Does external debt drive inflation in Sudan: evidence from symmetric and asymmetric ARDL approaches

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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 – The authors 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 ARDL (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 affect inflation in the long run. The estimated long-run elasticity coefficients of 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.

Keywords External debt, Exchange rate, Inflation, Money supply, NARDL, Sudan

Paper type Research paper

JEL Classification — E31, E52, F34, O24

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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 perceived as a helpful tool for many low-income countries to supplement domestic savings and achieve their development objectives, principally if the funds are used to increase productive capacities (Ezeabasili *et al.*, 2011). Hence, external borrowing could accelerate 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 could harm economic and price stability. Additionally, a debt overhang could create uncertainty and limit a country's future access to financing, hindering investment and sustainable economic growth (Atique and Malik, 2012).

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 $23bn, representing about 92% of the Sudanese 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 evolved to examine the relationship between external debt and inflation in several countries over different periods and using different econometric approaches with mixed findings. For a recent literature review, see Aimola and Odhiambo (2020).

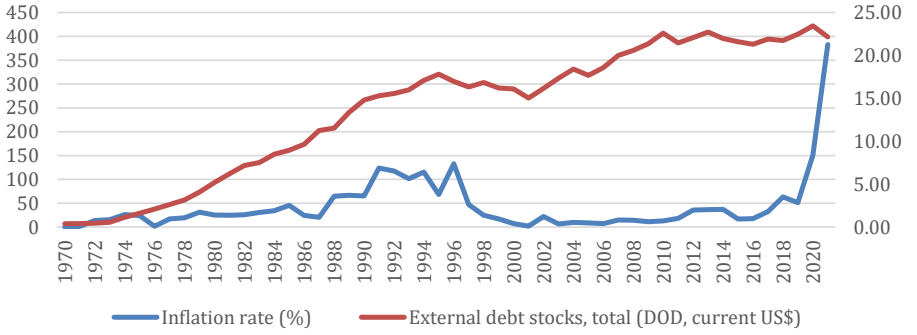
The mixed findings in the literature could be due to the failure of previous related studies to account for the potential asymmetry in the relationship between external debt and inflation. To date, no empirical study has assessed the external debt-inflation nexus in Sudan, and the current study aims to fill this gap in the literature. Specifically, 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 symmetric nexus between the external debt and the inflation rate within a multivariate framework by including the money supply and the nominal exchange rate as additional drivers of inflation. The asymmetric effect of external debt 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.

The current study's findings would provide important insights into the factors driving inflation in Sudan and external debt's role 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, then discussed in Section 6. Section 7 concludes the paper.

2. Evolution of external debt and inflation rate in Sudan

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



Source(s): Authors' compilation based on data from the World Development Indicators

Figure 1.
Evolution of inflation rate and external debt level in Sudan over the period 1970–2021

Sudan's external debt was relatively low at the start of the 1970s. However, factors such as the 1973 oil crisis, 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 1980 and 1990s, Sudan witnessed a sharp increase in its external debt, with the highest recorded in 1995, amounting to $17.8bn. 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 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 significantly devalued 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 $22bn 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.

In summary, 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 the cause of inflation. Two widely recognized standpoints are the monetarist theory and the fiscal theory of price level. Monetarists believe that inflation is a monetary phenomenon that 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 hypothesizes that if the government runs large budget deficits, it could increase inflation rates. This theory was initially proposed by Sargent and Wallace (1981) and has been further developed by subsequent researchers such as Leeper (1991) and Woodford (2001).

Appropriate coordination between fiscal and monetary policies has been proposed as an effective scheme to control inflation rates. For example, Woodford (2001) argues that achieving price stability requires a commitment to suitable monetary and appropriate fiscal policies. 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 Taylor's 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; Ghaly, 2023), others have found a negative relation (see, e.g. Sulaiman and Azeez, 2012), while another group of studies found no statistically significant relationship (see, e.g. Essien *et al.*, 2016).

Aimola and Odhiambo (2020) comprehensively reviewed the literature on the relationship between public debt and inflation. The findings generally 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, 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 debt depend on ownership and denomination, as foreign-held debt is inflationary, but domestically-held 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. In a recent study, Ghaly (2023) found a positive relationship between debt levels and inflation in Egypt from 1976 to 2020.

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 and 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. For example, Essien *et al.* (2016) reported that the external and domestic debt level does not significantly influence Nigeria's overall price level and output. Similarly, Aimola and Odhiambo (2021) utilized the ARDL framework to investigate the impact of total public debt on inflation in Nigeria between 1983 and 2018. Their research concluded that public debt did not significantly affect inflation in Nigeria, whether in the short or long term, suggesting that other factors likely played a more significant role in determining inflation in the country.

The literature on the debt-inflation nexus in Sudan is sparse and does not directly examine the relationship between external debt and inflation. Very few studies on Sudan mainly focus on the relationship between external debt and economic growth while skipping other crucial macroeconomic factors such as inflation. 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 affected 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 affects Sudan's economy.

All the studies mentioned above share a common assumption of a symmetrical relationship between inflation and external debt in their time-series models. The possibility of inflation responding asymmetrically to the decrease or the increase in external debt is not considered in these studies. However, recently, it has been shown that significant nonlinearities and asymmetries characterize the adjustment behavior of most economic variables. As a result, the relationship between external debt and inflation can be asymmetric. This underscores the importance of conducting asymmetric analysis when examining the debt-inflation nexus to unmask any potential nonlinearity in this relationship, yielding more robust findings that could benefit the design of effective policy measures to mitigate the negative consequences associated with high external debt levels.

Based on the aforementioned reviewed studies, the existing empirical literature on the impact of external debt on inflation is extensive and has yielded inconclusive findings. While an increase in debt could lead to inflation in some situations, this is not always the case and must be evaluated in context. The type of debt and the country's economic circumstances may play a role in determining the impact of external debt on inflation. Despite the lack of a clear consensus on the relationship between external debt and inflation, empirical evidence suggests that further research is necessary to comprehend the intricacies of this connection fully.

The current study augments the extant literature and postulates that the mixed empirical evidence regarding the impact of external debt on inflation could be in part due to the failure of previous studies to consider the potential asymmetry in the inflationary impact of external debt, which we try to overcome.

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). In addition to external debt, the choice of the other variables in the empirical model is based on theoretical and empirical grounds. There is considerable empirical evidence that supports the pass-through of exchange rate changes to inflation in many African countries. For example, using an ARDL model, Balcilar *et al.* (2019) found a complete exchange rate pass-through to inflation in both the long and short run in Nigeria, and the pass-through was incomplete for South Africa from 1986 to 2016. In another study, Baharumshah *et al.* (2017) find that sharp currency depreciation episodes in the long-run largely drive inflation in Sudan.

The Monetarists believe that inflation is a monetary phenomenon caused by an increase in the money supply relative to the output of goods and services in the economy. This monetary theory of inflation has considerable empirical support. For instance, Benati (2021) used data from 27 countries and found a one-for-one relationship between broad money growth and long-term inflation. For additional evidence on the role of money supply in inflation, see the findings of Abate (2020) for Ethiopia, Kumar and Dash (2020) for India, and Helmy (2022) for evidence in Egypt.

$$\mathrm{PI_t} = \beta_0 + \beta_1 \mathrm{Debt_t} + \beta_2 \mathrm{MS_t} + \beta_4 \mathrm{NER_t} + \varepsilon_t \tag{1}$$

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. In addition to the conventional unit root tests (ADF and PP), we also conduct Zivot and Andrew's (1992) unit root test to account for the potential structural breaks in the data.

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

$$\begin{aligned}\Delta \mathrm{PI}_t = {} & \alpha_1 + \sum_{\mathrm{i}=1}^{\mathrm{k}} \mu_{1\mathrm{i}} \Delta \mathrm{PI}_{t-\mathrm{i}} + \sum_{\mathrm{i}=1}^{\mathrm{l}} \mu_{2\mathrm{i}} \Delta \mathrm{Debt}_{t-\mathrm{i}} + \sum_{\mathrm{i}=1}^{\mathrm{m}} \mu_{3\mathrm{i}} \Delta \mathrm{MS}_{t-\mathrm{i}} \\ & + \sum_{\mathrm{i}=1}^{\mathrm{n}} \mu_{4\mathrm{i}} \Delta \mathrm{NER}_{t-1} + \varphi_1 \mathrm{PI}_{t-1} + \varphi_2 \mathrm{Debt}_{t-1} + \varphi_3 \mathrm{MS}_{t-1} + \varphi_4 \mathrm{NER}_{t-1} + \varepsilon_t\end{aligned} \tag{2}$$

In which Δ is a first difference operator, and the rest of the variables are defined as before. k, l, m, n are the optimal lag order determined based on the Schwarz Information Criterion (SIC).

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

$$\begin{aligned}\Delta \mathrm{PI}_t = {} & \lambda_0 + \sum_{\mathrm{i}=1}^{\mathrm{a}} \lambda_{1\mathrm{i}} \Delta \mathrm{PI}_{t-\mathrm{i}} + \sum_{\mathrm{i}=1}^{\mathrm{b}} \lambda_{2\mathrm{i}} \Delta \mathrm{Debt}_{t-\mathrm{i}} + \sum_{\mathrm{i}=1}^{\mathrm{c}} \lambda_{3\mathrm{i}} \Delta \mathrm{MS}_{t-\mathrm{i}} + \sum_{\mathrm{i}=1}^{\mathrm{d}} \lambda_{4\mathrm{i}} \Delta \mathrm{NER}_{t-1} \\ & + \pi \mathrm{ECT}_{t-1} + \varepsilon_t\end{aligned} \tag{3}$$

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 ($\text{debt}_t^- = \sum_{i=1}^{t} \Delta\text{debt}_t^- = \sum_{i=1}^{t} \min(\text{debt}_i, 0)$), and positive fluctuations ($\text{debt}_t^+ = \sum_{i=1}^{t} \Delta\text{debt}_t^+ = \sum_{i=1}^{t} \max(\text{debt}_i, 0)$), 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.

$$\Delta\text{PI}_t = \varphi_1 + \sum_{i=1}^{p} \eta_{1i}\Delta\text{PI}_{t-i} + \sum_{i=1}^{s} \eta_{2i}\Delta\text{MS}_{t-i} + \sum_{i=1}^{m} \eta_{3i}\Delta\text{NER}_{t-1} + \sum_{i=1}^{l} \eta_{4i}\Delta\text{debt}_{t-i}^{+} + \sum_{i=1}^{v} \eta_{5i}\Delta\text{debt}_{t-i}^{-} + \omega_1\text{PI}_{t-1} + \omega_2\text{MS}_{t-i} + \omega_3\text{NER}_{t-i}\,\omega_4\text{Debt}_{t-1}^{+} + \omega_5\text{Debt}_{t-1}^{-} + \varepsilon_t \quad (4)$$

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).

$$\Delta\text{PI}_t = \varphi_1 + \sum_{i=1}^{p} \eta_{1i}\Delta\text{PI}_{t-i} + \sum_{i=1}^{s} \eta_{2i}\Delta\text{MS}_{t-i} + \sum_{i=1}^{m} \eta_{3i}\Delta\text{NER}_{t-1} + \sum_{i=1}^{l} \eta_{4i}\Delta\text{debt}_{t-i}^{+} + \sum_{i=1}^{v} \eta_{5i}\Delta\text{debt}_{t-i}^{-} + \pi\text{ECT}_{t-1} + \varepsilon_t \quad (5)$$

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

5. Empirical results

Results of the PP and the 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. The Zivot and Andrew unit root test results, presented in Table 2, show that only NER is stationary at level with a single structural break in 1992. More importantly, the results indicate that all the variables, at their first difference, are stationary with time breaks shown in the table since the t-statistics are statistically significant. Given that all the series are I(1), the ARDL cointegration bounds test is valid and can be used to test cointegration.

The Schwarz information criterion 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 3, 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.

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 4. The estimated short-run

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

Note(s): *, **, *** indicate rejection of the null hypothesis
(series is non-stationary) at the 10%, 5%, and 1% significance level, respectively. Lag length is based on the Schwarz Information Criterion. *p*-values are in parenthesis
Source(s): The table is constructed by the authors

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 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.

	At level		At first difference	
	T-statistic	Time break	*T*-statistic	Time break
PI	−4.25	1988	−4.89**	1997
MS	−3.69	1991	−4.52**	1997
NER	−6.82***	1992	−6.72***	1997
Debt	−3.41	1996	−6.12***	1981

Note(s): *, **, *** indicate rejection of the null hypothesis that the series is non-stationary with a structural break at the 10%, 5%, and 1% significance level, respectively. Lag length is based on the Schwarz Information Criterion

Source(s): The table is constructed by the authors

Table 2. Results of the Zivot and Andrews unit root test

Dependent variable	Explanatory variables	Specification	*F*-statistic	95% critical bounds I(0)	95% critical bounds I(1)
Δ(PI)	*MS*, *NER*, Debt	ARDL (3, 1, 0, 2)	5.40	3.5	4.7
			T-statistic	I(0)	I(1)
			−3.83	−2.86	−3.78
Δ(PI)	*MS*, *NER*, $Debt^{+}$, $Debt^{-}$	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

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

Source(s): The table is constructed by the authors

Table 3. Results of the cointegration bounds test

	ARDL (3, 1, 0, 2)		NARDL (3, 2, 0, 3, 0)	
	Coefficients	Standard errors	Coefficients	Standard errors
Panel (A)				
Short run coefficients				
Constant	−3.301***	0.671	−6.104***	1.008
ΔPI_{t-1}	0.363***	0.133	0.362***	0.122
ΔPI_{t-2}	0.333***	0.125	0.285**	0.119
ΔMS	0.572***	0.142	0.752***	0.139
ΔMS_{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 checks				
Serial correlation	$\chi^2(2) = 2.54$		$\chi^2(2) = 0.67$	
	p value (0.27)		p value (0.40)	
Heteroskedasticity	$\chi^2(9) = 14$		$\chi^2(12) = 9.98$	
	p value (0.12)		p value (0.61)	
Functional form	F (2,36) = 2.01		F (2,32) = 0.40	
RESET test	p value (0.14)		p value (0.66)	
Normality	Jarque-Bera = 3.16		Jarque-Bera = 0.20	
	p value (0.20)		p value (0.90)	

Note(s): *, **, *** indicate statistical significance at the 10%, 5%, and 1% significance level, respectively
Source(s): The table is constructed by the authors

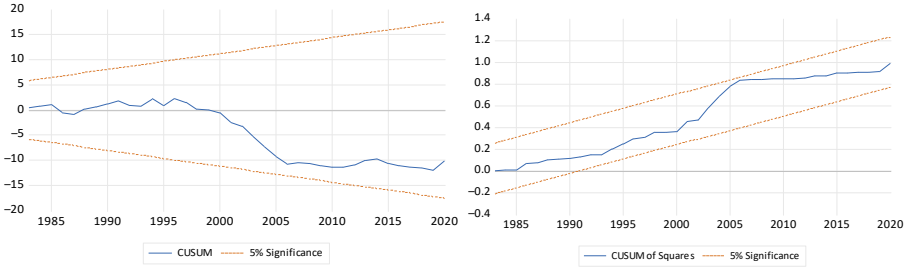
Table 4.
Estimated coefficients of the ARDL (3, 1, 0, 2) and NARDL (3, 2, 0, 3, 0) models

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 statistically impact inflation in the long run at the 1% significance level. 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%.

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 4, 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.

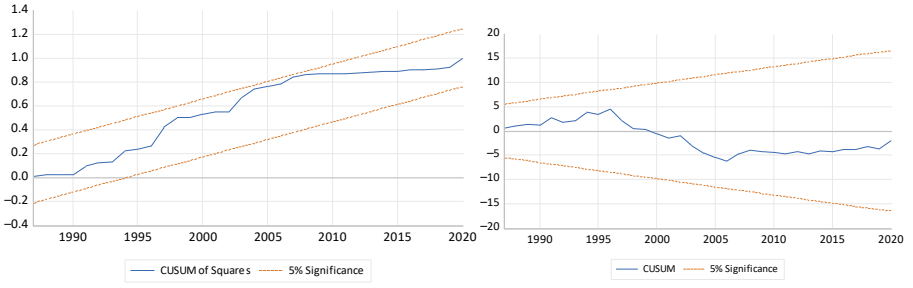
Figures 2 and 3, which display the parameters stability diagnostics, including the cumulative sum of recursive residuals (**CUSUM**) test and the cumulative sum of squares of recursive residuals (**CUSUMSQ**) test, show that the coefficients of the estimated linear and nonlinear ARDL models are stable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

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.



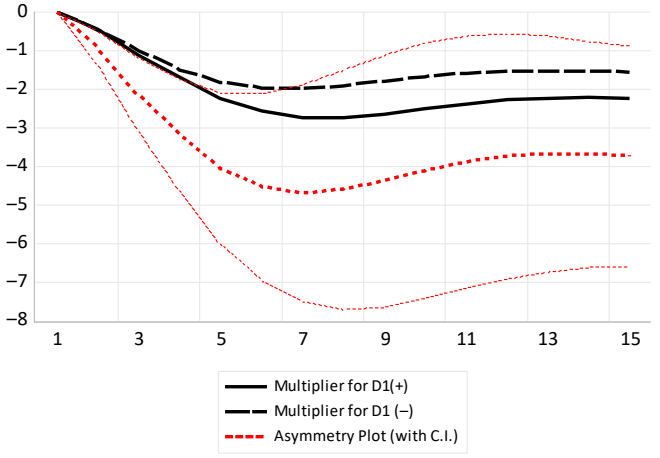
Source(s): The figure is constructed by the authors

Figure 2. CUSUM and CUSUMSQ stability plots of the ARDL (3, 1, 0, 2) model



Source(s): The figure is constructed by the authors

Figure 3. CUSUM and CUSUMSQ stability plots of the NARDL (3, 2, 0, 3, 0) model



Source(s): The figure is constructed by the authors

Figure 4. Dynamic asymmetric multiplier of the NARDL model

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.

6. Discussion

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. Using the NARDL model to assess the impact of external debt's positive and negative shocks on inflation in Sudan is a novel approach that has not been employed in previous studies about this country.

Findings of the linear ARDL model indicate that external debt has no effect on inflation in the long run. Therefore, it does not play a significant role in determining price levels in Sudan over time. This result aligns with the findings of Aimola and Odhiambo (2021), which suggest that public debt has no significant effect on inflation in Nigeria. The lack of a statistically significant inflationary impact of external debt as per the linear ARDL model results is also similar to the findings of 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 affect overall price levels and output.

The lack of a statistically significant inflationary effect of external debt in the long run, as per the linear ARDL model result, contradicts the conventional belief that excessive external debt can lead to inflation through currency devaluation and increased demand for imports. 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 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 statistically impact 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 asymmetric 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 behavior of economic variables, with many findings have 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 and 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 study's asymmetry analysis reveals a significant long-run impact of external debt shocks on inflation, indicating the importance of accounting for nonlinearities. The research highlights that positive and negative external debt shocks have a statistically significant influence on inflation, suggesting that changes in external debt levels can have a noticeable impact on inflation over time. Furthermore, the study finds that the relationship between

external debt and inflation is nonlinear, meaning that the magnitude and direction of the shock can alter the effect of external debt on inflation, emphasizing the need for careful management of external debt levels to maintain macroeconomic stability.

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. This result is in line with the findings of Abate (2020) of a long-run positive relationship between money supply and inflation in Ethiopia from 1985 to 2018. It also aligns with the findings of Kumar and Dash (2020) in India and Helmy (2022), who found money supply to have a statistically significant positive impact on inflation in Egypt in the long run, using quarterly data from 2000 to 2020. Also, this monetary theory of inflation is supported by the findings of Benati (2021), who used data on 27 countries and found a one-for-one relationship between broad money growth and long-term inflation.

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. This exchange rate pass-through to inflation result is in line with the findings of Baharumshah *et al.* (2017), who utilized a NARDL model and found that inflation in Sudan is largely driven by sharp currency depreciation episodes in which a ten percent depreciation in the Sudanese pound leads to approximately an eight percentage point increase in consumer price levels in the long-run.

7. Conclusion

The study's findings shed new light on the factors contributing to Sudan's inflation and the exacerbating effect of external debt. This offers crucial understanding and helpful guidance for policymakers. Additionally, the study emphasizes the significance of using econometric techniques like the NARDL framework to explain the complex relationships among macroeconomic indicators. Overall, policymakers need to carefully manage external debt, money supply, and exchange rates to control inflation, as highlighted by the findings of this study.

The current study has three main limitations. Firstly, it employs annual data, which may not adequately capture short-term fluctuations and dynamics of inflation and external debt. Using more granular data, like monthly or quarterly data, could yield a more accurate estimation of the relationship between external debt and inflation by capturing short-term fluctuations and dynamics. Secondly, the analysis only covered until 2020 due to a lack of data. However, numerous crucial global and local events have transpired since then that would have undoubtedly significantly impacted the study's variables. Notably, the Russian-Ukrainian crisis at the global level and the events that occurred in Sudan, beginning with the substantial devaluation of the Sudanese pound at the start of 2021, followed by the political tensions that have been ongoing since April 2023. Finally, until 2011, the data reflected the Republic of Sudan and South Sudan. However, starting from 2012, the data was only related to the Republic of Sudan after South Sudan's secession in 2011.

Despite these limitations, the current study provides valuable insights into the role of external debt in fueling inflation in Sudan, which would guide policy makers when setting appropriate inflation control measures.

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