# Does External Debt Drive Inflation in Sudan? Evidence from Symmetric and Asymmetric ARDL approaches

Sharaf, Mesbah Fathy and Shahen, Abdelhalem Mahmoud

Department of Economics, Faculty of Arts, University of Alberta, Edmonton, Canada, Department of Economics, Faculty of Economic Studies and Political Science, Alexandria University, Alexandria, Egypt

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**Mesbah Fathy Sharaf** [*, a]        **Abdelhalem Mahmoud Shahen** [b,c]

[a] Department of Economics, Faculty of Arts, University of Alberta, Edmonton, Canada.
[b] Department of Economics, Faculty of Economic Studies and Political Science,  Alexandria University, Alexandria, Egypt.
[c] Egyptian Cabinet, (IDSC), Cairo, Egypt.
[*] Corresponding Author Email: Sharaf@ualberta.ca

## Abstract

**Purpose**: This study aims to examine the symmetric and asymmetric impact of external debt on inflation in Sudan from 1970 to 2020 within a multivariate framework by including money supply and the nominal effective exchange rate as additional inflation determinants.

**Design/methodology/approach**: We utilize an Auto Regressive Distributed Lag (ARDL) model to examine the symmetric impact of external debt on inflation, while the asymmetric impact is examined using a nonlinear Auto Regressive Distributed Lag (NARDL) model. The existence of a long-run relationship between inflation and external debt is tested using the bounds-testing approach to cointegration, and a vector error-correction model is estimated to determine the short parameters of equilibrium dynamics.

**Findings**: The linear ARDL model results show that external debt has no statistically significant impact on inflation in the long run. On the contrary, the results of the NARDL model show that positive and negative external debt shocks statistically impact inflation in the long run. The estimated long-run elasticity coefficients of both the linear and nonlinear ARDL models reveal that the domestic money supply has a statistically significant positive impact on inflation. In contrast, the nominal effective exchange rate has a statistically significant negative impact on inflation.
**Practical implications:** The reliance on symmetric analysis may not be sufficient to uncover the existence of a linkage between external debt and inflation. Proper external debt management is crucial to control inflation rates in Sudan.

**Originality/Value**: To date, no empirical study has assessed the external debt-inflation nexus and its potential asymmetry in Sudan, and the current study aims to fill this gap in the literature.

## 1. Introduction

The welfare costs of inflation are well acknowledged in the literature. It has been shown that high and non-predictable inflation rates lead to inefficient resource allocation and depress economic growth by distorting relative prices and economic agents' inter- and intra-temporal decisions (Lucas, 2000; Sharaf, 2015). These distortionary effects have motivated a growing literature to examine the drivers of inflation rates, and external debt has been considered one of these drivers.

Traditionally, external borrowing has been widely viewed as a helpful tool for many low-income countries to supplement domestic savings and achieve their development objectives, mainly if the funds are channeled towards increasing productive capacity (Ezeabasili et al., 2011). External borrowing could contribute to accelerated economic growth and support macroeconomic stability. Nevertheless, the accumulation of external debt also carries risks, including excessive debt servicing charges and the potential for a debt overhang, which can harm economic and price stability (Atique & Malik, 2012). Additionally, a debt overhang could create uncertainty and limit a country's future access to financing, hindering investment and sustainable economic growth.

Like many low-income countries, Sudan has increasingly depended on external borrowing to meet its financial needs. In the meantime, Sudan has also witnessed increased rates of inflation. In 2021, the inflation rate in Sudan reached an unprecedented level of over 382%, and Sudan's external debt was over $23 billion, representing 91.8 percent of the country's gross national income in 2020.

Understanding the nature of the relationship between external debts and inflation rates has gained growing interest among academics and policymakers. A growing empirical literature has emerged to investigate the relationship between external debt and inflation in several countries over different periods and using different econometric techniques with inconclusive findings. For a recent literature review, see Aimola & Odhiambo (2020).

We postulate that the mixed findings in the literature could in part be due to the failure of previous related studies to account for the potential asymmetry in the relationship between external debt and inflation. To date, no empirical study has assessed

the external debt-inflation nexus in Sudan, and the current study aims to fill this gap in the literature. In particular, the main objective of the current study is to investigate the impact of external debt on inflation rates in Sudan from 1970 to 2021. We utilize an Auto Regressive Distributed Lag (ARDL) model to examine the nexus between the external debt and the rate of inflation within a multivariate framework by including money supply and the nominal exchange rate as additional drivers of inflation.

The current study's findings would provide important insights into the factors driving inflation in Sudan and the role that external debt plays in exacerbating this problem. By shedding new light on this research topic, the study offers valuable guidance for policymakers seeking to address economic challenges in Sudan and other countries facing similar difficulties.

The rest of the paper is organized as follows: Section 2 overviews the evolution of inflation and external debt in Sudan over the study period. A brief discussion of the theoretical and empirical literature is done in Section 3. Section 4 presents the data and the empirical methodology. The results are presented in Section 5, and Section 6 concludes the paper.

## 2. Evolution of external debt and inflation rate in Sudan

Figure 1 depicts the external debt stocks in billions (DOD, current US$) and the inflation rate (%) in Sudan from 1971 to 2021, highlighting the link between the two variables.

**Insert Figure 1 here.**

Sudan's external debt was relatively low at the start of the 1970s. However, various factors, such as the oil crisis of 1973, rising global interest rates, and increased borrowing to finance development projects, caused rapid growth in external debt and were accompanied by inflationary pressures. Over the 1980s and 1990s, Sudan witnessed a sharp increase in its external debt, with the highest recorded in 1995, amounting to $17.8 billion. The rise in external debt was attributed to various factors, including civil conflict, economic mismanagement, and external shocks. In the 1990s, Sudan's economic policies encountered a significant shift from state-controlled policies to free market policies in

1992, prompting the government to initiate an economic recovery program to boost economic growth (Ebaidalla, 2014). However, this transformation was accompanied by a significant rise in inflation, with Sudan experiencing its highest inflation rate of over 132% in 1996, the largest recorded during that period.

During the mid-1990s and early 2000s, Sudan's external debt was restructured through the Highly Indebted Poor Countries (HIPC) initiative, which helped to ease the burden of debt servicing on the government's finances. This restructuring and the economic recovery program contributed to some improvements in inflation rates (Sudan to Receive Debt Relief Under the HIPC Initiative, 2021). Despite the restructuring of external debt and the improvements in inflation rates in the mid-1990s and early 2000s, the Sudanese economy faced new challenges in the late 2010s, including increased borrowing, falling oil prices, and the global financial crisis of 2008-2009, resulting in a rise in external debt and inflation rates once again.

After South Sudan's secession in 2011, Sudan lost a significant portion of its oil production and the accompanying revenue, a primary source of income for the country. This loss has led to a decrease in foreign exchange reserves and a significant depreciation of the Sudanese pound (Omer, 2019). As a result, inflation rates have been high, and the country has struggled to fund its budget and maintain its economic stability. Additionally, the country has faced other economic challenges, such as the expansion of the informal economy and limited foreign investment (Ebaidalla, 2016).

At the beginning of 2021, Sudan's transitional government launched a managed floating exchange rate system, which resulted in a significant devaluation of the Sudanese pound (Sudan's Exchange Rate, 2021). This devaluation led to a surge in inflation rates, with the annual inflation rate reaching over 382%, the highest rate over the whole study period. In addition, Sudan's external debt remained high, at over $22 billion in 2021. This disadvantaged economic situation has been attributed to various factors, including political instability, economic sanctions, and the COVID-19 pandemic creating difficulties in accessing international aid and trade and hindering Sudan's capacity to sustain economic stability.

To sum up, Sudan has struggled with high external debt and inflation levels for many years. The country's economic difficulties have been exacerbated by the close correlation

between these two economic variables, with external debt levels contributing to inflationary pressures, particularly during economic difficulty.

## 3. Theoretical and Empirical Literature

Several theoretical frameworks have been presented in the literature to explain inflation. Two widely recognized standpoints are the monetarist theory and the fiscal theory of price level. Monetarists believe that inflation is a monetary phenomenon which is caused by an increase in the money supply relative to the output of goods and services in the economy. They argue that if the money supply grows faster than the productive capacity of the economy, then the excess money will increase aggregate demand and ultimately result in higher prices (Friedman, 1968).

The fiscal theory of price level posits that fiscal deficits and debt levels predominantly influence changes in inflation rates. This theory suggests that if the government runs large budget deficits, it may increase inflation rates. This theory was initially proposed by Sargent & Wallace (1981) and has been further developed by subsequent researchers such as Leeper (1991) and Woodford (2000).

Appropriate coordination between fiscal and monetary policies has been proposed as an effective scheme to control inflation rates. For example, Woodford (2000) argues that achieving price stability requires a commitment to suitable monetary policy and appropriate fiscal policy. While the Ricardian equivalence suggests that fiscal policy is insignificant, except for specific policies referred to as "Ricardian policies," it does not imply that fiscal policy is irrelevant. An ideal monetary-fiscal regime would combine a Taylor rule for monetary policy with nominal-deficit targeting as a fiscal policy commitment to achieving desirable outcomes.

A growing empirical literature has emerged to investigate the relationship between external debt and inflation via various estimation techniques and for different countries with mixed findings. While some studies found a positive relationship between debt and inflation (see, e.g. Choong et al., 2010; Sunder-Plassmann, 2020), others have found a negative relation (see, e.g. Sulaiman & Azeez, 2012), while another group of studies found no statistically significant relationship (see, e.g. Essien et al., 2016).

Aimola & Odhiambo (2020) comprehensively reviewed the literature on the relationship between public debt and inflation. The findings suggest a positive relationship between public debt and inflation, but the magnitude of this relationship varies and may change over time. Sunder-Plassmann (2020) investigated the relationship between Mexico's sovereign debt, default, and inflation. By incorporating a mixed debt structure, which includes domestic and foreign borrowing in both nominal and real terms, the author found that a shift away from external debt contributed to the disinflation observed in the mid-1990s. The results also showed that the effects of increasing nominal debt depend on ownership and denomination, as foreign-held nominal debt is inflationary, but domestically-held nominal debt lowers inflation. Choong et al. (2010) examined the impact of the different types of debt on Malaysia's long-term economic growth and found that debts generally have a negative growth effect. The study also explored the relationship between external debt and inflation. It argued that external borrowing leads to monetization, which can impact inflation.

Contrary to the previously mentioned studies that suggest a positive relationship between external debt and inflation, a second group of studies suggest a negative relationship. For instance, Wheeler (1999) examined the macroeconomic impacts of government debt and found support for the Ricardian equivalence hypothesis, where an increase in government debt leads to a decrease in wealth, resulting in lower interest rates, output, and price levels. Sulaiman & Azeez (2012) found that the buildup of external debt in Nigeria significantly burdens the country. Servicing this debt presents a major threat to the nation's economic growth. The researchers also found a negative relationship between external debt and inflation.

A third group of empirical studies found no statistically significant relationship between external debt and inflation rate. For example, Essien et al. (2016) find that the level of external and domestic debt does not significantly impact the overall price level and output in Nigeria.

The empirical literature does not directly examine the relationship between external debt and inflation in Sudan. Nonetheless, it is essential to note that three related studies, such as Mohamed (2005), Ahmed (2010), and Mohamed (2018), may still provide valuable insights into the potential relationship between external debt and inflation in

Sudan, although not in a direct manner. The first study by Mohamed (2005) examines the impact of external indebtedness on Sudan's economic growth from 1978-2001. The study found that Sudan was experiencing a debt overhang problem during the period under consideration and that external debt and inflation negatively impacted economic growth. The second study by Ahmed (2010) analyzes the impact of external debt on the Sudanese government's efforts to reduce poverty, sustain growth, and promote peace. The third study by Mohamed (2018) analyzes the relationship between external debt and economic growth in Sudan. The study concludes that external debt positively impacts Sudan's economy.

Overall, we noted that the studies on Sudan highlight the relationship between external debt and economic growth and the need for policy interventions to address the negative impacts of external debt and promote sustainable growth, poverty reduction, and peace promotion.

To sum up, the relationship between external debt and inflation is complex, depends on various factors, and could differ across countries and time periods. While an increase in debt can lead to inflation in some situations, this is not always the case and must be evaluated in context. The existing empirical literature on the impact of external debt on inflation is extensive, covering different estimation methods, sample periods, and countries. However, the findings of the studies are inconclusive and need to provide a clear consensus on the nature of the relationship between external debt and inflation. Some studies suggest a positive/negative relationship between the two, while others show no significant relationship. Therefore, further research is required to establish a robust and generalizable relationship between external debt and inflation in Sudan.

We postulate that the mixed findings in the empirical literature regarding the impact of external debt on inflation could be due to the failure of these studies to consider the potential asymmetry in the inflationary impact of external debt.

## 4. Data and methods

The empirical analysis utilizes time series data on the consumer price index (PI), the total external debt stock (debt), the nominal effective exchange rate (NER), and the broad money (MS). The analysis covers the period from 1970 to 2020. The PI, debt, and MS data are obtained from the World Development Indicators. Data on the NER is obtained from Bruegel's database Darvas (2021). All the variables are measured in natural logarithmic form.

The empirical analysis will incorporate the three factors debt, MS, and NER, which are widely identified in the literature as primary drivers of the inflation rate, as shown in Equation 1.

$$PI_t = \beta_0 + \beta_1 \, Debt_t + \beta_2 MS_t + \beta_4 NER_t + \varepsilon_t \qquad (1)$$

The time series analysis typically starts with checking the order of integration of the variables under investigation. The ARDL bounds test of cointegration is valid when the order of integration of the series is less than two. The order of integration of the variables is checked using the Augmented Dickey-Fuller (ADF) and the Phillips- Perron (PP) unit root tests. We run two versions of the tests; one allows for an intercept, and a second allows for an intercept and a deterministic trend.

To examine whether a symmetric (linear) relationship exists between external debt and inflation, we use the ARDL model presented in Equation (2).

$$\Delta PI_t = \alpha_1 + \sum_{i=1}^{k} \mu_{1i}\Delta PI_{t-i} + \sum_{i=1}^{l} \mu_{2i}\Delta Debt_{t-i} + \sum_{i=1}^{m} \mu_{3i}\Delta MS_{t-i} +$$
$$\sum_{i=1}^{n} \mu_{4i}\Delta NER_{t-1} + \varphi_1 PI_{t-1} + \varphi_2 \, Debt_{t-1} + \varphi_3 \, MS_{t-1} + \varphi_4 NER_{t-1} + \varepsilon_t \qquad (2)$$

In which $\Delta$ is a first difference operator, and the rest of the variables are defined before. $k, l, m, n$ are the optimal lag order determined based on the SIC information criterion.

The error correction representation of the linear ARDL model presented in Equation (2) is shown in Equation (3).

$$\Delta PI_t = \lambda_0 + \sum_{i=1}^{a} \lambda_{1i}\Delta PI_{t-i} + \sum_{i=1}^{b} \lambda_{2i}\Delta Debt_{t-i} + \sum_{i=1}^{c} \lambda_{3i}\Delta MS_{t-i} +$$

$$\sum_{i=1}^{d} \lambda_{4i}\Delta NER_{t-1} + \pi ECT_{t-1} + \varepsilon_t \qquad (3)$$

To examine the nonlinear (asymmetric) impact of external debt on inflation, we use the nonlinear autoregressive distributed lag (NARDL) model of Shin et al. (2014). In this model, the external debt fluctuations are decomposed into negative fluctuations, $(debt_t^- = \sum_{i=1}^{t} \Delta debt_t^- = \sum_{i=1}^{t} \min(debt_i, 0))$ ,and positive fluctuations, $(debt_t^+ = \sum_{i=1}^{t} \Delta debt_t^+ = \sum_{i=1}^{t} \max(debt_i, 0))$ , where the $debt_t^-$ and $debt_t^+$ are the partial sums of the negative and positive fluctuations in the external debt, respectively.

The model in Equation 1 can be formulated as a nonlinear ARDL model as in Equations (4) to unmask the existence of an asymmetric equilibrium relationship between external debt and the rate of inflation while controlling for the other determinants of inflation, *N*ER, and MS.

$$\Delta PI_t = \varphi_1 + \sum_{i=1}^{p} \eta_{1i}\Delta PI_{t-i} + \sum_{i=1}^{s} \eta_{2i}\Delta MS_{t-i} + \sum_{i=1}^{m} \eta_{3i}\Delta NER_{t-1} +$$

$$\sum_{i=1}^{l} \eta_{4i}\Delta debt_{t-i}^+ + \sum_{i=1}^{v} \eta_{5i}\Delta debt_{t-i}^- + \omega_1 PI_{t-1} + \omega_2 MS_{t-i} + \omega_3 NER_{t-i} \omega_4 Debt_{t-1}^+ +$$

$$\omega_5 Debt_{t-1}^- + \varepsilon_t \qquad (4)$$

To identify the short-run asymmetric impact of external debt on the rate of inflation, the nonlinear ARDL model presented in Equation (4) is expressed in an error correction form as in Equation (5).

$$\Delta PI_t = \varphi_1 + \sum_{i=1}^{p} \eta_{1i}\Delta PI_{t-i} + \sum_{i=1}^{s} \eta_{2i}\Delta MS_{t-i} + \sum_{i=1}^{m} \eta_{3i}\Delta NER_{t-1} +$$

$$\sum_{i=1}^{l} \eta_{4i}\Delta debt_{t-i}^+ + \sum_{i=1}^{v} \eta_{5i}\Delta debt_{t-i}^- + \pi ECT_{t-1} + \varepsilon_t \qquad (5)$$

The error correction term coefficient, $\pi$, in Equations (3) and (5) measures the adjustment speed of the variables to their long-run equilibrium path. Dynamic stability requires $\pi$ to have a negative sign and be less than unity.

## 5. Empirical Results

Results of the PP and ADF unit root tests, presented in Table 1, show that all the variables are non-stationary at levels but become stationary at their first difference across the two versions of the tests. Given that all the series are I(1), the ARDL cointegration bounds test is valid and can be used to test cointegration.

**Insert Table 1 here**

The Akaike information criterion (AIC) selected a linear ARDL (3, 1, 0, 2) and a nonlinear ARDL (3, 2, 0, 3, 0) model. Results of the ARDL and NARDL cointegration bounds test, presented in Table 2, show both a linear and a nonlinear cointegration between PI, MS, NER, and Debt since both the F- and t- statistics are greater than the upper bound of their critical value at the 5% significance level.

**Insert Table 2 here**

**Insert Table 3 here**

The short-run and long-run coefficients of the estimated linear ARDL (3, 1, 0, 2) and nonlinear ARDL (3, 2, 0, 3, 0) models are presented in Table 3. The estimated short-run coefficients of both models show that domestic money supply has a statistically significant positive impact on inflation. The results also show that past inflation levels positively affect current inflation. As for the impact of external debt, the results of the linear ARDL model show that external debt has a statistically significant negative impact on inflation in the short run. In comparison, the results of the nonlinear ARDL model show that only positive shocks to external debts have a statistically significant effect on inflation.

The estimated error-correction term coefficient of both the linear ARDL (3, 1, 0, 2) and nonlinear ARDL (3, 2, 0, 3, 0) models has a negative sign and is statistically significant at the 1% significance level, where 33% of the last period's disequilibrium is corrected in the current period. This means that following a shock, it takes about three years for PI, MS, NER, and external debt to restore their long-run equilibrium relationship.

The estimated long-run elasticity coefficients of both the linear and nonlinear ARDL models reveal that the domestic money supply has a statistically significant positive impact on inflation. In contrast, the nominal effective exchange rate has a statistically significant negative impact on inflation at the 1% significance level. According to the linear ARDL model, a 1% increase in domestic money supply increases inflation by 0.66% in the long run. A 1% increase in the nominal effective exchange rate of the Sudanese pound lowers inflation by 0.37% in the long run. The sign of these estimated elasticities was the same, but the magnitude was more than double for the nonlinear ARDL model. In particular, according to the nonlinear ARDL model, a 1% increase in domestic money supply raises inflation by 1.7%. In comparison, a 1% rise in the nominal effective exchange rate of the Sudanese pound lowers inflation by 0.69% in the long run.

As for the impact of external debt, the results of the linear ARDL model show that external debt has no statistically significant impact on inflation in the long run at any of the typical significance levels. On the contrary, the nonlinear ARDL model results show that positive and negative external debt shocks have a statistically significant impact on inflation in the long run at the 1% significance level. A 1% increase in external debt lower inflation by 2.19% in the long run while a 1% drop in external debt lowers inflation by 1.48 percent.

The quality of the estimated linear and nonlinear ARDL models is assessed using a set of diagnostic tests to check residuals serial correlation, heteroscedasticity, non-normality and specification error. The results of these tests, presented in the lower section of Table 3, indicate that the estimated linear ARDL and nonlinear ARDL models are free from specification errors, heteroskedasticity, autocorrelation, non-normality of the residuals at the 5% significance level.

Figure 2 and Figure 3, which display the parameters stability diagnostics, including the cumulative sum of recursive residuals test and the cumulative sum of squares of recursive residuals test, show that the coefficients of the estimated linear and nonlinear ARDL models are stable at the 5% significance level.

**Insert Figure 2 here.**

**Insert Figure 3 here.**


Figure 4 portrays the dynamic asymmetric multiplier of the nonlinear ARDL (3, 2, 0, 3, 0) model and reveals asymmetry, in terms of magnitude, in the long-run adjustment patterns following an external debt shock. The solid black line of the dynamic multiplier plots shows that a 1% increase in external debt lowers the inflation rate by 2.19% in the long run. Similarly, the black-dashed line of the dynamic multiplier plots reveals that a 1% decline in external debt lowers the inflation rate by 1.48% in the long run.

**Insert Figure 4 here.**

## 6. Discussion and Conclusion


This study augments the sparse literature on the macroeconomic impact of external debt in Sudan. We offer a rigorous and comprehensive analysis of the relationship between external debt and inflation in Sudan from 1970 to 2020 using linear and nonlinear ARDL models in conjunction with the bounds-testing approach to cointegration.

Findings of the linear ARDL model indicate that external debt does not significantly affect inflation in the long run. Therefore, it does not play a significant role in determining price levels in Sudan over time. These findings are in line with Essien et al.'s (2016) study on the impact of public sector borrowing on prices, interest rates, and output in Nigeria, where they also found that the level of external debt did not significantly impact overall price levels and output.

The conventional belief is that excessive external debt can lead to inflation through currency devaluation and increased demand for imports, which concludes that external debt has no statistically significant impact on inflation in the long run in the linear ARDL model surprising. However, it is crucial to consider the asymmetric effect when examining the relationship between external debt and inflation. This effect means that the influence of external debt on inflation may not be uniform when debt is increasing or decreasing. Therefore, it is essential to consider both the direction of external debt

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changes when investigating its link with inflation. Failing to do so could lead to erroneous conclusions about the impact of external debt on inflation.

To account for the potential asymmetry in the inflationary impact of external debt, we utilized a nonlinear ARDL model. The motive behind using the nonlinear ARDL model is that the relationship between external debt and inflation may not be symmetrical and could be contingent on the direction of the shock in external debt. The nonlinear ARDL model results demonstrate that positive and negative external debt shocks have a statistically significant impact on inflation in the long run. We found that a 1% increase in external debt lowers inflation by 2.19% in the long run, while a 1% drop in external debt lowers inflation by 1.48% in the long run. This finding highlights the importance of accounting for nonlinearities in the relationship between external debt and inflation.

These results are consistent with the theory that economic variables behave differently across different stages of business cycles, indicating asymmetry in their evolution (Chirilaa, 2012). Similarly, several applied studies have emphasized asymmetric effects in the adjustment behaviour of economic variables, with many finding different results when using nonlinear ARDL approaches. For example, previous studies, which used a linear ARDL approach, did not find any notable long-term effects of currency depreciation on Japan's domestic production prior to Bahmani-Oskooee & Mohammadian (2017). However, their utilization of the nonlinear ARDL approach revealed that alterations in Japan's exchange rate have asymmetrical impacts on domestic production.

The positive and statistically significant impact of domestic money supply on inflation is consistent with the quantity theory of money, which posits that increases in the money supply lead to higher prices. The negative and statistically significant impact of the nominal effective exchange rate on inflation is also consistent with economic theory, as a stronger currency can lead to lower inflation by reducing the cost of imports and improving the competitiveness of domestic producers.

Overall, this study provides valuable insights into the determinants of inflation in Sudan and highlights the need for policymakers to carefully manage the country's external debt, money supply, and exchange rate to ensure macroeconomic stability and sustainable economic growth.

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**Table 1. Results of the ADF and PP unit root tests**

| | PI | | MS | | NER | | Debt | |
|---|---|---|---|---|---|---|---|---|
| | ADF | PP | ADF | PP | ADF | PP | ADF | PP |
| | Unit root tests of variables in levels | | | | | | | |
| Constant | 0.1075 (0.9632) | 0.0096 (0.9548) | 0.1832 (0.9688) | 0.4279 ( 0.9823) | 0.0771 (0.9608) | -0.1037 (0.9432) | -2.2072 (0.2064) | -2.1689 ( 0.2199) |
| Constant & Trend | -3.2523* ( 0.0868) | -1.7628 (0.7077) | -2.9050 (0.1703) | -1.9478 ( 0.6148) | -1.8145 (0.6825) | -1.8151 (0.6825) | -2.1485 (0.5069) | -2.0716 (0.5485) |
| | Unit root tests of variables in first difference | | | | | | | |
| Constant | -2.8501** ( 0.03) | -2.8909** (0.03) | -3.1501** (0.0293) | -3.1219** (0.0314) | -5.4320*** (0.0000) | -5.4254*** (0.0000) | -7.2824*** (0.0000) | -7.3231*** (0.0000) |
| Constant & Trend | -2.8444** ( 0.045) | -2.9576** ( 0.039) | -3.1491* (0.09) | -3.1316* (0.09) | -5.3896*** (0.0003) | -5.3840*** (0.0003) | -7.2600*** (0.0000) | -7.3189*** (0.0000) |

\*, \*\*, \*\*\* indicate rejection of the null hypothesis (series is non-stationary) at the 10%, 5%, and 1% significance level, respectively. Lag length is based on SIC. P-values are in parenthesis

**Table 2: Results of the Cointegration bounds test**

| | | | | 95% Critical bounds | |
|---|---|---|---|---|---|
| Dependent variable | Explanatory variables | Specification | F-statistic | I(0) | I(1) |
| $\Delta(PI)$ | $MS, NER, \text{Debt}$ | ARDL(3, 1, 0, 2) | 5.40 | 3.5 | 4.7 |
| | | | t-statistic | I(0) | I(1) |
| | | | -3.83 | -2.86 | -3.78 |
| $\Delta(PI)$ | $MS, NER, \text{Debt}^+, \text{Debt}$ | NARDL(3, 2, 0, 3, 0) | F-statistic | I(0) | I(1) |
| | | | 6.34 | 3.136 | 4.416 |
| | | | t-statistic | I(0) | I(1) |
| | | | -3.75 | -2.57 | -3.66 |

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

**Table 3: Estimated short run and long run coefficients of the ARDL (3, 1, 0, 2) and NARDL (3, 2, 0, 3, 0) models**

| | ARDL (3, 1, 0, 2) | | NARDL (3, 2, 0, 3, 0) | |
|---|---|---|---|---|
| **Panel (A)** | | | | |
| **Short run coefficients** | Coefficient | Standard errors | Coefficient | Standard errors |
| $constant$ | -3.301*** | 0.671 | -6.104*** | 1.008 |
| $\Delta PI_{t-1}$ | 0.363*** | 0.133 | 0.362*** | 0.122 |
| $\Delta PI_{t-2}$ | 0.333*** | 0.125 | 0.285** | 0.119 |
| $\Delta MS$ | 0.572*** | 0.142 | 0.752*** | 0.139 |
| $\Delta MS_{t-1}$ | | | 0.268 | 0.167 |
| $\Delta Debt$ | -0.090* | 0.053 | | |
| $\Delta Debt_{t-1}$ | -0.124*** | 0.045 | | |
| $\Delta Debt^{+}$ | | | -0.460*** | 0.090 |
| $\Delta Debt_{t-1}^{+}$ | | | 0.031 | 0.065 |
| $\Delta Debt_{t-2}^{+}$ | | | 0.176*** | 0.048 |
| $ECT_{t-1}$ | -0.3313*** | 0.0686 | -0.3319*** | 0.0557 |
| **Panel (B)** | | | | |
| **Long run coefficients** | | | | |
| MS | 0.6688*** | 0.0716 | 1.7091*** | 0.4077 |
| NER | -0.3735*** | 0.0945 | -0.6961*** | 0.1254 |
| Debt | -0.0329 | 0.1040 | | |
| Debt + | | | -2.1963*** | 0.7852 |
| Debt - | | | 1.4890*** | 0.5730 |
| **Diagnostic tests** | | | | |
| A: Serial correlation | $\chi^2(2) = 2.54$ P value (0.27) | | $\chi^2(2) = 0.67$ P value (0.40) | |
| B: Heteroskedasticity | $\chi^2(9) = 14$ P value (0.12) | | $\chi^2(12) = 9.98$ P value (0.61) | |
| C: Functional form RESET test | F (2,36)=2.01 P value (0.14) | | F (2,32)=0.40 P value (0.66) | |
| D: Normality | Jarque-Bera =3.16 P value (0.20) | | Jarque-Bera = 0.20 P value (0.90) | |

*, **, *** indicate rejection of the null hypothesis (series is non-stationary) at the 10%, 5%, and 1% significance level, respectively. Lag length is based on AIC.

**Figure 1: Evolution of inflation rate and external debt level in Sudan over the period 1970-2021**
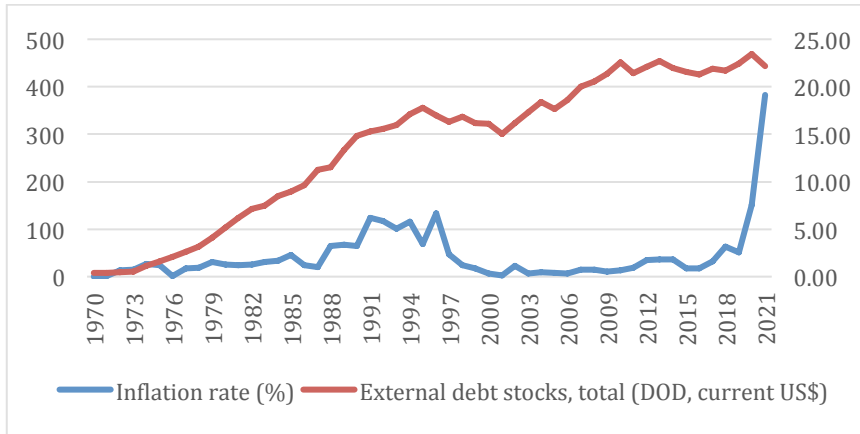


Source: Authors' compilation based on data from WDI

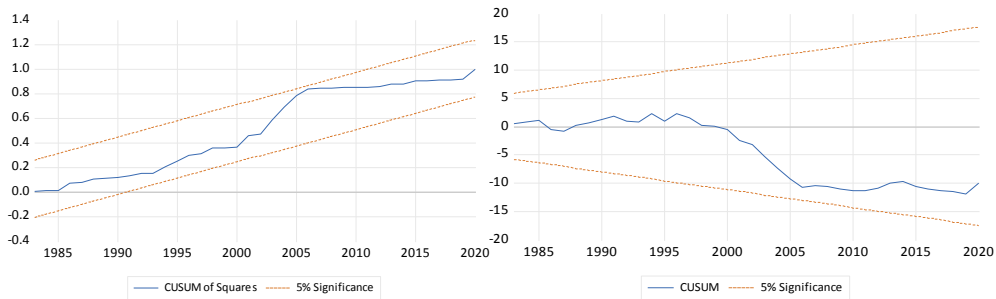**Figure 2: ARDL (3, 1, 0, 2) CUSUM and CUSUMSQ stability plots**



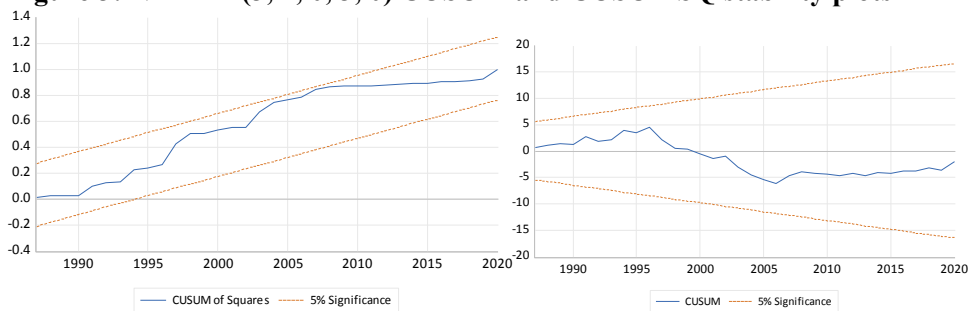**Figure 3: NARDL (3, 2, 0, 3, 0) CUSUM and CUSUMSQ stability plots**

**Figure 4. NARDL (3, 2, 0, 3, 0) dynamic asymmetric multiplier**