one could predict the coefficient signs in the equation (1). Further, in line with classical theory, the $\beta_1$ sign could be either positive or negative. When the $\beta_1$ is predicted to be negative, then ($\beta_1 < 0$). This infers that with increasing Sudanese real income $Y_t,$ the imports volume also get increased which negatively impacts the trade balance. Magee (1973) stressed that the sign of $\beta_1 > 0$ could be easily positive since the imports are nothing but the difference that arise out of domestic production and consumption patterns. With increase in the real income, the domestic production of importable also experience an increase compared to consumption. This scenario diminishes the volume of imports i.e., increase in $Y_t$ is attributed to increased production of import-substituted goods. In line with this, $\beta_2$ is also predicted to be either positive or at times, negative too. $\beta_2$ sign is dependent on the fact, when supply side factors exert a dominance over demand side factors.

The main aim of the current research work is to explore the impact of real exchange rate (RER) upon trade balance (TB) i.e., whether the currency devaluation can enhance trade balance in the long-run. RER is defined as the units of domestic currency per unit of foreign currency and the RER parameter is expected to be positive sign. With decrease in RER i.e., depreciation of domestic currency, there is a decline in imports observed with increasing exports. So, the trade balance is predicted to get improved. In order to ensure this scenario occurs, the coefficient of (RER) should be positive: $\beta_3 < 0.$

For the purpose of ensuring all the models are free from scale effects and to interpret the coefficients as elasticities, the variables are either expressed or converted into natural logarithm (ln) to capture log-linear relationships.

$$\ln(TB)_t = \beta_0 + \beta_1 \ln Y_t + \beta_2 \ln Y^*_t + \beta_3 \ln(RER)_t + \mu_t$$ (2)

In order to determine the long-run relationship that exists between real exchange rate and trade balance, the following equation was formulated.

$$\ln(TB)_t = \beta_0 + \beta_1 \ln Y_t + \beta_2 \ln Y^*_t + \sum_{i=0}^{n} \beta_i \ln(RER)_{t-i} + \mu_t$$ (3)

As the assessment of J-curve phenomenon is the focal point of current research article, a lag structure is imposed on real exchange rate variable.
In the equation (3) given above, the general description of long-run relationship between income levels and real exchange rates is provided. The dynamic adjustment mechanism is collated into equation (3) so as to have a close watch on the adjustments. Following this, the error-correction model is hypothesized to capture the speed of adjustment.

The short run equation given below corresponds to long-run equation (1) given earlier. This is used to determine the Error Correction Model (ECM) so as to capture the short-run REER dynamic on the trade balance of Sudan. In order to determine the J-curve phenomenon, the short-run dynamics must be incorporated into error-correction modelling i.e., long-run model, which is given below. Being annual observations, for maximum order of the lags in ARDL model, the current study selects 2 and estimation is done for the period spanning 1978 and 2017. Following is the equation for error-correction version of ARDL (2,2,2) model with regards to variables in (1).

\[
\Delta \ln TB_t = \beta_0 + \sum_{i=1}^{n} \beta_1 \Delta \ln TB_{t-i} + \sum_{i=1}^{n} \beta_2 \Delta \ln Y_{t-i} + \sum_{i=1}^{n} \beta_3 \Delta \ln Y^* + \sum_{i=1}^{n} \delta_i \Delta \ln RER_{t-i} \\
+ \delta_1 \ln TB_{t-1} + \delta_2 \ln Y_{t-1} + \delta_3 \ln Y^*_{t-1} + \delta_4 \ln RER_{t-1} + \mu_t \tag{4}
\]

The variables are deemed to be co-integrated with jointly significant \((\delta_1 - \delta_4)\).

Depreciation’s short-run effects can be understood by \(\delta_i'\) estimates. To be specific, Magee (1973) asserted that J-curve can be detected only after checking the support in which the estimate of \(\delta_i\) has negative signs (values) at lower lags, followed by positive signs (values) at higher lags consistent with J-curve hypothesis.

Equation (2) is rewritten as follows so as to know the disequilibrium error.

\[
\mu_t = \ln(TB)_t - \beta_0 - \beta_1 \ln Y_t - \beta_2 \ln Y^*_t - \beta_3 \ln(RER)_t \\
\tag{5}
\]

The order of estimated residual \(\mu_t\), must be analyzed to conduct Error Correction Model. In the presence of co-integration regression, the disequilibrium errors in equation (5) must create into a stationary time series with zero mean during when \(\mu_t\) should be stationary, I(0) with \(E(\mu_t) = 0\).

It is rare to observe long-run equilibrium though it is a common phenomenon to move towards equilibrium. So, Error Correction Model is utilized to denote long-run (static) as well as short-run (dynamic) relationships among foreign income, trade balance, domestic income and real exchange rate.

Vector Error Correction model is an apt choice to determine the impact of real exchange rate on trade balance. The Error Correction Model is denoted in equation (6).

\[
\Delta \ln TB_t = lagged(\Delta TB_t, \Delta Y_t, \Delta Y^*_t, \Delta (RER)_t) - \lambda \mu_{t-1} + \nu_t \tag{6}
\]

Where \(\mu_{t-1}\) represents the residual term at \(t-1\) in long-term.

The long-run relationship is estimated with the help of co-integration tests whereas the short-run relation between trade balance and REER is analyzed with the help of Error Correction Model (ECM). Due to the fact that equation (3) incorporates short-run as well as long-run coefficients, it is the correct choice to handle J-curve subject. This can be executed through a comparison of
short-run coefficients at short lags with those at longer lags, as judged by the size and significance of the estimated coefficients of the first-differenced variables (Bahmai-Oskooee and Hegerty, 2010).

Method of Estimation:

Unit root tests:

It is an established practice to start the analysis by analyzing the time-services characteristics of the data. In macroeconomic data, Augmented Dickey-Fuller (ADF) and Phillip and Perron (PP) tests are widely used to test the stationarity.

Cointegration Process: The purpose of co-integration process is to assess the long-run relationship between the variables so as to find a solution for spurious regression problem and violation assumptions of the classical regression model. The formula is as follows

$$(TB)_t, Y_t, Y_t^*, and (RER)_t$$

A linear combination of two or more non-stationary series may be stationary, according to Engle and Granger (1987). In the presence of such stationary linear combination, the non-stationary time series is said to be co-integrated. This stationary linear combination is otherwise termed as co-integrating equation. This might be understood as a long-run equilibrium relationship among the variables as well. The co-integration test is generally conducted to identify the pattern of co-integration in a group of non-stationary series. One of the ways for co-integration testing is to develop test statistics from the residuals to co-integrating regression. It is possible to capture the short-run dynamics as well as the movement towards equilibrium with Vector Error-Correction Model (VECM). In this model, the long-run equilibrium relationship enters into a short-run model (Quantitative Micro Software, 1994-2000).

Autoregressive Distributed Lag (ARDL) Approach

The current study made use of testing and estimation procedure developed in Pesaran et al. (1996), and Pesaran and Shin (1995) which attempts to assess the relationship between the variables. The primary advantage in this testing and estimation strategy is that it can be incorporated when the regressors are either I(0) or I(1). This makes sure that there is no protesting challenges associated with standard co-integration analysis, which demands the variables be classified into I(1) and I(0). Autoregressive Distributed Lag (ARDL) approach can avoid such classification of variables into I(1) or I(0). Pesaran, Shin and Smith (2001) proposed a bound testing procedure in which the long-run trade balance equation (1) is incorporated into Error Correction Model (ECM). This ensures the parallel estimation of long-run as well as short-run coefficients, a primary advantage in this approach. This method is mostly used in studies that are focused on the existence of J-curve effect.

The Autoregressive Distributed Lag (ARDL) cointegration procedure:

The Autoregressive Distributed Lag (ARDL) cointegration model is valid whether the variables are I(0) or I(1). The ARDL bounds test approach developed by Pesaran et al. (2001) is used to estimate Equation (1). The choice of this methodology is based on several considerations:
1. Autoregressive Distributed Lag (ARDL) cointegration model remains valid irrespective of whether the variables are I(0) or I(1). Pesaran et al. (2001) developed ARDL bounds test approach to estimate Equation (1). This methodology is selected on the basis of various considerations.

2. ARDL methodology bypasses the challenges involved in the order of integration associated with Johansen-likelihood approach.

3. The bound test is an apt one for small sized sample studies only, unlike other traditional multivariate cointegration procedures which are valid for large sample size.

4. In general, this technique produces unbiased estimates of long-run model and valid t-statistics, even in the presence of some endogenous repressors. Inder (1993) and Pesaran and Pesaran (1997) decoded the addition of dynamics may aid in overcoming the endogeneity bias.

ARDL model specification:

There are two stages present in ARDL approach in which the first stage analyzes the existence of a long-run equilibrium relationship (cointegration) among the observed variables i.e., there exists cointegration among trade balance (TB), real exchange rate (RER), and (GDP) in case when the coefficients $\theta_1$, $\theta_2$ and $\theta_3$ are different from zero. To be specific, the research analyzed the null hypothesis of the non-existence of long-run relationship. So, there is no long-run equilibrium, a definition of null hypothesis, is defined as follows

$$H_0: \theta_1 = \theta_2 = \theta_3 = 0$$

This is analyzed against an alternative hypothesis:

$$H_1: \theta_1 \neq \theta_2 \neq \theta_3 \neq 0$$

This denotes the existence of co-integration.

The relevant statistic remains the very-common F-statistic for joint significance of $\theta_1$, $\theta_2$ and $\theta_3$. The bounds testing procedure is conducted on the basis of F or Wald-statistics and remains one of the steps in ARDL cointegration method. In other words, F-test or Wald test is a relevant statistic test to experiment on the null hypothesis. The null hypothesis $H_0$ is rejected in case when the calculated F-statistic is above the upper limit of bands. During this case, the variables are co-integrated. The null hypothesis is not rejected when the F-statistic is below the lower band since the variables are not co-integrated then. At last, the test becomes inconclusive if the F-statistic falls into bounds i.e., area inside the band becomes inconclusive area. One cannot make any statement with regards to co-integration in such scenario. After determining co-integration, the error-correction term is defined in the second stage, especially the cointegration vector.

Granger Causality Test:

It is possible to identify the direction of causality statistically, while temporally, there exists a lead-lag relationship between two variables (Gujarati 1995, p.620). According to an assumption in Granger causality test, the information related to forecasting of respective variables TR and RE is completely contained in time series data on these variables. The test involves the determination of following regressions.
\[ TR_t = \sum_{i=1}^{n} \alpha_i RE_{t-i} + \sum_{j=1}^{n} \beta_j TR_{t-j} + \mu_{1t} \]  
(7)

\[ RE_t = \sum_{i=1}^{m} \lambda_i RE_{t-i} + \sum_{j=1}^{m} \delta_j TR_{t-j} + \mu_{2t} \]  
(8)

In these equations, the disturbances \( \mu_{1t} \) and \( \mu_{2t} \) remain uncorrelated.

According to Equation (7), the current TR has a relationship with past TR values and RE values whereas the equation (8) postulates a similar behavior for \( RE_t \).

So, we classify the four cases which are given herewith.

1. Unidirectional causality from RE to TR is denoted when the determined coefficients on lagged RE in (7) are statistically different from zero as a group (i.e., \( \sum \alpha_i \neq 0 \)). A set of estimated coefficients on lagged TR in (8) is statistically indifferent from zero (i.e., \( \sum \delta_i = 0 \)).

2. On the contrary, there is an existence of unidirectional causality from TR to RE when the lagged RE coefficients in (7) is statistically indifferent from zero (i.e., \( \sum \alpha_i = 0 \)) and the set of lagged TR coefficients in (8) is statistically indifferent from zero (i.e., \( \sum \delta_i \neq 0 \)).

3. Bilateral causality or feedback starts with interdependence between real exchange rate and trade ratio. This scenario occurs when the above-mentioned two factors are at work, and the sets of RE and TR coefficients remain statistically and significantly different from zero in both regressions.

4. In case when RE and TR coefficients are statistically non-significant in both regressions, the independence is suggested. It can be defined as the absence of any causality by the analysis. Both real exchange rate as well as trade ratio may tend to grow or even move together. However, they do not exert influence upon each other whereas any changes in both happen, due to other independent factors.

In general, it is impossible to predict the past with future information and likewise variable X (Granger) causes variable Y and when there is a change in X, it should reflect in Y too. So, when Y regresses on other variables (including its own past values) and when past or lagged values of X are included, it notably enhances the prediction of Y which can be concluded as X (Granger) causes Y. This definition is similar if Y (Granger) causes X.

The null hypothesis is \( H_0 : \sum \alpha_i = 0 \), that is, lagged RE terms do not belong in the regression. F test is used herewith to test this hypothesis. The null hypothesis is rejected, when the computed F value is above the critical F value at selected significant levels. In such case, the lagged RE belongs to regression. In other words, the RE causes TR.

**EMPIRICAL RESULTS**

*Unit Root tests:*

ARDL bounds test is conducted on the basis that the variable is either I(0) or I(1). So prior to this test application, the time series characteristics of the series were investigated. Table 1 shows the
list of ADF test results on the levels and first differences of variables. With the help of Schwarz Criterion (SC) the lag length was chosen. In table 2, the PP tests are reported for unit root on both level and the first difference of the variables. A different stationary process is followed to analyze the null hypothesis in ADF tests and PP tests.

Table 1: Augmented Dickey-Fuller (ADF) Test

<table>
<thead>
<tr>
<th>Variable</th>
<th>Level</th>
<th>First Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Series</td>
</tr>
<tr>
<td>lnTB</td>
<td>-2.80</td>
<td>-2.84</td>
</tr>
<tr>
<td>lnY</td>
<td>-1.22</td>
<td>-1.89</td>
</tr>
<tr>
<td>lnY*</td>
<td>-1.74</td>
<td>0.91</td>
</tr>
<tr>
<td>lnRER</td>
<td>-1.57</td>
<td>-3.37</td>
</tr>
</tbody>
</table>

Source: Output from Eviews (10).

Table 2: Phillips – Perron (PP) Test

<table>
<thead>
<tr>
<th>Variable</th>
<th>Level</th>
<th>First Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Series</td>
</tr>
<tr>
<td>lnTB</td>
<td>-2.81</td>
<td>-2.83</td>
</tr>
<tr>
<td>lnY</td>
<td>-1.22</td>
<td>-1.95</td>
</tr>
<tr>
<td>lnY*</td>
<td>-3.10</td>
<td>-4.23</td>
</tr>
<tr>
<td>lnRER</td>
<td>-1.58</td>
<td>-3.46</td>
</tr>
</tbody>
</table>

Source: Output from Eviews (10).

The results of the stationarity tests infer that almost all the variables remain non-stationary at level for ADF test, while they remain stationary during first difference. So, it is important to conclude that all the variables are integrated in the order of one. For the PP test shows that all the variables are stationary at the first difference, except foreign income was stationary at the level. This means that the PP test, which was used upon the first difference of data series, rejected the null hypothesis of nonstationary for all the variables used in this study, except foreign income in Table 2.

ARDL Bounds for cointegration

We apply the ARDL cointegration technique to analyze the long-run relationships and short-run dynamic interactions among the variables considered in the study such as real exchange rate, domestic income, trade ratio and foreign income. Since F (Dlntr/DlnY,DlnY*,DlnRER)=12.76 exceeds the upper bound of the critical value band, at 5% level given by 2.79 and 3.67, lower and upper bonds respectively, it is possible to reject the null hypothesis of no long-run relationship among TR, Y, Y* and RER without considering the order of integration such as I(0) or I(1). The columns which are showing the header ‘I(0)’ denotes lower-band critical values which were calculated when whole set of k regressors are I(0). While ‘I(1)’ headed columns contains figures which denote the upper-bound critical values. These are determined based on the assumption that
all k regressors are I(1)” (Pesaran and Pesaran 1997b, p.477). The test results are found to be ahead of upper-bound critical value. This phenomenon denotes that the null hypothesis of no cointegration is rejected. Thus one can infer the existence of long-run relationship among TR, Y, Y* and RER. So the variables Y, Y* and RER, can be treated as ‘long-run forcing’ variables to explain TR. This can be understood as simultaneous travel of all the variables in long-run.

Table 3: F-Bound test

<table>
<thead>
<tr>
<th>Test Statistic</th>
<th>Value</th>
<th>Sign.</th>
<th>I(0)</th>
<th>I(1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F-statistic</td>
<td>12.76035</td>
<td>10%</td>
<td>2.37</td>
<td>3.2</td>
</tr>
<tr>
<td>K</td>
<td>3</td>
<td>5%</td>
<td>2.79</td>
<td>3.67</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.5%</td>
<td>3.15</td>
<td>4.08</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1%</td>
<td>3.65</td>
<td>4.66</td>
</tr>
</tbody>
</table>

Source: Output from Eviews (10).

J-curve Effect by estimating Error-correction Model

The short-run currency depreciation results in deterioration of trade balance prior to improvement i.e., J-curve effect. The J-curve effect is thus examined in the current study after analyzing ECM estimates corresponding to long run trade balance equation given above and by determining the impulse response of trade balance after shock from real exchange rate. After establishing co-integration relationship, an ECM can be determined to find the dynamic behavior of trade balance model.

Table 4: ECM Regression

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CointEq(-1)*</td>
<td>-1.232422</td>
<td>0.145713</td>
<td>-8.457855</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

Source: Output from Eviews (10).

The lagged error-correction term \((E_{t-1})\) coefficient, estimated at -1.232422(0.145713) carries its correct negative sign. This seemed to be heavily significant in most of the cases that support cointegration. It further recommends the validity of a long-run equilibrium relationship among the variables in equation (1) and recommends a moderate speed of convergence to equilibrium. From the estimated value of the coefficient of \((E_{t-1})\), it can be understood that the speed adjustments in the system clears its previous period’s level of disequilibrium by 1.2 per cent a year. If the error correction coefficient (in absolute value) is larger, then the economy’s return to its equilibrium is faster after the shock (Pesaran and Pesaran 1997b).

Lagrange Multiplier (LM) Test for Serial Correlation:

Lagrange Multiplier is one of the alternatives for general serial correlation. It makes use of Breusch-Godfrey large sample test for autocorrelated disturbances. This test can be applied irrespective of whether disturbances follow \(AR(\rho)\) or \(MA(\rho)\) process. Here \(\rho\) is specified as any
positive order. Further, it can also be applied irrespective of appearance of lagged values of the dependent variable among the regressors, i.e. presence of a lagged dependent variable on the right-hand side of the equation. So it is recommended to calculate Breush-Godfrey statistic and respond to any indication of autocorrelation disturbances. Because it is almost certainly more dangerous to incorrectly suppose that autocorrelation is not present than to incorrectly suppose that it is” (Quantitative Micro Software, 1994 & 1995). If $R^2$ exceeds the critical chi-square value at the chosen level of significance, we can reject the null hypothesis, in which case at least one $\rho$ is significantly different from zero (Gujarati 1995). The result indicates that there was evidence of autocorrelation, because the p-value is more that 5%.

Table 5: Breusch-Godfrey Serial Correlation LM Test

<table>
<thead>
<tr>
<th>F-statistic</th>
<th>Prob. F(2,31)</th>
<th>0.8346</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obs*R-squared</td>
<td>0.440597</td>
<td>Prob. Chi-Square(2)</td>
</tr>
</tbody>
</table>

Source: Output from Eviews (10).

**Granger Causality test:**

In this section we estimate equations 7 and 8. That is, whether trade ratio Granger causes real exchange rate or vice versa. Since these two variables are stationary and we assume that their residuals are uncorrelated, which are the conditions of Granger Causality test, and the optimum lag is 3, which is the lowest Akike Information Criteria (AIC), we can proceed to test Granger causality. We test the null hypothesis by using F-test, and the guidelines for that is the p-value, and %5 level of significance.

Table 6: Granger Causality Tests

<table>
<thead>
<tr>
<th>Null Hypothesis:</th>
<th>Obs</th>
<th>F-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>LONTR does not Granger Cause LONRE</td>
<td>36</td>
<td>8.56626</td>
<td>0.0003</td>
</tr>
<tr>
<td>LONRE does not Granger Cause LONTR</td>
<td>0.55049</td>
<td>0.6519</td>
<td></td>
</tr>
</tbody>
</table>

Source: Output from Eviews (10).

The null hypothesis cannot be rejected since TR pose no Granger cause RE because it has strong predictive power, and we accept the alternative hypothesis that TR does Granger cause RE, but the null hypothesis is not rejected since RE does not cause TR because it has little predictive power and the hypothesis of no Granger causality is easily accepted. So, it is assured that Granger causality runs in unidirectional manner from TR to RE and not vice versa.

**Impulse Response Functions (IRFs):**

IRF is the optimal method to derive proof from the J-curve. So, the current study used general IRF which showcases many insights about dynamic relationships present. This further showcases the response of a variable to an unpredented shock in another variable in each time horizon (Kalyoncu et al. 2009). For the purpose of providing add-on information into dynamic responses of trade balance, the current study made use of generalized IRFs. In spite of the fact that the tests were done for complete variables in the system, here we’ve reported only those results of trade balance responses to innovation in exchange rate. The primary aim of the study is to identify whether or not, J-curve exists for Sudan. In case of its presence, the trade balance response to devaluation is portrayed in the form of J-shape. This indicates that devaluation indeed deteriorates the trade
balance, while improvement occurs only after several years. The impulse response functions attempt to find the effects of a shock to endogenous variable on the other variables in the system. The IRFs track the trade balance’s dynamic response with one standard deviation. IRFs can be utilized to decode the presence of J-curve theory in Sudan economy. Figure 1 shows the results of the study.

Figure 1: Response to Cholesky one standard deviation real exchange rate innovation. Response to Cholesky One S.D. (d.f. adjusted) Innovations

Figure 1 shows the results that Sudanese trade balance follows no J-curve after RER. To be specific, the estimates obtained recommend that there was a deterioration in the trade balance in first two years upon RER. However it got improved and reached the equilibrium after 5 years of time. But, it then got deteriorated, following S-curve pattern.

The current study applied the established CUSUM and CUSUMQ tests to the residuals of optimum model in order to assess the stability of short-run as well as long-run coefficient estimates in equation (2). The CUSUM test checks the residuals’ cumulative sum. The plot developed in this test has cumulative sum against time. There are two critical lines shown herewith. The test identifies the parameter instability, when the cumulative sum is out of the area between two critical lines.
The researchers plotted CUSUM and CUSUMQ statistics against break points or break dates. In case if the plots of these statistics stay back within 5% significance level, it can be understood that the coefficients are stable. It is to be noted that 5% critical values get altered with break points and are projected as two straight lines. Since the blue lines lay inside the red lines means that the model is stable.
CONCLUSION AND POLICY RECOMMENDATIONS

We have investigated in the present research article whether J-curve pattern is observed in Sudanese pound devaluation with a decline in trade balance during the initial times coupled with improvement in long-run. The current study made use of secondary data from different sources such as Direction of Trade Statistics, International Financial Statistics, various issues, both published by IMF and Central Bureau of Statistics, Khartoum, Sudan and Central Bank of Sudan. The methodology used was based on ARDL “bounds-testing” approach advanced by Pesaran and Pesaran et al., a wide application in this type of research and generalized impulse response function. The results inferred the proof for co-integration among the variables such as foreign income, domestic income, trade balance, and real exchange rate variables.

The generalized impulse response function analysis results indicate that J-curve could not be seen for a short-run. Granger causality test is executed in unidirectional way from trade ratio to real exchange rate and not vice versa. As a result, the real exchange rate devaluation exerted no significant positive long run impact on trade balance in Sudan. Therefore, a continuously devaluing currency may lead to further deficits in balance of trade. Sudan’s government should give more attention not only to agricultural sector, but also the manufacturing sector to produce the consumption goods, and benefit from the value added, capital inflows-mainly foreign investment, foreign aid and financial remittances of Sudanese working abroad, to cause the real exchange rate to appreciate. Private sector can contribute to narrowing the trade deficit by investing in import-substitution and export products. Tourism sector should be activated, because Sudan is access with natural views and historical antiquities that attract tourists.

Exchange rate policy and trade liberalization are key issues to address serious trade imbalance in Sudan. The trade balance determinations of Sudan may be explained by two major propositions i.e., real exchange rate movements and trade balance are heavily impacted by exogenous factors. Thus, the change in one of the variables can explain the change in other variable only up to certain extent. Further, the relationship between the variables remain bidirectional. We come to conclude that the devaluation of the Sudanese pound is necessary, but it remained insufficient to arrive at an insightful transformation in the competitive advantage position of the country. Therefore, we recommend some policy measures to be taken by the government to be reliable with reduction of imports and increasing exports.

Limitations and further research:

The cointegration model estimation demands huge sample size to develop sufficient degrees of freedom for assessment. Likewise, the small sample size data remains a challenge as Sudan is yet to publish its high frequency data. This challenge exists for annual data records too in terms of comprehensiveness, consistency, availability, creditability, and reliability. But there are some cointegration studies using annual data with relatively small sample size. The future studies are recommended to have large sample size so that the results can be reliable and robust. Further few other limitations also need to be overcome in future studies. The limitations, on the contrary, open new paths for developing new research investigations. The current study made the community aware of few variables which influence the concludes and emphasized the need for international studies and in-depth analyses.
REFERENCES

21. International Monetary Fund, Directions of Trade, various issues.