ERF Working Papers Series

The Effects of Exchange Rate Changes on Sudanese Output: An Asymmetric Analysis using the NARDL Model

Mesbah Fathy Sharaf and Abdelhalem Mahmoud Shahen

Economic Research Forum
منتدى البحوث الاقتصادية

Working Paper No. 1640
July 2023

THE EFFECTS OF EXCHANGE RATE CHANGES ON SUDANESE OUTPUT: AN ASYMMETRIC ANALYSIS USING THE NARDL MODEL

Mesbah Fathy Sharaf and Abdelhalem Mahmoud Shahen

Working Paper No. 1640

July 2023

Send correspondence to:
Mesbah Fathy Sharaf
Department of Economics, Faculty of Arts, University of Alberta, Canada
Email: sharaf@ualberta.ca

First published in 2023 by
The Economic Research Forum (ERF)
21 Al-Sad Al-Aaly Street
Dokki, Giza
Egypt
www.erf.org.eg

Abstract

This study tests the hypothesis that the real effective exchange rate changes have an asymmetric impact on the domestic output in Sudan from 1960 to 2020. The analysis uses a multivariate framework by controlling for the various channels through which exchange rate changes could affect domestic output. To disentangle the potential asymmetric impact of exchange rate changes on domestic income, we use the nonlinear autoregressive distributed lag (NARDL) framework of Shin et al. (2014) to separate real currency appreciations from depreciation. The results show that fiscal policy has no statistically significant effect on domestic output, while monetary policy has a statistically significant long-run contractionary effect. Results of the NARDL model show long-run asymmetry in the effect of real currency appreciations and depreciations. In particular, real currency appreciations (depreciations) have an expansionary (contractionary) effect on domestic output. There is a considerable difference in the magnitude of the effect of the positive exchange rate shocks compared to the negative shocks, in which the magnitude of the effect of the real currency appreciations on domestic output is almost double that of real currency deprecations. Monetary authorities in Sudan can use the real exchange rate as an effective instrument to affect domestic output in the long run.

Keywords: nonlinear ARDL, asymmetric effects, real effective exchange rate, domestic production, Sudan.

JEL Classification: F31, F41, F62

ملخص

تهدف هذه الدراسة إلى اختبار فرضية أن تغيرات سعر الصرف الحقيقي الفعال لها تأثير غير متماثل على الناتج المحلي في السودان خلال الفترة (1960 2020). ولتحقيق ذلك الهدف تستخدم الدراسة المنهج التحليلي القياسي في ظل نموذج متعدد المتغيرات، من خلال التحكم في القنوات المختلفة التي يمكن أن تؤثر من خلالها تغيرات أسعار الصرف على الناتج المحلي، وبهدف تحليل التأثير غير المتماثل المحتمل لتغيرات سعر الصرف على الدخل المحلي، تستخدم الدراسة نموذج وقد أوضحت النتائج أن (NARDL). الانحدار الذاتي ذي الفجوات الزمنية الموزعة غير الخطية السياسة المالية ليس لها تأثير ذو معنوية إحصائية على الناتج المحلي، في حين أن السياسة النقدية لها أن هناك (NARDL) تأثير انكماشي من الناحية المعنوية في الأجل الطويل. وتظهر نتائج نموذج عدم تماثل طويل الأجل في تأثير ارتفاع قيمة العملة الحقيقية وانخفاض قيمتها. على وجهـ الخصوص، فإن ارتفاع قيمة العملة الحقيقية (انخفاض القيمة) لهـ تأثير توسعي (انكماشي) على الناتج المحلي. كما أوضحت النتائج أن هناك فرق كبير في حجم تأثير الصدمات الإيجابية لسعر الصرف مقارنة بالصدمات السلبية، حيث يكون حجم تأثير ارتفاع قيمة العملة الحقيقية على الناتج المحلي تقريبًا ضعف تأثير انخفاض قيمة العملة الحقيقية. وتعد الدراسة الحالية هي الأولى من نوعها التي تبحث في الآثار غير المتماثلة لتغيرات سعر الصرف الحقيقي على الإنتاج المحلي في السودان .وتوصي الدراسة السلطات النقدية في السودان باستخدام سعر الصرف الحقيقي كأداة فعالة للتأثير على الناتج المحلي في الأجل الطويل.

1. Introduction

Changes in the exchange rates are widely perceived to affect most macroeconomic variables, including consumption, investment, interest rates, exports, imports, inflation, and domestic production (Bahmani-Oskooee & Mohammadian, 2016). Also, currency changes are becoming increasingly important, with varying effects on economic growth in developing countries (Kandil & Mirzaie, 2005). Traditionally, a country devalues or allows its currency to depreciate to become more competitive by exporting more and expanding its domestic production (Bahmani-Oskooee & Arize, 2020). Previous studies examining the impact of exchange rate changes on domestic income mostly focused on developed nations, with limited attention given to developing countries. Developing economies, such as Sudan, have received little attention in this regard, possibly due to a lack of research interest and data unavailability.

The impact of exchange rate fluctuations on domestic production in Sudan is timely and germane, given the significant changes in the Sudanese exchange rate in recent years. In Sudan, we are apriori unsure about the effects of currency fluctuations on output. As a result, the question of whether currency devaluation helps economic growth in Sudan is still to be empirically resolved. Previous related studies did not find any evidence of a significant relationship between Sudan's output and the real value of the Sudanese pound. This lack of a significant relationship could be due to the implicit assumption in these earlier studies that exchange rate fluctuations have symmetric effects on output. As a result, the current study aims to test the hypothesis that the Sudanese real effective exchange rate changes have an asymmetric effect on domestic production. The motive behind using asymmetric analysis is that recent theoretical and empirical studies found that most economic variables have significant nonlinearities and asymmetries in their adjustment behaviour (Nusair, 2021). Nonlinearity analyses also help to find and verify the asymmetric long-run impact of exchange rate fluctuations on output. This asymmetric analysis for Sudan is the first attempt in the literature the authors are aware of.

Based on the hypothesis that changes in the real exchange rate may have an asymmetric influence on output, our objective is to examine the short- and long-run relationship between Sudan's real GDP and the real effective exchange rate during the period 1960-to 2020, and investigate the asymmetric effects of currency appreciations and depreciation on the domestic output of Sudan, by making use of the nonlinear autoregressive distributed lag (NARDL) method of Shin et al. (2014), to be able to isolate currency depreciation from appreciations. We will use the real effective exchange rate (ER) to measure the real exchange rate. This metric uses a weighted average of the real exchange rates for a country's trading partners based on various weighting criteria.

The rest of the paper is organized as follows. Section 2 briefly overviews the evolution of the exchange rate regimes in Sudan. Section 3 presents a snapshot of the related empirical literature. Section 4 discusses the data and the econometric methodology. Section 4 presents and discusses the results, and Section 5 concludes the paper.

2. Evolution of the Exchanger rate regimes in Sudan: An overview

Over the past decades, Sudan has been alternating between several exchange rate regimes, and in general, Sudanese pound (the Republic of Sudan's fundamental currency) has been devalued many times during the study period as shown in figure (1). Following the 1956's declaration of independence until September 1978, the monetary authority adopted a fixed exchange rate regime in which the exchange rate was set at around one Sudanese pound to 2.85 US dollars (Arabi, 2020).

Insert figure 1 here.

With the assistance of the International Monetary Fund (IMF) and the World Bank's structural adjustment programs, the Sudanese government transitioned from a fixed to a floating exchange rate system in 1979 (Ebaidalla, 2016). Starting 1980s, Sudan's currency rate saw a series of successive devaluations, but it was slight, where it ranged between 0.0005 and 0.0045 during the period (1980-1990). Following the early 1990s' economic transformations, Sudan's economy turned from the state-controlled policies of the 1970s and 1980s to free-market policies in 1992. The authorities subsequently initiated an economic recovery program, outlawed black-market currency rates and declared them illegal (Ebaidalla, 2014). Accordingly, the government significantly devalued the pound between 1991 and 1996 from 0.007 to 1.3 pounds per U.S. dollar.

When the United States implemented economic sanctions on Sudan in 1997, the Sudanese pound's external value dropped again. This devaluation continued to reach significantly to about 2.5 pounds per U.S. $ in 1999. Starting from the year 2004, there was an improvement in the value of the Sudanese currency, but due to the 2008 global financial crisis, and the following reduction in oil prices, another series of devaluations happened in the exchange rate. In addition, South Sudan's separation from the Republic of Sudan resulted in a considerable loss for the Sudanese economy, which lost two-thirds of its oil production and caused a sharp decline in the sources of foreign currencies. All these adverse shocks prompted the Sudanese monetary authorities to devalue the Sudanese currency significantly (Omer, 2019). By the end of 2015, the exchange rate was approximately six pounds per dollar, as shown in figure (1).

Since the year 2016, the downturn in the economy has continued to reflect more devaluations in the Sudanese currency due to the aforementioned problems, which resulted in an unprecedented shortage of foreign currencies, especially after the government cut energy subsidies (fuel and electricity). Consequently, the exchange rate of the Sudanese pound against the dollar has reached unprecedented levels, from 6.2 pounds per dollar in 2016 to 54 by the end of 2020.

At the beginning of the year 2021, a tremendous and unusual devaluation happened in the pound of Sudan, where Sudan's transitional government launched a managed floating exchange rate system. This resulted in an increase in the exchange rate of the U.S. dollar against the Sudanese pound from fifty-three pounds (the average in 2020) to 375 (in Feb 2021), which means that the Sudanese national currency lost more than 600% of its external value. Consequently, the rate of inflation in Sudan reached 304 percent, considered one of the world's highest (*Sudan’s Exchange Rate*, 2021). After that period, severe fluctuations in the exchange rate continued. According to the Central Bank of Sudan, in April 2022, the exchange rate for Sudan increased to 445 pounds per U.S. dollar and crossed 630 pounds in the black market (CBOS, 2022). This abnormal loss of external value of the Sudanese pound during the past decade was reflected in the deteriorating economic conditions and caused more loosening of inflation levels.

3. Theoretical and Empirical Literature

Theoretically, exchange rate changes could affect domestic output through their effect on the domestic aggregate demand and aggregate supply (Kandil & Mirzaie, 2005). A devaluation or a depreciation of a country's currency makes its exports more competitive in the global markets, leading to an increase in net exports which would have an expansionary effect on the aggregate demand. However, if a country is heavily dependent on imports for manufacturing, a devaluation or depreciation in the external value of the local currency can also lead to an increase in production costs which would have a contractionary impact that acts by shrinking the aggregate supply (Krugman & Taylor, 1978). To sum up, currency depreciation or devaluation, as per the macroeconomic theory, affects output via two channels: first, on the demand side, through the effect on exports, imports, and domestic expenditures, and second on the supply side, through the effect on the cost of imported inputs (Gylfason & Schmid, 1983). The overall effect on output depends on the balance between the expansionary effect on aggregate demand and the contractionary effect on aggregate supply.

Most of the early attempts that investigated the impact of currency changes on domestic output used panel models, and not time-series models, probably due to the lack of long time-series data for many countries (Bahmani-Oskooee & Mohammadian, 2016). For instance, Morley (1992) used cross-section data to check the impact of real devaluations on output within the less developing countries' stabilization programs and found that such devaluations significantly negatively affected output. Panel cointegration techniques were also widely utilized during the years 1993 to 2000. For example, Miteza (2006) examined the influence of devaluations on aggregate output for five transition economies (Poland, Hungary, the Czech Republic, Slovakia, and Romania) and found that currency devaluations are contractionary in the long run.

In recent years, there has been a trend of increased use of time-series models in investigating the exchange rate-output nexus due to the availability of long-term time-series data from the 2000s (Bahmani-Oskooee & Mohammadian, 2017). While some investigations show evidence of expansionary devaluations, others found indications of contractionary devaluations. Depreciation or devaluation of a currency could have a stimulatory impact on domestic output, which is consistent with the traditional view. However, most of the available research on the effects of exchange rate changes on domestic output empirically supports the “Contractionary Devaluations” hypothesis, meaning that there is a negative relationship between the exchange rate and domestic output. For empirical evidence on contractionary devaluations hypothesis, see the findings of Kamin & Rogers (2000) for Mexico, El-Ramly & Abdel-Haleim (2008) for Egypt, Shahbaz et al. (2012) for Pakistan and An et al. (2014) for Asian countries.

In contrast, a second group of studies adhere to the traditional perspective and support the view that devaluations or depreciation have an expansionary impact on domestic output. Examples of this viewpoint can be found in the work of Gylfason & Schmid (1983) in a group of developed and developing countries, Bahmani-Oskooee & Rhee (1997) in Korea, Narayan & Narayan (2007) in Fiji, and Ratha (2010) in India.

A third group of studies found that devaluation or depreciation could have mixed effects (positive and negative) on output. For instance, Mills & Pentecost (2001) studied the relationship between changes in the real exchange rate and output in four transitional economies and found that in some countries, such as the Czech Republic and Hungary, the real exchange rate is not a significant indicator of long-term GDP levels. The results were expansionary in the case of Slovakia but contractionary in Poland. Ayen (2014) found that currency devaluations in Ethiopia could be contractionary in the long run but have a neutral impact in the short run. Finally, real exchange depreciation or devaluation may not affect output. The findings of several studies support this neutrality hypothesis. For example, Upadhyaya & Upadhyay (1999) conducted a study on this relationship in a group of Asian emerging nations (India, Malaysia, Pakistan, the Philippines, Sri Lanka, and Thailand) and found that currency devaluations had no impact on output.

Few studies have investigated the linkage between exchange rate changes and domestic output in Sudan. For example, Elsheikh et al. (2012) examined the relationship between the exchange rate, world prices and Sudan's agricultural sector, focusing on food security and welfare. They found that currency depreciations could increase domestic production and exports, while currency appreciations would have the opposite effect. In another study, Azharia et al. (2010) used a CGE model to analyze the effects of the exchange rate policy on the Sudanese economy. They found that depreciation leads to an increase in GDP and improved trade balance, while appreciation leads to a decrease in GDP and an increase in private consumption. The study concluded that currency depreciations favours the economy and agricultural sector more than appreciations.

Earlier research considered that the impact of currency changes on domestic output is symmetrical. Consequently, linear models like the linear autoregressive distributed lag (ARDL) were often used. This means that a depreciation of X% would lead to a reduction in domestic output by Y%, and an appreciation of X% would result in an increase in domestic output by Y% (similar proportion) (Bahmani-Oskooee & Arize, 2020). In practice, changes in the exchange rate may have an asymmetric impact on output. A devaluation or a depreciation of the currency that increases net exports could have an expansionary effect. However, the impact on exports and domestic output may not be immediately apparent due to lags in adjustment, such as production delays, decision delays, delivery delays, and recognition delays. This can result in a contractionary depreciation (Bahmani-Oskooee & Mohammadian, 2016; Nusair, 2021).

Recent empirical studies have shown that the econometric results of the nonlinear models that involve asymmetry analysis are considerably more accurate than those based on linear models. For instance, when Bahmani-Oskooee et al. (2018) used the linear ARDL model to estimate the long-run relationship between exchange rate changes and output in Turkey, they found no long-term association. However, once they employed the nonlinear ARDL model, the results were completely different, where both currency depreciation and appreciation were shown to be expansionary. Several studies have employed the nonlinear autoregressive distributed lag (NARDL) technique to differentiate currency appreciations from depreciations and found evidence of asymmetric impacts of exchange rate fluctuations on domestic output. For evidence on the asymmetric impact of exchange rate changes on the domestic output, see the findings of Bahmani-Oskooee & Mohammadian (2016) for Australia, Bahmani-Oskooee & Mohammadian (2017) for Japan, and Sharaf & Shahen (2023) for Egypt.

Several recent studies have examined the potential asymmetric output responses to exchange rate changes for various countries and have generally found evidence of asymmetric impacts (Bahmani-Oskooee & Arize, 2020). This shows that currency appreciations might affect a country's output differently than currency depreciations. Following this growing research, to the best of the authors' knowledge and to date, the current study is among the first attempts to examine the potential asymmetric impact of real exchange rate changes on domestic output in Sudan over a long time period ranging from 1960 to 2020.

4. Data and methods

In the current study, we adopt the model in Equation (1) following several earlier studies, such as Nusair (2021), and Sharaf & Shahen (2023). The merit of this model is that it captures the aggregate demand and the aggregate supply channels via which the exchange rate could affect domestic output within a multivariate framework.

$$Y_t = \beta_0 + \beta_1\, ER_t + \beta_2\, G_t + \beta_3\, MS_t + \beta_4\, oil\ price_t + \varepsilon_t \qquad (1)$$

Where Y_t is the real gross domestic product, ER_t is the real effective exchange rate, MS_t is the money supply, as a proxy for the monetary policy, G_t is the government spending, a proxy for the fiscal policy, $oil\ price_t$ is the global price of oil (included to capture the aggregate supply channel), ε_t is the random error term.

The analyses cover the period from 1960 to 2020. The data on all the variables, except the real effective exchange rate, is drawn from the World Development Indicators. The real effective exchange rate is obtained from Bruegel's database Darvas (2021).

All the variables are in real terms, in local currency units, and are expressed in natural logarithmic form. The global oil price, which is converted to local currency units using the official nominal exchange rate. For more details on how the real effective exchange rate is constructed see Darvas (2021).

Cointegration between the variables is tested using the bounds test for cointegration within a NARDL-UECM model. The validity of the bounds tests of cointegration requires the order of integration of all the variables to be less than two I(2). In this regard, the order of integration of the variables is checked using the Augmented Dickey-Fuller

(ADF) unit root test. If cointegration is founded between the variables, the long-run and short-run asymmetric impact of the ER on Y is estimated by decomposing the ER changes into positive changes, ($ER_t^+ = \sum_{i=1}^{t} \Delta ER_t^+ = \sum_{i=1}^{t} \max(ER_i, 0)$), and negative changes, ($ER_t^- = \sum_{i=1}^{t} \Delta ER_t^- = \sum_{i=1}^{t} \min(ER_i, 0)$) . Where the ER_t^+ and ER_t^- are the partial sums of the positive and negative changes in the ER, respectively.

To disentangle the potential asymmetric impact of exchange rate changes on domestic income, we use the nonlinear autoregressive distributed lag (NARDL) framework of Shin et al. (2014) to separate real currency appreciations from depreciation. Equation (2) presents the NARDL model to examine the presence of an asymmetric equilibrium relationship between the ER and Y in both the short-run and the long-run.

$$\Delta Y_t = \varphi_1 + \sum_{i=1}^{p} \eta_{1i} \Delta Y_{t-i} + \sum_{i=1}^{r} \eta_{3i} \Delta G_{t-i} + \sum_{i=1}^{s} \eta_{4i} \Delta MS_{t-i} + \sum_{i=1}^{m} \eta_{5i} \Delta oil\, price_{t-1} + \sum_{i=1}^{l} \eta_{6i} \Delta ER_{t-i}^+ + \sum_{i=1}^{v} \eta_{7i} \Delta ER_{t-i}^- + \omega_1 Y_{t-1} + \omega_3 G_{t-1} + \omega_4 MS_{t-1} + \omega_5 oil\, price_{t-1} + \omega_6 ER_{t-1}^+ + \omega_7 ER_{t-1}^- + \varepsilon_t \quad (2)$$

In which Δ is a first difference operator, and the rest of the variables are as defined before. p, q, r, s, m, l, v are the optimal lag order determined based on the AIC information criterion.

The bounds test approach for cointegration uses an F-test for the joint significance of the coefficients of the lagged level variables (H_0: $\omega_1 = \omega_2 = \omega_3 = \omega_4 = \omega_5 = \omega_6 = \omega_7 = 0$). Cointegration between the variables is established if the F- statistic exceeds the upper bound critical values.

To estimate the asymmetric short run impact of the ER on Y, equation 2 has to be expressed as an error correction model, as depicted in equation (3).

$$\Delta Y_t = \omega_1 + \sum_{i=1}^{p} \alpha_{1i} \Delta Y_{t-i} + \sum_{i=1}^{r} \alpha_{3i} \Delta G_{t-i} + \sum_{i=1}^{s} \alpha_{4i} \Delta MS_{t-i} + \sum_{i=1}^{m} \alpha_{5i} \Delta oil\, price_{t-1} + \sum_{i=1}^{l} \alpha_{6i} \Delta ER_{t-i}^+ + \sum_{i=1}^{v} \alpha_{7i} \Delta ER_{t-i}^- + \mu\, ECT_{t-1} + u_t \quad (3)$$

The speed of adjustment of the variables to their long-run equilibrium following any shock is captured by the coefficient of the error-correction term μ. The ER's short-term and long-run asymmetric impact on Y is also examined by deriving the cumulative dynamic multiplier, which measures the percentage point change in Y resulting from a one percent change in ER^{+}_{t-1} and ER^{-}_{t-1}.

5. Empirical Results

The ADF unit root test results, displayed in Table 1, reveal that none of the variables is integrated of an order greater than one, which would validate the use of the cointegration bounds test.

Insert Table 1 here

The Schwarz information criterion selected a NARDL (2, 0, 0, 0, 0, 0) model. Results of the cointegration bounds test, presented in Table 2, show a nonlinear long-run cointegration relationship between Y, ER, G, MS, and oil price since the F-statistic is greater than the upper bound of the critical value at the 5% significance level.

Insert Table 2 here

Table 3 presents the short-run and long-run coefficients of the estimated NARDL (2, 0, 0, 0, 0, 0) model. The estimated short-run coefficients show that none of the variables, G, MS, ER, and oil price, affect domestic output in the short run. The estimated error-correction term coefficient has a statistically significant negative sign at the 1% significance level, where 17% of the last period's disequilibrium is corrected in the current period. This means that following a shock, it takes about 5.8 years for Y, G, MS, ER and oil prices to restore their long-run equilibrium relationship.

Estimates of the long-run coefficients reveal that while fiscal policy has a long-run expansionary effect on domestic output, the estimated coefficient is not statistically significant. Monetary policy has a statistically significant long-run contractionary effect on domestic output, where an increase in money supply by 10% reduces domestic output by about 6%. The price of oil has a statistically significant positive long-run effect on domestic output.

As for the effect of the ER, results of the NARDL model show long-run asymmetry, in terms of the magnitude, in the effect of currency appreciations and depreciations. In particular, real currency appreciations have a statistically significant expansionary effect on domestic output, while real currency depreciations have a statistically significant contractionary impact on domestic output at the 10% significance level. There is a considerable difference in the magnitude of the effect of the positive exchange rate shocks compared to the negative shocks, in which the magnitude of the effect of the real currency appreciations on domestic output is almost double that of real currency deprecations.

The competence of the estimated NARDL model is assessed using a set of diagnostic checks. These include the Lagrange multiplier (L.M.) test of residual serial correlation, Ramsey's RESET test for specification error, Jarque-Bera's normality test based on the skewness and kurtosis of residuals, and the Breusch-Pagan-Godfrey's heteroscedasticity test. These tests' results indicate that the estimated NARDL model is free from serial correlation, heteroskedasticity, non-normality of the residuals, and specification errors at the 5% significance level.

Parameters stability diagnostics, including the cumulative sum of recursive residuals test and the cumulative sum of squares of recursive residuals test that are displayed in Figure 2, show that the coefficients of the estimated NARDL models are stable at the 5% significance level.

Insert Figure 2 here.

Figure 3 depicts the dynamic asymmetric multiplier of the NARDL (2, 0, 0, 0, 0, 0) model and reveals an apparent asymmetry, in terms of magnitude, in the long-run adjustment patterns following a shock to the ER. The solid black line of the dynamic multiplier plots shows that a 1% increase in the ER raises the real GDP in the long run by 0.55%. Similarly, the black-dashed line of the dynamic multiplier plots reveals that a 1% decline in the ER lowers real GDP by 0.33% in the long run. Remarkably, the net effect of the ER (thick red-dashed line) is positive and converges to around 0.2% in the long run.

Insert Figure 3 here.

A NARDL asymmetric effects test is conducted to test symmetry in the effect of the ER on domestic output and it. The results show that the null hypothesis of symmetry in effect is rejected in the long run as the p-value of the chi-square statistic is less than the 5% significance level. This result is consistent with the long-run estimates of the NARDL model and the dynamic asymmetric multiplier.

6. Discussion and Conclusion

In this study, we revisited the real exchange rate-output nexus in Sudan over an extended period and by overcoming several caveats in earlier related studies. The very few studies that have addressed this research topic in Sudan generally assumed symmetry in the effect of exchange rate on domestic output. However, the response of output to currency appreciations may differ from that of depreciations, which constitutes a major drawback in these studies. By introducing the asymmetry hypothesis, which considers the nonlinear adjustment of the exchange rate, a new approach can be taken to address the limitations of previous research. Thus, our methodology in this study utilizes the nonlinear autoregressive distributed lag framework proposed by Shin et al. (2014).

In this paper, for the first time, we examine the hypothesis that fluctuations in the real effective exchange rate have an asymmetric impact on the Sudanese domestic output from 1960 to 2020. The methodology also involves a multi-variable approach to consider various factors influencing the relationship between exchange rate and domestic output.

The findings indicate that fiscal policy does not have a statistically significant impact on domestic output, while monetary policy has a long-term negative impact that is statistically significant. By separating real currency appreciations from depreciations and introducing the nonlinear adjustment of the exchange rate, results of the NARDL model indicate that both appreciations and depreciations have statistically significant long-term effects on domestic output in Sudan, but asymmetrically. Notably, our results show that the effect of real currency appreciations on domestic output is nearly twice as strong as real currency depreciations, leading to a marked difference in magnitude.

A real appreciation of the Sudanese pound results in an expansionary effect. This may occur because the rise in the currency's external value makes the imported inputs cheaper, reducing production costs and expanding aggregate supply, outweighing the decrease in aggregate demand. In contrast, real currency depreciations bring about a contractionary effect.

These asymmetric results are similar to the findings of several earlier studies, such as Sharaf & Shahen (2023) for Egypt, Bahmani-Oskooee & Arize (2020) for Algeria, Kenya, Morrocco, Tanzania, and Uganda and Bahmani-Oskooee et al. (2018) for Hungary, in which real currency appreciation are expansionary in their effect on output. Our results are also in line with those of Nusair (2021) for Malaysia and Bahmani-Oskooee & Arize (2020) for Cameron Ethiopia, Kenya, Mauritius, and Morocco, under which depreciation results in contractionary effects.

Based on the result that real currency depreciations have a contractionary output effect, one policy implication would be that relying on the exchange rate devaluations to stimulate exports and increase aggregate demand for promoting economic growth is not viable for Sudan. Additionally, this finding could provide the Central Bank of Sudan with a basis to defend its foreign exchange interventions against depreciations and not depend on currency devaluation.

On the other side, the result that real appreciation of the currency results in an expansionary effect implies that a robust Sudanese pound would be more favourable for Sudan's output. In conclusion, our research suggests that the monetary authorities in Sudan can use the real exchange rate to affect domestic output in the long run. This new finding, which introduces the consideration of nonlinear exchange rate adjustment, is not present in the existing literature.

References

An, L., Kim, G., & Ren, X. (2014). Is devaluation expansionary or contractionary: Evidence based on vector autoregression with sign restrictions. *Journal of Asian Economics*, *34*, 27–41. https://doi.org/10.1016/j.asieco.2014.03.003

Arabi, K. (2020). *Optimum Exchange rate and Economic Growth in Sudan* [MPRA Paper]. https://mpra.ub.uni-muenchen.de/104128/

Ayen, Y. W. (2014). The effect of currency devaluation on output: The case of ethiopian economy. *Journal of Economics and International Finance*, *6*(5), 103–111. https://doi.org/10.5897/JEIF2013.0548

Azharia, A., Elbushra, A., Elsheikh, O., & Salih, A. (2010). Impact of exchange rate reforms on Sudan's economy: Applied general equilibrium analysis. *African Journal of Agricultural Research*, *5*, 442–448.

Bahmani-Oskooee, M., & Arize, A. C. (2020). Asymmetric response of domestic production to exchange rate changes: Evidence from Africa. *Economic Change and Restructuring*, *53*(1), 1–24. https://doi.org/10.1007/s10644-018-9240-y

Bahmani-Oskooee, M., Halicioglu, F., & Mohammadian, A. (2018). On the asymmetric effects of exchange rate changes on domestic production in Turkey. *Economic Change and Restructuring*, *51*(2), 97–112. https://doi.org/10.1007/s10644-017-9201-x

Bahmani-Oskooee, M., & Mohammadian, A. (2016). Asymmetry Effects of Exchange Rate Changes on Domestic Production: Evidence from Nonlinear ARDL Approach. *Australian Economic Papers*, *55*(3), 181–191. https://doi.org/10.1111/1467-8454.12073

Bahmani-Oskooee, M., & Mohammadian, A. (2017). Asymmetry effects of exchange rate changes on domestic production in Japan. *International Review of Applied Economics*, *31*(6), 774–790. https://doi.org/10.1080/02692171.2017.1324410

Bahmani-Oskooee, M., & Rhee, H.-J. (1997). Response of Domestic Production to Depreciation in Korea: An Application of Johansen's Conintegration Methodology. *International Economic Journal*, *11*(4), 103–112. https://doi.org/10.1080/10168739700000029

CBOS. (2022). *Daily Rates for Foreign Currency | CBOS*. https://cbos.gov.sd/en/exchange-rates

Ebaidalla, E. (2014). The Effects of Oil Price Volatility on the Sudanese Economy. *Eastern Africa Social Science Research Review*, *30*, 1–26. https://doi.org/10.1353/eas.2014.0000

Ebaidalla, E. (2016). Understanding the Sources of Exchange Rate Fluctuation in Sudan. *Eastern Africa Social Science Research Review*, *32*, 21–40. https://doi.org/10.1353/eas.2016.0004

El-Ramly, H., & Abdel-Haleim, S. (2008). The Effect of Devaluation on Output in the Egyptian Economy: A Vector Autoregression Analysis. *International Research Journal of Finance and Economics ISSN Issue*, *14*, 1450–2887.

Elsheikh, O., Elbushra, A., & Salih, A. (2012). Impacts of Changes in Exchange Rate and International Prices on Agriculture and Economy of the Sudan: Computable General Equilibrium Analysis. *Sustainable Agriculture Research*, *1*. https://doi.org/10.5539/sar.v1n2p201

Gylfason, T., & Schmid, M. (1983). Does Devaluation Cause Stagflation? *The Canadian Journal of Economics / Revue Canadienne d'Economique*, *16*(4), 641–654. https://doi.org/10.2307/135045

Kamin, S. B., & Rogers, J. H. (2000). *Output and the real exchange rate in developing countries: An application to Mexico*. 3.

Kandil, M., & Mirzaie, I. (2005). The Effects of Exchange Rate Fluctuations on Output and Prices: Evidence from Developing Countries. *The Journal of Developing Areas*, *38*(2), 189–219.

Krugman, P., & Taylor, L. (1978). Contractionary effects of devaluation. *Journal of International Economics*, *8*(3), 445–456. https://doi.org/10.1016/0022-1996(78)90007-7

Mills, T. C., & Pentecost, E. J. (2001). The real exchange rate and the output response in four EU accession countries. *Emerging Markets Review*, *2*(4), 418–430. https://doi.org/10.1016/S1566-0141(01)00027-9

Miteza, I. (2006). Devaluation and Output in Five Transition Economies: A Panel Cointegration Approach of Poland, Hungary, Czech Republic, Slovakia and Romania, 1993-2000. *Applied Econometrics and International Development*, *6*(1). https://ideas.repec.org/a/eaa/aeinde/v6y2006i1_6.html

Morley, S. A. (1992). On the Effect of Devaluation During Stabilization Programs in LDCs. *The Review of Economics and Statistics*, *74*(1), 21–27. https://doi.org/10.2307/2109538

Narayan, P. K., & Narayan, S. (2007). Is devaluation expansionary or contractionary? Empirical evidence from Fiji. *Applied Economics*, *39*(20), 2589–2598. https://doi.org/10.1080/00036840600707266

Nusair, S. A. (2021). The Asymmetric Effects of Exchange Rate Changes on Output: Evidence from Asian Countries. *The International Trade Journal*, 1–26. https://doi.org/10.1080/08853908.2021.1940392

Omer, O. (2019). *Real Effective Exchange Rate in Sudan,Measurement and Trend Analysis (1975-2017)*. *2*, 192–208.

Ratha, A. (2010). Does Devaluation work for India? *Economics Bulletin*, *30*(1), 247–264.

Shahbaz, M., Islam, F., & Aamir, N. (2012). Is devaluation contractionary? Empirical evidence for Pakistan. *Economic Change and Restructuring*, *45*(4), 299–316. https://doi.org/10.1007/s10644-011-9119-7

Sharaf, M. F., & Shahen, A. M. (2023). Asymmetric impact of real effective exchange rate changes on domestic output revisited: Evidence from Egypt. *International Trade, Politics and Development*. https://doi.org/10.1108/ITPD-09-2022-0020

Shin, Y., Yu, B., & Greenwood-Nimmo, M. (2014). Modelling Asymmetric Cointegration and Dynamic Multipliers in a Nonlinear ARDL Framework. In R. C. Sickles & W. C. Horrace (Eds.), *Festschrift in Honor of Peter Schmidt: Econometric Methods and Applications* (pp. 281–314). Springer. https://doi.org/10.1007/978-1-4899-8008-3_9

Sudan's exchange rate: New report on how to sustain progress and pre-empt risks. (2021). Radio Dabanga. https://www.dabangasudan.org/en/all-news/article/sudan-s-exchange-rate-new-report-on-how-to-sustain-progress-and-pre-empt-risks

Upadhyaya, K. P., & Upadhyay, M. P. (1999). Output effects of devaluation: Evidence from Asia. *The Journal of Development Studies*, *35*(6), 89–103. https://doi.org/10.1080/00220389908422603

Appendix

List of Tables

Table 1. ADF unit root test results of the variables in level and first difference

	Y	**MS**	**G**	**ER**	**Oil price**
ADF Unit root test of variables in levels					
With Constant	-1.0078 (0.7451)	-1.1611 (0.6856)	-0.0224 (0.9524)	-3.1566** (0.0277)	-2.3136 (0.1711)
With Constant & Trend	-1.6884 (0.7441)	-1.9061 (0.6390)	-1.0928 (0.9216)	-3.1197 (0.1112)	-2.8076 (0.2004)
Without Constant & Trend	2.2825 (0.9941)	2.4046 (0.9957)	2.2210 (0.9932)	-0.0496 (0.6623)	-0.9853 (0.2872)
ADF Unit root test of variables in first difference					
With Constant	-5.5458*** (0.000)	-6.6288*** (0.000)	-7.7491*** (0.000)	-9.3962*** (0.000)	-7.1316*** (0.000)
With Constant & Trend	-5.5506*** (0.000)	-6.5756*** (0.000)	-7.7697*** (0.000)	-9.3073*** (0.000)	-7.0988*** (0.000)
Without Constant & Trend	-4.8543*** (0.000)	-6.1893*** (0.000)	-7.2417*** (0.000)	-9.4796*** (0.000)	-7.1740*** (0.000)

* , **, *** imply rejection of the null hypothesis at the 10%, 5%, and 1% significance level, respectively. Lag length is based on SIC. P-values are in parenthesis. The null hypothesis is that the series is nonstationary.

Table 2: Results of the Cointegration bounds test

				95% Critical bounds	
Dependant variable	Explanatory variables	Specification	F-statistic	I(0)	I(1)
$\Delta(Y)$	$G, MS, oil\ price, ER^{+}ER^{-}$	NARDL (2, 0, 0, 0, 0, 0)	5.64	3.407	4.632

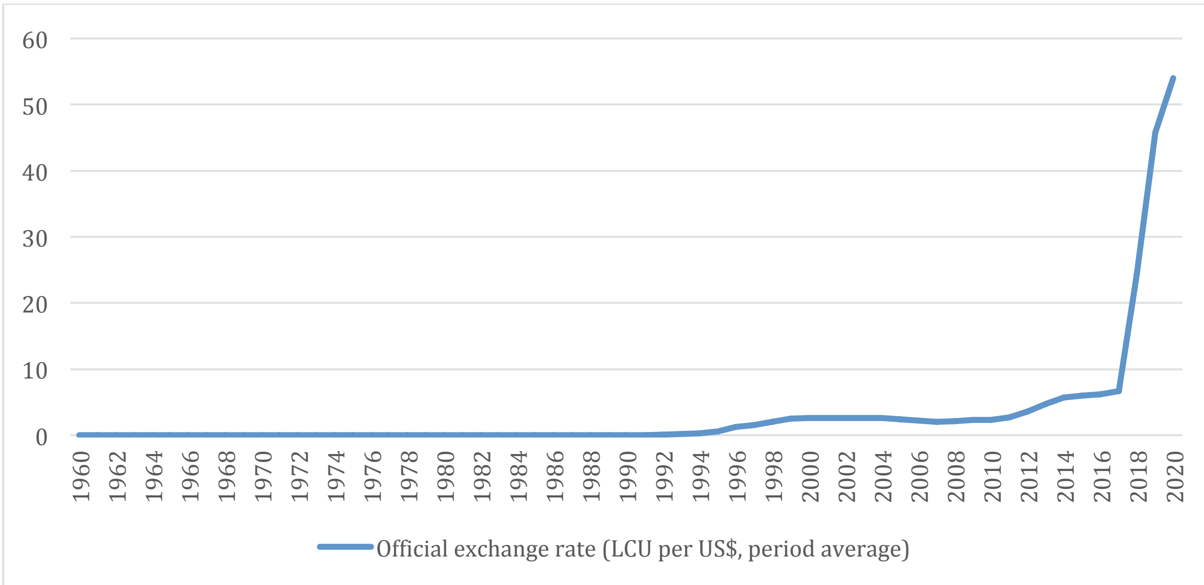
The lower and upper bound critical values are obtained from Pesaran et al (2001)

Table 3: Estimated short run and long run parameters of the NARDL (2, 0, 0, 0, 0, 0) model

	NARDL (2, 0, 0, 0, 0, 0)	
Panel (A)		
Short run coefficients		
$constant$	4.3308***	1.0297
$trend$	0.0032***	0.0009
ΔGDP_{t-1}	0.3908***	0.1159
ECT_{t-1}	-0.1704***	0.0408
Panel B		
Long run coefficients		
MS	-0.6151**	0.312
G	0.1928	0.135
Oil price	0.3989***	0.160
ER^{+}	0.5551*	0.339
ER^{-}	0.3304*	0.196
Diagnostic tests		
Serial correlation	$\chi^2(2) = 0.27$ P value (0.87)	
Heteroskedasticity	$\chi^2(8) = 8.07$ P value (0.42)	
Functional form RESET test	F (1,49) = 0.50 P value (0.48)	
Normality	Jarque-Bera =2.86 P value (0.23)	

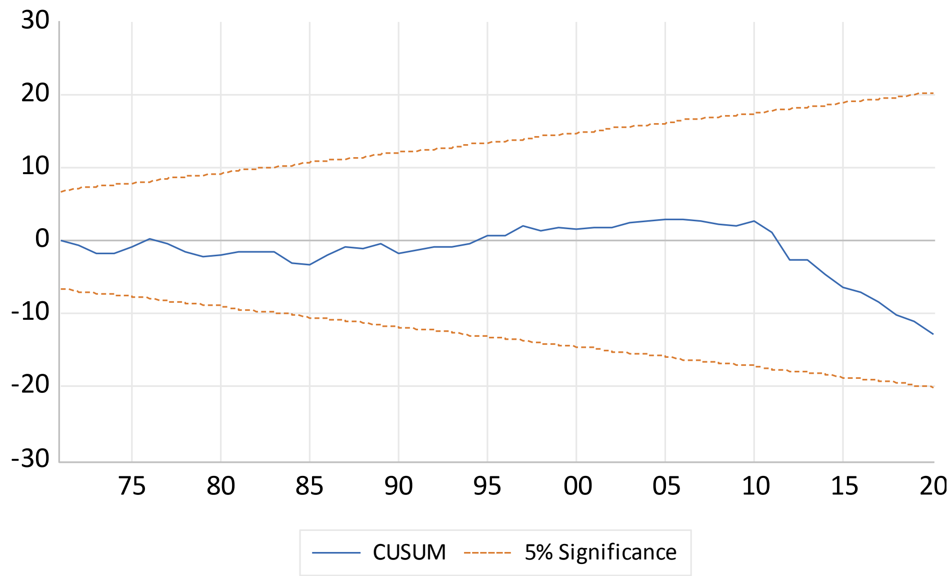
List of Figures

Figure 1. Official exchange rate in Sudan over the period 1960-2020.



Source: Authors' compilation based on data from WDI

Figure 2. **NARDL (2, 0, 0, 0, 0, 0) CUSUM and CUSUMSQ stability plots**



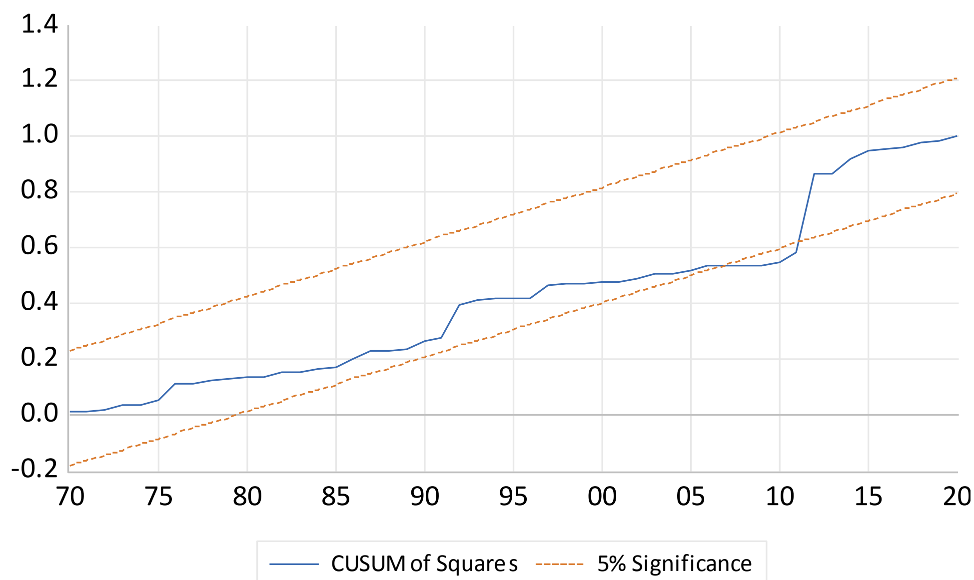


Figure 3. NARDL (2, 0, 0, 0, 0, 0) dynamic asymmetric multiplier