MEASURING NON-LINEAR EFFECTS OF EXCHANGE RATE MOVEMENTS ON RESERVE HOLDINGS

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Abstract

Due to flaws in fiscal and financial structures, currency rate changes have detrimental effects on emerging economies. The lack of financial protection tools and insufficient levels of financial market development leaves African nations exposed to such harmful consequences of rates of exchange volatility. This study attempted to investigate the impact of exchange rate movements on the volume of reserves held by African countries struggling to maintain enough earnings to warrant floating their currency against the dollar. The non-linear autoregressive distributed lag (NARDL) of Shin et al. (2014) filters movements in exchange rates into the negative and positive partial sum, respectively. We found that devaluation weakens reserve volume in Morocco, Namibia, Nigeria, South Africa, Zambia, Kenya, Malawi and Mauritius. Exchange rate appreciation significantly decreases Ghana, Kenya, South Africa, and Mauritius reserves. The magnitude of exchange rate devaluation, 0.94, 0.85, and 0.91 in Nigeria, Malawi, and Zambia, as reported by the positive cumulative sum of the changes in the exchange rate, exceeded the magnitude of appreciation, 0.12, 0.10, and 0.17, respectively. Accordingly, the effects of exchange rates on reserves in Ghana, Malawi, Morocco, Nigeria, Namibia, and Zambia are asymmetric, while the impact in Egypt, Kenya, South Africa, and Mauritius is symmetric.

Keywords: Non-Linear Autoregressive Distributed Lag (NARDL), Currency Devaluation, Exchange Rate Movements, Reserves, African Countries

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1. INTRODUCTION

Generally, due to flaws in fiscal and financial structures, currency rate changes have detrimental effects on emerging economies. The lack of financial protection tools and insufficient financial market development levels leave The unpredicted change and volatility in the rates of currency exchange should result in a harmful impact on global trade cum economic development due to their effect on profitability. According to Demir (2013) the damaging consequences of changes in exchange rates of currencies present themselves in the following ways: Lower the price of credit from the financial sector through contraction impact on workers and business start-ups in nations at lower stages of economic growth, lower labour productivity with overall growth, reduce employment and by raising inflation unpredictability, harm the balance of payments and negatively affect change by raising interest rates. The volume of foreign reserves is affected.

Unarguably, the volume of foreign exchange reserves plays a fundamental role in Africa's economies. The reasons are not farfetched. One, residents of those countries depend mainly on imports for consumption. Two two-thirds of the local industries in Africa rely on imports of capital goods for production. Thirdly, the governments of these countries rely on imported refined petroleum products. Accordingly, the depletion of reserves has many adverse effects on governments, industries, and individuals, as the case may be, especially when such funds are needed for importation.

Moreover, low reserve holding further weakens the value of local currencies as the apex bank is rendered powerless in providing defence for such currencies because the bank lacks the adequate volume of reserves needed for intervention in the foreign exchange market. Further, when funds available to a country are below the threshold, it intensifies the demand for foreign currency instantaneously. This, in turn, results in excessive devaluation of the local currency with the underlying attendant negative consequences for the economies involved.

The conceptual/theoretical framework of Obstfeld and Rogoff (1995) is applied in this study. It follows from the fact that the framework reveals that forex rate fluctuations are expensive to the local economy because of their direct and indirect impacts on individuals and companies. Its first impact is premised on the idea that families remain unsatisfied with exchange rate fluctuations owing to the challenges of smoothing consumption and the unpredictability of leisure expenditure. The indirect effect, on the other hand, implies that to hedge against forex risk, firms set higher fees to pay on insurance (Alagidede & Ibrahim, 2017). Accordingly, we had the following research questions as guides:

RQ1: How does the external reserves position of selected African countries respond to exchange rate devaluation/depreciation?

RQ2: How has exchange rate appreciation/ revaluation affected the reserve volume of the same economies?

This research's broad objective is to provide a comparative understanding of the role of exchange rate devaluation and appreciation, as the case may be in ten African economies. Specifically, this study examines the existence or otherwise of an asymmetric effect of exchange rate movements on the volume of reserves held by African countries struggling to maintain enough earnings to warrant floating their currency against the dollar. The selected ten African economies based on data availability include Egypt, Ghana, Kenya, Malawi, Mauritius, Morocco, Namibia, Nigeria, South Africa and Zambia.

This paper contributes to the empirical literature in not less than four ways. First, it models the non-linear impact of movements in the exchange rate in the form of currency devaluation and appreciation on reserves in the African economies. Currency devaluation and revaluation is a common practice among the African economies struggling to maintain enough earnings to warrant floating their currency against the dollar and other internationally recognised currencies for trading. Therefore, knowledge of the currency movement could prove relevant for monetary policymakers to effectively guide against ongoing price instabilities and harmful inflationary expectations, as the case may be. Secondly, by evaluating the non-linearity of the effects of exchange rates on reserve holdings, the paper goes a long way to strengthen empirical literature regarding the impact of exchange rates on reserves in Africa. Thirdly, the form implements an autoregressive distributed lag estimation method, allowing joint estimation of short-run and long-run model parameters. Overall, it further allows statistical inference based on short-run and long-run asymmetric tests on exchange rate effects, facilitating joint analysis of the model's parameters. In particular, considering the asymmetric nature of exchange rate movements clarifies the possibility of stable statistical inference.

The study is also significant as it adds to the previous studies on reserve holdings considering changes in the exchange rate as a determinant. It provides a policy guide to the central banks on needing backup funds to defend their local currencies' value, especially when such currencies suffer exchange rate devaluation. It does this by selling accumulated reserves in the money market so that depreciation can be checked and the value of a local currency is regained. It goes out to stimulate foreign trade.

The structure of this paper is as follows: Section 2 presents the literature review. Section 3 explains the research methods. Section 4 presents the results. Section 5 discusses the study's results. Finally, Section 6 highlights the conclusion of this research.

2. LITERATURE REVIEW

Studies had attempted to verify the beneficial effect of reducing the value of trade balance by examining the Marshall-Lerner (M-L) condition, which states that every nation's trade balance. It was established by Magee (1973) that such influence above might emerge after an amount of time when the balance of trade falls, and they developed the term "J-curve" to characterise it. Since then, a variety of research has tried empirically analysing the correlation between exchange rate variation and commerce. Studies have been undertaken in different nations to investigate the trade effect of exchange rate movements (Umoru & Hussaini, 2022; Bao & Le, 2021; Umoru, 2021; Umoru et al., 2022; Umoru, 2020; Umoru & Odjegba, 2013; Umoru & Oseme, 2013; Umoru & Eborieme, 2013; Eboreime & Umoru, 2016; Bahmani-Oskooee & Ratha, 2004; Umoru & Okungbowa, 2016; Umoru & Tizhe, 2016; Umoru & Isedu, 2018; Phong, 2019; Umoru, 2020).

Many J-curve studies assume that exchange rates and commercial trade have a symmetric relationship (Bahmani-Oskooee & Aftab, 2017). To investigate the J-curve phenomena, this collection of research used a variety of methodologies. The approach for assessing the J-curve effect encompasses permitting unavoidable delays in the exchange rate and then measuring the change of signs. Using the Engle-Granger co-integration methodology, Rose and Yellen (1989) found negative short-run exchange rate coefficients mixed with positive long-run coefficients in trade US trade balance. Value reduction of the home currency has long been thought to improve an economic trade account, prompting a few researchers to put this theory to the test to inform policymakers on how to devise successful policies to boost exports and improve trade accounts.

Many studies provided insignificant results, with previous research pointing to two leading causes: aggregate prejudice and linearity hypothesis (Iyke & Ho, 2018). One, while evaluating the impact of the real exchange rate on a country's trade account with the rest of the globe at the aggregate level may be pretty valuable and give important information about a country's international commerce as a whole, the results may be skewed (Phong et al., 2018). Researchers use data at the bilateral and commodity levels in trade between a nation and each of its partners to try to eliminate aggregation bias and find more significant evidence of exchange rate implications on commercial balance accounts (Bahmani-Oskooee & Ratha, 2007; Bahmani-Oskooee & Hajilee, 2009). Also, the fact that a 1% devaluation and 1% appreciation of the home currency have an equivalent effect on trade balance explains the failure of studies to identify the impact.

In 2020, there was the EU-Vietnam free trade agreement (FTA) agreement, while in 2021, the UK-Vietnam FTA agreement emphasised the significance of Vietnam's commerce with the EU-27 and the UK. Furthermore, the aforementioned free trade agreements have significantly affected Vietnam's economic integration with the countries involved. The fact that the United States designated Vietnam as a currency manipulator draws increased responsiveness to Vietnam's forex management. With USD accounting for about 90% of Russia's total trade value, an adjustment in the USD/VND exchange rate affect the trade balance with the US of Russia, the EU and the UK (Mohsin & McCormick, 2020).

To Ahiabor and Amoah (2019), currency volatility negatively impacted Ghana's economic development between 1980 and 2015. They also had consistent findings when they estimated models using market fragility as a variable. Javed and Farooq (2009) examine the relationship between macroeconomic development and exchange rate fluctuations in Pakistan using an autoregressive distributed lag (ARDL) model. Except for exports and imports, growth, exchange rate volatility, reserves, and production have a long-term co-integration connection with domestic economic performance.

Aliyu (2010) examined the influence of forex fluctuation on Nigeria's non-oil exports from 1986 Q1 to 2006 Q4 using vector error-correction (VEC) and the vector autoregression (VAR) framework. The study revealed a long-run steady and negative association between Nigerian non-oil exports and Naira exchange rate variation. The result benefited non-oil exports and USD exchange rate volatility in the alternative. Joseph (2011) used the generalized autoregressive conditional heteroskedasticity (GARCH) model to analyse annual datasets on trade flows in Nigeria from 1970 to 2009. According to this study, exchange rate fluctuations and aggregate trade have a negative and statistically negligible association. The negative result of utilising annual time series datasets aligns with Aliyu's findings (2010).

Odili (2015) studied the correlation between natural exchange rate variation and the economic development of Nigerian imports and exports using yearly records from 1971 to 2012. Nigeria's commerce was primarily impacted by exchange rate volatility, foreign income, terms of trade, actual gross domestic product, and exchange rate policy switch in both the near and distant future, according to the study. The data also show forex rate variation has a remote future detrimental impact on commercial flow and trade. Javed and Farooq (2009) examine the relationship between macroeconomic development and exchange rate fluctuations in Pakistan using an ARDL model. Except for exports and imports, growth, exchange rate volatility, reserves, and production have a long-term co-integration connection.

With ninety-seven commodities, Bahmani-Oskooee et al. (2019) reported significant long-run and short-run asymmetric effects for one-third and two-thirds of items, respectively. Relatively, Akoto and Sakyi (2019) reported the adverse impact of devaluation on trade in Ghana. Contrary to the results Akoto and Sakyi (2019) obtained, Bahmani-Oskooee and Arize (2019) found asymmetric effects of exchange rate movements in some African countries covered by their research. These effects were significant. Similarly, Bahmani-Oskooee and Baek (2019) found that trends in exchange rates had short/long-run non-linear effects on Korean trade.

In several more recent empirical papers, Keho (2021) reported the non-linear impact of fluctuations in the real exchange rate in Cote d'Ivoire. Bahmani-Oskooee and Gelan (2020) said the asymmetric influence of movements in the exchange rate in 19 and 14 industries, respectively, in the bilateral trade between South Africa and the U.S. Bahmani-Oskooee and Arize (2020) reported asymmetric effects of exchange rate movements in Africa. Bahmani-Oskooee and Fariditavana (2020) said the non-linear impact of actions in the exchange rate in 161 and 62 industries, respectively, in the bilateral trade of the US with Canada. For Nigeria, Keho (2021) related negative and positive shocks in the Naira exchange rate to detrimental effects on the trade balance. According to Nathaniel (2020), adverse surprises in the real exchange rate exerted more substantial long-term effects on the trade balance.

3. RESEARCH METHODOLOGY

The theoretical work of Obstfeld and Rogoff (1995) reveals that forex rate fluctuations are expensive to the local economy because of their direct and indirect impacts on individuals and companies. Its first impact is premised on the idea that families remain unsatisfied with exchange rate fluctuations owing to the challenges of smoothing consumption and the unpredictability of leisure expenditure. The indirect effect, on the other hand, implies that to hedge against forex risk, firms set higher fees to pay on insurance (Bahmani-Oskooee & Xi, 2012; Alagidede & Ibrahim, 2017).

The non-linear ARDL (NARDL) model was developed by Shin et al. (2014) as an offshoot of the error correction model specification of the ARDL model, which captures the asymmetric/differential effect of an increase and decrease in one of the explanatory variables on the regressand. In this study, where we are interested in examining the impact of exchange rate devaluation/depreciation and exchange rate appreciation/revaluation, the NARDL model best estimates this function. Following the works of Schorderet (2003) and Shin et al. (2014) as modelled in Ibrahim and Ahmed (2014), our asymmetric long-run model of reserve holdings given exchange rate movements becomes:

$$\ln ressss_t = \Phi_0 + \Phi_1 \ln fdi + \Phi_2 excratee^+ + \Phi_3 excratee^- + V_t \quad (1)$$

where, $\ln ressss_t$ is a log of foreign reserves, ϕ_0 is constant, ϕ_1 is an autoregressive lag of reserve holdings in Africa, ϕ_3, ϕ_4 are the long-run coefficient of decomposed time series, exchange rate *excratee*, *fdi* is a foreign direct investment which captures foreign money inflows, and $excratee^+$ is exchange rate appreciation (positive impact) effect while $excratee^-$ is exchange rate devaluation (negative result), Φ_1, Φ_2, Φ_3 are long-term parameters of ln*fdi*, appreciation and depreciation in exchange rate respectively. Accordingly, therefore, equations (2) and (3) capture exchange rate movements in the form of devaluation and appreciation individually.

$$excratee^+ = \sum_{i=l}^{T} \Delta excratee_i^+ = \sum_{i=l}^{T} \max(\Delta excratee_i, 0) \quad (2)$$

$$excratee^- = \sum_{i=l}^{T} \Delta excratee_i^- = \sum_{i=l}^{T} \min(\Delta excratee_i, 0) \quad (3)$$

Following the specification of Shin et al. (2011), Pesaran and Shin (1999) and Pesaran et al. (2001), our asymmetric long-run equation becomes:

$$\Delta ressss_t = \phi_0 + \phi_1 ressss_{t-1} + \phi_2 fdi_{t-1} + \phi_3 s^+ excrateee_t^+ + \phi_4 s^- excrateee_t^- + \sum_{i=0}^{p} \rho_i \Delta ressss_{t-i} + \sum_{j=1}^{q} \alpha_j^+ \Delta excrateee_{t-j}^+ + \sum_{j=1}^{q} \alpha_j^- \Delta excrateee_{t-j}^- + v_t \quad (4)$$

Equivalently, the following NARDL model specification guides our estimation procedure:

$$\Delta ressss_t = \phi_0 + \phi_1 ressss_{t-1} + \phi_2 fdi_{t-1} + \phi_3 excrateee_t^+ + \phi_4 excrateee_{t-1}^- + \sum_{i=1}^{p} \rho_i \Delta ressss_{t-i} + \sum_{i=0}^{q} \beta_i \Delta fdi_{t-i} + \sum_{i=0}^{s} [\alpha_i^+ \Delta exctatee_{t-i}^+ + \alpha_i^- \Delta excratee_{t-i}^-] + v_t \quad (5)$$

where, $ressss_t$ is foreign reserves, ϕ_0 is constant, ϕ_1 is an autoregressive lag of reserve holdings in Africa, ϕ_3, ϕ_4 are the long-run coefficient of decomposed exchange rate movements, ρ is the short-run coefficient of differenced (Δ) reserves and β is the short-run coefficient of the differenced foreign money inflow. The asymmetric rationalisation is such that both dynamics of exchange rate movements are expected to go in the same direction. Asymmetric long-run effects of exchange rate movements (devaluation or appreciation) on foreign reserve holdings in Africa are measured by these coefficients accordingly:

$$\Phi_2 = -\phi_3/\phi_1, \Phi_3 = -\phi_4/\phi_1 \quad (6)$$

Similarly, the short-run impact of exchange rate appreciation is given as $\sum_{i=0}^{+} \alpha_i^+$ while that of exchange rate devaluation $\sum_{i=0}^{+} \alpha_i^-$. Equation (5) above assumes a time series playing the role of the explanatory variable on reserve holdings could have an asymmetric effect whereby a depreciation in the official exchange rate of an African country can impact foreign exchange reserves holdings which differ in magnitude when compared to an appreciation of currency exchange rate. In this case, the exchange rate is decomposed into a positive increase $eexctatee_t^+$ and a negative decrease $excrateee_t^-$. The null hypothesis of the bounds test for long-run asymmetric co-integration, which we are aiming to reject, is obtained as:

$$\alpha_1 = s^+ = s^- = 0 \quad (7)$$

Regarding data description and research methods, this study adopts monthly data from 2002M06 to 2021M12. Sourced from International Monetary Fund (IMF) publication, the data are transformed to logarithm form. Exchange rate movements were calculated daily as local currency exchange rates per USD. Reserves were measured as the volume of total foreign reserves, excluding gold. Capital flows were measured as remittances from overseas into the countries covered by the study. Over time, movements and variations in a currency rate are influenced by factors such as interest rate changes, global competitiveness, and each economy's respective economic prospects. Certain regressors are endogenous, requiring instrumental variable estimation provided orthogonality conditions are met (Iyoha et al., 2022). In addition, as a result of correct lag selection, the residual connection is decreased, and the endogeneity problem is mitigated (Matar & Bekhet, 2015). Undeniably, the error correction model (ECM) can combine short-run changes with long-run equilibrium. Unfortunately, this is achieved using a linear translation that keeps details about the long time horizon intact (Igan et al., 2016). Outlier correction utilising impulse factors (Marques et al., 2019) is another method suitable for conducting the research. Also, we have the non-linear mean reversion modelling of actual exchange rate movements. Inappropriately, the observed hypothesis under this non-linear mean reversion modelling framework assumes a linear autoregressive process, implying that exchange rate adjustment is of a constant speed, not minding the deviation size from purchasing power parity. Relatively, there is the smooth transition autoregressive modelling technique. It represents a weak characterisation of non-linear exchange rate adjustment (Granger & Terasvirta, 1993). Lamentably, such transitions may not be smooth between regimes and symmetric adjustment when deviations are below or above the equilibrium real exchange rate.

Also, the Markov-Switching models could be conveniently applied in regressing movements in exchange rates. Regrettably, such models have frequently failed to generate efficient random walk process forecasts. Researchers can now distinguish the impact of local currency depreciation from appreciation following Shin et al.'s (2014) construction of the NARDL framework. Such modelling of asymmetric shocks had long been recognised as a beneficial technique for ascertaining the impact of adjustable exchange rates. In this study, therefore, we adopted the Shin et al. (2014) estimation method. The study first examines our series' stationarity level to ensure any variable integrated of order (2) (which means a variable is stationary after differencing twice) is not captured in the model. The bounds test for co-integration is then obtained. After that, the NARDL model was estimated using the NARDL. Pesaran and Shin (1999) pioneered the ARDL system, sometimes known as the Bounds test, and Pesaran et al. (2001) developed it further. The ARDL system's capacity to tolerate various delays in various variables makes it extremely attractive, adaptive, and versatile. It is, in addition to its ability to accommodate sufficient delays, provided for the specification of the data-generating process approach (Pesaran et al., 2001) while allowing the estimation of both tests for both short-run and long-run asymmetry in exchange rate movements.

4. RESULTS

Table 1 presents the descriptive statistics for the exchange rate, reserves and capital flows of Egypt, Ghana, Kenya, Malawi and Mauritius. Kenya's exchange rate is also high, with a mean value of 86.42 and a standard deviation of 13.06. Mauritius is next in order of mean value exchange rate magnitude in Table 1. The countries' external reserves are high for Egypt, with a standard deviation of 671.64, followed by Kenya, with a standard deviation of 230.25 and then Ghana. Table 1 also presents the summary statistics for Morocco, Namibia, Nigeria, South Africa and Zambia. The exchange rate of Nigeria is relatively high among these countries, with a standard deviation of 577.93. The exchange rate of Nigeria is quite a high mean ranking as it stood at 787.44. Namibia and South Africa are next in mean ranking order with the mean value of 150 and 110.00 and standard deviations of 13.29 and 16.28, respectively.

Table 1. Descriptive statistics

Measures	***Egypt***	***Ghana***	***Kenya***	***Malawi***	***Mauritius***	***Morocco***	***Namibia***	***Nigeria***	***South Africa***	***Zambia***
	excrateee	*excrateee*	*excrateee*	*excrateee*	*excrateee*	*excrateee*	*excrateee*	*excrateee*	*excrateee*	*excrateee*
Mean	8.18	4.77	1.75	13.06	272.93	29.17	150.00	787.44	110.00	107.20
Sd	19.51	3.41	40.36	62.03	46.60	10.99	13.29	577.93	16.28	14.69
min	59.89	18.73	5.90	113.14	822.17	7.26	5.63	98.90	5.63	2.66
max	3.99	-0.46	-0.98	-1.14	-1.32	11.97	18.13	411.25	18.06	22.64
kurtosis	-1.44	-0.46	-1.98	-1.09	-4.65	0.10	-1.00	-0.08	-1.01	1.98
	lnressss	*lnressss*	*lnressss*	*lnressss*	*lnressss*	*lnressss*	*lnressss*	*lnressss*	*lnressss*	*lnressss*
Mean	15131.63	2391.07	3225.89	238.49	2007.33	12809.81	885.67	20491.02	20107.43	846.30
Sd	671.64	170.22	230.25	169.61	131.97	175.85	137.87	163.11	110.59	133.72
min	5819.68	95.37	536.46	46.76	462.07	3374.27	172.65	4279.18	3979.31	6.45
max	29227.40	7060.61	7282.00	660.11	5336.66	2396.96	2052.01	3986.63	3674.02	2462.76
kurtosis	-1.02	-0.50	-1.46	-1.05	-0.65	-0.14	-1.17	-0.78	-1.26	-0.48
	lncflows	*lncflows*	*lncflows*	*lncflows*	*lncflows*	*lncflows*	*lncflows*	*lncflows*	*lncflows*	*lncflows*
Mean	1243.01	234.102	102.23	125.68	256.087	900	718	625	500	719
Sd	1.280	0.230	0.237	1.279	1.0283	0.209	0.378	0.356	0.917	1.378
min	69.376	120.634	32.387	83.36	30.587	29.65	17.24	32.387	83.36	30.587
max	157.89	190.37	56.789	100.27	178.20	230.568	103.19	379.058	182.0	378.59
kurtosis	-0.409	0.762	1.30	3.494	1.082	1.20	1.479	0.947	0.279	0.920

Note: excrateee is exchange rate, lnressss is reserved, lncflows is capital flows.
Source: Authors' estimation.

The panel unit root test is presented in Table 2. At the level, this exchange rate and reserves do pose unit root. At first difference, the variable becomes stationary. Capital inflows measured as remittances at the level and first difference are stationary.

Table 2. Breitung panel unit root test

Variables	*Breitung t-stat statistic*	*Probabilities ***
excrateee	-0.23	0.01
dexcrateee	-34.75	0.00
lnressss	0.95	0.00
dlnressss	-13.34	0.00
lncflows	-6.09	0.00
dlncflows	-9.21	0.00

*Note: ** Probabilities are computed assuming asymptotic normality.*
Source: Authors' estimation.

We also deployed the Levin et al.'s (1993) panel unit root test for reliability. The panel unit root test results are presented in Table 3. At this level, the exchange rate and reserves do pose a unit root. At first difference, the variables became stationary. Capital inflows main dormant properties at the level and first difference accordingly.

Table 3. Levin et al.'s (1993) panel unit root test

Variables	*Levin et al.'s (1993) t-statistic*	*Probabilities***
excrateee	-1.90	0.03
dexcrateee	-61.18	0.00
lnressss	-1.80	0.01
dlnressss	-45.65	0.00
lncflows	-10.53	0.00
dlncflows	-85.29	0.00

*Note: ** Probabilities are computed assuming asymptotic normality.*
Source: Authors' estimation.

We examine the Im et al.'s (2003) test using the panel unit root test. The panel unit root test is presented in Table 4.

Table 4. Im et al.'s (2003) panel unit root test results

Variables	*Im et al.'s (2003) W-stat statistic*	*Probabilities***
excrateee	-1.32	0.09
dexcrateee	-46.37	0.00
lnressss	-0.35	0.36
dlnressss	-37.15	0.00
lncflows	-2.57	1.00
dlncflows	-64.02	0.00

*Note: ** Probabilities are computed assuming asymptotic normality.*
Source: Authors' estimation.

At this level, the exchange rate and reserves pose a unit root. At first difference, the variable becomes stationary. We then assess the level of co-integration between these variables using the Pesaran et al. (2001) bounds test. Before interpreting our NARDL model estimates, we must assess the relationship based on the bounds test for co-integration. The results are presented in Table 5. Table 5 indicates an asymmetric co-integrating relationship for all countries except in the case of Namibia, which was inconclusive. The presence of co-integration indicates the NARDL model inferences on the reserves, exchange rate, and capital flows are informative, and the relationship can be interpreted. In all, co-integration was not established for Malawi and Namibia. Inconclusive results appear for Egypt. Hence, it became imperative to model the observed relationship using the non-linear relationship.

Table 5. Co-integration results for non-linear ARDL model

Country	*Critical value I(0) – I(1)*	*F-stat*	*Conclusion*
Egypt	2.45–3.61	6.69	YES
Ghana	2.62–3.79	4.96	YES
Kenya	2.86–4.01	6.13	YES
Malawi	2.62–3.79	9.66	YES
Mauritius	2.45–3.61	3.73	YES
Morocco	2.45–3.61	7.59	YES
Namibia	2.62–3.79	2.92	INC
Nigeria	2.86–4.01	6.21	YES
South Africa	2.86–4.01	10.13	YES
Zambia	2.86–4.01	12.48	YES
Country	*F-stat*	*Critical value I(0) – I(1)*	*Co-integration*
Egypt	4.58	3.79–4.85	INC
Malawi	1.1	3.79–4.85	NO
Mauritius	9.18	3.79–4.85	YES
Morocco	10.31	3.79–4.85	YES
Namibia	1.52	3.79–4.85	NO
Nigeria	21.02	3.79–4.85	YES
South Africa	14.12	3.79–4.85	YES
Zambia	8.2	3.79–4.85	YES

Source: Authors' estimation.

5. DISCUSSION

Table 6 presents the NARDL model estimates. Table 6a displays the results for Egypt, Ghana, Kenya, Malawi and Mauritius. Table 6b shows the results for Morocco, Namibia, Nigeria, South Africa and Zambia. Our primary focus is exchange rate devaluation/depreciation, proxied as an increase in the exchange rate, and exchange rate appreciation/revaluation, proxied as a decrease in the exchange rate. For Egypt, Ghana, Malawi and Mauritius, a reduction in the exchange rate (appreciation) denoted as *excratee_neg* had a statistically significant impact on reserves in each respective country. Whereas a 1% appreciation of the Malawi kwacha increased reserves by 0.1%, a percentage point decrease in the exchange rate (appreciation) of the Ghanaian cedi translated to a minute 0.01% increase in reserve holdings. In Egypt, a 1% appreciation of the Egyptian pound caused reserve holdings to rise by 0.34%.

Conversely, an increase in the exchange rate (devaluation) denoted as *excratee_pos* leads to a statistically significant reduction in reserves by 0.28% and 0.85% in Ghana and Malawi, respectively, while causing an increase of 0.19% in the accounts of Egypt. It portrays the exchange rate's asymmetric impact on Ghana and Malawi. In Kenya and

Mauritius, a 1% appreciation of their currencies depleted reserves levels by 0.29% and 0.33%, respectively. Unfortunately, a 1% devaluation in the exchange values of those countries' money decreases their accounts holding by 0.41% and 0.23%, respectively.

For Namibia, Nigeria, South Africa and Zambia, an increase in currency devaluation significantly impacted reserves in each respective country. Regrettably, a 1% devaluation in their currencies, namely, the Namibia dollar, Nigerian naira, South African rand, and Zambian kwacha, translated to a reduction in reserves by 0.16%, 0.94%, 0.05%, and 0.91%, respectively. Conversely, a 1% appreciation in exchange values of the currencies of the same countries led to a statistically significant decline of 0.13% in the reserve holdings of South Africa while it increased the reserve levels of Namibia, Nigeria, and Zambia by 0.35%, 0.12%, and 0.17% respectively. It could be explained by the fact that currency depreciation had failed in its objective to shift consumption from foreign goods to domestic goods in these countries, thereby pointing to unfavourable changes in terms of trade with the implication of income diversion over the years from currency devaluation countries to their trading partners. In Morocco, a 1% devaluation in the exchange rate led to a significant decline of 0.27% in her reserve holdings, while a 1% appreciation of the Moroccan dirham stimulated a 0.01% rise in the country's reserve holdings, respectively. Thus, the hypothesis of a non-linear impact of exchange rate movements on reserve holdings could not be established for Morocco, Namibia, Ghana, Nigeria, Malawi, and Zambia, respectively. In line with our estimates, exchange rate appreciation and devaluation depleted the volume of foreign reserves of Ghana, Kenya, Mauritius, and South Africa. These results are similar to the long-run estimates of Table 7.

Our results invalidate the results obtained by Aliyu (2011) but corroborate the findings of Sanusi et al. (2019) for South African countries. However, the magnitude of exchange rate devaluation in Nigeria (0.94), Malawi (0.85), and Zambia (0.91), as reported by the positive cumulative sum of the changes in the exchange rate, exceeded the magnitude of exchange rate appreciation in the same countries. By implication, a negative cumulative sum of changes in exchange rate increases the reserve of assets and foreign currencies while exchange rate upward movements as captured by positive cumulative sum deplete the volume of resources.

Capital flows had a statistically significant effect in all the countries. A percentage point increase in capital flows leads to 0.32%, 1.54%, 0.06%, 0.14%, 0.25%, 0.42%, and 0.02% accumulation in reserves for Egypt, Ghana, Kenya, Malawi, Mauritius, Morocco, and South Africa respectively. A negative flow of 1% resulted in 0.14%, 0.21%, 0.01%, 0.03%, 0.07%, 0.17%, and 0.18% rise in reserves. By implication, the effect of capital flows on resources in these countries is symmetric. The positive coefficient portends capital inflows whereby money and investments that came into Egypt, Ghana, Kenya, Malawi, Mauritius, Morocco, and South Africa from foreign countries exceed the assets that left these countries overseas. This, in turn, results in reserve accumulation. The positive and significant impact of capital inflow on reserve holdings substantiates the findings of Sun and Mei (2009). In Namibia, Nigeria and Zambia, negative capital flows induced 0.35%, 0.41%, and 0.61%, while positive flows stimulated 0.11%, 0.39%, and 0.13% capital outflows. It implies that money and investments left these three countries and, by extension, depleted reserves holdings in the countries. The adjustment coefficient (ECM) is significant and negative in all countries. Consequently, convergence to long-run equilibrium is assured after a short-term perturbation to African reserve holdings.

Table 6a. Non-linear ARDL model estimates for Egypt, Ghana, Kenya, Malawi, and Mauritius

Variables	*Egypt*	*Ghana*	*Kenya*	*Malawi*	*Mauritius*
Constant	0.1	0.64***	0.86***	1.10***	0.12*
	(0.09)	(0.15)	(0.19)	(0.20)	(0.07)
lnressss(t - 1)	0.001	0.09***	0.12***	0.24***	0.02
	(0.71)	(0.02)	(0.03)	(0.04)	(0.01)
d(excrateee_pos)	0.19***	-0.98***	-0.41***	-0.85***	-0.23
	(0.05)	(0.11)	(0.06)	(0.83)	(0.45)
d(excrateeee_neg)	0.34***	-0.01***	-0.29**	0.10*	-0.33***
	(0.08)	(0.38)	(0.04)	(0.06)	(0.11)
d(excratee_pos)(t - 1)	0.31***	-0.14**	0.10**	-0.04**	-0.09***
	(0.08)	(0.00)	(0.04)	(0.00)	(0.01)
d(excratee_neg)(t - 1)	0.12**	-0.02**	-0.19**	0.17***	-0.16
	(0.00)	(0.01)	(0.00)	(0.00)	(0.25)
dlncflows_pos(t - 1)	0.32	1.54***	0.06***	0.14	0.25***
	(0.29)	(0.00)	(0.01)	(0.83)	(0.00)
dlncflows_neg(t - 1)	0.14***	0.21***	0.01***	0.03	0.07
	(0.00)	(0.00)	(0.01)	(0.26)	(0.56)
ECM(t - 1)	-0.32**	-0.49**	-0.72*	-0.54***	-0.25***
	(0.02)	(0.00)	(0.00)	(0.00)	(0.00)
Observations	230	230	231	230	230
R^2	0.15	0.1	0.1	0.18	0.09
Adjusted R^2	0.13	0.08	0.08	0.16	0.07
Residual std. error	0.06 (df = 223)	0.10 (df = 224)	0.05 (df = 226)	0.18 (df = 224)	0.03 (df = 223)
F-statistic	6.69*** (df = 6; 223)	4.96*** (df = 5; 224)	6.13*** (df = 4; 226)	9.66*** (df = 5; 224)	3.73*** (df = 6; 223)

*Note: * p < 0.1; ** p < 0.05; *** p < 0.01. p-values are reported in ().*
Source: Authors' estimation.

Table 6b. Non-linear ARDL model estimates for Morocco, Namibia, Nigeria, South Africa, and Zambia

Variables	*Morocco*	*Namibia*	*Nigeria*	*South Africa*	*Zambia*
Constant	0.10	0.39***	0.17**	0.22***	0.28***
	(0.09)	(0.13)	(0.08)	(0.06)	(0.11)
ressss(t-1)	0.01	0.10***	0.005	0.02***	0.05**
	(0.01)	(0.03)	(0.01)	(0.01)	(0.02)
d(excrateee_pos)	-0.27***	-0.16**	-0.94***	-0.05***	-0.91**
	(0.13)	(0.05)	(0.00)	(0.00)	(0.05)
d(excrateee_neg)	0.01***	0.35	0.12***	-0.13***	0.17**
	(0.15)	(0.26)	(0.01)	(0.01)	(0.03)
d(excratee_pos)(t - 1)	0.65***	0.14	-0.15***	-0.34	0.11***
	(0.14)	(0.16)	(0.14)	(0.26)	(0.04)
d(excratee_neg)(t - 1)	-0.30*	-0.01***	0.10	0.15***	-0.01
	(0.16)	(0.00)	(0.46)	(0.00)	(0.20)
dlncflows_pos(t - 1)	0.42	-0.11***	-0.39***	0.02***	-0.13***
	(0.00)	(0.00)	(0.01)	(0.83)	(0.00)
dlncflows_neg(t - 1)	0.17	-0.35***	-0.41***	0.18	-0.61***
	(0.90)	(0.00)	(0.01)	(0.28)	(0.00)
ECM(t - 1)	-0.40	-0.29**	-0.32***	-0.64***	-0.30***
	(0.72)	(0.00)	(0.00)	(0.00)	(0.00)
Observations	230	230	231	231	231
R^2	0.17	0.26	0.21	0.15	0.14
Adjusted R^2	0.15	0.04	0.08	0.14	0.03
Residual std. error	0.03 (df = 223)	0.12 (df = 224)	0.05 (df = 226)	0.03 (df = 226)	0.09 (df = 226)
F-statistic	7.59*** (df = 6; 223)	2.92** (df = 5; 224)	6.21*** (df = 4; 226)	10.13*** (df = 4; 226)	2.48** (df = 4; 226)

*Note: * p < 0.1; ** p < 0.05; *** p < 0.01. p-values are reported in ().*
Source: Authors' estimation.

Table 7 presents the long-run relationship. As earlier established, asymmetric co-integrating relationships exist for Namibia and Zambia. Focusing on the countries with co-integrating relations, the external reserves of Ghana, Kenya, Mauritius, Nigeria, South Africa, and Zambia decrease significantly due to favourable exchange rate movements. Nigeria, South Africa, and Zambia's external reserves increase slightly due to negative exchange rate movement.

Table 7. Long-run (LR) relationships

Variables	*Egypt*	*Ghana*	*Kenya*	*Malawi*	*Mauritius*	*Morocco*	*Namibia*	*Nigeria*	*South Africa*	*Zambia*
	Stat	*Stat*	*Stat*	*Stat*	*Stat*	*Stat*	*Stat*	*Stat*	*Stat*	*Stat*
ln(excrateee_pos)	0.26	-1.03**	-0.20***	0.42	-1.11	1.64***	1.05***	-0.13	-1.67***	-1.44***
	(0.35)	(0.00)	(0.00)	(0.35)	(0.46)	(0.02)	(0.00)	(0.11)	(0.00)	(0.00)
ln(excrateee_neg)	0.83	-1.05	-0.91***	-1.06***	-1.05***	-0.28	-1.6***	0.02***	-0.22***	0.01***
	(0.02)	(0.00)	(0.00)	(0.00)	(0.00)	(0.72)	(0.00)	(0.97)	(0.00)	(0.00)
lncflows_pos(t - 1)	0.16***	1.04***	0.78***	0.02***	0.05***	0.45***	-0.29***	-0.48***	1.06***	-0.98***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)	(0.00)
lncflows_neg(t - 1)	0.10	0.04	0.12***	0.05	0.19***	0.13***	-0.67***	-0.39***	0.28***	-0.10
	(0.20)	(0.56)	(0.00)	(0.11)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)	(0.37)

*Note: * p < 0.1; ** p < 0.05; *** p < 0.01. p-values are reported in ().*
Source: Authors' estimation.

Table 8 presents the model diagnostics of the NARDL model. The Breusch–Godfrey (BG) test for autoregressive conditional heteroscedasticity (ARCH) test indicates the absence of heteroscedasticity for all the countries except Malawi. The Lagrange Multiplier (LM) for autocorrelation (ARCH test) shows that the model estimates for all the countries do not suffer from autocorrelation. The absence of heteroscedasticity and serial correlation indicates our model estimates presented in the following tables are robust and unbiased. The short-run asymmetric test (SR asymmetric) shows the lack of short-run and long-run asymmetric (LR asymmetric) effects of exchange rate movements on reserves for Egypt, Kenya, South Africa, and Mauritius. The analysis confirms the asymmetric results of exchange rate movements on reserves in Morocco, Ghana, Malawi, Nigeria, Namibia, and Zambia.

Table 8. NARDL model diagnostics and asymmetric tests

Tests	*Egypt*	*Ghana*	*Kenya*	*Malawi*	*Mauritius*	*Morocco*	*Namibia*	*Nigeria*	*South Africa*	*Zambia*
	Stat	*Stat*	*Stat*	*Stat*	*Stat*	*Stat*	*Stat*	*Stat*	*Stat*	*Stat*
BG test	0.22	0.12	0.16	5.62* *	3.17	1.76	0.89	2.34	0.25	0.39
ACRH test	0.65	3.03	1.9	0.47	0.01	11.43	19.84	1.76	2.45	0.03
Norm test	0.82***	0.91***	0.81***	0.91***	0.98***	0.92***	0.97***	0.96***	0.84***	0.76***
SR asymmetric	1.52	5.03***	0.07	13.15***	0.25	11.89**	120.5***	181.35***	1.81	24.72**
LR asymmetric	1.39	6.57***	1.02	23.68***	1.17	42.91***	39.07***	10.69**	0.38	16.52***

*Note: * p < 0.1; ** p < 0.05; *** p < 0.01.*
Source: Authors' estimation.

Table 9. Linear ARDL model diagnostics

Country	Test	Stat
Egypt	LM	0.63
	BP	14.72**
	DW	0.83***
Kenya	LM	0.8
	BP	7.17
	DW	0.81***
Malawi	LM	0.04
	BP	51.69***
	DW	0.93***
Mauritius	LM	1.36
	BP	25.77***
	DW	0.98***
Morocco	LM	1.81
	BP	2.81
	DW	0.92***
Namibia	LM	0.7
	BP	31.37**
	DW	0.96***
Nigeria	LM	1.08
	BP	6.2
	DW	0.94***
South Africa	LM	0
	BP	15.54**
	DW	0.82**
Zambia	LM	0.23
	BP	6.32
	DW	0.82***

*Note: *** 0.01, ** 0.05 significance level. LM — Lagrange Multiplier test, BP — Breusch-Pagan test, DW — Durbin Watson test.*
Source: Authors' estimation.

The diagnostics test for the linear ARDL is presented in Table 9. The LM test for serial correlation indicates the absence of serial correlation for all the countries. The null hypothesis of the studentised Breusch-Pagan test implies the presence of homoscedasticity. Table 9, is rejected for Malawi, Mauritius, Namibia, and South Africa, indicating the models suffer from heteroscedasticity. For the rest countries, the model estimates do not suffer from heteroscedasticity.

6. CONCLUSION

This study adopts the non-linear ARDL model of Shin et al. (2014) to examine the nature of the effects of exchange rate movements on reserve holdings among ten African countries, which are Morocco, Egypt, Ghana, Namibia, Kenya, Malawi, Nigeria, Mauritius, South Africa and Zambia between 2002 to 2021. The findings showed that with a non-linear model, exchange rate movements in the form of devaluation and appreciation could have an asymmetric effect on foreign reserve holdings in some countries of Africa using capital flows as a control variable in our analysis. Following the findings, the exchange rate is a significant determinant that enhances reserves holding in both study periods. We found that devaluation weakens reserve volume in Morocco, Namibia, Nigeria, South Africa, Zambia, Kenya, Malawi and Mauritius. Exchange rate appreciation leads to a significant decrease in reserves in Ghana, Kenya, South Africa, and Mauritius. The magnitude of exchange rate devaluation stood at 0.94 as against an appreciation effect of 0.12% in Nigeria. In Malawi, it was 0.85% against 0.1%, while Zambia was 0.17% and Ghana was 0.98%. In the case of Ghana, appreciation also plunged reserve volume by 0.01%. Hence, the magnitude of devaluation, as reported by the positive cumulative sum of the changes in the exchange rate, exceeded the importance of appreciation, respectively. In sum, we found that domestic-currency depreciation adversely affected reserves since these countries are relatively more import-dependent. Also, a long/short-run asymmetric co-integrating link exists between exchange rates and resources in Ghana, Malawi, Morocco, Namibia, Nigeria and Zambia. Short/long-run symmetric relations exist between movements in exchange rates and the reserve holdings of Egypt, Kenya, Mauritius and South Africa. Consequently, convergence to long-run equilibrium is assured after a short-term perturbation to African reserve holdings.

There is the absence of short/long-run asymmetric effects of exchange rate movements on reserves for Egypt, Kenya, South Africa and Mauritius. Instead, the analysis confirms the asymmetric results of exchange rate movements on accounts in Ghana, Malawi, Morocco, Nigeria, Namibia, and Zambia. The positive coefficients of capital flow in Egypt, Ghana, Kenya, Malawi, Mauritius, Morocco, and South Africa signify capital inflows whereby money and investments that came into those countries from overseas exceed the assets that left these countries for foreign sources. By extension, capital flows led to the accumulation of reserves in the countries mentioned above. In Namibia, Nigeria and Zambia, both negative and positive flows of capital induced capital outflows. It suggests that money and investments left these three countries and, by extension, depleted reserves holdings in the countries. By implication, the effect of capital flows on reserves is symmetric for all the countries in the study.

These countries' governments must be cautious of continuous devaluation which it can transmit to increasing price instability and worsening inflation expectations. The policymakers of these countries have to weigh the trade benefits associated with exchange rate devaluation and revaluation since there is a trade-off. In the instance where it does translate to increasing reserves, cautions have to be taken to ensure the price level is not escalated due to devaluation and countries' trade competitiveness is not hampered in the case of exchange rate appreciation. In sum, governments should be committed to managing the exchange rate that guarantees competitiveness needed to stimulate inflows of external reserves. Our study strengthens the empirical literature regarding the effects of exchange rates on African reserves by applying a novel econometric technique, the NARDL.

Notwithstanding, it suffices to point out a need for further research to measure the non-linear effects of exchange rates on the volume of reserves in a larger sample of African countries using other non-linear econometric models. Moreover, the future empirical analysis could capture volatility in exchange rates as a measure of the shock of uncertainty. Besides, further studies could employ a non-linear logistic smooth transition VAR modelling approach. This permits the modelling of the types of non-linear effects of movements in exchange rates.

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