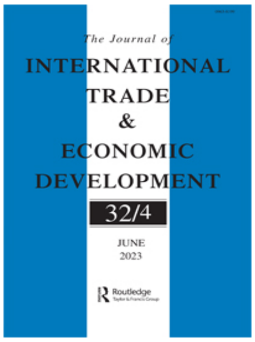

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Asymmetric impact of multifarious exchange rate shocks on stock prices: Fresh insights from multiple thresholds nonlinear autoregressive distributed-lag approach

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ABSTRACT
Exchange rate extreme shocks affect stock prices differently, depending on the sign and the magnitude of changes. This study, therefore, examines the asymmetric impact of multifarious exchange rate shocks on stock prices in sub-Saharan Africa between 1 March 2013 and 14 January 2023, using the novel, multiple thresholds nonlinear autoregressive distributed-lag (MTNARDL) model. This model estimates the effects of extremely small and extremely large positive and negative shocks in exchange rate on stock prices. The study partitioned the sample into pre-COVID-19 and COVID-19 era. The study's outcome indicates: first, exchange rate shocks below 25th percentile affect stock prices positively but above the 25th percentile and below the upper quantiles (75th percentile) the effects is mixed; second, at the upper quantiles (75th percentile), both exchange rate depreciation and appreciation adversely affect the value of stocks; third, the link between the series is highly sensitive to global shocks; fourth, causality result upholds the flow-oriented model in four out of the six countries. The policy implications are: (i) the responses of stock prices to exchange rates changes are sensitive to the sign and size of the shock, as well as sensitive to global shocks. Consequently, specific policy recommendations have been suggested.

KEYWORDS MTNARDL; asymmetry; stock price; exchange rate; multifarious shocks; SSA

JEL CLASSIFICATIONS B41, C32, C52, E22, F21

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1. Introduction

The outbreak of Corona Virus (COVID-19) pandemic in late 2019 which affected the world financial markets have rejuvenated the already existing debates amongst policy makers and researchers on the connectivity between exchange rate movements and

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stock market index (Amewu, Owusu Junior, and Amenyitor 2022; Lee, Yahya, and Razzaq 2022; Nwosa 2021). Following the outbreak of the pandemic which originated in the Chinese city of Wuhan in late 2019, exchange rates and stock index markets of many developing and emerging economies deteriorated markedly (IMF 2020; Sohag, Gainetdinova, and Mariev 2022). Baker et al. (2020) observed that the world stock market recorded anomalous leaps consequent upon the outbreak. The IMF (2020) report predicted worse economic effects of the outbreak than that of the global financial crisis of 2008/2009. The IMF prediction and the fear of the global shutdown drove the risk-repugnance investors into seeking investment protection in more developed capital markets or alternative assets that are capable of eliding risk vulnerability or hedge against financial losses. Consequently, less developed stock markets especially those in sub-Saharan Africa (SSA) were inversely affected by this action (IMF 2020; Owusu Junior et al. 2021; Siahaan and Robiyanto 2021; Yousaf et al. 2021). This reawakened and prompted very many studies on the co-movements of the series with different approaches especially in the Asian countries.

Hypothetically, stock index responds to currency changes in different ways. This view is known as flow-oriented model (Dornbusch and Fischer 1980; Phylaktis and Ravazzolo 2005). The first perspective posits that changes in the worth of a currency cause a rise in total export, and hence, boost firm's output and profit. An increased business profit results to huge boost in a nation's stock prices (Sui and Sun 2016). The second perspective argues that depreciation of home currency increases input prices, which reduces enterprises' profits and pushes down stock prices (Bahmani-Oskooee and Saha 2016). In contrast to the first view, this view contends that local currency gain may have the opposite effect on domestic multinational corporations' shareholders by depreciating their stock value (Bahmani-Oskooee and Saha 2016). Another strand of view posits that lack of productive capacities to sustain stable exchange rate has made exchange rate to be very volatile, and thus introducing some degrees of uncertainty and extreme exchange rate dynamics in the financial markets (Ikpe et al. 2021; Muoneke, Okere, and Onuoha 2022). This has prompted many studies in recent times on the extreme exchange rate dynamics, and its effects on macroeconomic variables such as trade balance (Hashmi, Chang, and Shahbaz 2021; Muoneke, Okere, and Onuoha 2022; Okere et al. 2023) and household spending (Uche, Chang, and Effiom 2022). The perspective of extreme exchange rate dynamics (minor, mild and major changes) on stock market index is yet to be given the much-needed attention, thus leaving the empirical question open for further investigation. Hence, this study assesses the impact of multifarious exchange rate shocks on stock prices in selected countries in Sub-Sahara African (SSA) countries using the novel multiple thresholds-based nonlinear autoregressive distributed lag (MTNARDL) model.

Considering that many firms in SSA countries depend on foreign materials as their factor inputs (Amewu, Owusu Junior, and Amenyitor 2022; Nwosa 2021; Owusu Junior et al. 2021), a change in the exchange rate can influence stock prices directly or indirectly, depending on whether the country is export-oriented or import-dependent (IMF 2020). Furthermore, depending on the extent of transmission, the severity of global shocks, policy interventions, and the level of susceptibility of the company to swings in a country's currency, different levels of currency swings or extreme exchange rate changes may have varying effects on a firm's output, profit, and consequently stock prices in the region (Bartram 2004; Habibi and Lee 2019; Luqman et al. 2021). According to IMF (2020) report, SSA stock markets are more prone to foreign exchange rate shocks than those in Asian countries. For example, following excessive demand for the US dollar due to

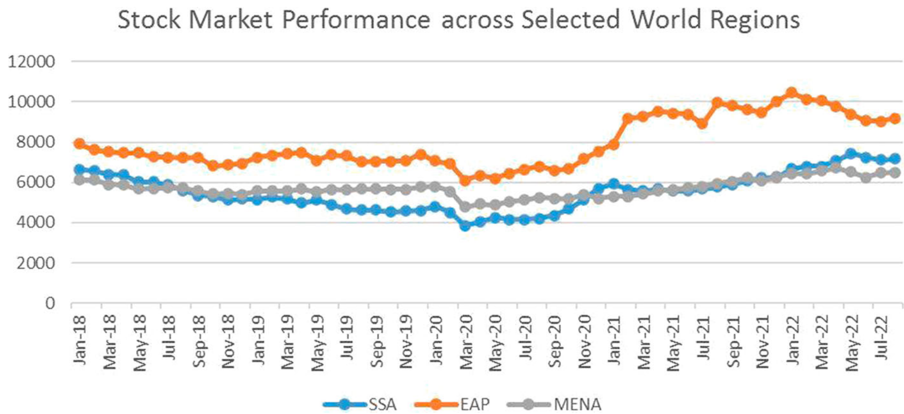

Figure 1. Trend of stock market performances in selected regions Source: Authors' computation MENA is the Middle East and North Africa region; EAP is the East Asia and Pacific region; and SSA is the sub-Saharan African region.

the fear of a global shutdown associated with the COVID-19 pandemic (IMF 2020), wherein the global investors shift investment from less developed countries' currencies to the US dollar as a safe haven currency (Baker et al. 2020; Yousaf et al. 2021), the stock markets in SSA countries dropped (IMF 2020; investin.com, 4 August 2022). Figure 1 shows the stock market indicators of selected regions, which demonstrates that stock prices in the Middle East and North Africa (MENA), East Asia and Pacific (EAP) and sub-Saharan African (SSA) regions declined by 17.2%, 17.5% and 25.8% respectively, between December 2019 and March 2020 (investin.com, 6 August 2022).

While there was a quick recovery in the stock markets of the East Asia and Pacific and the Middle East and North African regions, that cannot be said of the SSA as it took it almost one year to recover partially from the shock of the outbreak. The stock markets in some SSA countries are fast developing, particularly in countries such as; South Africa, Nigeria, and Kenya while some are still in their infant stage (IMF 2020). Thus, the size and development of the stock markets, exchange rate system, as well as data availability are considerable factors in the selection of the countries in this study (see Owusu Junior and Tweneboah 2020). All the selected countries, except South Africa that practises market determined exchange rate system, practise managed float exchange rates system where the regulatory body periodically intervenes in the foreign exchange markets to stabilize the exchange rates using diverse instruments.

Several studies exist on the exchange rate-stock prices connection in developing and Asian countries, but a greater number of the studies focused on either symmetric influence (Javangwe and Takawira 2022;; Lee, Yahya, and Razzaq 2022 Nwosa 2021; Okpara and Odionye 2012; Zubair 2013) or exchange rate volatility-stock prices nexus (Chang and Chang 2023; El-Masry and Badr 2020; Fapetu et al. 2017; Lakshmanasamy 2021; Tule, Dogo, and Uzonwanne 2018; Mitra 2017). Theoretically, exchange rate may have nonlinear or asymmetric relationship with other economic variables due to the hysterical behaviour of economic factors (Dixit 1989), rachet effects and the attributes of price rigidity (Bussiere 2013; Karoro, Aziakpono, and Cattaneo 2009; Odionye and Chukwu 2021). Some studies such as Bahmani-Oskooee and Saha (2016), Salisu, Isah, and Ogbonnaya-Orji (2020), Fasanya and Akinwale (2022). Saidi et al. (2021), Mohamed and Elmahgop (2020) Adeniyi and Kumeka (2020), Nusair and Al-Khasawneh (2022), Wong (2021), and Nusair and Olson (2022) investigated the sign-based asymmetric link between the series. Most of these studies are carried out outside the purview of SSA, except Adeniyi and Kumeka (2020), Fasanya and Akinwale (2022), and Owusu Junior and Tweneboah (2020). Furthermore, the asymmetric responses of stock prices to exchange rates may vary based on sign (Bahmani-Oskooee and Saha 2016; Wong 2021 and Nusair and Olson 2022), and size (Gokmenoglu, Eren, and Hesami 2021; Lee, Yahya, and Razzaq 2022; Owusu Junior and Tweneboah 2020). While the sign-based asymmetric connection between exchange rates and stock prices has been widely studied, the size-based perspective is yet to be given the much-needed attention. None of the past studies in the context of SSA countries examined the effect of exchange rate diverse shocks on stock prices; or studied whether the responses of the value of the stock to exchange rate changes are sensitive to the sign and magnitude of change. Empirically, this aspect is lacking in the stock price-exchange rate nexus literature.

This study adds to the existing literature by estimating sign-based (appreciation/depreciation) and magnitude-based asymmetric (minor appreciation/depreciation and major appreciation/depreciation) impacts of exchange rate shocks on the stock market using the novel MTNARDL model. Secondly, it examines whether the link between the exchange rate diverse shocks and stock prices is sensitive to global shocks, a case of COVID-19 pandemic. The MTNARDL, because of its several advantages over other quantile-based model (Quantile regression, QARDL, QR, etc), has been widely used in exchange rate-trade balance nexus (Hashmi, Chang, and Shahbaz 2021; Muoneke, Okere, and Onuoha 2022; Okere et al. 2023) and exchange rate-household spending (Uche, Chang, and Effiom 2022). One of the benefits of this model is that it provides both the magnitude and direction of extreme (minor/major) positive and extreme (minor/major) negative changes of the independent variables(s) on the response variable. Such knowledge is significant because not all exchange rate changes (appreciation or depreciation) can drive demand to change or switch from import to export, however, some will change and cause demand to move, affecting firm's export, profit and share prices, or affect stock prices via firm's input prices. The implementation of the MTNARDL model is critical in the context of the current enquiry to provide the response of stock prices to exchange rate misalignment at each extreme.

In addition to the introductory section, the remaining parts of the study are organized as follows: section two reviews the literature, section three discusses the methodological framework, section four discusses empirical results and findings, and section five concludes with policy implications and recommendations.

2. Literature review

There are two contending theories about the relationship between exchange rate and the stock market, namely, the flow-oriented model and the portfolio balance approach. Dornbusch and Fischer's (1980) flow-oriented models are based on the current account or trade balance. According to this model, changes in currency affects a country's productive capacity, which determines the firms' predicted future cash flows and their stock values, besides their global competitiveness and current account surplus positions. The following is a full logical deduction of the hypothetical connection: changes in exchange rates affect a company's ability to compete since many businesses borrow money in foreign currencies to finance their operations, which may adversely affect a company's stock price. Contingent upon whether a company exports or uses a lot of foreign products, the consequences could go one of two ways. If a company exports, both the company and its worth will rise, this will raise stock prices. Conversely, a domestic currency appreciation lowers an exporting company's revenues because there is less demand for its goods abroad. Consequently, the value of stocks will drop. This is contrary to the situation of an importing firm as exchange rate changes (Abdalla and Murinde 1997; Dornbusch and Fischer 1980; Phylaktis and Ravazzolo 2005).

The portfolio balance approach put forth by Frankel (1983) contradicts Dornbusch and Fischer's (1980) flow-oriented model and thus argues in favour of reverse causality between stock prices and exchange rates. According to Frankel (1983), the exchange rate is analogous to goods and services, and as such is influenced by market forces. Theoretically, a bullish stock market draws capital into a nation, which puts pressure on the domestic currency as investors bid it up. The domestic currency appreciates as a result of the increased demand. On the other hand, when the market is bearish, capital leaves and the local currency weakens. Consequently, the portfolio balance approach suggests that stock prices and exchange rates have an inverse relationship. The above theories explain the relationship between the exchange rate and the stock market in such a way that the two different relationships suggested by the theories can be evident in a specific market, necessitating further research (Afshan et al. 2018).

2.1. Empirical evidence

Numerous studies have investigated the relationship between exchange rates and stock prices using various models, including but not limited to linear ARDL, nonlinear ARDL, or both. For example, studies conducted separately by Mohamed and Elmahgop (2020), and Çakır (2021) on the Sudanese stock market found that the exchange rate has significant positive effects on the stock market in the short run but not in the long run based on ARDL estimates. However, NARDL results showed an asymmetric relationship between the two variables, with exchange rate depreciation having a significant positive effect on the stock market in the long run while appreciation did not significantly impact it. Likewise, Saidi et al. (2021) revealed evidence of a significant impact of exchange rate on stock market indices in the case of Indonesia using the ARDL model, and a significant impact of both exchange rate and volatility on stock prices by the study also demonstrates asymmetric impact IDR/USD exchange rate and volatility have on stock prices based on NARDL model estimates.

Interestingly, Fasanya and Akinwale (2022), who conducted a sectorial study of the Nigeria stock exchange, discovered a matching positive association between the exchange rate and the majority of the sectors in both the short and long run using a linear ARDL model, whereas the NARDL model revealed the same asymmetric relationship between the exchange rate and only the financial services sector. Though Luqman et al. (2021) find a significant link between the exchange rate and stock prices in the G8, five selected emerging economies, and Pakistan, the ARDL estimates show a mix of negative and positive correlations. The NARDL findings confirmed earlier research by showing that the exchange rate drives stock indices in all 14 countries in an asymmetrical manner. Wong (2021), using both models, finds mixed results as well, both in terms of signs and significance, using ARDL, as an increase in exchange rates causes a decline in stock prices across the board, both in the short and long term, except in Malaysia, where it has the opposite effect, and Japan, Korea, the UK, and Hong Kong it has no effect. Furthermore, the NARDL model estimates revealed a mix of positive and negative changes in the exchange rate, either increasing or decreasing stock prices in the short run, long run, or both, depending on the country; however, no asymmetry between the variables was observed in Malaysia. Adeniyi and Kumeka (2020) find no asymmetric relationship between the exchange rate and stock prices of 54 firms listed on the Nigerian Stock Exchange using the NARDL model, similar to Wong (2021) in the case of Malaysia, and even the linear model was unable to establish significant links between the two variables.

Also, in contrast to Adeniyi and Kumeka's (2020) result was Bahmani-Oskooee and Saha (2016) who find an asymmetric relationship between exchange rates and stock prices in nine countries, particularly in the short run based on NARDL; and the results from ARDL show that exchange rates have a significant short-term impact on stock prices, with the effect only persisting over the long term in Korea. While ARDL estimates revealed a significant impact of exchange rate on stock prices for all countries in the short run, with such an effect lasting up to the long run for Korea, the Philippines, and Singapore, Nusair and Al-Khasawneh (2022) find similar asymmetric effects for ASEAN-5 and Big3 countries only in the short run. Similarly, Nusair and Olson (2022) used NARDL and find evidence of short-run nonlinearity effects of exchange rates on stock prices in six of the G-7 countries, as well as long-run asymmetric effects of stock prices on exchange rates in four of the countries, whereas the ARDL model only showed a significant impact in the short run.

Studies that looked at the correlation between exchange rates and stock prices solely using the NARDL model, like Habibi and Lee (2019), find an asymmetric short-term relationship between exchange rates and stock prices in all G-7 countries, though it did not last in Canada, France, Italy, or the United States over long run. Salisu and Ndako (2018) found similar asymmetric relationships for changes in nominal and real exchange rates over both the short and long terms. They did this by using a nonlinear panel ARDL approach in investigating the portfolio balance theory in the OECD and other smaller country groups. Equally, Salisu, Isah, and Ogbonnaya-Orji (2020) identified short-term asymmetry as the dominant pattern in the relationship between US stock returns and exchange rates using a nonlinear panel. They also discovered more positive than negative coefficients in terms of significance and magnitude.

The quantile-on-Quantile (QQR) analysis was used by Gokmenoglu, Eren, and Hesami (2021) to examine how exchange rates and stock prices relate to one another. Although most quantiles in each country had symmetric positive slope coefficients, the study still found evidence of significant asymmetries in the relationship between stock markets and exchange rates in nations like India and Mexico. According to the evidence, when both are at a low quantile, the exchange rate has a bigger impact on the stock market. This exemplifies the different effects that exchange rates have on bullish and bearish markets. Gokmenoglu, Eren, and Hesami (2021) findings were confirmed by Lee, Yahya, and Razzaq (2022), who used a quantile autoregressive distributive lag (QARDL) approach which is similar to QQR to investigate the relationship between exchange rates and stock prices in China. However, they were unable to explain stock market performance at the high quantile.

Using quantile regression analysis (QRA) and quantile-on-quantile (QQR) techniques based on ensemble empirical mode decomposition (EEMD), Junior and Tweneboah (2020) examined the relationship between exchange rates and stock prices in eight African stock markets. Their research suggested that exchange rates and stock prices have asymmetric time-varying relationships. Chang and Chang (2023) used a Bayesian Multivariate Quantile-on-Quantile with the GARCH approach to investigate a similar thing, but now on oil-importing nations like China. Although the link was stronger in the bearish market, the study showed evidence of a negative asymmetric link between the variables in both bullish and bearish markets, which is to an extent comparable with Junior and Tweneboah (2020) which produced asymmetric results. Sikhosana and Aye (2018) used a rather different model; the Multivariate Exponential Generalized Autoregressive Conditionally Heteroskedastic (EGARCH), GJR GARCH, and APARCH to find a similar asymmetric relationship, as greater volatility in stock prices is caused by negative exchange rate shocks than by positive shocks of the same size, and positive stock price shocks boost exchange rate volatility more than negative shocks of the same size.

He et al. (2020) found that Turkish stock market returns have a stronger negative relationship with USD/TRY than EUR/TRY in the short- and medium-term, which also holds true over the long term. The same methodology is used by Amewu, Owusu Junior, and Amenyitor (2022) to discover a correlation between the cedi-to-dollar exchange rate and the Ghana stock exchange composite index as well as global equity markets during the pre-COVID and COVID periods. Contrary to the results of He et al. (2020), albeit being weak only the short- to medium-term but not long-run correlation between the exchange rate and the Ghana Stock Exchange Composite Index and the global equity markets was found, and this was weaker in the pre-COVID period than the COVID era. Using the same wavelet coherence analysis, Dahir et al. (2018) show evidence of strong interdependence between exchange rate and stock market index for all BRICS countries in the short to long run, except for China, in contrast to the weak co-movement found in the study of Amewu, Owusu Junior, and Amenyitor (2022).

Closely related to this study in terms of methodology are Uche, Chang, and Effiom (2022), Muoneke, Okere, and Onuoha (2022) and Okere et al. (2023) all in African countries, which used MTNARDL. While Uche, Chang, and Effiom (2022), investigated exchange rate-household nexus, Muoneke, Okere, and Onuoha (2022) and Okere et al. (2023) examined exchange rate-trade balance connectivity.

This study differs from the above studies in the following areas; (i) it focuses on multifarious exchange rate shocks on stock prices, (ii) it decomposed the shocks in exchange rate into quadrumvirate with 25th and 75th quantiles being the lower and upper quantiles respectively (iii) it examines the sensitivity of the series connectivity to global shocks, a case of COVID-19 pandemic and, (iv) given that the selected countries had adopted many exchange rate regimes, to account for this regime change in time series, the study employed Zivot-Andrews test of stationarity with a structural break.

3. Methodological issues

Following Li and Guo (2022), this study adopted the Multiple Threshold Nonlinear Autoregressive Distributed Lag (MTNARDL) model as developed by Pal and Mitra (2015; 2016) to examine the effect of diverse changes in the exchange rate on stock prices in selected sub-Saharan Africa countries. The MTNARDL model utilized the nonlinear autoregressive distributed lag (NARDL) as developed by Shin, Yu, and Greenwood-nimmo (2014) whereby the predictor variables are separated into positive and negative partial sum components.

Table 1. Data descriptions.

Series	Notation	Unit of measurement	Source
Stock Prices	SPR	Stock Exchange All Share Index	investing.com
Exchange Rate	ERT	Country's currency against USD	investing.com
Oil Prices	OPR	Brent Crude oil per barrel in USD	investing.com

In order to investigate structural breaks in the series, this study used both Zivot and Andrews (1992) unit root test with structural break in addition to the conventional ADF unit root test to scrutinize the time series features.

3.1. Data description

The study's data description and its measurement, as a summary, is illustrated in Table 1.

The data covered the period between 1 March 2013 and 14 January 2023 for six selected sub-Saharan African (SSA) countries namely South Africa, Kenya, Nigeria, Uganda, Rwanda and Tanzania. The study period is split into two sub-periods: pre-COVID-19 and COVID-19 periods. The pre-COVID-19 era (PCE) covered the period between 1 March 2013 and 10 March 2020, while the COVID-19 era (CE) covered between 11 March 2020 and 14 January, 2023. The daily stock prices and exchange rates are obtained from the investing.com. The stock prices are measured in a country's local currency, while the world oil price is measures in United States dollar and the exchange rate is the ratio of local currency to United States dollars, in line with the World Bank definition. The choice of the selected countries was predicated on the recent categorization of SSA into three non-overlapping groups, namely; oil exporters, middle-income and low-income countries by the World Bank (World Economic Outlook, 2021). The size and development of the stock markets were also factors in the selection of these countries (see Owusu Junior and Tweneboah 2020). In this regard, the study chose three of the largest stock exchange markets in SSA, namely South Africa, Nigeria, and Kenya, as well as three of the smallest, namely Tanzania, Rwanda, and Uganda. The aim was to select at least one country from each of the groups to determine the relativity in terms effect of diverse exchange rate swings on stock prices among the groups.

3.2. The model

To model MTNARDL, we first model ARDL as propounded by Pesaran, Shin, and Smith (2001):

$$\Delta Y_t = \alpha_0 + \alpha_1 Z + \eta ECT + \sum_{j=1}^{q} \delta_i \Delta Y_{t-j} + \sum_{j=0}^{p} \delta_i \Delta Z_{t-j} + \mu_t \tag{3.1}$$

where Y is the explained variable and Z's are the explanatory variables. The ECT term indicates the degree of convergence to equilibrium; η and δ_i are the long-term and short-term coefficients respectively.

Following the Flow-Oriented Model by Dornbusch and Fischer (1980) that stock prices are determined by changes in the exchange rate and consistent with previous studies (see Bahmani-Oskooee and Saha 2016 and Owusu Junior and Tweneboah 2020), this study specifies the functional forms as

$$SPR = f(ERT) \tag{3.2a}$$

where SPR is the stock prices and ERT represents the exchange rate. Theoretically, oil prices can affect firms' input cost and hence profit and share values of firms (see Chang and Chang 2023; Zhang and Shang 2023). In view of this hypothetical concept and in line with the works of Nwosa (2021), Tabash et al. (2022), Zhang and Shang (2023), Gourene and Mendy (2018), and Chang and Chang (2023), we included oil price as a control variable. Aside the hypothetical view and prior studies that link oil prices with stock prices, this study utilized high frequency data (daily) and to ensure alignment in data frequency of the series, the study included daily oil prices as a control variable.

$$SPR = f(ERT, OPR) \tag{3.2b}$$

where OPR represents world oil price used as control variable to evade the omitted series bias.

Equation (3.3) specifies the ARDL model in tandem with (3.1)

$$\Delta LSPR_{it} = \theta_{i0} + \phi_{i1} LERT_{it} + \phi_{i2} LOPR_{it} + \gamma_i ECT_i + \sum_{m=1}^{p} \eta_{mi} \Delta LSPR_{it-m} + \sum_{m=0}^{q} \eta_i \Delta LERT_{it-m} \sum_{m=0}^{q} \eta_i \Delta LOPR_{it-m} + \varepsilon_{it} \ldots \tag{3.3}$$

where SPR, ERT and OPR are as defined above, $L =$ natural log, i represents ith selected SSA country η measures the short-run coefficients and φ denotes the long-run coefficients. ε is the error term and Δ is the difference operator, p and q are the maximum lag value. The coefficient of ECT measures the speed of adjustment to equilibrium. Exchange rate (ERT) and oil prices (OPR) change in diverse degrees such as minor, moderate and large. Therefore, ERT and OPR are disintegrated into three diverse changes namely minor (ERTMNC and OPRMNC), moderate (ERTMRC and OPRMRC) and large (ERTLGC and OPRLGC), respectively.

Introducing the asymmetric parts in equation (3.3), we dichotomize the explanatory variables (ERT and OPR) into positive and negative components in tandem with Shin, Yu, and Greenwood-nimmo (2014). Thus, ERT and OPR are expressed in 3.4a and 3.4b as

$$LERT_t = LERT^0 + \mathrm{LERT}_t^{po} + \mathrm{LERT}_t^{ne} + \varepsilon_t \ldots \tag{3.4a}$$

$$LOPR_t = LOPR^0 + \mathrm{LOPR}_t^{po} + \mathrm{LOPR}_t^{ne} + \varepsilon_t \ldots \tag{3.4b}$$

where $\mathrm{LERT}^{\mathrm{po}}$ and $\mathrm{LERT}^{\mathrm{ne}}$ stand for increase (depreciation) and decrease (appreciation), while $\mathrm{LOPR}^{\mathrm{po}}$ and $\mathrm{LOPR}^{\mathrm{ne}}$ represent increase and decrease in oil prices respectively and L stands for natural log.

Depreciation and appreciation of exchange rate are expressed as (3.5a) and (3.5b) while increase and decrease in oil prices are expressed in 3.6a and 3.6b

$$LERT_{it}^{po} = \sum_{j=1}^{p} \Delta LERT_{it-j}^{po} = \sum_{j=1}^{q} \max(\Delta LERT_{ij}, 0) \ldots \tag{3.5a}$$

$$LERT_{it}^{ne} = \sum_{j=1}^{p} \Delta LERT_{it-j}^{ne} = \sum_{j=1}^{q} \min(\Delta LERT_{ij}, 0) \ldots \tag{3.5b}$$

$$LOPR_{it}^{po} = \sum_{j=1}^{p} \Delta LOPR_{it-j}^{po} = \sum_{j=1}^{q} \max(\Delta LOPR_{ij}, 0) \ldots \tag{3.6a}$$

$$LOPR_{it}^{ne} = \sum_{j=1}^{p} \Delta LOPR_{it-j}^{ne} = \sum_{j=1}^{q} \min(\Delta LOPR_{ij}, 0) \ldots \tag{3.6b}$$

The NARDL model is therefore specified in 3.7 based on equations (3.5a), (3.5b), (3.6a), and (3.6b).

$$\begin{aligned} \Delta LSPR_{it} = {} & \varphi_{i1} LERT_{it}^{po} + \varphi_{i2} LERT_{it}^{ne} + \varphi_{i3} LOPR_{it}^{po} + \varphi_{i4} LOPR_{it}^{ne} + \delta ECT_i \\ & + \sum_{m=1}^{p} \varpi_{im} \Delta LSPR_{it-m} + \sum_{m=0}^{q} \eta_{im} \Delta LERT_{it-m}^{po} \\ & + \sum_{m=0}^{q} \eta_{im} \Delta LERT_{it-m}^{ne} + \sum_{m=0}^{q} \eta_{im} \Delta LOPR_{it-m}^{po} \\ & + \sum_{m=0}^{q} \eta_{im} \Delta LOPR_{it-m}^{ne} + \varepsilon_t \ldots \end{aligned} \tag{3.7}$$

Where the variables are as described above. The first four terms on the right-hand side are the long-run asymmetric parameters, the fifth term is the error correction component and the last four terms are the short-term asymmetric parameters. The short run and the long asymmetric can be examined using the standard Wald test. There is no long-run asymmetric effect if $\phi_1 = \phi_2 = \phi_3 = \phi_4 = 0$. The bound test is used to determine the presence of cointegration.

3.3. Multiple thresholds

The study employed the newly developed MTNARDL model as proposed by Pal and Mitra (2015, 2016) as a preferred option to one threshold approach by Shin, Yu, and Greenwood-nimmo (2014) due to its advantages as it decomposed the explanatory variable (LERT) into different quantiles to examine the asymmetric effects of the variable based on minor, moderate and large shocks. Thus, in line with Li and Guo (2022) with a slight modification, this study introduced two thresholds at 25th and 75th quantiles to disintegrate the changes in exchange rate into three partial sums as expressed in equation (3.8):

$$LERT_{it} = LERT_{it}^{0} + \mathrm{LERT}_{it}^{mnc} + \mathrm{LERT}_{it}^{mrc} + \mathrm{LERT}_{it}^{\lg c} \ldots \quad (3.8)$$

Where mnc, mrc and lgc represent minor change, moderate change and large change in exchange rate and oil price, respectively. The right-hand components of equation (3.8) are the partial sum estimated as:

$$\mathrm{LERT}_{it}^{mnc} = \sum_{m=1}^{p} \lambda_{im} \Delta\mathrm{LERT}_{im}^{mnc} = \sum_{m=1}^{p} \Delta LERT_{im}^{I}(\Delta LERT_{im} \leq \tau_{25}) \ldots \quad (3.9)$$

$$\mathrm{LERT}_{it}^{mrc} = \sum_{m=1}^{p} \lambda_{ij} \Delta\mathrm{LERT}_{im}^{mrc} = \sum_{m=1}^{p} \Delta LERT_{im}^{I}(\tau_{25} < \Delta LERT_{im} \leq \tau_{75}) \ldots \quad (3.10)$$

$$\mathrm{LERT}_{it}^{\lg c} = \sum_{m=1}^{p} \lambda_{im} \Delta\mathrm{LERT}_{im}^{\lg c} = \sum_{m=1}^{p} \Delta LERT_{im}^{I}(\Delta LERT_{im} > \tau_{75}) \ldots \quad (3.11)$$

Where I (.) represents the dummy variable that satisfies the pre-requisite condition in (.) when it is equal unity and zero otherwise.

The multiple thresholds nonlinear ARDL model is therefore specified in equation (3.12) as:

$$\Delta LSPR_{it} = \sum_{j=1}^{3} LERT_{it}^{\lambda_j}(po) + \sum_{j=1}^{3} LERT_{it}^{\lambda_j}(ne) + \varpi_i ECT_i + \sum_{m=1}^{p} \pi_{it} \Delta LSPR_{t-m} + \sum_{j=1}^{3}\sum_{m=0}^{q} \eta_{it} \Delta LERT_{it-m}^{\lambda_j}(\mathrm{po}) + \sum_{j=1}^{3}\sum_{m=0}^{q} \eta_{it} \Delta LERT_{it-m}^{\lambda_j}(\mathrm{ne}) + \varepsilon_{it} \ldots \quad (3.12)$$

where the first two terms on the right hand-side are the asymmetric long-run components decomposed into positive (po) and negative (ne), ECT indicates the speed of adjustment to equilibrium, and the last two terms measure the positive (po) and negative (ne) short-run coefficient, λ is exchange rate shock and the subscript j is the rate of shock (j = 1, 2, and 3) 1 = minor shock (mnc) given as changes below or equal 25th percentile change; 2 = moderate shock (mrc) changes above 25th percentile but below or equal 75th percentile changes; and 3 = large shock (lgc) given as changes above the 75th percentile, p and q are maximum lag length, $\varepsilon = \mathrm{iid}(0, \sigma)$. The null hypothesis of no cointegration is expressed as $\phi_1 = \phi_2 = \phi_3 = 0$. The rejection of the hypothesis implies a long-run nexus in the model. The study applied the Wald test to examine for symmetric both in the short and long term. Recently, the MTNARDL model has widely been used due to its several advantages over NARDL as it permits the study of asymmetric diverse nature of shocks effects on response variables (Li and Guo 2022; Pal and Mitra 2015; 2016). The precondition for estimating MTNARDL is that the order of integration of the series should not exceed 1. Also, it requires a large sample size since the sample size reduces as the number of thresholds increases. To estimate a two-threshold model, a minimum of 90 sample size is required (N > 30) for it to be sufficiently large for estimation (Li and Guo 2022). The study sample size for each country is adequately large as we have more than 2600 observations in each series.

4. Empirical result

4.1. Descriptive analysis

In this study, we first presented the description of the variables to examine their behavioural pattern using descriptive statistics (Table 2).

Table 2 demonstrates the descriptive statistics which was carried out before the variables were log-transformed to enable us ascertain their true behavioural patterns. The average value for minor shock (ERT_MNC) is negative for all the countries while those with moderate shock (ERT_MRC) and large shock (ERT_LGC) are positive for all the countries except South Africa and Uganda with an average moderate change in the exchange rate of −0.73 and −23.78 respectively. The standard deviation indicates volatility, mostly in large and minor changes in the exchange rate in all the countries, while a moderate swing in exchange rate exhibits low exchange rate volatility. This suggests that large and minor exchange rate movements (positive or negative) are more volatile than moderate changes. The standard deviation further indicates that, relatively, the Rwandan exchange rate is highly volatile with a standard deviation value of (2927.7) in large changes, followed by Uganda (2579), Tanzania (965.4), Nigeria (486.9) and South Africa is the least (32.01). An inference drawn from this is that the strength of a country's currency influences how volatile the currency is; a relatively strong currency is less volatile than a weak currency. This is shown as the mean value of South African and Kenyan exchange rates are relatively low (13.5 and 100.7) while those of Uganda, Tanzania, Rwanda and Nigeria are 3381, 2129, 830 and 282 respectively. All the variables in the selected countries are abnormally distributed given the Jarque-Bera statistics. Kurtosis statistics indicate abnormal peak (< 3) for all the variables in the countries except for the exchange rate series of South Africa, Tanzania and Kenya. The skewness statistics confirm the asymmetric shape of the curve as it indicates skewness in almost all the series. The abnormal distribution of the series as indicated in the Jarque-Bera statistics is an indication of high volatility in the series and justifies the use of nonlinear model (Ullah et al. 2022).

4.2. BDS test

The Broock et al. (1996) test, also known as the BDS test, was used to confirm the nonlinear feature of our data series. The null hypothesis in this test assumes independent and identically distributed (i.i.d) residuals, while the alternative presupposes that the residual series deviates from independence, indicating nonlinear dependence.

As indicated in Table 3, except the exchange rate variable in Rwanda, the outcome demonstrates the rejection of the null hypothesis of the BDS in the variables, and in favour of the alternative hypothesis. The estimation establishes that the data series exhibited nonlinear behaviour, requiring the use of a nonlinear methodology (Ullah et al. 2021; Ullah et al. 2022)

4.3. Unit root test

The stationarity attributes of the series were examined to ascertain the series order of integration. The study employed both the conventional stationarity test approaches, ADF and KPSS, as well as the structural break unit root test (Zivot-Andrews) to account

Table 2. Descriptive statistics.

Series	Mean	Maximum	Std_Dev	Skewness	Kurtosis	J_B Stat.
Uganda						
SPR	1646.98	2270.0	235.63	0.31	2.44	65.32**
OPR	70.077	127.9	23.74	0.47	2.15	167.70**
ERT	3381.32	3935	431.84	−1.11	2.61	472.28**
ERT_MNC	−4035.75	0.000	2172.74	0.44	1.91	183.77**
ERT_MRC	−23.78	16.0	22.09	−0.34	2.15	110.85**
ERT_LGC	4802.81	8277.35	2578.51	−0.59	1.99	228.11**
Tanzania						
SPR	2122.65	2850.1	309.33	0.24	2.27	73.88**
OPR	70.077	127.9	23.74	0.47	2.15	167.70**
ERT	2129.42	2365.0	255.87	−1.22	2.76	577.01**
ERT_MNC	−1585.23	−1.00	783.44	0.84	2.24	325.88**
ERT_MRC	4.83	8.90	3.25	−0.03	1.51	212.45**
ERT_LGC	1954.86	2866.22	965.43	−0.997	2.42	411.63**
South Africa						
SPR	151.34	196.57	16.72	0.03	2.37	38.63**
OPR	70.077	127.9	23.74	0.47	2.15	167.70**
ERT	13.56	19.09	2.04	−0.21	2.59	33.19**
ERT_MNC	−42.09	0.00	30.03	−0.16	1.71	171.77**
ERT_MRC	−0.73	0.30	0.49	−0.11	1.91	118.86**
ERT_LGC	47.36	104.46	32.01	0.12	1.71	166.06**
Rwanda						
SPR	137.64	563.59	12.11	19.66	678.08	43345818**
OPR	70.077	127.9	23.74	0.47	2.15	167.70**
ERT	830.83	1040.01	124.41	−0.18	2.78	17.61**
ERT_MNC	−3760.33	0.00	2825.97	0.11	1.33	268.19**
ERT_MRC	41.36	100.39	25.91	0.62	2.42	174.73**
ERT_LGC	3938.71	7979.27	2927.74	−0.11	1.34	265.44**
Nigeria						
SPR	33963.19	54085.30	6794.61	0.39	2.52	79.35**
OPR	70.077	127.9	23.74	0.47	2.15	167.70**
ERT	282.81	416.51	85.63	−0.10	1.75	154.82**
ERT_MNC	−575.93	−0.68	409.99	0.21	1.21	327.53**
ERT_MRC	3.03	6.77	2.23	0.19	1.58	209.66**
ERT_LGC	699.49	1253.25	486.98	−0.24	1.28	306.28**
Kenya						
SPR	151.34	196.57	16.72	0.03	2.37	38.63**
OPR	70.077	127.9	23.74	0.47	2.15	167.70**
ERT	100.71	117.85	8.11	−0.48	2.56	109.60**
ERT_MNC	−64.46	−0.40	34.04	0.01	1.85	128.68
ERT_MRC	7.79	20.86	5.18	0.48	2.48	115.69**
ERT_LGC	66.54	116.93	33.28	−0.19	2.05	102.17**

Notes: Authors' computation. ** (*) represent rejection of null hypothesis at 1% (5%) level of significance. SPR denotes stock prices; OPR denotes oil prices, ERT represents exchange rate; ERT_MNC represents minor changes in exchange rate; ERT_MRC signifies moderate changes in exchange rate and ERT_LGC represents large changes in exchange rate.

for a structural break in the series. The summary of the result is presented in Table 4. The choice of the best lag for each of the series was guided by information criteria.

Panels A, B and C indicate the URT results for the full sample, PCE and CE respectively. The ADF_URT indicates uniform order of integration of the series in all the

Table 3. Summary of BDS outcomes.

Dimension	LSPR	LOPR	LERT	LERT_MNC	LERT_MRC	LERT_LGC
Uganda						
$M = 2$	0.195**	0.196**	0.209**	0.209**	0.197**	0.209**
$M = 3$	0.331**	0.334**	0.356**	0.356**	0.335**	0.356**
$M = 4$	0.426**	0.431**	0.457**	0.459**	0.430**	0.459**
$M = 5$	0.490**	0.497**	0.527**	0.531**	0.496**	0.531**
$M = 6$	0.534**	0.542**	0.577**	0.581**	0.541**	0.582**
Tanzania						
$M = 2$	0.195**	0.196**	0.209**	0.211**	0.209**	0.211**
$M = 3$	0.333**	0.334**	0.354**	0.359**	0.356**	0.358**
$M = 4$	0.429**	0.431**	0.456**	0.461**	0.458**	0.460**
$M = 5$	0.495**	0.497**	0.526**	0.532**	0.529**	0.532**
$M = 6$	0.540**	0.542**	0.575**	0.582**	0.579**	0.582**
South Africa						
$M = 2$	0.194**	0.196**	0.199**	0.209**	0.200**	0.209**
$M = 3$	0.328**	0.334**	0.339**	0.355**	0.339**	0.355**
$M = 4$	0.420**	0.431**	0.428**	0.458**	0.437**	0.458**
$M = 5$	0.483**	0.497**	0.505**	0.530**	0.504**	0.530**
$M = 6$	0.526**	0.542**	0.552**	0.580**	0.550**	0.581**
Rwanda						
$M = 2$	0.202**	0.196**	−1.54E-06	0.209**	0.207**	0.208**
$M = 3$	0.343**	0.334**	−4.63E-06	0.355**	0.353**	0.355**
$M = 4$	0.441**	0.431**	−9.26E-06	0.458**	0.456**	0.458**
$M = 5$	0.509**	0.497**	−1.54E-05	0.530**	0.528**	0.530**
$M = 6$	0.556**	0.542**	−2.31E-05	0.581**	0.579**	0.581**
Nigeria						
$M = 2$	0.202**	0.196**	0.210**	0.210**	0.207**	0.211**
$M = 3$	0.340**	0.334**	0.357**	0.357**	0.353**	0.358**
$M = 4$	0.438**	0.431**	0.459**	0.460**	0.456**	0.500**
$M = 5$	0.504**	0.497**	0.529**	0.531**	0.528**	0.531**
$M = 6$	0.549**	0.542**	0.578**	0.581**	0.579**	0.581**
Kenya						
$M = 2$	0.193**	0.196**	0.206**	0.208**	0.207**	0.208**
$M = 3$	0.328**	0.334**	0.351**	0.355**	0.353**	0.355**
$M = 4$	0.420**	0.431**	0.453**	0.458**	0.455**	0.458**
$M = 5$	0.483**	0.497**	0.524**	0.530**	0.527**	0.530**
$M = 6$	0.576**	0.542**	0.575**	0.581**	0.577**	0.581**

Notes: Authors' computation. ** and * indicate rejection of null hypothesis of linearity at 1% and 5% level of significance. SPR denotes stock prices; OPR depicts oil prices, ERT represents exchange rate; ERT_MNC represents minor changes in exchange rate; ERT_MRC signifies moderate changes in exchange rate and ERT_LGC represents large changes in exchange rate.

countries (panel A), except for LERT_MNC for Uganda and Kenya which were integrated of order zero while the ZAURT (panel D) shows varying order of integration for series in all the countries except Kenya. The ZAURT result supports the view that unit root results are sensitive to structural breaks and that failure to account for a structural break can lead to misleading inference (Odionye and Chukwu 2021; Perron,1989; 1997). ADF_URT (Panels B and C) indicates varying order of integration. The KPSS_URT further confirms that the series are mixture of order one and zero as all the series are

Table 4. Unit roots test (URT) result.

	UGANDA		TANZANIA		SOUTH AFRIC		RWANDA		NIGERIA		KENYA	
Variables	ADF	KPSS	ADF	KPSS	ADF	KPSS	ADF	KPSS	ADF	KPSS	ADF	KPSS
Panel A: Full Sample												
LSPR	−59.6*	0.06*	−18.3*	0.09*	−48.5*	0.10*	−23.1*	0.22*	−34.8*	0.27*	−58.2*	0.11*
	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]
LOPR	−49.6*	0.155*	−49.6*	0.16*	−49.6*	0.16*	−49.6*	0.19*	−49.6*	0.17*	−49.6*	0.17*
	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]
LERT	−27.6*	0.245*	−36.3*	0.24*	−48.5*	0.12*	−12.3*	0.17*	−61.8*	0.05*	−43.9*	0.33*
	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]
LERT_MNC	−4.1*	0.06*	−9.5*	0.01*	−47.5*	0.44*	−10.3*	0.24*	−5.2*	0.16*	−4.5*	0.21*
	[1(0)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(0)]	[1(1)]
LERT_MRC	−49.2*	0.034*	−6.0*	0.33*	−48.4*	0.14*	−12.7*	0.31*	−48.6*	0.41*	−19.5*	0.34*
	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]
LERT_LGC	−6.9*	0.279*	−7.1*	0.01*	−31.2*	0.41*	−10.2*	0.34*	−24.7*	0.18	−7.9*	0.31*
	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]
Panel B: Pre-COVID-19 ERA (PCE)												
LSPR	−2.69*	0.11*	−32.1*	0.45*	−3.03*	0.21*	−3.4*	0.15*	−29.4*	0.13*	−3.03*	0.21*
	[1(0)]	[1(1)]	[1(1)]	[1(1)]	[1(0)]	[1(1)]	[1(0)]	[1(1)]	[1(1)]	[1(1)]	[1(0)]	[1(1)]
LOPR	−49.9*	0.14*	−44.5*	0.15*	−44.8*	0.16*	−44.6*	0.15*	−44.9*	0.15*	−44.8*	0.15*
	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]
LERT	−24.4*	0.22*	−15.8*	0.21*	−41.4*	0.09*	−10.6*	0.16*	−54.6*	0.15*	−40.4*	0.39*
	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]
LERT_MNC	−3.4*	0.18*	−8.3*	0.35*	−40.3*	0.28*	−9.02*	0.34*	−4.7*	0.39*	−36.9*	0.29*
	[1(0)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(0)]	[1(1)]	[1(1)]	[1(1)]
LERT_MRC	−41.7*	0.10*	−6.0*	0.37*	−41.8*	0.04*	−56.5*	0.31*	−3.19*	0.37*	−44.5*	0.25*
	[1(1)]	[1(1)]	[1(0)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(0)]	[1(1)]	[1(1)]	[1(1)]
LERT_LGC	−5.9*	0.003*	−6.4*	0.03*	−39.9*	0.29*	−8.93*	0.34*	−21.0*	0.42*	−8.28*	0.33*
	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]	[1(1)]

(*continued*)

Table 4. Continued.

	UGANDA		TANZANIA		SOUTH AFRIC		RWANDA		NIGERIA		KENYA	
Variables	ADF	KPSS	ADF	KPSS	ADF	KPSS	ADF	KPSS	ADF	KPSS	ADF	KPSS
Panel C: COVID-19 ERA (CE)												
LSPR	−3.04* [1(0)]	0.20* [1(0)]	−24.2* [1(1)]	0.12* [1(1)]	−22.7* [1(1)]	0.17* [1(1)]	−2.91* [1(1)]	0.45* [1(1)]	−25.3* [1(1)]	0.13* [1(1)]	−22.2* [1(1)]	0.25* [1(1)]
LOPR	−3.31* [1(0)]	0.09* [1(1)]	−3.27* [1(0)]	0.09* [1(1)]	−3.27* [1(0)]	0.09* [1(1)]	−3.56* [1(0)]	0.07* [1(1)]	−49.6* [1(1)]	0.23* [1(1)]	−3.3* [1(0)]	0.07* [1(1)]
LERT	−16.8* [1(1)]	0.44* [1(1)]	−27.2* [1(1)]	0.27* [1(1)]	−28.7* [1(1)]	0.04* [1(1)]	−18.3* [1(1)]	0.25* [1(1)]	−3.15* [1(0)]	0.22* [1(1)]	−14.2* [1(1)]	0.31* [1(1)]
LERT_MNC	−23* [1(1)]	0.42* [1(1)]	−2.92* [1(0)]	0.37* [1(1)]	−3.49* [1(0)]	0.21* [1(1)]	−4.6* [1(0)]	0.69* [1(1)]	−3.6* [1(0)]	0.35 [1(1)]	−4.77* [1(0)]	0.24* [1(1)]
LERT_MRC	−2.83* [1(1)]	0.23* [1(1)]	−27.8* [1(1)]	0.42* [1(1)]	−28.7* [1(1)]	0.41* [1(1)]	−3.65* [1(1)]	0.20* [1(1)]	−5.05* [1(1)]	0.31* [1(1)]	−3.17* [1(1)]	0.36* [1(1)]
LERT_LGC	−11.2* [1(1)]	0.22* [1(1)]	−28.2* [1(1)]	0.23* [1(1)]	−4.39* [1(1)]	0.31* [1(1)]	−5.04* [1(0)]	0.78* [1(1)]	−3.81* [1(0)]	0.27* [1(1)]	−4.98* [1(0)]	0.25* [1(1)]
Panel D: Zivot-Andrews unit root test (ZAURT) with a break												
	ZA	**B-*P***	**ZA**	**B-*P***	**ZA**	**B-*P***	**ZA**	**B-*P***	**ZA**	**B-*P***	**ZA**	**B-*P***
LSPR	−23.8* [1(1)]	2/10/17	−30.1* [1(1)]	10/17/14	−46.6* [1(1)]	2/15/15	−20.9* [1(1)]	7/30/15	−40.1* [1(1)]	8/22/16	−58.4* [1(1)]	3/10/17
LOPR	−19.6* [1(1)]	7/06/15	−19.6* [1(1)]	7/06/15	−19.6* [1(1)]	7/06/15	−19.6* [1(1)]	7/06/19	−19.6* [1(1)]	7/06/19	−19.6* [1(1)]	7/06/19
LERT	−12.8* [1(1)]	10/16/15	−6.6* [1(0)]	12/22/14	−48.6* [1(1)]	1/19/16	−8.2* [1(0)]	11/23/16	−5.7* [1(0)]	6/20/16	−14.4* [1(1)]	9/08/15
LERT_MNC	−9.3* [1(0)]	6/23/15	−8.1* [1(0)]	6/25/15	−48.3* [1(1)]	12/14/1	−10,1* [1(0)]	8/08/17	−7.9* [1(1)]	7/29/16	−13.8* [1(1)]	11/17/17
LERT_MRC	−27* [1(1)]	10/16/20	−9.6* [1(1)]	4/24/17	−29.3* [1(1)]	4/10/18	−14.2* [1(1)]	2/05/19	−22.3* [1(1)]	3/16/20	−11.6* [1(1)]	8/31/20
LERT_LGC	−8.9* [1(0)]	5/22/15	−6.2* [1(0)]	12/22/14	−16.5* [1(1)]	8/14/16	−9.6* [1(1)]	8/09/17	−5.3* [1(0)]	6/20/16	−8.7* [1(1)]	9/17/16

Notes: Authors' computation. 0 and 1 indicates the order of integration of the given series. ** (*) shows the variable is stationary at a 1% (5%) level of significance.

non-level stationary except LSPR in panel C. Thus, NARDL and MTNARDL are the most suitable estimation techniques for this study.

4.4. Lag length selection

The best lag value for the series was selected based on the lag length information criteria and the result is presented in Table 5.

Table 6 indicates that lag 2 is the best lag value for Nigeria, Kenya while lag 3 is selected for Uganda and South Africa. The optimum lag value for Tanzania and Rwanda are 6 and 8 respectively. The choice of optimal lag length was based on Bayesian lag length criteria. Following therefore, the NARDL and MTNARDL were estimated based on the selected lag values to ensure parsimony.

4.5. Cointegration test

Given that the condition for bound cointegration in the MTNARDL model is satisfied, we estimate bound cointegration within the model frameworks of NARDL and MTNARDL and the summary of results are presented in Table 6 for both full sample and sub-samples.

Table 6 (Panel A) indicates a strong long-run relationship between exchange rate changes and stock prices for South Africa, Rwanda, Nigeria and Kenya in the two models whereas in the case of Uganda and Tanzania, a long-run nexus exists between the variables in the NARDL model. Panel B demonstrates no long-run connection between the series for Tanzania in both the NARDL and MTNARDL models, while for Uganda, no long-run link exists between the series. In the case of the CE (Panel C), NARDL shows long-run nexus between the series for all except Uganda while it is Tanzania that does not have a long-run relationship between the variables.

4.6. Nonlinear ARDL model estimation of the nexus between exchange rates and stock prices (Full sample)

Following the existence of a long-run relationship between the variables in all the countries and considering the fact that the BDS test as well as Jarque–Bera test favour nonlinear model (Ullah et al. 2021; 2022), we first estimated the nonlinear ARDL model in tandem with equation (3.7) and the results, for brevity, is presented in Table 7.

As indicated in the short-run result of Table 7 (panel A), exchange rate depreciation (LERT_POS) has positive and significant effects on stock prices in Uganda, Tanzania, Rwanda and Nigeria in the short-run but in the case of exchange rate appreciation (LERT_NEG), it has an inverse effect on stock prices only in Nigeria while insignificant effect exists in those of Uganda, Tanzania and Rwanda. It further shows that exchange rate appreciation reduces the value of stock prices in South Africa and Kenya as the coefficient of exchange rate appreciation (LERT_NEG) is negative and significant for both countries. This outcome suggests that exchange rate depreciation in Nigeria, Uganda, Tanzania and Rwanda increase the international competitiveness of the country and hence attract foreign portfolio investors in the local firms and hence improvement in their stock prices upholding the flow-oriented model of Dornbusch and Fischer (1980). While in the case of Kenya and South Africa, exchange rate appreciation reduces stock prices which implies that a reduction in foreign investors'

Table 5. Lag length selection based on information criteria.

	UGANDA		TANZANIA		SOUTH AFRICA		RWANDA		NIGERIA		KENYA	
Lag	AIC	SBC	AIC	SBC	AIC	SBC	AIC	SBC	AIC	SBC	AIC	SBC
0	−1.825	−1.803	−2.01	−1.98	−2.11	−2.09	−2.81	−2.81	0.31	0.32	−2.80	−2.79
1	−1.789	−1.78	−2.03	−2.03	−2.13	−2.13	−9.95	−9.92	−16.65	−16.62	−19.95	−19.92
2	−17.59	−17.56	−18.01	−17.98	−16.51	−16.48	−10.36	−10.31	−16.78*	−16.73*	−19.99	−19.94*
3	−17.65*	−17.57*	−18.25	−18.20	−16.54*	−16.49*	−10.54	−10.47	−16.78	−16.71	−19.99*	−19.92
4	−17.63	−17.56	−18.29	−18.21	−16.54	−16.47	−10.64	−10.55	−16.78	−16.69	−19.98	−19.89
5	−17.63	−17.54	−18.32	−18.23	−16.54	−16.45	−10.70	−10.59	−16.78	−16.67	−19.98	−19.87
6	−17.64	−17.52	−18.48*	−18.36*	−16.54	−16.42	−10.74	−10.60	−16.77	−16.64	−19.98	−19.85
7	−17.63	−17.49	−18.47	−18.34	−16.53	−16.39	−10.76	−10.61	−16.77	−16.62	−19.98	−19.82
8	−17.62	−17.47	−18.47	−18.31	−16.53	−16.38	−10.79*	−10.62*	−16.77	−16.59	−19.99	−19.81

Note: * indicates lag order selected by the criterion.

Table 6. Bound cointegration test.

Model	Uganda	Tanzania	South Africa	Rwanda	Nigeria	Kenya
Panel A: Full Sample						
NARDL	5.5**	4.96**	7.1***	8.4***	5.8***	5.7**
MTNARDL	1.8	3.2	5.1**	3.7**	5.8***	8.4***
Panel B: Pre-COVID-19 Era (PCE)						
NARDL	5.2**	2.8	4.5**	7.2***	5.1**	6.0**
MTNARDL	1.5	2.9	8.1***	7.4***	5.6***	9.1***
Panel C: COVID-19 Era (CE)						
NARDL	1.2	6.7***	6.1***	3.9**	5.0***	7.1***
MTNARDL	4.8***	1.9	6.1***	3.9**	6.1***	2.6

Note: *** (**) [*] indicates rejection of null hypothesis at 1% (5%)[10%] level of significance.

shares value following exchange rate appreciation may warrant them to sell their shares which will cause a further decline in stock prices. This result supports the empirical findings of Bahmani-Oskooee and Saha (2016), Mitra (2017) for South Africa, Okere, Muoneke, and Onuoha (2021), Saidi et al. (2021) Luqman et al. (2021) for G8 countries, Wong (2021). Wong (2021) found a mixed result for the Asian countries. Salisu et al., observed that asymmetric link exists between exchange rate and the US stock prices.

Regarding oil prices, the study's outcomes demonstrate that an increase in oil price (LOPR_POS) significantly reduces stock market prices of all the countries except Nigeria in the short-term whereas oil price decline has an inconsequential influence on stock prices (Panel B). This outcome divulges that an increase in oil prices inversely influences firms share values via an increase in input cost and hence firms' profits and thus, upholds the theoretical view. This outcome agrees with the findings of Zhang and Shang (2023) for China, Abdo (2022) for US, China and Japan, Gourene and Mendy (2018) for selected African countries. Gourene and Mendy (2018) examined the co-movement between oil prices and stock prices in Africa using Wavelet coherence estimation process and observed mixed outcomes. The coefficients of determination and its adjusted confirmed good fit of the models as the R^2 and adjusted R^2 are all greater than 0.7 (well fitted) except for Uganda with a moderate fit of 0.68 coefficient. Expectedly, the overall parameters are significant in all the countries given the F-statistics. The error correction terms for all countries indicate a low rate of convergence to equilibrium.

The long-run result (panel B) indicates that only depreciation in exchange rate significantly increases the stock prices of Nigeria and Uganda while for other countries, both exchange rate depreciation and appreciation are insignificantly influencing stock prices in the long run. As demonstrated in Panel B, elevated oil price significantly reduces stock prices in SSA in the long run. The empirical outcome alludes that increased oil price hurts the stock index significantly.

Robustness of the models shows that the residuals for all the countries are not normally distributed. These results further attest to the high volatility of the series and justify the use of an alternative nonlinear model for estimation. The autocorrelation test confirmed the absence of serial correlation in the model for all the countries except Rwanda.

Table 7. Summary of nonlinear ARDL results (full sample).

Variables	Uganda	Tanzania	South Africa	Rwanda	Nigeria	Kenya
Panel A: Short Run Result						
D(LSPR(-))	−0.24**	−0.45**	−0.19**	−0.84**	0.31**	−0.19**
D(LSPR(−2))	−0.02	−0.19**		−0.73**	0.002	
D(LSPR(−3))	0.04	−0.12**		−0.63**	−0.02	
D(LSPR(−4))	0.06**			−0.53**	0.03	
D(LERT_POS)	0.06	0.03**	−0.05	0.24**	0.06**	−0.67
D(LERT_POS(−1))	0.29*		−0.02	0.17**	0.04*	
D(LERT_POS(−2))	0.31*		−0.11*		0.03	
D(LERT_NEG)	0.08	0.04	0.08	−0.12**	−0.08**	
D(LERT_NEG(−1))	−0.55**	0.17		−0.06	0.007	−0.49**
D(OPR_POS)	−0.16	−0.07	−0.18**	−0.34**	0.17**	−0.14**
D(OPR_POS(−1))	0.17	−0.03	−0.21**	−0.07**	0.01	−0.18**
D(OPR_NEG)	−0.03	−0.03	−0.23	0.16	0.61	−0.15
ECT(−1)	−0.008**	−0.004**	−0.009**	−0.04**	−0.001*	−0.008
F_Stat	15.8**	60.9**	10.8**	178**	14.6**	34.3**
R^2	0.68	0.78	0.76	0.89	0.72	0.74
(Adj R^2)	(0.68)	(0.77)	(0.75)	(0.88)	(0.71)	(0.73)
Panel B: Long Run Result						
LERT_POS	1.19**	−0.277	−0.325	−0.03	3.38**	−1.35
LERT_NEG	−1.55	0.242	−0.339	−0.04	4.01	−1.61
LOPR_POS	−0.12**	−0.16*	−0.15**	−0.06**	−0.09**	−0.11**
LOPR_NEG	−0.12	−0.01	0.01**	−0.01	0.001**	−0.03
Panel C: Test of Robustness						
J-B Test	162828**	104336**	4795543**	1.4E + 08**	207408**	496344**
SR_Wald	7.4**	77.9**	12.6**	12.6**	3.3**	437**
LR_Wald	5.6**	3.5**	5.2**	1.2	3.5**	3.3**
B-G_S_ test	0.003	0.748	0.81	5.05**	1.34	1.16
B-*P*-G H_test	0.162	1.87*	8.18**	0.06	3.4**	22.3**
R-R_ Test	0.295	1.71	0.77	5.9**	0.15	1.24
Cusum	Unstable	Stable	Unstable	Stable	Stable	Unstable
Cusum sqr.	Stable	Unstable	Unstable	Unstable	Stable	Unstable
Recur_Coeff.	Stable	Stable	Stable	Stable	Stable	Stable

Notes: *Authors' estimation from Eviews 12. ** (*) shows the variable is stationary at a 1% (5%) level of significance.* J-B test is a test of normality, B-G_S test represents q order of autocorrelation, B-*P*-G-_H is a test for constant variance, R-R test represents the test of model specification. SR_Wald represents the short run Wald test of symmetry; LR _Wald is the long run test of symmetry.

The Breusch-Pegan-Godfrey heteroskedasticity test (B-P-G-H) indicates constant variance in residual in only Uganda and Rwanda while for the other countries, it indicates the presence of unequal variance in residual. This is not surprising considering the highly volatile nature of the series. The Ramsey RESET test (R-R test) indicates the correct specification of the model except that of Rwanda. Also, the residuals exhibit constant variance as signified by the test of heteroskedasticity. While the Recursive coefficients graphs indicate the stability of parameters within the 5% level in all the countries, the CUSUM graph shows stability in the coefficients at the 5% level for Tanzania, Rwanda and Nigeria, and the CUSUM square graph indicates stable parameters only in Uganda and Nigeria whereas others exhibit mild instability in parameters within the 5% margin. The Wald test of symmetric relationship (SR_Wald and LR_Wald) indicates the existence of short-run asymmetric effects of exchange rate on stock prices in all the selected SSA countries while in the case of long-run, except Rwanda, other selected countries show asymmetric relationship between the variables.

Table 8. Summary of MTNARDL results (full sample).

Variables	Uganda	Tanzania	South Africa	Rwanda	Nigeria	Kenya
Panel A: Short Run Result						
D(LSPR(−1))	−0.24**	−0.45**	−0.20**	−0.81**	0.31**	−0.191**
D(LSPR(−2))	−0.02			−0.71**	0.003	−0.195**
D(LERT_MNC_POS)	0.02**	0.06**	0.01**	−0.11	0.20**	0.12**
D(LERT_MNC_NEG)	0.65	0.23	0.11**	0.25	−0.019**	0.19**
D(LERT_MRC_POS)	−0.15**	−0.18**	0.11**	0.23**	−0.11**	0.009**
LERT_MRC_POS(−1)	0.13*			0.19*	−0.17**	
D(LERT_MRC_NEG)	0.02	−0.11**	−0.46**	0.02	−0.02	−0.25
D(LERT_LGC_POS)	−0.44**	−0.50**	−0.1	−0.62**	−0.92**	−0.50**
D(LERT_LGC_NEG)	−0.22*	−0.04**	−0.10	−0.22*	−0.32**	−0.10**
ECT(−1)	−0.007**	−0.006**	−0.009**	−0.07**	−0.011**	−0.017**
F_Stat	17.0**	95.7**	11.9**	15.7**	17.8*	19.9**
R^2	0.77	0.87	0.86	0.84	0.81	0.80
(Adj R^2)	(0.76)	(0.87)	(0.84)	(0.83)	(0.80)	(0.79)
Panel B: Long Run Result						
LERT_MNC_POS			5.16*	0.55**	0.51**	0.27**
LERT_MNC_NEG			0.35**	1.46	−0.36	0.12**
LERT_MRC_POS			4.49*	−1.68	−0.48**	0.19
LERT_MRC_NEG			−0.24**	−0.35	−0.55*	−0.54**
LERT_LGC_POS			0.06	−0.63**	−2.03**	−0.36**
LERT_LGC_NEG			−0.68**	−0.23**	−0.73**	−0.59**
Panel C: Test of Robustness						
Arch LM	0.93	0.60	0.02	0.599	0.92	3.6
SR_Wald	4.95**	115.9**	3.59**	10.1**	4.12**	4311**
LR_Wald			4.31**	3.8**	3.4**	2.1*
B-G_S_ test	1.94	0.50	1.11	1.7	0.11	0.54
B-*P*-G H_test	0.28	0.34	1.19	0.14	0.33	0.91
R-R_ Test	0.48	1.79	2.93	5.9**	4.1**	0.97
Cusum	Stable	Stable	Stable	Stable	Stable	Unstable
Cusum sqr.	Stable	Unstable	Unstable	Unstable	Stable	Unstable
Recur_Coeff.	Stable	Stable	Stable	Stable	Stable	Stable

Notes: *Authors' computation. Using Eviews 12. ** (*) shows rejection of null hypothesis at a 1% (5%) level of significance.*, Arch LM test represents a test of ARCH effect, B-G_Serial test represents q order serial autocorrelation, B-*P*-G- Het is a test for constant variance, R-RESET represents a test of model specification. SR_Wald represents the short-run wald symmetry test; LR _Wald is the long-run symmetry test.
. LERT_MNC is mild shocks in the exchange rate, LERT_MRC depicts moderate shocks in the exchange rate; LERT_LGC represents large shocks in the exchange rate. POS is positive (depreciation) while NEG means negative (appreciation).

4.7. Asymmetric impact of multifarious shocks in exchange rate on stock prices (Full sample)

The study examined the asymmetric effects of different sizes of exchange rate shocks on stock prices in selected SSA countries, using the MTNARDL estimation approach in line with equation (3.11) and the result is summarized in Table 8.

As stated in the previous section, the study decomposed shocks in exchange rate into lower and upper quantiles in line with Li and Guo (2022) with slight modification; Li and Guo used 30th and 70th quantiles for lower and upper quantiles while this study used 25th and 75th quantiles to construct three thresholds of shocks (small, moderate and large) to determine the effects of various exchange rate shocks on stock prices in some selected SSA countries. The result in Table 8 has three segments, namely the short run, the long run and the diagnostic test results.

Panel A indicates that mild exchange rate depreciation (LERT_MNC_POS) significantly increases stock prices in all the selected countries except in Rwanda, which is insignificant, while mild exchange rate appreciation (LERT_MNC_NEG) significantly reduces stock prices in Nigeria, and those of South Africa and Kenya are significantly indifferent as it has the same effect with mild depreciation. The direct response of stock prices to mild exchange rate depreciation result validates the flow-oriented model of Dornbusch and Fischer (1980), suggesting that a mild exchange rate depreciation within 25th percentile changes will increase the countries' international competitiveness and hence attracts foreign portfolio investors into the countries and this will, in turn, lead to an increase in firms' stock values. This outcome supports the findings of Mohamed and Elmahgop (2020), Mitra (2017), Salisu, Isah, and Ogbonnaya-Orji (2020), Çakır (2021) for Sudan. Nusair and Olson (2022) for G7. Nusair and Olson (2022) observed exchange rate changes significantly affect the stock index of 6 out of the 7 countries investigated. Moderate exchange rate depreciation (LERT_MRC_POS) significantly increases stock prices in South Africa, Kenya and Rwanda while in the case of Nigeria, Uganda and Tanzania it reduces firms' stock returns. The mixed results in the moderate swings in exchange rate suggest that exchange rate changes (positive or negative) will depend on whether the country is import-dependent or export-oriented. This implies that firms in Nigeria, Uganda, and Tanzania are mostly dependent on foreign materials for their raw material as a moderate swing in exchange rate affects their cost of production inversely and hence reduction in both firms' profits and stock supporting the flow-oriented model. However, exchange rate changes, high and above 75th percentile (upper quantile), inversely affect stock prices. At the upper quantile, both depreciation and appreciation negatively affect stock prices in all the selected countries in the short run. The implication of this result is that a small change in exchange (whether depreciation or appreciation) is healthy for the economy and stock prices in particular, but as the changes increase towards the middle and third quantile, the effects become harmful depending on whether the country in question is import-dependent or export-oriented as well as policy response of the government. However, exchange rate swings high and above the 75th percentile will perniciously worsen the firms' output and stock values.

Panel B in table indicates that in the long run, mild exchange rate depreciation directly influences stock prices in all the selected countries except in Uganda and Tanzania, where the long-run tests were not applicable since the MTNARDL bound test indicated the absence of a long-run relationship between the variables. Similar to the short-run coefficients results, as the swings in exchange rate increase towards the upper quantile, the negative asymmetric effects of exchange rate shocks on stock prices increase further implying that the inverse nexus between the variables is directly related to the magnitude of shocks in the exchange rate. It further shows that in the long run extremely large exchange rate depreciation adversely affects stock prices more than appreciation in Nigeria and Rwanda while an astronomical increase in exchange rate appreciation severely hurts stock returns more than depreciation in South Africa and Kenya. The implication is that an extremely large appreciation of a relatively strong currency will inversely affect stock prices than depreciation will do as foreign investors' shareholders' wealth reduces following huge appreciation, which would lead to panic sale of shares to avoid further loss, and hence a reduction in stock prices. This outcome supports the findings of Chang and Chang (2023), Gokmenoglu, Eren, and Hesami (2021) and Lakshmanasamy (2022). Gokmenoglu, Eren, and Hesami (2021) used QQR model to establish that exchange rate large change significantly affects the stock prices at low quantile, which is in tandem with the finding of Lakshmanasamy (2022),

The validity of the MTNARDL results is confirmed by the absence of the ARCH effect, constant variance and absence of serial correlation in all the selected countries as the null hypotheses of ARCH effects, no serial correlation at different lags and constant variance cannot be rejected given the statistics of the ARCH LM test, Breusch–Godfrey serial correlation test and Breusch–Godfrey-Pegan heteroskedasticity test, respectively. Also, the recursive coefficient graphs indicate stable parameters at a 5% significant level for all the selected countries. The Ramsey RESET test indicates the correct specification of models for all the countries except Nigeria and Rwanda as the null hypothesis of the correct model specification was rejected for Nigeria and Rwanda. The CUSUM graph shows stability of the parameters at a 5% level for all the countries except for Kenya whereas the CUSUM square indicates stability of the parameters at 5% only in Uganda and Nigeria while other countries show unstable parameters at a 5% level.

4.8. Is the asymmetric link between exchange rate diverse shocks and stock prices sensitive to global shocks: the case of COVID-19?

The study further decomposed the sample period into the PCE and the CE in order to provide information on whether the asymmetric link between the series is sensitive to global shocks. The study of Amewu, Owusu Junior, and Amenyitor (2022) has also considered the link between the series from the viewpoint of PCE and CE. The innovation in this study is whether the response of stock prices to extremely small or extremely large swings in exchange rates varies across the PCE and during CE periods.

4.8.1. Asymmetric link between the series in the PCE and during CE

Table 9 demonstrates the asymmetric link between exchange rate and stock prices in the PCE and the CE. The result is divided into three parts: panels A and B show the short-run and long-run asymmetric tests, while panel C indicates the robustness checks. Based on the summarized results in Table 9 (Panel A) generated from the NARDL, it is imperative to highlight that among other interesting outcomes, stock market is self-reinforcing in both the PCE and the CE. This outcome is illustrated by the positive and significant link existing between the past value of stock index [D(LSPR(−1))] and its present values. This result largely indorses the weak form hypothesis that past stock prices can be used to predict its current value before and during global shocks.

The result (Panel A) further indicates that exchange rate depreciation (D(LERT_POS)) increases significantly the stock index of Uganda, Rwanda and Nigeria by 0.39%, 0.01% and 0.04% respectively in the PCE, while depreciation deteriorates the stock prices of Tanzania and South Africa in the short-run. However, during the CE, depreciation significantly reduces the stock prices of all the selected countries except South Africa. This outcome, on the basis of its magnitude and significant, clearly demonstrates that the asymmetric link between the series is highly sensitive to global shocks in the short-run. Pertaining to exchange rate appreciation (D(LERT_NEG)), the finding indicates that appreciation largely reduces the stock prices of Rwanda, Nigeria and Kenya in both the PCE and CE in the short-run while in the case of Uganda, it increases the stock prices only in the PCE. The outcome indicates that exchange rate appreciation for South Africa increases the country's stock prices, only in the CE. In what seems to uphold the view that the relationship between the series is sensitive to global shocks is that, on

Table 9. Summary of nonlinear ARDL Results of Pre and During COVID-19 Pandemic Era (Model 4, 2, 1, 1, 1, 0)

Model	PRE-COVID-19 ERA (01/03/2013–10/03/2020)						COVID-19 ERA (11/03/2020-14/01/2023)					
Series	UGA	TAZ	SAF	RWA	NIG	KEN	UGA	TAZ	SAF	RWA	NIG	KEN
Panel A: Short Run Result												
D(LSPR(-))	0.23**	0.38**	−0.19**	0.1**	0.16**	0.09**	0.97**	0.33**	0.25**	0.84**	0.41**	0.21**
D(LSPR(−2))				0.01**				0.12**		−0.73**		
D(LSPR(−3))										−0.63**		
D(LSPR(−4))										−0.53**		
D(LERT_POS)	0.07	−0.1**	−0.01*	0.01**	0.04**	−0.35	−0.7**	−0.3**	−0.25**	0.24**	0.08**	−0.56
D(LERT_POS(−1))	0.39**			0.02**	0.04*				−0.02	0.17**	0.05*	
D(LERT_POS(−2))									−0.31*			
D(LERT_NEG)	0.11	−0.009	0.01	−0.09**	−0.02**		−0.03	0.184	0.08	−0.12**	−0.12**	
D(LERT_NEG(−1))	0.56*					−0.15**				−0.06		−0.27**
D(OPR_POS)	0.05	−0.002	−0.03**	−0.01**	0.11**	−0.06**	−0.61	−0.28	−0.1**	−0.34**	0.19**	−0.1**
D(OPR_POS(−1))	−0.05*		−0.01**						−0.81			
D(OPR_NEG)	0.01	−0.008	−0.23	0.16		−0.09	−0.1**	9.91	−0.10	−0.08**		−0.13
ECT(−1)	−0.01**	−0.01**	−0.002**	−0.02**	−0.001*	−0.003*	−0.03	−0.02**	−0.003**	−0.07**	−0.003*	−0.02**
F_Stat	23.6**	18.6**	20.8**	17.8**	22.6**	30.3**	15.6**	23.6**	16.**	178**	25.6**	19.3**
R^2	0.69	0.75	0.73	0.89	0.70	0.76	0.65	0.62	0.70	0.89	0.73	0.71
(Adj R^2)	(0.68)	(0.75)	(0.72)	(0.88)	(0.69)	(0.71)	(0.63)	(0.61)	(0.69)	(0.88)	(0.71)	(0.70)
Panel B: Long Run Result												
LERT_POS	0.47		−0.10	−0.12	056**	−0.65		−7.6**	−0.01**	−0.23*	−1.4**	0.11
LERT_NEG	0.81		−0.04	−0.23	0.7	−0.81		−7.4**	−0.09	−0.02	0.04	−0.08
LOPR_POS	0.001		−0.09**	−0.03**	0.04**	−0.09**		0.04	−0.2**	−0.1**	0.01**	−0.24**
LOPR_NEG	−0.02		0.02	−0.01	0.001	−0.8		−0.01	0.01**	−0.003	0.032	−0.07

(*continued*)

Table 9. Continued.

Model	PRE-COVID-19 ERA (01/03/2013–10/03/2020)						COVID-19 ERA (11/03/2020-14/01/2023)					
Series	UGA	TAZ	SAF	RWA	NIG	KEN	UGA	TAZ	SAF	RWA	NIG	KEN
Panel C: Test of Robustness												
SR_Wald	10.1**	5.51**	26.3**	9.6**	3.3**	17.4**	4.6*	4.9**	42.6**	11.3**	3.3**	24.6**
LR_Wald	7.32**		19.6**	9.2**	3.5**	9.6**		0.7	21.6**	11.7**	8.5**	8.6**
B-G_S_ test	0.08	1.30	1.2	5.05**	1.07	2.51	1.15	1.07	0.81	0.134	0.61	1.87
B-*P*-G H_test	9.9**	10.1**	7.8**	7.1**	0.87	9.8**	1.33	0.9	8.2**	11.1**	5.2*	7.1**
R-R_ Test	0.89	1.89	1.18	5.9**	0.43	1.37	0.81	1.28	0.91	1.34	0.98	1.81
Cusum	S	S	U	S	S	S	S	S	S	S	S	S
Cusum sqr.	S	S	S	S	S	S	U	U	S	S	S	U

Notes: *Authors' estimation from Eviews 12. ** (*) shows the variable is significant at a 1% (5%) level of significance.* J-B test is a test of normality, B-G_S test represents q order of autocorrelation, B-*P*-G-_H is a test for constant variance, R-R test represents the test of model specification. SR_Wald represents the short run Wald test of symmetry; LR _Wald is the long run test of symmetry. S and U signify stable and unstable respectively.

the basis of the magnitude of influence and the significant, we find that both appreciation (D(LERT_NEG)) and depreciation (D(LERT_POS)) significantly affect stock prices more in the CE than the PCE. The long-term test (Panel B) further confirms the sensitivity of the series connectivity to global shocks. This upshot illustrates that, following COVID-19 outbreak, exchange rate depreciation (LERT_POS) reduces stock prices of Tanzania, South Africa, Rwanda and Nigeria by 7.6%, 0.01%, 0.23% and 1.4% respectively whereas, Kenya stock prices respond inconsequentially to changes in exchange rate in the PCE. This outcome further upholds the sensitivity of the series connectivity to global shocks, corroborating the findings of Baker et al. (2020) and Amewu, Owusu Junior, and Amenyitor (2021). Amewu, Owusu Junior, and Amenyitor (2021), in the context of Ghana, found a more connection in the series during the pandemic era than before the era. Baker et al. (2020) illustrated that world stock market chronicled anomalous drop consequent upon the outbreak.

Regarding the coefficient of oil price, the results from both the PCE and CE demonstrate that elevated oil price (LOPR_POS) significantly reduces stock market prices of all the countries except Nigeria in the short-term whereas oil price decline has inconsequential influence on stock prices in all the countries except Uganda (PCE period) and Rwanda (CE). The inconsistent results are expected, as the influence of oil price on stock prices depends on whether the country is oil exporter or oil importer. This outcome divulges that an increase in oil prices inversely influences firms share values via an increase in input cost and hence firms' profits and thus, upholds the theoretical view. This outcome agrees with the findings of Zhang and Shang (2023) for China, Abdo (2022) for US, China and Japan, Gourene and Mendy (2018) for selected African countries.

The tests of the robustness (Table 9) show the absence of serial correlation (B_G_S_test) in the model for all the countries except Rwanda in the PCE. The Breusch-Pegan-Godfrey heteroskedasticity test (B-P-G-H) indicates constant variance in only Nigeria (PCE), Uganda and Tanzania (CE), while for the other countries, it indicates the presence of unequal variance in residual. The Ramsey RESET test (R-R test) indicates the correct specification of the model except that of Rwanda (PCE). While the CUSUM graph indicates stability in the coefficients at the 5% level for all the countries except South Africa (PCE), the CUSUM square graph indicates stable parameters for all except Uganda, Tanzania and Kenya (CE) within the 5% margin. The Wald test of symmetric relationship (SR_Wald) indicates the existence of short-run asymmetric effects of exchange rate on stock prices in all the selected SSA countries while in the case of long-run (LR_Wald), except Tanzania, other selected countries show the asymmetric long-run connection between the series. Considering the inconsistence result in the robustness test (B-P-G-test) which obviously indicates high volatility of the series and thus and justifies the use of an alternative nonlinear model for estimation.

4.8.2. Asymmetric impact of exchange rate multifarious shocks on stock prices in the PCE and during CE

Table 10 demonstrates the asymmetric impact of exchange rate multifarious shocks on stock prices in the PCE and the CE. The soundness of the MTNARDL results is established by the absence of ARCH effect (Panel C), constant variance and absence of serial correlation in both the PCE and the CE, for all the selected countries; as the null hypotheses of ARCH effects, no serial correlation at different lags and constant variance cannot be rejected Also, the recursive coefficient graphs indicate stable parameters at a 5% significant level for all the selected countries. The Ramsey RESET test indicates the correct specification of models for all the countries except Rwanda (PCE) and Nigeria (CE); as the null hypothesis of the correct model specification cannot be rejected for all except in Nigeria and Rwanda. The CUSUM graph shows the stability of the parameters at the 5% level for all the countries except for South Africa (PCE), whereas the CUSUM square indicates the stability of the parameters at the 5% level for except Nigeria (PCE), and Uganda and Tanzania for the CE.

The long-run result (Panel B) indicates that extremely large (LERT_LGC_P and LERT_LGC_N) change in exchange rate (depreciation and appreciation) significantly deteriorates the stock prices of the selected countries, especially during the global crisis. The negative influence of exchange rate large change increased from 0.06%, 0.21% and 0.1% in the PCE to 0.8%, 1.5% and 0.6% in the CE in South Africa, Rwanda and Nigeria respectively, while the exchange rate large appreciation (LERT_MRC_N) significantly reduces stock prices of South Africa, Rwanda and Nigeria by 0.07%, 0.2, and 0.7%, respectively, in the PCE. During the CE, exchange rate large appreciation reduces the respective countries stock prices by 0.23%, 0.2% and 0.4%. These outcomes apparently uphold the view that the series co-movement is sensitive to global shocks. This discovery supports the findings of He et al. (2020), Salisu et al. (2020), Wong (2021), Baker et al. (2020) and Amewu, Owusu Junior, and Amenyitor (2021). While He et al. (2020) and Salisu et al. (2020), discovered the sensitivity of the series connectivity to world financial crisis, Wong (2021) found the sensitivity of the series nexus to both the Asian and global financial crisis. Baker et al. (2020) and Amewu, Owusu Junior, and Amenyitor (2021) found that the nexus between the series is sensitive to COVID-19 pandemic.

4.9. Toda-Yamamoto causality test

Consequent upon the two conflicting theories of stock prices-exchange rates connection; the portfolio balance approach put forth by Frankel (1983) and the Dornbusch and Fischer’s (1980) flow-oriented model, this study conducted the causality test suggested by Toda and Yamamoto (1995) to ascertain the direction of the relationship between the series. Table 11, in brevity, demonstrates the Toda-Yamamoto test results for the full sample, PCE and CE.

The result, for the full sample, strongly supports the flow-oriented model (Panel A) for all except South Africa and Rwanda. In the context of the PCE, a one-way direction of causality, running from exchange rate to stock price exists only for Uganda and Tanzania while no causality exists for the other countries. However, in the CE, the result upholds the flow-oriented model, as causality runs from exchange rate to stock prices in South Africa, Rwanda and Kenya, but two-way direction between the series for Uganda and Rwanda. In the case of Tanzania, no direction of causality exists between the investigated series. The implication of this study is that the nature of causality between the series is episodic and supports the studies of El-Masry and Badr (2020) and Nusair and Olson (2022). El-Masry and Badr (2020) observed a one-way causality from exchange rate to stock prices before the revolution in Egypt but no causality in the post-evolution era. Nusair and Olson (2022) observed a mixed direction of causality between the series. However, this outcome tends to favour the flow-oriented model. The implication of this study is that extreme changes in exchange rate significantly influence stock prices more than the reverse process.

Table 10. Summary of MTNARDL results before and during COVID-19 pandemic era.

Model	Model 1: PRE-COVID-19 era						Model 2: COVID-19 era					
Series	UGA	TAZ	SAF	RWA	NIG	KEN	UGA	TAZ	SAF	RWA	NIG	KEN
Panel A: Short Run Result												
D(LSPR(−1))	0.23**	0.38**	0.01**	0.11**	0.16**	0.09**	0.97**	0.33**	0.11**	0.84**	0.41**	0.21**
D(LERT_MNC_*P*)	0.01**	0.02**	0.01**	−0.01	0.20**	0.09**	0.08**	0.1**	−0.2**	−0.09	−0.18**	−0.1**
D(LERT_MNC_N)	0.05	0.01	0.2**	0.12	0.01	0.14**	0.01	0.15*	0.03	−0.23	−0.01*	−0.24
D(LERT_MRC_*P*)	−0.21**	−0.11**	0.23**	0.20**	−0.21**	0.02**	−0.35**	−0.17**	−0.31*	−0.08**	−0.26**	−0.04*
LERT_MRC_*P*(−1)	0.13*			0.19*			0.13*			−0.31*		
D(LERT_MRC_N)	0.02	−0.14**	−0.27**	0.01	−0.02	−0.15	0.02	−0.21**	−0.41**	0.03	−0.16	−0.13
D(LERT_LGC_*P*)	−0.25**	−0.34**	−0.2	−0.4**	−0.52**	−0.45**	−0.67**	−0.57**	−0.5*	−0.57**	−0.74**	−0.61**
D(LERT_LGC_N)	−0.12*	−0.01**	−0.01	−0.17*	−0.25**	−0.1**	−0.19*	−0.02**	−0.19	−0.26*	−0.29**	−0.3**
ECT(−1)	−0.03**	−0.01**	−0.01**	−0.06**	−0.01**	−0.02**	−0.023**	−0.04**	−0.006**	−0.1**	−0.001**	−0.06**
F_Stat	19.0**	35.4**	22.5**	17.7**	36.4*	34.6**	26.0**	23.1**	15.6**	21.6**	14.6*	13.7**
R^2	0.79	0.85	0.71	0.86	0.82	0.81	0.73	0.83	0.8	0.84	0.69	0.74
(Adj R^2)	(0.77)	(0.87)	(0.70)	(0.84)	(0.81)	(0.79)	(0.72)	(0.87)	(0.81)	(0.83)	(0.68)	(0.74)
Panel B: Long Run Result												
LERT_MNC_*P*			4.11*	0.14**	0.21**	−0.65	0.16**		0.16*	0.01*	−0.01*	
LERT_MNC_N			0.21**	0.87	−0.12	−0.81	0.09**		0.19**	0.31	−0.11	
LERT_MRC_*P*			0.49*	−0.25	−0.3**	−0.09	0.12		0.01*	−0.37*	−0.2**	
LERT_MRC_N			−0.18**	−0.16	−0.45*	−0.10	−0.32**		−0.21**	−0.01	−0.37*	
LERT_LGC_*P*			−0.06**	−0.21**	−1.0**	−0.31**	−0.13**		−0.81**	−1.5**	−0.6**	
LERT_LGC_N			−0.27**	−0.2**	−0.7**	−0.8	−0.25*		−0.23**	−0.1**	−0.4**	

(*continued*)

Table 10. Continued.

Model	Model 1: PRE-COVID-19 era						Model 2: COVID-19 era					
Series	UGA	TAZ	SAF	RWA	NIG	KEN	UGA	TAZ	SAF	RWA	NIG	KEN
Panel C: Test of Robustness												
Arch LM	0.70	1.87	0.98	2.01	1.45	0.87	1.78	0.98	0.76	0.91	2.1	2.6
SR_Wald	12.6**	4.6	31.6**	7.6**	9.1**	17.4*	2.6*	4.9*	16.2**	11.1*	6.7**	24.6
LR_Wald			14.5**	9.2**	7.3**	10.7**	9.6*	9.7*	18.5**	0.98	8.7*	
B-G_S_ test	0.65	2.56	1.2	0.25	1.07	2.51	1.15	1.07	0.91	1.3	0.45	1.87
B-*P*-G H_test	0.76	1.45	1.41	0.14	2.6	0.87	1.33	0.9	0.58	0.98	1.56	0.11
R-R_ Test	0.89	1.89	1.7	5.7**	0.96	1.37	0.81	1.28	0.98	1.09	6.8*	1.81
Cusum	S	S	U	S	S	S	S	S	S	S	S	S
Cusum sqr.	S	S	S	S	U	S	U	U	S	S	S	S

*Notes: Authors' computation. Using Eviews 12. ** and (*) show rejection of null hypothesis at a 1% (5%) level of significance.*, Arch LM test represents a test of ARCH effect, B-G_Serial test represents q order serial autocorrelation, B-*P*-G- Het is a test for constant variance, R-R Test represents a test of model specification. SR_Wald represents the short run Wald test of symmetry; LR _Wald is the long run test of symmetry. LERT_MNC is mild shocks in the exchange rate, LERT_MRC depicts moderate shocks in the exchange rate; LERT_LGC represents large shocks in the exchange rate. *P* is positive (depreciation) while N means negative (appreciation). S and U signify stable and unstable respectively.

Table 11. Toda-Yamamoto causality test.

Model	Uganda	Tanzania	South Africa	Rwanda	Nigeria	Kenya
Panel A: Full Sample (01/03/2013–14/01/2023)						
LSPR = f(LERT)	33.02**	14.9**	5.25	2.76	19.55**	15.91**
LERT = f(LSPR)	3.004	5.5	0.47	1.22	3.84	0.04
Panel B: Pre-COVID-19 (01/03/2013–10/03/2020)						
LSPR = f(LERT)	59.09**	12.18**	0.60	0.85	2.23	3.28
LERT = f(LSPR)	2.73	4.68	2.30	0.02	3.58	0.13
Panel C: COVID-19 (11/03/2020–14/01/2023)						
LSPR = f(LERT)	25.28**	1.44	6.34*	8.37*	30.00**	6.51*
LERT = f(LSPR)	17.07**	1.79	1.78	10.59**	0.44	1.26

Note: *Authors' computation. Using Eviews 12. ** and (*) show rejection of null hypothesis at a 1% (5%) level of significance.*

5. Conclusion and policy recommendation

The study investigated the asymmetric effects of multifarious shocks in the exchange rate on stock prices in selected sub-Saharan African countries using a newly developed multiple thresholds NARDL model. Cognisance upon the view that depreciation and appreciation of exchange rate can influence stock prices differently, the sensitivity of the response of stock prices to sign and the magnitude of exchange rate changes were examined in import-dependent SSA. From the descriptive analysis, one remarkable policy implication is that the strength of a country's currency influences how volatile its currency is; a relatively strong currency is less volatile than a weak currency. The NARDL results indicate that exchange rate depreciation increases stock prices significantly in Uganda, Tanzania, Rwanda and Nigeria while conversely, exchange rate appreciation has an inverse effect on stock prices only in Nigeria but an insignificant effect in Uganda, Tanzania and Rwanda. It further shows that exchange rate appreciation reduces the value of stock prices in South Africa and Kenya as the coefficient of exchange rate appreciation is negative and significant for both countries. The relevance of these findings is that policy makers should be aware that changes in exchange rate largely affects stock prices. Thus, prompt and timely policy intervention to stabilized exchange rate markets and reduce uncertainty should be put in place.

Another important policy implication from the MTNARDL outcome is that the responses of stock prices to exchange rate changes is sensitive to the size of shock (infinitesimal, moderate and extremely large shocks). Specifically, the result indicates that exchange rate swings below the 25th percentile affect stock prices positively but as changes increase above the 25th percentile but below upper quantiles (75th percentile) the effects become mixed as it significantly increases stock prices in South Africa, Kenya and Rwanda while in the case of Nigeria, Uganda and Tanzania it reduces firms stock returns significantly. However, the effects of exchange rate shocks on stock prices become pernicious if it is astronomically large above the 75th percentile. At the upper quantile, both exchange rate depreciation and appreciation affect the value of stocks in all the selected countries in the short. Remarkably, stock prices respond positively to exchange rate shocks below first quantile but exchange rate shocks between 25th and 75th percentile, its effect on stock prices is unidirectional as it depends on whether the country is import-dependent or export-oriented country's currency as well as policy response.

Similarly, in the long run, mild exchange rate depreciation directly influences stock prices in all the selected countries but as the swings in exchange rate increase towards the upper quantile, the negative asymmetric effects of exchange rate shocks on stock prices increase further implying that the inverse nexus between the variables is directly related to the magnitude of shocks in the exchange rate. This study, therefore, recommends that monetary authorities should be proactive in formulating the right combination of policy interventions to ensure stability in foreign exchange rate markets as a monumental swing in the exchange rate will devastatingly hurt the firms' value of stocks. Specifically, a combination of fiscal and monetary interventions is necessary to ensure stability in foreign exchange rate markets. The regulatory body needs to adopt a mix of instruments, including a flexible exchange rate system, and a temporary increase in the nominal interest rate. However, nominal interest rate will increase to such an extent that nominal interest rate will increase less than inflation. The inter-bank interest rate should be set between a ceiling and a floor and be able to change daily depending on market pressures. The ceilings for net domestic assets and the floor for net international reserves should be compatible with the use of reserves to meet current account needs. Restrictive fiscal policies that are not overly contractionary should be put in place. This includes a reduction in fiscal deficits by a reduction in external debt and recurrent spending.

The study further indicates that the impacts of exchange rate multifarious shocks on stock prices are sensitive to global shocks. Thus, policy makers should take cognisance of this development and make policies that will serve as a shock absorber bridge against global shocks, and hence evade its potential devastating effects on stock markets. Also, plans that can reinforce the stock market resilience to global shocks should be put in place. Furthermore, the study's outcome from causality test indicates that exchange rate significantly influences stock prices more in the CE. This is a confirmation of the flow-oriented model as changes in exchange rate drive stock price movements.

5.1. Limitation of the study and suggestion for further study

The study carried out is limited to the asymmetric impact of multifarious exchange rate shocks (very small and very large) on stock prices in the selected SSA countries. The study focused on countries that operate similar exchange rate (float or managed float) system. Because of the high-frequency nature (daily data) of the data utilized, the study selected only oil price as a control variable to evade the problem of omitted variable biased. Thus, the study is constrained to two explanatory variables; exchange rate and oil prices in its model. Further studies may adopt a lower frequency data (quarterly or monthly) and other relevant series such as monetary policy variables and other macroeconomic fundamentals. Other studies may select some other countries that practice fixed exchange rate system based on data availability, to ascertain whether the outcome is sensitive to exchange rate system.

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Ethical approvalstatement

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

Data availability statement

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

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