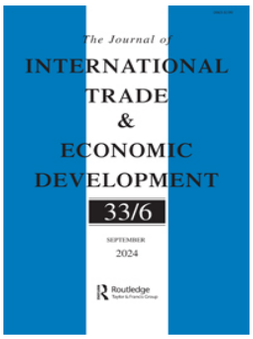

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Threshold-based influence of currency devaluation on external debt sustainability: Insights from smooth transition regression and multiple thresholds nonlinear ARDL approaches

Joseph Chukwudi Odionye [a], Augustine C. Odo[b], Anthony Orji[c], Ndubuisi Agoh[d], Veronica Adaku Ihezukwu[a], Richard O. Ojike[e] and Roy M. Okpara[a]

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ABSTRACT

This study offers unique insights into the threshold-based influence of currency devaluation (CD) on external debt sustainability (EDS) in designated Sub-Saharan African (SSA) countries. The absence of evidence from this viewpoint, particularly in SSA, inspires this new assessment. On this premise, the study utilizes two innovative estimation procedures: smooth transition regression (STR) and multiple thresholds nonlinear ARDL (MTNARDL) to estimate the sign-based and magnitude-based asymmetric influence of CD on EDS. The outcomes indicate that first, an average CD threshold of 21.1% is consistent with EDS in the designated nations; second, a small CD significantly reduces the external debt–GDP ratio and improves sustainability, while a very high CD largely worsens the EDS problem; third, in the CD regime, devaluation has more detrimental effects on external debt burden; fourth, exceedingly large changes in exchange rate (whether positive or negative) essentially affect the countries' EDS negatively; and fifth, the adverse effect of large depreciation on EDS is greater than that of large appreciation. The study recommends, amongst others, that heavily indebted countries with sizeable external debt denominated in foreign currency should, as a matter of urgency, avoid excessive and escalated large percentages of devaluation or exchange rate depreciation.

KEYWORDS Currency devaluation; external debt sustainability; threshold-based; STR; MTNARDL SSA

JEL CLASSIFICATIONS C32, E62, F31, F34

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1. Introduction

The post-World War II economic wonders of West Germany and some East Asian nations in the 1990s and 2000s have all been linked to depreciation or currency

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devaluation (CD) (Dooley, Folkerts-Landau, and Garber 2004). As a result of this, the International Monetary Fund (IMF) promoted nominal CD within the context of its loan conditionality, particularly in the 1980s and 1990s, for some economically disadvantaged nations (EDNs) to enhance global competitive benefits (Dreher 2009; Stubbs, et al. 2020). However, scientific research on the efficiency of CD in promoting economic growth frequently comes to contradictory verdicts (Acevedo et al. 2015; Habibi and Lee 2019; Odionye and Chukwu 2021; Odionye, Odo et al. 2023). The policy conundrum surrounding the macroeconomic effects of CD is thus far from being addressed. While CD can boost net exports and output, assuming the traditional Marshall–Learner rules are satisfied, a substantial risk exists related to a rise in local price and foreign currency-based debt (FCBD). Domestic CD may have detrimental consequences on assets and may increase the severity of national threat, as a result (Bernoth and Harwatz 2019). So, the total effects of CD depend on whether the 'FCBD effects' of depreciation are more potent than 'the trade balance (TB) medium' (Fisera, Tiruneh, and Hojdan 2021). It is uncertain whether and to what extent CD might be an effective tool for boosting the convergence process in developing nations, particularly the African countries. The foreign exchange medium appears to be critical in the region, which is eminent by the elevated level of foreign currency debt (IMF 2023). Furthermore, given the contrasting perspectives on the effects of CD through the FCBD effects advocated by the structuralists and the traditional view through the trade balance effects, is there a specific level or threshold of CD that boosts TB over FCBD? Beyond this threshold, does it escalate FCBD over TB, thus exacerbating the external debt sustainability (EDS) problem? Put differently, is EDS asymmetrically sensitive to the magnitude of devaluation? This study, therefore, evaluates the threshold-based asymmetric influence of CD on EDS in some designated countries in sub-Saharan Africa (SSA), using the novel Smooth Transition Regression (STR) and Multiple Thresholds Nonlinear ARDL (MTNARDL) analytical frameworks.

Despite the hypothetical and scientific disagreements, the changing patterns of external debt driven by movements in the nation's exchange rate remain of immense importance to economists, financial analysts, and policymakers especially in EDNs. As a result, the problem of these nations relying on FCBD to fund their budgetary shortfalls lies in the issue of external debt sustainability (EDS), given that it is significantly vulnerable to risk due to swings in the domestic exchange rate. Because of the valuation effect, CD will raise the value of FCBD in its currency, thereby increases the burden and cost of servicing the external debt. The affected countries, due to their relatively less matured financial systems, may be compelled to obtain more loans from other countries to pay off older foreign currency-based debt. This could result in a surge in external debt that is even higher, which could raise borrowing costs and ultimately jeopardize their EDS. Because of this, the rise in external debt occasioned by domestic CD might not merely be a passing trend that is subsequently reversed by domestic currency appreciation but rather a more long-lasting situation (Fisera, Tiruneh, and Hojdan 2021; Odionye and Chukwu 2021).

The trajectory and dynamics of external debt profiles in emerging economies particularly, the SSA, has continued to surge, especially after the COVID-19 era. The pandemic, the elevated cost of living, and the shortfall in food supply have all simultaneously affected EDNs, straining their governmental resources and thus propelling them to obtain external loans (IMF 2023). The growing concern is that many of these nations are challenged with exchange rate gyrations, which might endanger the issue of sustainability (Ikpe et al. 2021; IMF 2023). As at 2023, 9 nations experienced debt difficulty,

and another 34 faced a substantial danger of experiencing it (Figure A1, Appendix A). In the EDNs, the annualized public debt in 2022 stood at 48.2 percent of GDP, marginally below the level in 2020. However, as their exchange rates depreciated, the debt load increased for nations that borrowed a significant amount in foreign currencies (IMF 2023). According to the recent IMF-Debt Sustainability Analysis (DSA) report (Figure A1, Appendix A), out of the nine nations in distress, eight are SSA countries, while only one is in South and Latin America (SLA). Figure A1 indicates further that Asian and Pacific nations (AAPA) are primarily in high jeopardy of distress, followed very closely by SSA. None of the highly indebted SSA countries is classified as low danger of sustainability nation. Relative to other regions, the SSA recorded the highest distress in terms of debt sustainability, while it closely tailed the other AAPA in terms of high risk of woe (Figure A1). The IMF (2023) reported that external debt in several EDNs is expected to keep growing, and some of these nations have requested debt reduction under the G20 Common Framework. This makes the region most susceptible to external debt sustainability woe.

Despite the depicted trajectory of debt crisis, notwithstanding the hypothetical connectivity and its relevance in the region, there are dearth of empirical investigations on the threshold-based asymmetric response of EDS to CD, especially in the context of EDNs such as SSA countries. A number of prior research focused on the conceivable macroeconomic or trade balance implications of CD (Aghion et al. 2007; Huchet-Bourdon and Korinek 2011; Odionye and Chukwu 2021; Odionye, Odo et al. 2023; Schnabl 2007) in addition to the effects caused by fluctuations in the value of the exchange rate (Ikpe et al. 2021; Muoneke, Okere, and Onuoha 2022; Okere et al. 2023). While several prior studies in EDNs examined the effect of external debt on exchange rate (Ahemen, Asue, and Ikyaator 2023; Aigbedion, Iyakwari, and Mairana 2020; Mendoza and Gonzalez 2022; Zareei et al. 2022), the few that considered the external debt effects of exchange rate are Fisera, Tiruneh, and Hojdan (2021) for designated EDNs, Augustine (2019) for selected emerging nations, Wahyuni, Muhammad, and Nazamuddin (2019) and Nazamuddin et al. (2022) for Indonesia. To the best of what we know, however, the impact of exchange rate swings on external debt has yet to be thoroughly investigated. This is a significant concern from a policy standpoint because exchange rate volatility may also result in elevated external debt, which would increase the likelihood of a nation's debt crisis. This is crucial for the EDNs, which are highly dependent on FCBD because their domestic currencies are largely unconvertible, making them vulnerable to the debt crises that could be caused by high exchange rate volatility. Moreover, the turbulence of exchange rates is more pronounced in these nations than in the advanced nations (Hausmann, Panizza, and Rigobon 2006; Ikpe et al. 2021). Furthermore, increased currency volatility may raise borrowing costs if foreign lenders view the economy as riskier, increasing the likelihood of a debt crisis even more. This may worsen their debt crises and, as a result, affect economic growth due to debt overhang, crowding-out effects, and uncertainties, which together make achieving debt sustainability a problematic task (Borensztein and Panizza 2008; Carrera and Vergara 2012; Krugman 1988; Reinhart and Rogoff 2010; Sachs 1986). The study is especially pertinent now that many emerging or developing economies are experiencing currency devaluation. The potential for an economic meltdown to be caused by currency composition makes our study more relevant.

This study advances on the works of Augustine (2019) and Fisera, Tiruneh, and Hojdan (2021) by providing a unique contribution to the existing body of literature in several

ways: first, unlike the prior studies, the study utilizes two novel estimation procedures namely (STR and MTNARDL) to ascertain the threshold-based EDS implications of CD in external debt crisis nations. While Augustine (2019) and Fisera, Tiruneh, and Hojdan (2021) employed heterogeneous panel and nonlinear ARDL estimation procedures respectively, the current study adopts STR and the multiple threshold version of NARDL as a robustness test to examine the EDS effects of threshold-based exchange rate change and asymmetric, diverse swings in exchange rate. These innovative procedures are well-suited for the estimation of threshold as well as the dichotomization of series into two regimes and have been widely used in recent studies following the benefits they possess (Bouattour, Kalai, and Helall 2024; Muoneke, Okere, and Onuoha 2022; Odionye, Odo et al. 2023; Odionye, Ojiaku, and Uba 2023; Odionye and Chukwu 2021; Okere et al. 2023; Terasvirta 1998; 2004; Ullah et al. 2021). Second, besides the threshold value, it estimates CD's asymmetric sign-based and quantile-based influence on EDS. Third, while Fisera, Tiruneh, and Hojdan (2021) studied the panel of developing countries, this study considers the comparative investigations of selected SSA countries that are prone to overseas debt crisis. Fourth, it accounts for the structural break in the stationary test to evade the problem of incorrect deduction. Among other desirable features, these procedures are noteworthy for their efficiency in fractionally integrated series (Odionye, Nwosu et al. 2023; Okere et al. 2023). Based on the sturdy procedures adopted in this study, it is anticipated that significant policy solutions will be implemented to mitigate the external debt crisis and enhance its sustainability.

Findings indicate that external debt sustainability asymmetrically responds to devaluation and non-devaluation regimes in all the countries, except for Nigeria and Mozambique, which is a non-monotonous transition function that is symmetric about the threshold coefficient as confirmed through the smooth transition regression (STR) test. Furthermore, the outcome indicates a significant CD threshold of −1.3%, −10.3%, 54.1%, 23.1%, −4.2% and 32.3%, and 11.3% and 41.4% for Malawi, Tanzania, Ghana, Kenya, Nigeria and Mozambique respectively. This implies that, on the average, a devaluation threshold value of 21.1% is consistent with external debt sustainability in the designated nations; CD high and above the threshold value will increase the external debt to GDP ratio of the countries and hence worsens EDS. The finding was further validated by the MYNARDL results, which indicate that an extremely small CD below 25th quantile significantly reduces the external debt–GDP ratio and thereby enhances EDS. At the same time, CD above it significantly worsens EDS in all the selected countries.

Other segments after the introduction are 2, 3, 4, and 5 comprising the review of pertinent literature, an overview of the data and estimation procedure, empirical estimates and discussions, and a conclusion and policy options, respectively.

2. Literature review

Devaluation of the currency or depreciation of the exchange rate is supposed to improve the trade balance and boost a nation's GDP. Significant theoretical discussions have been held on the expansionary or contractionary nature of devaluation, particularly in emerging countries, with varying perspectives held by various schools of thought. These opinions can be primarily split into two groups: structuralists and traditionalists. While structuralists believe that devaluation could have detrimental consequences

due to an economy's existing structure, traditionalists believe that devaluation is expansionary (Caves, Frankel, and Jones 1996; Cooper 1971; Edwards 1986; Krugman and Tailor 1978; Van Wijnbergen 1986). The traditionalist viewpoints are primarily based on elasticity approach which explicates the link between CD and trade balance. To this end, the study reviews six major links through which CD can affect the economy namely: the trade balance channel, imported input cost and inflationary channel, cost of capital channel, capital flight channel, investment channel, and the external debt channel.

2.1. Trade balance channel of CD

The elasticity approach suggested by the Marshall–Lerner condition is prominent among the traditional views which is regarded as trade balance channels of CD (Lerner 1944; Marshall 1923). The elasticity approach to the BOP is credited to the Marshall–Lerner condition, which was worked out independently by these two economists. It explicates the conditions under which exchange rate movements restore equilibrium in the BOP through the devaluation of a country's currency. This approach is related to the price effect of devaluation. The theory's basic assumptions are that supplies of imports and exports are perfectly elastic and that the prices of goods are fixed in local currency. When a country devalues its currency, the local prices of its imports are raised, and the foreign prices of its exports are reduced. This will increase total exports and decrease aggregate imports, thereby improving a country's trade balance and output. This increased output will reduce external debt–GDP ratio and hence enhances EDS. However, the extent of the effect of devaluation depends on the country's price elasticities for local demand for imports and foreign demand for exports. This is popularly known as the Marshall–Lerner condition, which states that when the sum of price elasticities of demand for exports and imports in absolute terms is greater than unity, devaluation will improve the country's BOP. In other words, if the demand for a country's exports and imports is more sensitive to changes in price than the supply of these goods, the balance of trade will improve after the currency depreciates. Conversely, if the sum of the price elasticities of demand for exports and imports, in absolute terms, is less than unity, devaluation will worsen the BOP. And if the sum of these elasticities in absolute terms equals unity, devaluation does not affect the BOP (Lerner 1944; Marshall 1923).

2.2. Imported input cost and inflationary channel

This channel is discussed in the studies of Krugman and Tailor (1978); Van Wijnbergen (1986); Bruno (1979); Hanson (1983), Branson (1986), Solimano (1986), Edwards (1986), and many others. Production activity is highly determined by imported inputs from raw materials, intermediates, or capital goods in many less developed countries. Devaluation leads to increased import prices, which will lead to a high cost of production due to the high cost of imported inputs. This will lead to inadequate inputs necessary for production. Inadequate inputs and high production costs will reduce production, lowering the overall supply and output. This reduction in output will adversely affect external debt–GDP ratio and hence EDS becomes problematic. This may even lead to high inflation due to a supply shock. A typical example of this problem is found in oil importing and many developing countries, which depend heavily on importing raw materials for production.

2.3. Cost of capital channels

The cost of working capital channel is another supply side through which devaluation may cause adverse effects on output (Bruno 1979). The traditional economic theory argues that capital as a factor of production is usually fixed in the short run. Thus labour, raw materials and intermediate inputs are the only variable costs. In an economy where the financial markets are developed, firms can easily borrow from the financial markets to meet their short-term financial needs. However, in developing countries, financial markets are undeveloped, making borrowing difficult and inaccessible. According to Van Wijnbergen (1986), under these circumstances, if devaluation occurs, the actual volume of credit available in the market falls, and interest rates tend to rise. This will lead to a high cost of production and, consequently, a decline in total output.

2.4. Capital flight channel

Depreciating the currency can help align official and market rates, stimulate exports, and reduce capital flight, especially when accompanied by financial market liberalization. Note that capital flight often occurs when the official rate is significantly different from the market rate. This flight involves acquiring foreign currency through unofficial channels, manipulating trade invoices, and the expectation of devaluation. Thus, by narrowing the gap between official and market rates, depreciation can help reduce capital flight. The reduction in capital flight can boost domestic investment and growth, and hence reduce external debt–GDP ratio. However, in severe cases, additional measures like interest rate adjustments are necessary to counter capital flight effectively.

2.5. Investment channel

Currency depreciation can impact investment in developing countries by influencing the importation of raw materials and capital goods, known as producer goods. Depreciation alters relative prices between domestic and foreign inputs, prompting substitution possibilities favouring domestic factors of production. However, the extent of substitution varies, with greater potential for raw materials than capital goods. Investment and growth can benefit from increased production of exports and import substitutes, especially where excess capacity exists and demand elasticity for exports is high. Confidence in domestic investment relative to foreign assets can also boost investment and output growth, affecting imports of producer goods.

2.6. External debt channel

The hypothetical link between the CD and public debt can be traced back to Keynes (1973), who had recommended a unilateral devaluation (causing a one-time rise in the price level) that would reduce the actual worth of government's country-specific debt in light of what was happening in France in the 1820s, when the national debt payment consumed practically all tax receipts. Since the actual debt holders and those who pay the taxes to serve it (workers, entrepreneurs), respectively, are not the same individuals, Keynes became worried about the calculating repercussions resulting from the need to service a growing stock of public debt. When governmental debt reduces private savings and capital formation below the ideal rate, there is also an efficiency argument to lower

its real value. Several authors had later-on adopted and modified Keynes's idea (Ize and Ortiz 1987; lze 1987; Trigueros and Fernandez 1986). They acknowledge that Keynes's presumptions, that the absence of price inertia and the long-term maturity of government debt do not apply to the debt of today's emerging nations. However, for countries with problematic debt, the supposition that exchange rate devaluation enhances the government budget has not been proven. When the actual interest paid on the net overseas debt, along with the non-interest budgetary shortfall on tradables, outweighs the current net overseas debt, a real depreciation has an adverse price effect on the government's budget even when there is no exchange rate overshooting. To put it another way, an actual depreciation will be most probable to help the fiscal condition when the government's spending on tradables is in an initial advantage or when the overall foreign exchange flow (new debt less interest to the government) is favourable. Since many EDNs are prone to record deficit trade balances, the effect of a real devaluation on the government's fiscal situation would likely be negative (Reisen 1989). One of the earlier studies on the influence of currency devaluation on external debt profile of countries was conducted by Caves, Frankel and Jones (1996). Caves, Frankel, and Jones (1996) showed this in the case of Mexico. After the devaluation of the Mexican currency in 1994, there was an increase in the cost of external debt which led to insolvency in some businesses and this contributed to the recession in the Mexican economy. In 2003, Tille (2003) discovered that more than 30 percent of the exponential increase in the US overseas borrowing between 1999 and 2001 was caused by the country's exchange rate swings.

2.7. Empirical literature

Across a spectrum of studies, the effects of exchange rate depreciation on external debt appear twofold. Numerous investigations highlight a positive correlation between exchange rate movements and external debt accumulation. For instance, Dawood, Baidoo, and Shah (2021) examining 32 Asian developing and transitioning economies, and Omar and Ibrahim (2021) in the context of Somalia, employing the generalized method of moments (GMM) and autoregressive distributed lag (ARDL) respectively, discovered that exchange rate fluctuations consistently impact external debt positively in both short and long-term scenarios. Similarly, Harsono, Kusumawati, and Nirwana (2023) analysing data from 52 samples across 5 ASEAN developing countries using ordinary least square (OLS) regression and moderated regression analysis (MRA), and Mijiyawa and Oloufade (2023) utilizing panel data spanning from 1970 to 2017, concurred that exchange rate movements exert a positive influence on external debt dynamics.

However, there are dissenting views within the literature. Abdullahi, Bakar, and Hassan (2015), utilizing the ARDL model, found a contrary relationship, indicating that exchange rate depreciation negatively impacts external debt levels over both short and long horizons. In contrast, Gokmenoglu and Rafik (2018), employing the VECM framework, observed a positive association between exchange rate changes and external debt in the short run, but an inverse relationship emerged in the long run.

Several other studies have delved into the intricate relationship between exchange rates, external debt, and fiscal sustainability across various nations, offering diverse insights. Martinez and Vergara (2009) concentrated on five Latin American countries, analysing the impact of both local and foreign currency debts on debt sustainability. Their investigation emphasized the importance of considering currency valuation

concerns in budgetary assessments. They highlighted that a devaluation in the home currency could significantly alter the trajectory of a sustainable fiscal strategy. Utilizing VAR models and panel regression with fixed effects, they discerned that the magnitude of necessary budgetary adjustments post-devaluation correlates with factors such as the devaluation's extent, adjustment duration, interest rates, growth impact, and the percentage of debt issued in foreign currencies. Contrastingly, Asonuma (2016) scrutinized the effects of exchange rate depreciation on external debt default using dynamic stochastic general equilibrium. This study distinguished between pre- and post-default epochs and identified a direct link between depreciation and the risk of default across 18 debt default incidents. It highlighted that pre-default exchange rate declines exacerbate debt servicing challenges, often leading to default. Post-default, the absence of market access intensifies real exchange rate depreciation. Longitudinal regression analyses affirmed this relationship. Fisera, Tiruneh, and Hojdan (2021) adopted a similar longitudinal framework, investigating the impact of currency devaluation on external debt sustainability. Their study, employing a heterogeneous longitudinal estimation approach and a nonlinear version of ARDL, found that devaluation prompts increased overseas borrowing, particularly for smaller nations. Moreover, they uncovered a strong asymmetric relationship between the series, with minor currency devaluations potentially leading to reduced overseas borrowing relative to GDP.

Augustine (2019) explored the interplay between exchange rates and foreign borrowing in selected emerging economies. By examining whether nations leverage exchange rate appreciation to alleviate mounting external debt, the study revealed an inverse relationship between these factors. Augustine's study indicated that many nations witness a surge in overseas borrowing post-currency devaluation, potentially exacerbating external debt sustainability issues. In the Indonesian context, Wahyuni, Muhammad, and Nazamuddin (2019) and Nazamuddin et al. (2022) explored the nexus between exchange rates and external debt. Both studies identified a long-term co-movement between these variables, but Nazamuddin et al. (2022) observed a detrimental effect of exchange rate on overseas borrowing, particularly in the long run. Conversely, Wahyuni, Muhammad, and Nazamuddin (2019) highlighted that exchange rate depreciation exacerbates a nation's external debt profile, necessitating strategies to stabilize exchange rates for sustainable overseas borrowing. Similarly, Kijjambu et al. (2024) investigated Uganda's debt sustainability, particularly in response to macroeconomic variables like exchange rates. Employing ARDL estimation, they revealed that exchange rate depreciation significantly impacts the country's debt sustainability, underscoring the importance of addressing exchange rate fluctuations in managing external debt burdens.

3. Data and empirical methodology

The SSA nations that formed part of the investigated nations are Nigeria, Ghana, Kenya, Tanzania, Mozambique, and Malawi. The study covered the period between 1980 and 2022. The choice of the countries under investigation was predicated on those that are in high or moderate danger of external debt crisis. The IMF classified nations into 4: low risk, moderate risk, high risk, and in-distress with respect to external and aggregate debt sustainability (IMF 2020). Accordingly, two countries were selected from the three groups (moderate risk, high risk, and in-distress) susceptible to EDS difficulty. Based on the recent debt sustainability analysis (DSA), Malawi and Mozambique are branded as in-distress of EDS (ID-EDS), while Ghana and Kenya are classified as high risk of

EDS (HR-EDS), and Tanzania and Nigeria are grouped under moderate risk of EDS (MR-EDS). Instructively, all the chosen nations operate a managed float exchange rate system, in which the regulatory agency occasionally takes action in the markets to stabilize the exchange rates, deploying a variety of tools. The exchange rate serves as our main regressor. For this reason and following several prior studies (Fisera, Tiruneh, and Hojdan 2021; Nazamuddin et al. 2022; Wahyuni, Muhammad, and Nazamuddin 2019), the study's primary method of measuring exchange rate is the value of the local currency relative to the US dollar. We use this measurement because the investigated nations' foreign debt is expressed in US dollars (IMF 2023). Since the nominal exchange rate variations affect the worth of foreign debt (expressed in domestic currency), borrowing costs, and debt service, we used the nominal exchange rate as our primary measure of exchange rate instead of the real exchange rate. The studies of Georgiadis, Muller, and Schumana (2021) and Gopinath et al. (2020) prove that international funding availability is influenced by the nominal devaluation of the national currency against the U.S. dollar, while Boz et al. (2022) noted that US dollar is the predominant foreign currency used in foreign transactions. In the case of the study's main explained variable, the study utilized the ratio of external debt to GDP as a measure of debt sustainability. IMF (2002) identified many measures of external debt sustainability which includes debt to GDP ratio, debt to export ratio and the short-term debt-to-reserve ratio. Aside from the fact that many researchers prefer the debt-to-GDP ratio over others as it measures sustainability in terms of the growth factor rather than the short-term liquidity requirement and export factor (Bernardo, Vasconcelos, and Rocha 2024; Fisera, Tiruneh, and Hojdan 2021; Nazamuddin et al. 2022; Wahyuni, Muhammad, and Nazamuddin 2019), data availability and consistency also contribute to its choice. This measure supports policymakers in managing their external debt. It is viewed as an assessment of the nation's solvency as it takes into account the debt stock at a given point in time relative to the nation's capacity to produce the necessary income to pay off the remaining amount (IMF, 2000; Muhanji and Ojah 2011, Bernardo, Vasconcelos, and Rocha 2024).

The study used Terasvirta's Smooth Transition Regression (STR) model to analyse how CD asymmetrically influence external debt sustainability (EDS) (Terasvirta 1998; 2004). To determine the proper model estimation, a number of pre-estimation tests, amongst them are, the BDS test of linearity, descriptive statistics, lag length selection, Durbin–Wu–Hausman endogeneity test, and unit root test, were performed. The study applied the Zivot and Andrews (1992) unit root test with a structural break to determine the stationarity features. Table 1 lists the data sources and measurements for the variables considered in this study.

3.1. Smooth transition regression (STR) model

The STR presents transitions in regimes as a continuous process conditioned by the regime-changing variable. This model assumes a smooth movement of an indicator from a specific regime to another, with nonlinear regime-switching behaviour incorporated in both unidentified and identified regime periods (Odionye, Odo et al. 2023; Odionye and Chukwu 2021; Terasvirta 1998, 2004). Because of its several benefits, the STR model has been extensively utilized in studies on currency markets (Odionye, Odo et al. 2023; Odionye and Chukwu 2021), energy and environmental research (Khaskheli et al. 2021; Ullah et al. 2021), and technology and industrial sector (Bouattour, Kalai, and Helall 2024). The STR model has several benefits, such as (i) estimating a threshold value that

Table 1. Variables portrayal and sources of data.

Names	Portrayal and measurement	Source
ECR	The country's nominal exchange rate vis-à-vis the US Dollars (National Currency/USD) – measured in direct quotation	PWT
GDP	GDP at constant prices expressed in billions of the local currency	WDI
EDS	The ratio of external debt stock (aggregate) to GDP at current prices	WDI
EDC	The external debt service expressed as a ratio of external debt burden (USD)	WDI
GEP	Total Government expenditure at constant local currency as a ratio of GDP	WDI
FND	Domestic credit to private sector expressed as a percentage of GDP	WDI

.WDI = World Development Indicators data (2022). PWT = Penn World Table (10.0) available on www.ggdc.net/pwt. *WEO = International Monetary Fund (IMF), World Economic Outlook (2022) Source: Compiled by the Author.*

splits the regressor(s) into distinct regimes; (ii) allowing for the regressor(s) at different regimes as a regime-switching model; (iii) producing robust results even in the presence of structural breaks and so on (Hansen 1999; 2011; Odionye and Chukwu 2021; Ullah et al. 2021). In its generic form, equation (1) expresses the STR operational design:

$$: Z_t = \varpi' x_t + \theta' x_t G(S_t; \gamma, c) + \mu_t \tag{1}$$

where $\mu_t \sim iid[0, \sigma^2], x_t = (w_t', x_t')'$ is an $((m+1) \times 1)$ vector of regressors, as the linear part is denoted by ϖ while θ stands for the nonlinear parameter. The continuous transition function G, conditioned upon the regime-switching factor S, takes the values of 0 and 1, with 0 signifying the zero-policy period in this framework, the non-devaluation regime (NDR), and 1 representing the devaluation regime (DR). γ designates the swiftness of change between diverse regimes, and c epitomizes the threshold value. Potentially, factors for the regime-switching are the regressors, lagged endogenous factor, or trend values (t) (Odionye, Odo et al. 2023; Terasvirta 2004). The initial step in the calculation method is to choose the regime-switching factor. This is accomplished by testing the null hypothesis for each potential regime-switching factor. This is followed by choosing the regime-switching function by testing a set of hypotheses against the supplementary polynomial orders in equation (2):

$$Z_t = \phi_0 x_t' + \phi_1 (x_t' S_t) + \phi_2 (x_t' S_t^2) + \phi_3 (x_t' S_t^3) + \mu_t \tag{2}$$

Hypothetically, equation (3) expresses the null form as

$$\begin{aligned} H_0^4 &: \phi_3 = 0 \\ H_0^3 &: \phi_2 = 0 | \phi_3 = 0 \\ H_0^2 &: \phi_1 = 0 | \phi_2 = \varphi_3 = 0 \end{aligned} \tag{3}$$

The class of F-tests (F^4, F^3, and F^2, correspondingly) are utilized to examine the formulated hypotheses. The decision rule is to choose the LSTR2 or the ESTR model if F^3 has the least p-value, while the LSTR1 is the most suitable model if either F^4 or F^2 has the smallest p-value (Terasvirta 2004).

3.2. Asymmetric influence of currency devaluation on external debt sustainability using STR model

Following the hypothetical view of Gylfason and Risager (1984) and Cooper (1971) and prior studies (Fisera, Tiruneh, and Hojdan 2021; Nazamuddin et al. 2022), the STR model in line with equation (1) is expressed in equation (3) as

$$LEDS_{it} = \lambda_0 + \sum_{j=0}^{m} \lambda_j LECR_{it-j} + \sum_{j=0}^{m} \lambda_j LEDC_{it-j} + \sum_{j=0}^{m} \lambda_j LGDP_{it-j} + \sum_{j=0}^{m} \lambda_j LGEP_{it-j} + \sum_{j=0}^{m} \lambda_j FND_{it-j} + G(S_{it};\gamma, c)\left(\sum_{j=0}^{m} \lambda_j LECR_{it-j}\right) + \mu_{it} \quad (4)$$

where EDS, ECR, EDC, GDP, GEP, and FND stand for external debt sustainability, exchange rate, external debt servicing, gross domestic product, government spending and financial development respectively, and L denotes natural log. The hypothetical viewpoints as well as the prior studies were what guided the choice of the control variables in equation (4) (Fisera, Tiruneh, and Hojdan 2021; Nazamuddin et al. 2022). Table 1 provides the portrayal and measurements of the variables

3.3. Asymmetric response of EDS to exceedingly small and exceedingly large CD

As a robustness check as well as to uncover the influence of exceedingly small and exceedingly large changes in CD on EDS, the study utilized the multiple thresholds nonlinear autoregressive distributed lag (MTNARDL) model as suggested by Pal and Mitra (2015, 2016). The model is a progression of the NARDL of Shin, Yu, and Greenwood-nimmo (2014) and has several advantages as it fragments the regressor, in this context, nominal exchange rate, into diverse quantiles (small, moderate and large) to examine their influence on EDS. The MTNARDL model is therefore expressed as

$$\Delta LEDS_{it} = \sum_{j=1}^{3} \varphi^{+} LECR_{it}^{\eta j}(pos) + \sum_{j=1}^{3} \varphi^{-} LECR_{it}^{\eta j}(neg) + \phi_i ECT_i + \sum_{j=1}^{n} \pi_{it} \Delta LEDS_{t-p} + \sum_{j=1}^{3} \sum_{p=0}^{m} \alpha_{it}^{+} \Delta LECR_{it-P}^{\eta j}(\text{pos}) + \sum_{j=1}^{3} \sum_{p=0}^{m} \beta_{it} \Delta LECR_{it-m}^{\eta j}(\text{neg}) + \sum_{i=0}^{m} \beta_{it} X_{it} + \mu_{it} \quad (5)$$

where the first two terms on the right-hand side are the asymmetric long-run segment, split into positive (pos) and negative (neg), ECT designates the rapidity to equilibrium convergence, and the last two components measure the positive (pos) and negative (neg) short-term elasticity, η demonstrates the change in CD, and the subscript j is the degree of change ($j = 1, 2,$ and 3) 1 = small change (sch), specified as changes in CD below or equal the 25th percentile; 2 = moderate change (mch), changes in CD between the 25th and 75th percentile; and 3 = large change (lch), specified as changes in CD above the 75th percentile, m and n are maximum lag length, $\mu = \text{iid}(0, \sigma)$. X represents a vector

of control variables. Hypothetically, no cointegration is stated, as $\alpha_1 = \alpha_2 = \alpha_3 = 0$. There is long-term relationship between the variables if the null hypothesis is rejected. The Wald test of symmetric is utilized to uncover the short-term and long-term asymmetries. Following Pal and Mitra (2015), the expression for small, moderate, and large changes in CD is given in equations (6), (7), and (8) respectively

$$\mathrm{LECR}_{it}^{sch} = \sum_{p=1}^{n} \theta_{ip} \Delta \mathrm{LECR}_{ip}^{sch} = \sum_{p=1}^{n} \Delta LECR_{ip}^{I}(\Delta LECR_{im} \leq \tau^{25}) \tag{6}$$

$$\mathrm{LECR}_{it}^{mch} = \sum_{p=1}^{n} \theta_{ij} \Delta \mathrm{LECR}_{ip}^{mch} = \sum_{p=1}^{n} \Delta LECR_{ip}^{I}(\tau^{25} < \Delta LECR_{ip} \leq \tau^{75}) \tag{7}$$

$$\mathrm{LECR}_{it}^{lch} = \sum_{p=1}^{n} \lambda_{ip} \Delta \mathrm{LECR}_{ip}^{lch} = \sum_{p=1}^{n} \Delta LECR_{ip}^{I}(\Delta LECR_{ip} > \tau^{75}) \tag{8}$$

As a result of its several benefits, the MTNARDL model has been extensively employed in recent times to study the influences of extreme changes in oil prices, stock prices, and exchange rate shocks (Li and Guo 2022; Odionye, Nwosu et al. 2023; Odionye and Chukwu 2023; Uche, Chang, and Effiom 2022). The limitation of the model is that it requires a large number of observations as the number of thresholds reduces its sample. The number of observations for each nation in this study is 43, which is sufficiently large. Also, the model variables should be either level stationary or first-difference stationary series (Li and Guo 2022; Odionye, Nwosu et al. 2023).

4. Results

4.1. Descriptive analysis

Traditionally, every scientific exposition commences with some preliminary statistical analysis that makes way for a more vigorous estimate. Accordingly, summary statistics were conducted to the relevant series for this enquiry. This analysis displays the form of the distributions as well as the series' behavioural inclination, amongst other things. The test results reported in Table 2 demonstrate that descriptive statistics, in particular, provide the evidence of the series' frequent mistrust.

As displayed in Table 2, the descriptive statistics which was conducted on the raw factor before they were log-converted, provides their true behavioural tendencies. The descriptive statistics demonstrate that the mean (maximum) values of external debt–GDP ratio (EDS) for Nigeria, Tanzania, Kenya, Ghana, Malawi, and Mozambique are 56.6 (228.6), 98.9 (126.1), 51.9 (131.9), 58.75 (129), 92.2 (177.4), and 113.7 (282.9) respectively. Statistically, Mozambique has the highest mean value of the external debt–GDP ratio, followed by Tanzania and Malawi in that order, while Kenya and Nigeria had the least. This is not surprising considering that Mozambique and Malawi are in distress of EDS, while Nigeria, with a relatively low external debt–GDP ratio, is at moderate risk of EDS. Regarding the exchange rate, the outcomes indicate the mean (highest) values for Nigeria, Tanzania, Kenya, Ghana, Malawi, and Mozambique as 109.9 (372.12), 893.2 (1931.9), 61.17 (104.1), 1.39 (6.41), 463.6 (733.0), and 24.9 (69.2), respectively. This shows that Tanzania has the largest mean (maximum) values, followed by Malawi and Nigeria, which portrays high gyrations in these countries' exchange rates. The standard

Table 2. Descriptive outcomes.

Variables	Mean	Maximum	Std_Dev	Skewness	Kurtosis	J_B Stat.
Nigeria						
EDS	56.63	228.64	61.18	0.92	3.06	6.07**
ECR	109.94	372.16	111.8	0.87	2.71	5.98**
EDC	0.098	0.518	0.09	2.94	13.3	251.5***
GDP	4.03E + 13	9.71E + 13	2.60E + 13	0.83	2.25	5.96**
GEP	0.852	1.204	0.137	−0.05	2.70	0.172
FND	9.549	19.63	3.556	0.91	3.34	6.105**
Tanzania						
EDS	98.87	126.09	0.511	0.80	4.49	8.56**
ECR	893.18	1931.9	672.6	0.05	1.55	8.75***
EDC	0.028	0.073	0.014	1.59	5.71	31.4***
GDP	2.53E + 10	6.37E + 10	1.64E + 10	0.95	2.63	6.72**
GEP	0.943	2.661	1.909	0.36	1.56	4.69**
FND	8.756	14.61	4.51	−0.25	1.39	6.05**
Kenya						
EDS	51.94	131.89	24.11	1.28	4.39	15.2***
ECR	61.17	104.06	32.47	−0.36	1.74	3.76
EDC	0.09	0.165	0.037	0.10	1.92	12.2***
GDP	2.45E + 12	5.04E + 12	1.15E + 12	0.81	2.46	5.21*
GEP	0.81	2.24	0.74	0.67	1.96	5.68**
FND	24.94	36.69	5.21	0.61	2.35	13.95***
Ghana						
EDS	58.75	129.32	28.77	0.78	2.86	7.37***
ECR	1.391	6.405	1.89	1.40	3.67	15.04***
EDC	0.074	0.174	0.029	1.08	4.92	14.98***
GDP	2.42E + 10	8.43E + 10	2.23E + 10	1.47	3.86	16.8***
GEP	1.119	3.702	1.32	0.67	1.72	6.17**
FND	10.02	18.07	5.61	−0.14	1.51	4.14
Malawi						
EDS	92.18	177.41	42.73	−0.02	2.30	0.88
ECR	463.6	733.04	124.48	−0.09	2.67	8.26**
EDC	0.052	0.139	0.034	1.01	2.89	7.26**
GDP	5.91E + 11	1.25E + 12	2.97E + 11	0.83	2.40	5.54*
GEP	1.01	4.13	1.30	1.18	3.02	10.04***
FND	21.68	83.15	13.63	2.18	10.6	138.7***
Mozambique						
EDS	113.71	282.93	77.99	0.95	2.66	5.89**
ECR	24.95	69.21	21.97	0.76	2.46	8.15***
EDC	0.039	0.207	0.039	2.57	10.2	123.7***
GDP	2.59E + 11	6.38E + 11	1.77E + 11	0.72	2.22	4.24
GEP	0.749	1.55	0.56	0.06	1.49	3.58
FND	22.55	164.1	29.76	3.03	14.5	267.3***

Authors' calculation. *** (**) [*] signify the decline of null hypothesis of normal distribution at 1% (5%)[10%] level of significance respectively. EDS designates external debt sustainability; ECR stands for the exchange rate, EDC represents external debt servicing, GDP means gross domestic product, INF is inflation rate. FND is financial development, while GEP is the government expenditure.

deviation further shows that, comparatively, the Tanzanian exchange rate is extremely volatile, with a standard deviation value of 672.6, followed by Malawi (124.4), Nigeria (111), Kenya (32.4), Mozambique (21.97), and Ghana with the most negligible value of 1.8. Instructively, the outcome demonstrates huge exchange rate dispersion across the

designated nations. The Jarque–Bera statistics indicate that the null hypothesis of normal distribution is rejected for the majority of the series in all of the samples studied. This experiment validates the usage of a nonlinear model (Odionye, Nwosu et al. 2023; Odionye, Ojiaku, Okpara et al., 2024; Ullah et al. 2022).

4.2. BDS test

The Broock et al. (1996) estimator, often identified as the BDS test, was performed to check the data series' nonlinearity. This hypothesizes that the residual is independent and identically distributed (i.i.d), while the alternative posits that the residual series departs from independence, demonstrating nonlinear dependence. In brevity, Table B1 (Appendix B) displays the upshots of the BDS test. The BDS upshots as displayed in Table B1 demonstrate the refutation of the null hypothesis in the residuals for both models (level and difference) in all the investigated nations, except for Kenya (dimensions 6) and Mozambique (dimensions 5 and 6). The outcomes uphold the nonlinearity of the model residuals and thus justify the use of nonlinear estimation technique in the study (Odionye, Odo et al. 2023; Odionye, Nwosu et al. 2023; Ozcelebi 2021; Ullah et al. 2022)

4.3. Hausman test of endogeneity

To further ensure the model's validity in terms of endogeneity bias, the study tested for the endogeneity in the model using the Durbin–Wu–Hausman (DWH) test of endogeneity. The test was conducted following Davidson and Mackinnon (1993) by including the residuals of each of the endogenous variables (GDP and ECR) as a function of the exogenous variables in the models (equations [4] and [5]). Next, we conducted an experiment to test the hypothesis that the residual is exogenous, or ordinary least square is appropriate as against the alternative that it is inappropriate. The outcome of the estimates in the summary is presented in Table B2 (Appendix B). The estimated outcome in Table B2 supports the single equation model since the *p*-values of the DWH test exceed the 5% level of significance. Thus the regressors in the model are exogenous (Dhrymes 2003; Durbin 1954; Hausman 1978; Wu 1973)

4.4. Unit root test

Because the investigated nations had adopted diverse exchange rate policies and had weakened their local currencies at some points, the study applied the Zivot and Andrews (1992) test of stationarity with a structural break, taking into consideration the policy change to circumvent inaccurate inferences (Odionye, Nwosu et al. 2023; Odionye, Ojiaku, Agoh et al., 2024; Odionye and Chukwu 2021; Odionye, Okanta, and Odo 2019; Perron 1989, 1997). The outcome of the test is portrayed in Table B3 for brevity. Table B3 (Appendix B) indicates that the series are fractionally integrated, thereby validating the choice of ARDL bound cointegration test.

4.5. Ideal lag value selection

The best lag value for the series was selected based on the lag length information criteria, and the result is presented in Table B4 (Appendix B). Table B4 indicates that lag 2 is the appropriate lag value for Nigeria, Tanzania, Kenya, Malawi and Mozambique, whereas

lag 3 is the ideal value for Ghana. The lag information principles guided the selection of the lag value. The subsequent tests (STR and MTNARDL) were conducted following the ideal lag length to guarantee parsimony.

4.6. Cointegration test

In the study, given that the requisite criteria for computing bound cointegration is met, the bound test within the NARDL and MTNARDL paradigm frameworks are conducted. The estimated outcome is summarized in Table B5. As demonstrated in Table B5 (Appendix B), the upshots from both NARDL and MTNARDL models indicate the presence of cointegration. This means that there exists a sturdy long-term co-movement between the enlisted variables.

4.7. Selection of suitable regime-switching factor and function

Conventionally, the initial step in the STR model is to select the most suitable regime-switching factor and the procedure routinely selects it. The exchange rate (ECR) was identified as the regime-switching factor, and the lag length information criteria preferred lag two (Table B4). The test for linearity of each regime-switching function was then carried out against the STR to identify the most fitting regime-switching function. In brevity, Table B6 (Appendix B) demonstrates the outcomes of linearity statistics.

The decision rule for selecting of the regime-switching function is based on a sequence of nested F-test named (F_4, F_3 and F_2), which is used to select the regime-switching function with the minutest p-value of the F-test. The LSTR_2 is the ideal function, if F_3 has the minimum p-value, whereas LSTR_1 is the most fitting function if F_2 or F_4 has the least p-value. However, the function is linear if F has the smallest p-value. Table B6 indicates that either F_2 or F_4 has the least p-value for all the countries except Nigeria and Mozambique, suggesting that logistic smooth transition regression (LSTR_1) is the suitable regime-switching function for Kenya, Malawi, Tanzania, and Ghana. In contrast, quadratic–logistic smooth transition regression (LSTR_2) is the most fitting model for Nigeria and Mozambique. What this means is that the regimes identified by nonlinear model relate to devaluation (depreciation) with $G = 1$, in contrast to non-devaluation with $G = 0$. In the end, this means that the sustainability of external debt asymmetrically responds to devaluation and non-devaluation regimes in all the countries. However, for Nigeria and Mozambique, the function is a non-monotonous transition function that is symmetric about the threshold coefficient (c). The regime-switching factors for Nigeria, Kenya, Malawi, and Mozambique are exchange rate at present period t ($\mathrm{ECR_t}$) whereas those of Tanzania and Ghana are exchange rate at lagged one (ECR_{t-1}).

4.8. Threshold-based asymmetric influence of CD on EDS

The estimated procedure, as earlier described in the preceding sections, is the summary of the STR, which permits the estimation of the influence of smooth policy change on a series based on the regime-switching factor. For brevity, the STR outcomes are displayed in Table B7.

The STR outcome, as displayed in Table B7 (Appendix B), has four sections. Panel A indicates that the threshold coefficients for Nigeria, Malawi, and Tanzania are negative and significant at a 1 percent level, whereas those of Ghana and Kenya are positive and significant. But in the context of Mozambique, it is positive but inconsequential. Two threshold levels branded by the quadratic smooth STR functions (LSTR2) are −0.042 and 0.323 for Nigeria and 0.113 and 0.414 for Mozambique, correspondingly. One intriguing feature of this threshold result is that it indicates the lower and upper threshold levels. In the case of Nigeria, exchange rate changes (depreciation or appreciation) within −4.2% (4.2% appreciation) and 32.3% depreciation are consistent with EDS, whereas exchange rate swings outside this range are inconsistent with EDS. The implication of this upshot is that although exchange rate depreciation or devaluation may seem to adversely affect external debt denominated in foreign currency, high exchange rate appreciation above 4.2% or depreciation above 32.3% will increase external debt–GDP ratio burden, making its sustainability problematic. In the case of Mozambique, exchange rate depreciation between 11.3% and 41.4% depreciation is consistent with external debt sustainability but outside this range, EDS becomes problematic. The negative threshold coefficients of −0.013 and −0.103 for Malawi and Tanzania, respectively, seem to favour exchange rate appreciation but appreciation of exchange rate high and above 1.3% and 10.3% will worsen the EDS problem in Malawi and Tanzania respectively. This means that, for Malawi that is in distress of EDS, policy option targeting exchange rate stability will improve its EDS situation. In the case of Ghana and Kenya, exchange rate depreciation below 54.1% and 23.1%, respectively, is consistent with EDS, but depreciation above the threshold levels will increase their respective external debt–GDP ratio. The threshold values indicate massive divergence across the designated nations. This is caused by high volatility in the countries' exchange rate as revealed by the descriptive statistics (Table 2), which may be the result of poor macroprudential policies, overdependent on imports, and lack of internal capacity (Ikpe et al. 2021; IMF 2023; Odionye, Odo et al. 2023). However, on the average, the outcome indicates a significant thresholds value of 21.1%, consistent with external debt sustainability. This means that, on average, a CD of 21.1% or less will boost the trade balance over FCBD. However, beyond this threshold, it escalates FCBD over the trade balance, thus exacerbating the external debt sustainability (EDS) problem.

The gamma parameters further show that the regime-switching between two extreme regimes (DR and NDR) is smooth for Nigeria, Kenya Malawi, and Tanzania but for Ghana and Mozambique, it is high, indicating a rather sudden transition (policy change). However, the gamma parameters are substantial for Nigeria, Ghana, Tanzania, and Mozambique since their p-values are less than 0.05 but are inconsequential for Kenya and Malawi. This implies that CD as a policy shift largely influences EDS for Nigeria, Ghana, Tanzania, and Mozambique while in the context of Kenya and Malawi, CD as a policy shift is insignificant. Mozambique has the maximum gamma parameter, which is significant, followed by Ghana and Nigeria in that order, with Kenya recording the lowest gamma coefficient.

The second section of the result (NDR), as shown in Table B7, demonstrates that the exchange rate is negative for all the countries and significant only for Nigeria, Ghana and Kenya, but in the case of Malawi, Mozambique, and Tanzania, the coefficient of exchange rate is negative but inconsequential. This means that in the NDR, which represents the period of relative exchange rate stability; a small depreciation reduces the ratio of external debt to GDP and thus improves EDS. This might be elucidated on the ground that

real depreciation increases a country's GDP through increases in exports or increases in capital inflow into the country via advantageous global competitiveness, and hence increases EDS.

Regarding external debt services (EDC), the coefficients of EDC as expected are positive and significant for Kenya, Malawi, and Tanzania, while the other countries are insignificant. What this means is that, in the non-devaluation regime, an increase in external debt service significantly increases the Kenyan, Malawian, and Tanzanian external debt–GDP ratio, thereby making it more difficult for countries to liquidate their external debt burdens and hence debilitating external debt sustainability. In the case of the other countries, the inconsequential positive coefficients suggest that although increase in EDC elevates external debt–GDP ratio and reduces countries' ability to pay-up its debt, it is not a sufficient reason for the EDS problem. In the case of GDP, the coefficients of GDP are negative for Nigeria, Kenya, and Ghana but positive for Malawi, Tanzania, and Mozambique. However, the coefficients are not significant except for Ghana. These negative coefficients contradict the 'a-priori' expectation.

The outcome further indicates that the ratio of external debt to GDP increases significantly in response to government expenditure in the non-devaluation regime for all the designated nations except Malawi and Mozambique which demonstrate inconsequential effect. The implication of these upshots is that increased government spending increases budgetary shortfall, which leads to an increase in overseas borrowing to fill the shortfall. This outcome supports the outcome of Fisera, Tiruneh, and Hojdan (2021). Financial development (FND) significantly reduces the external debt of Nigeria, Ghana, and Kenya in line with the hypothetical view. The implication of this outcome is that, in the non-devaluation era, increase in financial sector development increases the GDP of the investigated countries and hence reduces their external debt–GDP ratio and thus enhances EDS. This outcome supports the findings of Fisera, Tiruneh, and Hojdan (2021).

Accordingly, the estimated outcomes from the Devaluation Era (Panel C) avail several pieces of empirical evidence capable of influencing the external debt–GDP ratio and, by extension, enhancing sustainability of external debt if painstakingly implemented. Expectedly, the results from the DR (Panel C) reveal that the coefficients of exchange rate (at current period and lagged value depending on the transition variable) are positive and significant in DR for Nigeria, Tanzania, and Mozambique, while they are negative but insignificant in the case of Ghana and Kenya (see the summary in Table B9, Appendix B). In the case of Malawi, the coefficient of exchange rate is positive but insignificant. The positive and significant coefficient of exchange rate for Nigeria, Tanzania, and Mozambique, in specific terms, suggests that 1 percent increase (depreciation) in exchange rate in the DR increases the external debt–GDP ratio of these countries and consequently reduces their EDS by 10.7%, 67.7%, and 11% correspondingly. The case of Tanzania indicates a significant large adverse effect on EDS following a small depreciation. This is because the estimated CD threshold (Panel A) for EDS in Tanzania favours currency appreciation. The implication is that depreciation as small as 1 percent will increase Tanzania's external debt–GDP ratio largely and hence malevolently affects its sustainability. The result further demonstrates that during the devaluation era, the external debt profile is worsened on account of exchange rate depreciation in these nations, and this will make further aggravates the external debt sustainability problems in these nations. These results support the structural school of thought, which contends that if a country with a large external debt denominated in foreign currency devalued its currency, it will affect

the economy adversely. This is a result of the fact that one unit of foreign currency now costs more units of domestic currency and this leads to an increase in the debt burden of both the private and public sectors and, hence a decrease in net wealth of a country (Cooper 1971; Gylfason and Risager 1984; Van Wijnbergen 1986). This corroborates the works of Caves, Frankel, and Jones (1996) in the case of Mexico, who found out that after the devaluation of the Mexican currency in 1994, there was an increase in the cost of external debt which led to insolvency in some businesses and this contributed to the recession in the Mexican economy. It also aligns with the works of Wahyuni, Muhammad, and Nazamuddin (2019), and Nazamuddin et al. (2022) for Indonesia, Zareei et al. (2022) for Iran, Demirkihc (2021) for Turkey, as well as Augustine (2019) and Fisera, Tiruneh, and Hojdan (2021) for some emerging economies. While Zareei et al. (2022) utilized the Markov switching model and observed high connectivity between exchange rate and external dept during devaluation regime, Demirkihc (2021) finds an inverse connection between external debt, currency mismatch, and investment following the huge depreciation in Turkey.

It is noteworthy that, upon comparing the results of the DR with the IMF's classification of debt sustainability, the EDS of Mozambique (in distress of EDS), and Nigeria and Tanzania (at moderate risk of EDS) deteriorated following CD. However, the cases of Ghana and Kenya (high risk of EDS) indicate increase but insignificant effects, while that of Malawi is negative but insignificant following CD. The implication of these mixed outcomes suggests that the impact of CD on EDS depends on other supporting policies and the proper utilization of external borrowing (IMF 2023; Odionye and Chukwu 2021). For instance, if a country's exchange rate market is stable but the external debts are not adequately utilized, or borrowed funds meant for investment purposes are diverted into private pockets, as is common in these nations (Ikpe et al. 2021; Odionye, Odo et al. 2023), the country will be marred with sustainability problem. IMF (2023) noted that the effect of policies such as CD depends on macroprudential policy and other supportive policies. This mixed outcome corroborates the view held by the structuralists that CD may have adverse effects on a country's economy, which depends on its structure and peculiarity (Krugman and Tailor 1978; Van Wijnbergen 1986)

The coefficients of EDC are positive for all the countries except Malawi but only significant at 5% level of significance for Nigeria, Kenya, Tanzania, and Mozambique. In specific terms, the upshots demonstrate that a percent increase in external debt service largely increases the ratio of external debt stock to GDP of Nigeria, Ghana, Kenya, and Tanzania by 22%, 6%, 36.7%, and 16.4% respectively. This result implies that depreciation or devaluation of exchange rate will increase the external debt burden of countries with sizeable debt denominated in foreign currency. This equally validates the structralist's view that the more the amount of external debt and interest rate charged on it, the more significant the deterioration in the net wealth of a country as a result of devaluation. This corroborates the works of Caves, Frankel, and Jones (1996) in the case of Mexico.

Pertaining to the coefficients of GDP, the outcome from the DR indicates that improvements in the countries' performance reflected in their GDP will reduce the external debt burden and hence increases its sustainability. Specifically, a percentage improvement in the GDP of Nigeria, Ghana, Kenya, Tanzania, and Mozambique largely reduces the countries ratio of external debt to GDP by 35%, 3.4%, 76%, 32%, 25% respectively. This outcome supports the theoretical postulation that proper investment and utilization of external debt boosts a country's productivity and, hence, increases

its sustainability. Similarly, increase in government expenditure significantly increases the investigated country's external debt profile, and this may hinder its sustainability, depending on its uses.

Considering a substantial R square above 70% (Panel D) in all the investigated nations except Ghana, where the R square is 68.1%, the corresponding coefficients of multiple determination and its adjusted results demonstrate that the variances in explanatory variables considerably predict the variance in the EDS.

The study performed a number of mis-specification evaluations (Panel D), including the Arch LM test, Jarque–Bera test, autocorrelation test, and parameter constancy test, to assess the accuracy of the generated model. The model fulfilled the primary diagnostic procedure in the majority of nations. As demonstrated in Panel D, all the sample countries have *p*-values of the Arch LM test above 0.05, signifying no arch impact in the model. For the Jarque–Bera test, the null hypothesis of the residuals having a normal shape was accepted for all the countries except Ghana, with *p*-value less than 0.05. Similarly, the upshots demonstrate that there is no sign of serial autocorrelation in the model for the sample countries, given that the *p*-values for autocorrelation (A/co (3)) are higher than 0.05. Furthermore, except in Kenya, the results demonstrate the confirmation of parameter constancy (PC), given the *p*-values more prominent than 0.05.

4.9. Asymmetric influence of exceedingly small change and exceedingly large change in the exchange rate on EDS

The study, as a robustness test, further assesses how EDS responds asymmetrically to exceedingly small and exceedingly large changes in the exchange rate in the investigated nations using the novel MTNARDL estimation procedure as demonstrated in equation (5). The innovation in this estimation is to understand whether the response of EDS to exchange rate is sensitive to the size and sign of changes in the exchange rate. Such information is imperative because not all exchange rate changes (appreciation or depreciation) can boost net exports and output or increase the risk related to FCBD. However, some will change and cause demand to move, affecting the firm's export and output, or EDS via FCBD. The execution of the MTNARDL model is necessary in the case of the present investigation to offer the response of EDS to exchange rate mismatch at each extreme. In brevity, the outcome of the MTNARDL is displayed in Table B8.

The study further assessed how EDS respond to exceedingly small and exceedingly large asymmetric swings in CD by decomposing changes in exchange rate lower and upper quantiles (Li and Guo 2022; Odionye, Nwosu et al. 2023; Odionye and Chukwu 2023) in line with equations (6)–(8). It is imperative to note that, amongst other exciting discoveries from the upshots summarized in Table B8, the external debt–GDP ratio reinforces itself in all the investigated countries (Panel A). The substantial direct connection between the preceding value of EDS and its current value serves as an example of this obvious outcome. Specifically, the current state of external debt ratio to GDP is largely elevated by roughly 0.08% (Nigeria), 0.12% (Tanzania), 0.07% (Kenya), 0.17% (Ghana), 0.51% (Malawi), and 0.35 (Mozambique) in response to 1% increase in its preceding values. The outcomes reveal that the response of the current state of the external debt–GDP ratio to its past value in terms of size is most pronounced in Malawi (0.51%) and closely followed by Mozambique (0.35%). The similarity of these two countries in terms of EDS is that they are already in distress. This means that an increase in external debt in the current year increases the need to obtain more loans from other countries

to sustain the existing ones. This cycle continues until the cumulative external debt burden becomes unsustainable. This outcome validates the findings of Fisera, Tiruneh, and Hojdan (2021)

The short-run estimation (Panel A) reveals that slight exchange rate depreciation (LECR_SCH_PO) largely reduces external debt burden and hence improves the studied countries' EDS. In contrast, slight appreciation in exchange rate (LECR_SCH_NE) significantly deteriorates EDS by increasing external debt burden in Malawi and Mozambique. In the case of Kenya and Ghana, a slight exchange rate appreciation largely reduces the ratio of external debt to GDP and thereby improves EDS while in Nigeria and Tanzania, it inconsequentially influences EDS. In specific terms, EDS via the ratio of external debt to GDP is improved by 0.07% (Nigeria), 0.07% (Tanzania), 0.1% (Kenya), 0.32% (Ghana), 0.21% (Malawi), and 0.27% (Mozambique) in reaction to a slight exchange rate depreciation. This upshot confirms the STR result in Table B7 (Panel B), suggesting that small depreciation enhances the country's global competitiveness, leading to export and output expansion and, hence, a reduction in external debt burden. The implication of this result is that the expansionary influence of small depreciation (via boost in export and output) outweighs the contractionary influence of devaluation through balance-sheet effect. These results further bolster the estimated thresholds from the STR model, which predicts that depreciation or CD within the average threshold of 21.1% will increase the investigated nations' exports and outputs, reduce the external debt-GDP ratio, and enhance EDS.

In a situation where there is moderate depreciation of exchange rate (LECR_MCH_PO), it significantly worsens EDS through an increase in the external debt-GDP ratio in all the studied nations except Malawi, whose EDS is aggravated following moderate exchange rate appreciation. Specifically, the EDS is largely enervated via the elevated external debt-GDP ratio by roughly 0.21% (Nigeria), 0.18% (Tanzania), 0.08% (Kenya), 0.26% (Ghana), and 0.08∗ (Mozambique) in response to 1% increase in exchange rate depreciation in the mid-quantile. However, the short-run estimation further demonstrates that external debt sustainability becomes highly problematic following a large exchange rate swing (appreciation and depreciation) (LECR_LCH_PO). In specific terms, following a large exchange rate depreciation above 75th percentile, EDS through elevated ratio of external debt to GDP in Nigeria, Tanzania, Kenya, Ghana, Malawi, and Mozambique reacts adversely by 0.46, 0.39, 0.56, 0.67, 0.80, and 0.38 percent respectively to 1 percent exchange rate (positive) depreciation. These outcomes imply that exchange rate depreciation above 25th percentile (both moderate – LECR_MCH_PO and large – LECR_LCH_PO) worsens the sample nations' external debt profile, further devastating the external debt sustainability problems in these nations. These outcomes uphold the hypothetical view that a country's economy would suffer if it devalued its currency because of its substantial external debt based on foreign currency. This is because a unit of foreign currency now costs more than one unit of domestic currency, which causes the debt load of both the public and private sectors to rise and, as a result, reduces a nation's net wealth. Instructively, it is noteworthy that a small CD improves the countries' EDS significantly, but if the CD is high and above the lower quantile (25th percentile), its influence becomes detrimental as the deteriorating influence of CD on EDS increases directly with the percentile change. This outcome aligns with the works of Augustine (2019) and Fisera, Tiruneh, and Hojdan (2021) for selected developing counties, Demirkihc (2021) for Turkey, Wahyuni, Muhammad, and Nazamuddin (2019), and Nazamuddin et al. (2022) both for Indonesia.

Regarding the long-run results (Panel B), the outcome demonstrates that small CD essentially improves EDS (decrease in the ratio of external debt to GDP) in Nigeria, Tanzania, Kenya, Ghana, and Mozambique. In the context of Malawi, it is insignificant. A small appreciation reduces EDS (decrease in externa debt-GDP ratio) of Tanzania and Malawi while it improves that of Mozambique. The mixed outcomes (see Table B9) indicate that CD's effect on factors such as EDS can be determined by the countries' policy response and macroprudential policy (IMF 2023; Odionye and Chukwu 2021). Similar to the short-run estimation, high exchange rate swing increases the external debt–GDP ratio astronomically, thereby worsening the EDS of the selected countries badly. The detrimental asymmetric effects caused by the CD on EDS also increase as the size of the CD moves closer to the higher quantile, demonstrating that the inverse nexus between the factors is directly correlated with the magnitude of CD. Although, large exchange rate swings (both appreciation – LECR_LCH_NE and depreciation – LECR_LCH_PO) have detrimental effects on EDS, their effects are more pronounced in depreciation than appreciation. Specifically, large depreciation increases the external debt–GDP ratio of Nigeria, Tanzania, Kenya, Ghana, Malawi, and Mozambique by 0.78%, 0.51%, 0.63%, 0.51%, 1.04%, and 0.24% respectively, whereas large appreciation significantly increases only those of Tanzania, Ghana, Malawi, Mozambique by 0.31%, 0.22%, 0.76%, and 0.21% respectively. This also establishes that exceedingly large CD has a more harmful long-term impact on external debt burden, perniciously affecting EDS in the studied nations than appreciation. The implication is that exceedingly large changes (whether positive or negative) largely affect the countries' EDS negatively. This is because the studied countries' major exports are primary products; an exchange rate appreciation above the 25th percentile increases the prices of exportable goods. This will reduce firms' exports and outputs and increase the external debt-to-GDP ratio. Also, a large exchange rate appreciation puts the nation's global competitiveness in a disadvantaged position, increases the cost of investment and production from a foreign investment perspective, and hence, reduces foreign investment. This will further worsen their investment positions and increase the need for external borrowing to fill the investment-saving gaps. Thus, rather than appreciation to reverse the detrimental effects of CD on overseas borrowing, it exacerbates further, making it extremely difficult to sustain the existing debt. This outcome aligns with the works of Augustine (2019) and Fisera, Tiruneh, and Hojdan (2021) for selected developing counties.

The validity check (Panel C) reveals the absence of the arch effect, given that the p-values for the ALM exceed 0.05 significance level. The estimated Wald test (SRW and LRW) upholds the asymmetric link between CD and EDS in the short run for all the studied countries but in the long run, it is asymmetric for all except Kenya. Furthermore, it indicates the absence of q-order serial correlation (BGAC). At the same time, the Breusch–Pegan–Godfrey heteroscedasticity test (BPGH) demonstrates constant spread in the residual for all except Ghana and Mozambique. The Ramsey RESET test (RRT) confirms that all of the model specifications are valid. The CUSUM graph (CUM) shows reliability in the coefficients at the 5% level for all except Malawi, while CUSUM square (CUMS) graph, with the exception of Kenya and Ghana, reveals reliable parameters in all the studied countries.

5. Conclusion and policy implication

Despite the fact that many EDNs are bedevilled with twin challenges of elevated external debt challenges occasioned by CD, which might snowball into the danger of its sustainability, as well as high gyrations in exchange as a result of lack of domestic capacity, there exists a dearth of studies on the link between external debt sustainability and CD, especially in the context of SSA. The study provides new insights into the threshold-based asymmetric influence of CD on EDS in the SSA region: On this premise, the study utilized two novel estimation procedures (STR and MTNARDL) to estimate the sign-based and magnitude-based asymmetric influence of the enlisted factors on external debt sustainability (EDS) in the context of the SSA region.

The upshots of the relative impact of devaluation on external debt sustainability reveal two levels of thresholds for Nigeria and Mozambique, which were represented by the lower and higher threshold levels featured by the quadratic smooth transition regression functions (LSTR2). In Nigeria, exchange rate changes (depreciation or appreciation) that fall between −4.2% (4.2% appreciation) and 32.2% depreciation align with the sustainability of external debt, but changes outside of this range are not. In contrast, it indicates a single threshold characterized by the logistics smooth transition regression (LSTR1) model for Malawi, Tanzania, Ghana, and Kenya as −1.3%, −10.3%, 54.1%, and 23.1%, respectively. This result provides an average threshold of 21.1% for the studied nations, which implies that a CD threshold of 21.1% is consistent with EDS in the designated nations; CD high and above the threshold value will increase the external debt–GDP ratio of the countries and hence worsens their EDS. The gamma factors revealed that whereas devaluation as a policy adjustment is insignificant for Kenya and Malawi, it is significant for Nigeria, Ghana, Tanzania, and Mozambique, implying that devaluation as a policy shift significantly affects EDS in Nigeria, Ghana, Tanzania, and Mozambique. The results from devaluation regime (DR) demonstrate that exchange rate depreciation largely increases external debt–GDP ratio and hence worsens external debt sustainability (EDS) in Nigeria, Tanzania, and Mozambique, while in the case of Ghana and Kenya, its effect is inconsequential. In Malawi's case, the exchange rate coefficient is negative but insignificant. The external debt service aggravates the countries' overseas debt sustainability problem. The result also showed that in the DR, interest rate on external debt largely increases external debt–GDP ratio and hence reduces EDS. Thus heavily indebted countries with sizeable external debt denominated in foreign currency should as a matter of urgency avoid excessively and escalated large percentage of devaluation or depreciation. The policy implication of this upshot is that there should be coordination between the debt management offices and the apex banks, as well as with the finance Ministries of these nations, to ensure that proactive policy intervention programs are in place to evade escalated exchange rate gyrations that may adversely affect EDS. Also, the short- and medium-term frameworks of their various debt offices should be set within the acceptable debt–GDP ratios, taking cognizance of the exchange rate policy and the intervention programs of the apex banks.

In general, the upshots (both from the STR threshold and the MTNARDL) indicate that small exchange rate depreciation below 25% essentially reduces external debt–GDP ratio and improves sustainability. In contrast, depreciation above 25% significantly increases the external debt–GDP ratio and thereby making sustainability of overseas debt problematic. In the DR regime, external debt service worsens, further aggravating the sustainability woe. This may lead to another round of woe as the countries

solicit further borrowing from other nations to off-set the existing ones. Thus market-determined exchange rates might not be the best option for these nations, particularly those with sizable FCBD. Furthermore, the outcome from the DR indicates that improvements in the countries' performance reflected in their GDP will reduce the external debt burden and, hence, increase their sustainability. The implication of this upshot is that proper investment and utilization of external debt will boost the country's productivity and, hence, increase its sustainability. Control of the level of external debt involves factors such as the degree of autonomy of the regulatory authority (Central Bank, Debt Management Offices and Ministry of Finance) to proactively act promptly to control and stabilize the foreign exchange market as needed.

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No potential conflict of interest was reported by the author(s).

Data availability

The data that supports the findings of this study are available from the corresponding author upon reasonable request.

Ethical approval

The article does not contain any studies with human participants or animal participants by any of the authors.

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Appendices

Appendix A

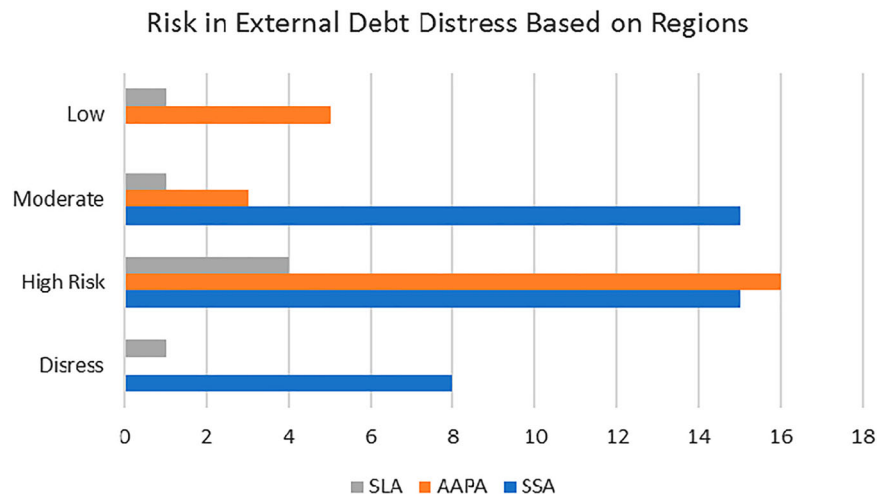

Figure A1. External debt distress in developing nations. Source: IMF – Debt Sustainability Analysis (2023) Report; SLA stands for South and Latin America, AAPA, depicts Asian and Pacific.

Appendix B

Table B1. Summary of BDS upshots.

Residual 1 Model: EDS = f [constant, ECR, EDC, GDP, GEP, FND]						
Dimension	Nigeria	Ghana	Kenya	Malawi	Tanzania	Mozambique
$D = 2$	0.037***	0.074***	0.018*	0.043***	0.039***	0.155***
	(0.006)	(0.000)	(0.078)	(0.000)	(0.001)	(0.000)
$D = 3$	0.078***	0.108***	0.040**	0.083***	0.068***	0.248***
	(0.000)	(0.000)	(0.017)	(0.000)	(0.000)	(0.000)
$D = 4$	0.086***	0.126***	0.068***	0.107***	0.079***	0.300***
	(0.002)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$D = 5$	0.079***	0.125***	0.073****	0.108***	0.090***	0.323***
	(0.005)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$D = 6$	0.068**	0.116***	0.066**	0.112***	0.097***	0.339***
	(0.016)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Residual 2 Model: d(EDS) = f [cons, d(ECR), d(EDC), d(GDP), d(GEP), d(FND)]						
$D = 2$	0.043**	0.036**	0.016*	0.111***	0.122***	0.124***
	(0.025)	(0.029)	(0.001)	(0.000)	(0.004)	(0.000)
$D = 3$	0.083***	0.145***	0.043**	0.060***	0.044***	0.042***
	(0.009)	(0.000)	(0.037)	(0.005)	(0.000)	(0.000)
$D = 4$	0.105***	0.043***	0.061**	0.046**	0.022***	0.016***
	(0.007)	(0.000)	(0.015)	(0.017)	(0.001)	(0.000)
$D = 5$	0.118***	0.034***	0.059**	0.0001	0.027***	0.008
	(0.005)	(0.009)	(0.024)	(0.996)	(0.005)	(0.844)
$D = 6$	0.117***	0.030***	0.058**	−0.005	0.014**	0.026
	(0.005)	(0.007)	(0.026)	(0.824)	(0.000)	(0.537)

**** and ** stand for the refutation of null hypothesis of linearity at 1% and 5% levels of significance. Statistics in parentheses are the p-values. The aloofness rate preferred by the test is 0.7.*

Table B2. Hausman test of endogeneity.

	Nigeria	Tanzania	Kenya	Ghana	Malawi	Mozambique
GDP_Residual	1.15	0.43	1.05	0.38	1.54	1.16
	(0.29)	(0.52)	(0.31)	(0.54)	(0.22)	(0.28)
ECR_Residual	3.03	0.22	1/43	1.36	0.87	0.27
	(0.09)	(0.64)	(0.27)	(0.24)	(0.36)	(0.61)

P-value < 0.05 signify OLS or single equation model inconsistent. *P*-values are in parentheses.

Table B3. Summary of Zivot-Andrews URT.

Country	Nigeria		Ghana		Kenya		Malawi		Tanzania		Mozambique	
Variables	UNT	I(D)	UNT	I(D)	UNT	I(D)	UNT	I(D)	UNT	I(D)	UNT	I(D)
ECRBP	−6.11*	1	−6.11**	0	−9.32**	1	−6.98**	1	−10.6**	1	−5.92**	0
	[1987]		[1986]		[1995]		[2004]		[2006]		[1987]	
EDS	−7.16**	1	−6.08**	1	−5.13*	0	−5.41*	0	−8.60**	1	−5.66**	1
BP	[2006]		[1993]		[1997]		[2006]		[2001]		[2001]	
EDC	−5.1*	0	−6.77**	1	−4.97*	0	−9.12**	1	−8.45**	1	−7.34**	1
BP	[2006]		[2011]		[2009]		[2017]		[2014]		[2015]	
GDP	−6.47**	1	−7.89**	0	−7.82**	1	−8.31**	1	−5.09*	1	−5.91**	1
BP	[2009]		[2010]		[2007]		[2008]		[2010]		[2009]	
GEP	−8.29**	1	−7.73**	1	−6.05**	0	−6.11**	1	−5.08*	1	−7.16**	0
BP	[2008]		[2005]		[2006]		[2008]		[2010]		[2011]	
FND	−9.11**	1	−5.06*	0	−7.23**	1	−7.92**	1	−6.83**	1	−8.92**	1
BP	[2013]		[2003]		[2010]		[2015]		[2019]		[2010]	

URT stands for unit root test, BP is the break point period in parenthesis ∗∗ (∗) signify that the series is stationary at 1% and 5% significance levels respectively. I(D) represents the series' order of integration.

Table B4. Lag length selection based on information criteria.

	Nigeria		Tanzania		Kenya		Ghana		Malawi		Mozambique	
Lag	AC	SB	AC	SB	AC	SB	AC	SB	AC	SB	AC	SB
0	−3.671	−2.872	−5.76	−5.71	−4.61	−4.33	−3.87	−3.53	0.92	0.87	−1.81	−1.71
1	−3.521	−2.701	−5.67	−5.51	−5.52	−4.96	−5.34	−4.91	−14.11	−12.13	−5.71	−4.82
2	−19.45*	−19.0*	−26.61*	−25.81*	−20.16*	−20.03*	−15.81	−14.87*	−18.7*	−17.3*	−15.71*	−15.0*
3	−17.72	−16.99	−24.11	−23.71	−19.51	−19.02*	−16.91*	−15.51*	−18.1	−17.0	−15.11	−14.92
4	−17.42	−16.83	−24.06	−23.61	−19.23	−18.92	−13.76	−12.14	−16.81	−14.21	−15.21	−13.81
5	−17.51	−17.02	−23.81	−21.76	−19.01	−17.62	−13.93	−12.10	−16.51	−13.91	−14.81	−11.91
6	−18.61	−17.11	−24.16	−22.71	−17.15	−17.09	−12.16	−12.04	−15.71	−13.11	−14.71	−13.82

∗ signifies the designated lag order preferred by the criterion.

Table B5. Bound cointegration test.

Model	Nigeria	Tanzania	Kenya	Ghana	Malawi	Mozambique
NARDL	8.4***	5.7**	8.9***	7.8***	5.7**	4.7**
MTNARDL	8.7***	6.7***	9.4***	4.8**	6.3***	6.2***

*** (**) [*] signify refutation of no cointegration at 1% (5%)[10%] level of significance.

Table B6. Test of Linearity against STR (ECR selected as regime-switching factor).

	Nigeria	Kenya	Malawi	Mozambique	Tanzania	Ghana
Null hypothesis	ECR_t	ECR_t	ECR_t	ECR_t	ECR_{t-1}	ECR_{t-1}
F	4.72E-02	5.63E-02	5.91E-02	7.23E-03	1.88E-02	4.18E-01
F_4	2.28E-01	2.15E-01	1.01E-01	4.31E-02	3.09E-05**	3.18E-01
F_3	1.01E-02**	4.21E-03	3.26E-01	2.12E-04**	4.97E-03	2.36E-02
F_2	3.63E-02	1.23E-05**	1.1E-02**	3.51E-01	3.16E-01	1.2E-04**
Designated model	**LSTR_2**	**LSTR_1**	**LSTR_1**	**LSTR_2**	**LSTR_1**	**LSTR_1**

Note: The figures are the *p*-values of LM linearity test. ** symbolizes a regime-switching function with the minimum *p*-values.

Table B7. Summary of STR results.

	Country					
Variables	Nigeria	Ghana	Kenya	Malawi	Tanzania	Mozambique
Panel A: Regime-switching and Threshold						
Threshold: C1	−0.042**	0.541**	0.231**	−0.013**	−0.10**	0.113
	(0.001)	(0.006)	(0.007)	(0.000)	(0.002)	(0.15)
C2	0.323*					0.414**
	(0.02)					(0.000)
rate of regime-switching γ	12.094*	30.761**	8.562	9.562	9.154*	34.29**
	(0.04)	(0.00)	(0.653)	(0.563)	(0.018)	(0.001)
Panel B: $G = 0$ Non-devaluation Regime (NDR)						
Constant	13.08**	10.87	−64.86	1.982*	12.89	−12.09
	(0.000)	(0.58)	(0.401)	(0.05)	(0.39)	(0.86)
LECR	−0.26*	−0.161**	−0.045**	−.075	−0.026	−0, 87
	(0.04)	(0.010)	(0.008)	(0.161)	(0.09)	(0.06)
LECR(−1)		−0.21*			−0.08	
		(0.04)			(0.19)	
LEDC	0.06	0.041	0.014**	0.206*	0.035*	0.121
	(0.59)	(0.88)	(0.01)	(0.03)	(0.05)	(0.639)
LEDC(−1)		−0.156			0.116	
		(0.27)			(0.08)	
LGDP	−1.87*	−0.041**	−2.67	0.971	0.415	2.05
	(0.86)	(0.009)	(0.112)	(0.67)	(0.35)	(0.61)
LGEP	0.06*	0.023**	0.04**	0.023	1.34**	0.43
	(0.02)	(0.00)	(0.006)	(0.08)	(0.006)	(0.06)
LFND	−0.13**	−0.026*	−0.23**	−0.018	1.23**	0.76
	(0.001)	(0.03)	(0.008)	(0.06)	(0.067)	(0.34)
Panel C: $G = 1$ Devaluation Regime (DR)						
Constant	12.67**	10.87	−12.76	9.981	−42.98	8.98**
	(0.000)	(0.45)	(0.48)	(0.07)	(0.65)	(0.08)
LECR	0.107*	−1.21	−0.19	0.098	0.045	0.11**
	(0.03)	(0.09)	(0.11)	(0.18)	(0.00)	(0.010)
LECR(−1)		0.281			0.677*	
		(0.14)			(0.04)	
LEDC	0.22**	0.06*	0.367*	0.171	0.164*	0.006
	(0.00)	(0.03)	(0.04)	(0.25)	(0.04)	(0.139)
LEDC(−1)		−0.24			0.06**	
		(0.08)			(0.00)	
LGDP	−0.35**	−0.034**	−0.76*	−0.011	−0.32*	−0.25**
	(0.00)	(0.00)	(0.02)	(0.08)	(0.03)	(0.01)
LGEP	1.65**	0.108**	0.76**	0.15*	1.06**	0.61*
	(0.00)	(0.00)	(0.001)	(0.04)	(0.002)	(0.05)
LFND	−0.002*	−0.17**	−0.09**	−0.201	−0.02*	−0.06
	(0.04)	(0.001)	(0.01)	(0.09)	(0.04)	(0.11)
Panel D: Validity test						
R^2	0.754	0.681	0.802	0.790	0.802	0.786
Adj. R^2	0.752	0.673	0.791	0.788	0.801	0.781
Arch Test	(0.09)	(0.98)	(0.97)	(0.19)	(0.08)	(0.07)
J.B Test	(0.06)	(0.00)	(0.10)	(0.08)	(0.09)	(0.08)
A/co (3)	(0.31)	(0.25)	(0.76)	(0.87)	(0.08)	(0.16)
PC	(0.24)	(0.25)	(0.01)	(0.78)	(0.82)	(0.26)

Figures in parenthesis are p- values of t-statistics. ∗∗ (∗) denote statistical significant at 1% and 5% levels of significance respectively. A/C represents LM test for no autocorrelation. PC denotes LM test for parameter constancy.

Table B8. Summary of MTNARDL outcomes.

Variables	Nigeria	Tanzania	Kenya	Ghana	Malawi	Mozambique
Panel A: Short-run result						
D(LEDS(−1))	0.08**	0.12**	0.07**	0.17**	0.51*	0.35**
D(LEDS(−2))	0.10	0.21**			0.02	0.05**
D(LECR_SCH_PO)	−0.07**	−0.07*	−0.10**	−0.32*	−0.21	−0.27**
D(LECR_SCH_NE)	0.04	0.12	−0.07*	−0.23*	0.26**	0.21**
D(LECR_MCH_PO)	0.21**	0.18**	0.08**	0.26**	0.07	0.08**
LECR_MCH_PO(−1)	0.24*			0.14	0.18	
D(LECR_MCH_NE)	0.04	0.10	0.31**	0.01	0.03*	0.17
D(LECR_LCH_PO)	0.46**	0.39**	0.56**	0.67**	0.80**	0.38**
D(LECR_LCH_NE)	0.13*	0.19**	0.11	0.16*	0.22*	0.09
ERT(−1)	−0.05**	−0.001**	−0.07**	−0.001**	−0.06*	−0.05**
F_Stat	25.7**	20.3**	18.3**	11.9**	14.1*	20.3**
R^2 (Adj R^2)	0.73 (0.70)	0.80 (0.78)	0.74(0.73)	0.66 (0.63)	0.74(0.72)	0.76 (0.77)
Panel B: Long-run result						
LECR_SCH_PO	−0.10**	−0.12**	−0.21*	−0.23**	−0.34	−0.31*
LECR_SCH_NE	0.07	−0.02*	0.001	1.41	−0.23*	0.09*
LECR_MCH_PO	0.09	0.22*	0.17*	0.24*	0.21**	0.13
LECR_MCH_NE	0.12	0.16	0.32	0.34	0.37*	0.33
LECR_LCH_PO	0.78**	0.51**	0.63*	0.51**	1.04**	0.86**
LECR_LCH_NE	0.21	0.31*	0.90	0.22**	0.76*	0.24*
Panel C: Test of robustness						
ALM	2.01	0.60	1.02	0.97	2.05	2.67
SRW	7.45**	14.7**	6.53*	17.98**	16.08**	78.84**
LRW	8.14**	8.23**	1.97	6.74**	6.09**	5.4*
BGAC	1.32	1.02	0.91	3.87	1.02	0.98
BPGH	1.04	1.02	2.36	4.87*	1.76	8.07
RRT	1.07	2.12	1.09	0.76	0.99	0.55
CUM	ST	ST	ST	ST	UST	ST
CUMS.	ST	ST	UST	UST	ST	ST

**(*) represents $p < 0.01$ ($p < 0.05$) ALM stands for ARCH influence, BGAC represents q-order serial autocorrelation, BPGH is a test for equal spread, RRT signifies mis-specification. SRW represents the short-run wald symmetry test; LRW is the long-run symmetry test, LECR_SCH, LECR_MCH and LECR_LCH stand for small, moderate and large change in exchange rate correspondingly; PO is positive (depreciation) while NE means negative (appreciation).

Table B9. Summary of findings.

Nature of change	Nigeria	Tanzania	Kenya	Ghana	Malawi	Mozambique
Model: STR						
Baseline (Appreciation)	Decrease*	Decrease*	Decrease*	Decrease	Decrease	Decrease
Large depreciation	Increase*	Decrease	Decrease	Increase	Increase*	Increase*
Model: MTNARDL; Short run						
Small depreciation	Decrease*	Decrease*	Decrease*	Decrease*	Decrease	Decrease*
Small appreciation	Increase	Increase	Decrease*	Decrease*	Increase*	Increase*
Moderate depreciation	Increase*	Increase*	Increase*	Increase*	Increase*	Increase*
Moderate appreciation	Increase	Increase	Increase*	Increase	Increase*	Increase
Large depreciation	Increase*	Increase*	Increase*	Increase*	Increase*	Increase*
Large appreciation	Increase*	Increase*	Increase	Increase*	Increase*	Increase
Model: MTNARDL; Long run						
Small depreciation	Decrease*	Decrease*	Decrease*	Decrease*	Decrease*	Decrease*
Small appreciation	Increase	Decrease*	Decrease	Decrease	Decrease*	Increase*
Moderate depreciation	Increase	Increase*	Increase*	Increase*	Increase*	Increase
Moderate appreciation	Increase	Increase	Increase	Increase	Increase*	Increase
Large depreciation	Increase*	Increase*	Increase*	Increase*	Increase*	Increase*
Large appreciation	Increase	Increase*	Increase	Increase*	Increase*	Increase*

∗Denotes it is significant, Decrease/Increase means decrease/increase in the ratio of external debt to GDP and hence increase/decrease in external debt sustainability.