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*Joseph Chukwudi Odionye**
*Jude Okechukwu Chukwu***

ASYMMETRIC REACTIONS OF STOCK PRICES AND INDUSTRIAL OUTPUT TO EXCHANGE RATE SHOCKS: MULTIPLE THRESHOLD NONLINEAR AUTOREGRESSIVE DISTRIBUTED LAG FRAMEWORK

ABSTRACT: *Motivated by swings in the exchange rate of many developing economies which exert influence on firms' input costs, output, stock prices, and profits, the study investigated the asymmetric reactions of stock prices and industrial output to various shocks in the exchange rate in Nigeria using a multiple threshold nonlinear autoregressive distributed lag model and high frequency series from January 1999 to December 2021. Empirical results suggest that stock prices and industrial output react asymmetrically in the opposite direction to exchange rate depreciation. It further indicates that the reactions of both stock prices and industrial output to exchange rate changes are sensitive to the size of shocks. Exchange rate shocks above the 25th percentile significantly and inversely affect both stock prices and industrial output, and the effects of exchange rate shocks on stock prices and industrial output become pernicious if above the 75th percentile. The main economic implication of the empirical finding is that in the upper quantile, both exchange rate depreciation and appreciation hurt industrial output, and hence, stock values. Thus, the multiple threshold nonlinear autoregressive distributed lag results suggest that the reactions of both stock prices and industrial output to exchange rate changes are highly sensitive to the extent of the shocks.*

KEY WORDS: *stock prices, industrial output, exchange rate, shocks, asymmetric reactions, nonlinear autoregressive distributed lag model, Africa.*

JEL CLASSIFICATION: B41, C32, C52, E44, N27.

* Abia State University, Department of Economics, Uturu, Nigeria
email: joseph.odionye@abiastateuniversity.edu.ng
ORCID: 0000-0001-7272-5965

** University of Nigeria, Department of Economics, Nsukka
ORCID: 0000-0002-4877-0560

1. INTRODUCTION

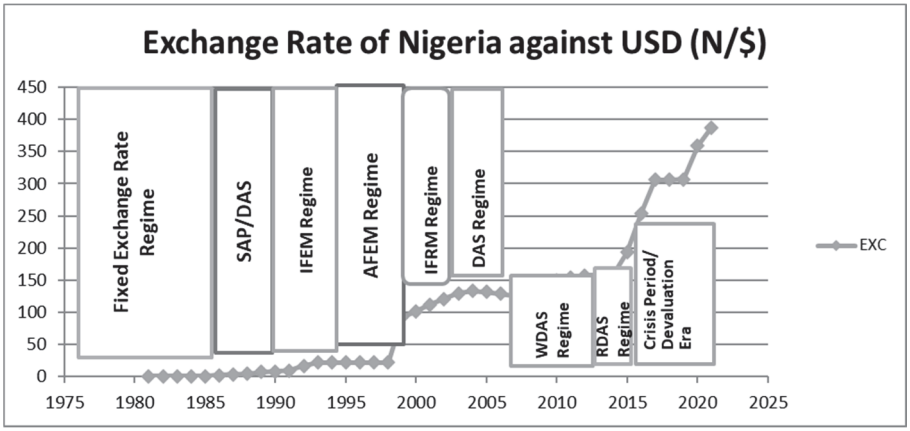
In recent times, economists and decision-makers in transition and developing economies have attached great importance to research on the connection between changes in currency value and stock prices. Since the 1997–1998 East Asian currency crisis, which caused a sharp decrease in the region's stock markets, numerous scholars have explored the connection between a nation's exchange rate and its stock market movement. Exchange rates are hypothetically related to stock market performance (Dornbusch & Fischer, 1980). The flow-oriented exchange rate concept holds that changes in currency value influence global efficiency and the trade balance, which has an effect on the revenue and output of firms. Since the current value of a company's cash inflows is reflected and factored into stock prices, stock prices are sensitive to currency movements (Dornbusch & Fischer, 1980; Phylaktis & Ravazzolo, 2005). The fragile Nigerian economy with highly intractable and pervasive macroeconomic instability maintains a dual exchange rate regime which has been in place for decades. The distinctive feature of the focus of this study revolves around massive swings in exchange rates, which have been exerting huge and unprecedented influence on firms' input costs, output, profits, and stock prices.

Considering how currency changes impact on stock prices, there are various viewpoints on this issue. Accordingly, the first perspective posits that changes in the value of a currency cause a rise in total exports and, hence, boost firms' output and profits. An increased business profit results in a huge boost in a nation's stock prices (Sui & Sun, 2016). The second perspective argues that depreciation of the home currency increases input prices, which reduces enterprises' profits and pushes down stock prices (Bahmani-Oskooee & Saha, 2016a). In contrast to the first view, the second perspective postulates the opposite effect of the exchange rates-stock values nexus. The third viewpoint, however, contends that local currency gains may have the opposite effect on domestic multinational corporations' shareholders by depreciating their stock value (Bahmani-Oskooee & Saha, 2016b). Contradictory theories about how changes in a country's currency affect the output of businesses and stock prices have led to empirical research on the possibility that currency changes asymmetrically affect businesses' output and stock market value (Habibi & Lee, 2019).

Thus, depending on the extent of transmission, the severity of shocks, and the level of susceptibility of firms to currency swings, different levels of currency swings may have varying effects on a firm's output, profit, and, consequently, stock prices (Bartram, 2004; Luqman et al., 2021). Exchange rate swings can range from mild to severe, contingent on the quality of policy interventions by monetary and fiscal authorities. Numerous studies on the asymmetric relationship and variability between the variables have been motivated by this (Fapetu et al., 2017; Luqman et al., 2021; Lakshmanasamy, 2021). For an open economy such as Nigeria, where any developments on the world market affect exchange rate swings and consequently determine stock market efficiency through firm output, determining the extent to which exchange rate shocks spread to industrial output and stock prices is of extreme significance. The expansion of every economy is crucial, and the stock market and industrial output are no exception (Okpara & Odionye, 2012; Zubair, 2013; Fapetu et al., 2017; Javangwe & Takawira, 2022).

The Nigerian currency market has recorded various degrees of changes since the mid-1980s (CBN, 2021) with the worst case being recorded since 2015. As indicated in Figure 1, since the 1980s when the structural adjustment programme (SAP) was introduced in the country, different exchange rate regimes have been introduced to stabilise the market. The remarkable aspect is the phases of exchange rate depreciation the market has undergone.

Figure 1: Exchange Rate Regimes and Exchange Rate Changes in Nigeria



Source: Authors' plot

Evidently, Nigeria's currency has weakened markedly in recent years. Relative stability existed in the market between 1981 and 1998, which may be regarded as an era of minor changes. Between 1999 and 2014, there was a moderate change in exchange rate depreciation as the Nigerian naira depreciated from ₦21.9 in 1998 to ₦92.6 and subsequently gradually moved to ₦153.6 in 2014. This period may be regarded as an era of moderate fluctuations in the exchange rate. Between 2015 and 2021, the market recorded major changes which have been regarded as a currency crisis period (CBN, 2021). During this period, the rate of exchange jumped by 144% to ₦387.7 in 2021 (CBN, 2021). The industrial sector output recorded its all-time low during this same period, recording a decline of -16.8% in the fourth quarter of 2016, and improved slightly to a decline of -2.6% in July 2021 (NBS, 2021; CBN, 2021). Consequently, it is imperative to decompose exchange rate shocks into mild, moderate, and severe, and examine how stock prices and industrial production respond to these diverse shocks in the exchange rate. Empirically, degrees of shocks may influence one or more variables asymmetrically (Pal & Miltra, 2015, 2016; Odionye & Chukwu, 2021; Li & Guo, 2022).

Several studies exist on the exchange rate-stock price and industrial output nexus in developing countries, including Nigeria, but a greater number of the studies focus on either the symmetric influence (Okpara & Odionye, 2012; Zubair, 2013; Fapetu et al., 2017) or the exchange rate-stock price asymmetry nexus and/or the industrial output-currency change nexus (Effiong & Bassey, 2018; Akanni & Isah, 2018; Adeniyi & Kumeka, 2020; Okere et al., 2021). None of the studies reviewed considered the effect of various shocks on stock prices and industrial production, or studied whether the responses of stock values and industrial production to currency depreciation are contingent upon the magnitude of the change. Empirically, this aspect is lacking in the stock-price-industrial output-exchange rate nexus literature. It has been established empirically that, contingent upon the severity of shocks, exchange rate swings can be transmitted at a distinct magnitude to a variable (Miltra, 2016, 2015; Luqman et al., 2021; Li & Guo, 2022). The closest work to this study in Nigeria is the work of Uche et al. (2022) on the household consumption-exchange rate nexus in selected countries in Africa. This study departs from Uche et al. (2022) by investigating the asymmetric reactions of stock prices and industrial output to various shocks in the exchange rate in Nigeria using the multiple threshold non-linear autoregressive distributed lag

model by decomposing the shocks in the exchange rate into mild shock, moderate shock, and severe shock.

This study further departs from Uche et al. (2022) in three main respects. First, it concentrates on the degree of the currency weakening shocks transmitted to stock prices and industrial output, whereas Uche et al. (2022) studied the exchange rate change-household expenditure asymmetric nexus. Second, this study uses the 25th and 75th percentiles as the lower and upper quantiles respectively, whereas Uche et al. (2022) used the 30th and 70th quantiles. Third, this study employs the Zivot-Andrews unit root test to account for structural breaks, unlike Uche et al. (2022).

The main contribution to knowledge is the emphasis on the degree of currency weakening shocks, which is probably due to the intensity of the effects of misaligned exchange rates transmitted to stock prices and industrial output. In terms of the broad objective, the study investigates the asymmetric reactions of stock prices and industrial output to exchange rate shocks in Nigeria using a multiple threshold nonlinear autoregressive distributed lag model and high frequency series from January 1999 to December 2021. Hence, the study hypothesises whether stock prices and industrial output asymmetrically react to exchange rate shocks in Nigeria. The rest of the article is organised as follows: section 2 surveys the related literature, section 3 explains the methodology used, section 4 discusses the empirical results and findings, while section 5 highlights the conclusion and policy implications of the findings.

2. LITERATURE REVIEW

2.1 What does theory tell us?

Dornbusch and Fisher's (1980) flow-oriented models are based on the current account or trade balance. According to this model, changes in currency affect a country's productive capacity, which determines the firms' predicted future cash flows and their stock values, in addition to their global competitiveness and current account surplus positions. The unsurprising hypothetical inter-relation is that changes in exchange rates affect a firm’s ability to be competitive since many firms take loans in hard currencies to finance their activities, which may adversely affect a firm’s stock price. Contingent upon whether a firm exports goods/services or uses many foreign products, the impact can be equal in two

different directions. An exporting firm rises both in worth and value, thereby raising prices of their stocks. Conversely, a domestic currency appreciation lowers an exporting firm's revenue because of decreased demand for its goods abroad. Consequently, the value of stocks will drop. This is contrary to the situation of an importing firm as the exchange rate changes (Dornbusch & Fisher, 1980; Abdalla & Murinde, 1997; Phylaktis & Ravazzolo, 2005).

2.2 Empirical Literature

Many studies on the currency change-stock price and industrial output connection deal with developing countries, including Nigeria, but most of the studies have focused on either a symmetric or an asymmetric exchange rate-stock price nexus and/or exchange rate-industrial output connection. None of the studies reviewed have considered the effect of multifarious shocks on stock prices and industrial production. It has been established that, contingent on the severity of the shock in a volatile variable, exchange rate swings are transmitted at distinct magnitudes to a variable (Pal & Miltra, 2016, 2015; Luqman et al., 2021; Li & Guo, 2022). The work closest to this study in Nigeria is the study by Uche et al. (2022) on the extreme household consumption-exchange rate dynamics in selected countries in Africa. Departing from Uche et al. (2022), this study investigates how stock prices and industrial output respond to various degrees of exchange rate shocks.

Zubair (2013) investigated the relationship between exchange rate and stock price index in Nigeria between January 2001 and December 2011. The work partitioned the study period into pre-crisis era and post-crisis era. It utilised a VAR model to establish a link between the variables. The study's result showed no direction of the link between the variables. This contradicted an earlier study by Okpara and Odionye (2012) that employed a similar method but different data frequency and found a one-way direction of causality. The discrepancies in the results may be a result of the particular data frequency employed.

Effiong and Bassey (2018) examined the stock price-exchange rate movement nexus in Nigeria. Their study utilised nonlinear ARDL using monthly data from January 2001 to December 2016 and found an asymmetric effect of exchange rate on stock prices. They also found that currency depreciation has a stronger pass-through effect on stock prices than appreciation does in the long run. This result

gives credence to a study on diverse exchange shocks transmittable to value of stocks.

Akanni and Isah (2018) used the ARDL and nonlinear ARDL models to ascertain the asymmetric effect of currency swings on stock prices in Nigerian firms. The study's result suggested a symmetric effect for most companies except for a few conglomerates, which showed evidence of symmetry. In a related and more recent study, Adeniyi and Kumeka (2020) investigated the asymmetric influence of currency changes on firms' stock prices in Nigeria between December 2001 and December 2017. The study also adopted both ARDL and nonlinear ARDL and found no indication of any influence. They recommended firms should not make decisions based on information on the exchange rate.

Mroua and Trabelsi (2019) explored the nexus between exchange rates and stock market indices in BRICS nations namely Brazil, Russia, India, China, and South Africa. The study utilised a panel GMM model and a panel ARDL model to ascertain the causal relationship between all stock market returns and exchange rate changes in the BRICS countries. The ARDL results suggest that exchange rate swings impact on the stock market indices for each of the BRICS nations.

Mohamed and Elmahgop (2020) examined whether an asymmetric link subsist between stock values and the exchange rate in Sudan. The study's motivation was anchored in this possibility since prior studies had not examined Sudan. Adopting the nonlinear ARDL, the study observed an asymmetric response of Sudanese stock prices to exchange rate changes both in the short term and long term. It concluded that modelling a linear function of the investigated series may produce a result that will mislead policy makers. In another related study, Amewu et al. (2022) examined the stock index-exchange rate connectivity in the COVID-19 era in Ghana. In order to capture the influence of COVID-19, the study partitioned the sample into two sub-samples of pre-COVID-19 era and COVID-19 era. The study utilised the wavelet estimation approach and observed, amongst others, that a link exists between elevated COVID-19 cases and exchange rate changes in the investigated nation. It further showed evidence of a weak link between the Ghanaian cedi and stock prices.

Mesagan et al. (2021) examined the effect of the domestic currency on the capital market and financial sector in Nigeria from symmetric and asymmetric

perspectives using data from January 2010 to April 2018. The work employed both linear and nonlinear ARDL models and the result showed an inverse connection between the exchange rate and the financial index in the short to long term. Using the same data frequency and models, Okere et al. (2021) investigated the existence and degree of symmetry in the nexus between exchange rate, oil prices, and stock prices in Nigeria. The ARDL shows that the relationship between the exchange rate and stock prices is not significant both in the short-run and long-run, whereas a short-term and long-term direct association exists between oil prices and stock prices.

Another study by Uche et al. (2022) explored the relationship between expenditure on household consumption and the relative change in exchange rate movement. The study employed the MTNARDL model on quarterly data for several selected African countries. Their results showed an asymmetric response of consumption expenditure to changes in the exchange rate of all the countries case-studied except Nigeria.

3. METHODOLOGY

3.1 Data and their Features

The secondary data used are high frequency (monthly) series from January 1999 to December 2021 inclusive. Data on the nominal exchange rate and data on stock prices (measured in naira) were sourced from the Central Bank of Nigeria (CBN) Statistical Bulletin (2021). The data for industrial output were converted from annual series to monthly series using a quadratic match-sum process in EViews version 12.0. The quadratic match-sum is a valuable procedure that converts data from its original form to a higher frequency form and allows seasonal adjustment by dropping end-to-end dispersion (Shahbaz et al., 2018; Sharif et al., 2020; Uche & Effiom, 2021).

3.2 Model Specification

Following Li and Guo (2022), this study adopted the MTNARDL model as developed by Pal and Mitra (2015, 2016) for the United States to examine the asymmetric reactions of stock prices and industrial output to various exchange rate shocks. The MTNARDL model utilised the NARDL by Shin et al. (2014) such

that the predictor variables are decomposed into non-negative and non-positive partial sum parts to measure the asymmetric influence.

The first step is to model ARDL in line with Pesaran et al. (2001) in its general form as

$$\Delta Y_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i \Delta Y_{t-1} + \sum_{i=0}^{p} \alpha_i \Delta Z_{t-1} + \phi_1 Z + \varphi ECT + \mu_t \quad (3.1)$$

where Y is the response variable and Z represents the predictor variables. The error correction term (ECT) measures the rate of convergence to equilibrium, ϕ is the long-run parameter, and α_i measures the short-term coefficient.

Following the economic viewpoint that exchange rate changes can determine industrial output and stock prices, the simple form of the model is as follows:

STP = f (ECR) and INP = f (ECR) (3.2)

where STP represents stock prices, ECR is the exchange rate, and INP represents industrial output.

Following equation (3.1), the ARDL model is expressed in equations (3.3) and (3.4) thus:

$$\Delta LNSTP_t = \varphi_1 LNECR_t + \varpi ECT + \sum_{t=1}^{r} \pi_j \Delta LNSTP_{j-t} + \sum_{i=0}^{s} \eta_i \Delta LNECR_{t-i} + \varepsilon_t \quad (3.3)$$

$$\Delta LNINP_t = \varphi_1 LNECR_t + \varpi ECT + \sum_{t=1}^{r} \pi_j \Delta LNINP_{j-t} + \sum_{i=0}^{s} \eta_i \Delta LNECR_{t-i} + \varepsilon_t \quad (3.4)$$

where STP, ECR, and INP are as described above, LN = natural log, η represents the short-run coefficients, and φ denotes the long-run coefficient in both models. ε represents a white noise stochastic term, Δ is the difference operator, and r and s represent the lag values. The coefficient of ECT measures the degree of convergence to equilibrium. Exchange rate (ECR) depreciation varies in degrees such as mild, moderate, and severe. In Nigeria, exchange rate depreciation has

passed through phases such as mild depreciation regimes which require no policy intervention by the central bank, moderate depreciation which requires some levels of policy intervention by the monetary authority, and the severe depreciation era, with this era provoking drastic measures, including rationing of foreign currency supply, as recorded in the country from 2015 till today (CBN, 2021). Thus, the exchange rate (ECR) is decomposed into three shocks, namely mild (ECR_MIS), moderate (ECR_MOS), and severe shocks (ECR_SES).

To incorporate the asymmetric components in equations (3.3) and (3.4), we separated the predictor variable (ECR) into negative and positive segments consistent with Shin et al. (2014). In this study, the ECR is specified as follows:

$$LNECR_t = LNECR^0 + \text{LNECR}_t^{pos} + \text{LNECR}_t^{neg} + \varepsilon_t \tag{3.5}$$

In equation (3.5), ECR^{pos} and ECR^{neg} represent an increase (depreciation) and a decrease (appreciation), respectively.

Depreciation and appreciation are specified as (3.6) and (3.8);

$$LNECR_t^{pos} = \sum_{j=1}^{r} \Delta LNECR_{t-j}^{pos} = \sum_{j=1}^{s} \max(\Delta \text{LNECR}_j, 0) \tag{3.6}$$

$$LNECR_t^{neg} = \sum_{j=1}^{m^1} \Delta LNECR_{t-j}^{neg} = \sum_{j=1}^{m^2} \min(\Delta \text{LNECR}_j, 0) \tag{3.7}$$

Based on (3.6) and (3.7), the study expresses the non-linear ARDL as

$$\begin{aligned} \Delta LNSTP_t = {} & \varphi_1 LNECR_t^{pos} + \varphi_2 LNECR_t^{neg} + \varpi ECT + \sum_{j=1}^{r} \pi_j \Delta LNSTP_{t-j} \\ & + \sum_{i=0}^{s} \eta_i \Delta LNECR_{t-j}^{pos} + \sum_{i=0}^{s} \eta_i \Delta LNECR_{t-j}^{neg} + \varepsilon_t \end{aligned} \tag{3.8}$$

$$\Delta LNINP_t = \varphi_1 LNECR_t^{pos} + \varphi_2 LNECR_t^{neg} + \varpi ECT + \sum_{j=1}^{r} \pi_j \Delta LNINP_{t-j} + \sum_{i=0}^{s} \eta_i \Delta LNECR_{t-j}^{pos} + \sum_{i=0}^{s} \eta_i \Delta LNECR_{t-j}^{neg} + \varepsilon_t \quad (3.9)$$

The first two components on the right-hand side measure the long-run asymmetric effects, the third component is the error correction term, and the last two are the short-term asymmetric coefficients. The short-run and the long-run asymmetric effects can be examined using the standard Wald test. There is no long-run asymmetric effect if $\phi_1 = \phi_2 = 0$. The bounds test is utilised to ascertain the existence of a cointegration relation.

3.3 Multiple Thresholds and their Justification

As stated earlier, this study adopted multiple thresholds as advanced by Pal and Mitra (2015, 2016) as an alternative to the one-threshold approach by Shin et al. (2014) and because of its merit in decomposing the predictor into different quantiles so as to ascertain the asymmetric effect of the predictor variable based on mild, moderate, and severe shocks.

Therefore, this study, somewhat consistent with Li and Guo (2022) albeit with a little modification, initiated two thresholds at the 25th and 75th percentiles to divide the exchange rate shocks into three partial sums thus:

$$LNECR_t = LNECR^0 + \text{LNECR}_t^{mis} + \text{LNECR}_t^{mos} + \text{LNECR}_t^{ses} \quad (3.10)$$

where the right-hand components of equation (3.10) are the partial sums estimated as:

$$\text{LNECR}_t^{mis} = \sum_{j=1}^{p} \lambda_j \Delta \text{LNECR}_j^{mis} = \sum_{j=1}^{p} \Delta LNECR_j^I (\Delta LNECR_j \le \tau_{25}) \quad (3.11)$$

$$\text{LNECR}_t^{mos} = \sum_{j=1}^{p} \lambda_j \Delta \text{LNECR}_j^{mos} = \sum_{j=1}^{p} \Delta LNECR_j^I (\tau_{25} < \Delta LNECR_j \le \tau_{75}) \quad (3.12)$$

$$\mathrm{LNECR}_t^{\mathrm{ses}} = \sum_{j=1}^{p} \lambda_j \Delta \mathrm{LNECR}_j^{ses} = \sum_{j=1}^{p} \Delta LN\,\mathrm{ECR}_j^{I}(\Delta LNECR_j > \tau_{75}) \tag{3.13}$$

where I (.) represents the dummy term that meets the requisite in (.) when it is equal to unity and zero otherwise.

The multiple threshold nonlinear ARDL is expressed for the two models as in (3.14) and (3.15):

$$\Delta LNSTP_t = \sum_{j=1}^{3} \phi_k LNECR_{t-i}^{\lambda_j} + \varpi ECT + \sum_{j=1}^{r} \pi_{ij} \Delta LNSTP_{t-j} + \sum_{j=1}^{3} \sum_{i=0}^{s} \eta_{kj} \Delta LNECR_{t-j}^{\lambda_j} + \varepsilon_t \tag{3.14}$$

$$\Delta LNINP_t = \sum_{j=1}^{3} \phi_k LNECR_{t-i}^{\lambda_j} + \varpi ECT + \sum_{j=1}^{r} \pi_{ij} \Delta LNINP_{t-j} + \sum_{j=1}^{3} \sum_{i=0}^{s} \eta_{kj} \Delta LNECR_{t-j}^{\lambda_j} + \varepsilon_t \tag{3.15}$$

where the first right-hand term is the long-run term; ECT measures the speed of adjustment to equilibrium; λ is the exchange rate shock; subscript j is the rate of shock (j = 1, 2, and 3) with 1 representing mild shocks (mis) for changes below or equal to the 25th percentile change, 2 representing moderate shocks (mos) with changes above the 25th percentile but below the 75th percentile changes, and 3 representing severe shocks (sos) for changes above the 75th percentile; and ε = iid (0, σ). The null hypothesis of no cointegration is expressed as $\phi_1 = \phi_2 = \phi_3 = 0$.

A rejection of the hypothesis suggests a long-run nexus in the model. The study applied the Wald test to examine for short-run and long-run symmetry. The MTNARDL model has been widely used in recent times given its merits over the NARDL as it enables the study of the impact of asymmetric degrees of shock on the response variables (Pal and Mitra, 2015, 2016; Li & Guo, 2022). The rationale for the choice of MTNARDL is that variables need not be integrated of order two. Furthermore, it requires a large sample size as the sample size reduces as the number of thresholds increases. A two-threshold model requires a minimum of 90 samples (where n > 30) for it to be adequately large for estimation (Li & Guo, 2022). The sample observation of this study is adequately large as it has more than 250 observations in each series.

3.4 Estimation Techniques

The descriptive statistics of the model variables were obtained. An optimal lag length selection test was conducted using information criteria. The Zivot-Andrews (1992) unit root test, which accounts for structural breaks, and a conventional ADF unit root test by Dickey & Fuller (1979) were conducted. To examine whether model variables are cointegrated, the study conducted the bounds cointegration test.

4. EMPIRICAL RESULTS

4.1 Descriptive Analysis

The descriptive statistics of the variables of the model are presented in Table 4.1:

Table 4.1: Descriptive Statistics

Statistics	STP	INP	ECR	ECR_MIS	ECR_MOS	ECR_SES
Mean	26879.9	1269.3	182.9	-26.54	1.91	121.9
Median	25988.9	1154.9	150.5	-30.8	1.74	93.35
Maximum	65652.4	3375.7	411.7	0.000	4.01	368.4
Minimum	4890.8	68.6	86.0	-46.7	0.00	0.000
Std Dev	12358.9	961.1	84.8	15.97	1.15	96.58
Skewness	0.31	0.54	1.15	0.33	0.3	0.97
Kurtosis	3.11	2.16	3.04	1.55	2.42	2.69
J_B Stat	4.56	22.09**	60.85**	29.32**	7.81*	43.23**

Source: *Authors' compilation*

Note: *** (*) rejection of null hypothesis at the 1% (5%) level of significance*

The average value for mild shocks (ECR_MIS) is negative, while those of moderate shocks (ECR_MOS) and severe shocks (ECR_MOS) are positive. The standard deviation indicates volatility in severe shocks given its statistics, while those of mild and moderate shocks exhibit relatively low volatility. All the variables except stock prices (STP) are not normally distributed, as determined by the Jarque Bera normality test statistics. The kurtosis statistics indicate a normal peak for STP, ECR, and severe shocks, while the other variables are platykurtic (<3). The descriptive statistics were carried out before the variables were log-transformed to enable us to ascertain their true behavioural patterns.

4.2 Optimal Lag Selection Result

The optimal lag length was selected using lag length information criteria as presented in Table 4:

Table 4.2 Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-1916.449	NA	333.824	14.324	14.364	14.340
1	107.381	3987.247	9.85e-05	-0.712	-0.551	-0.647
2	152.501	87.882	7.52e-05	-0.981	-0.699	-0.868*
3	166.738	27.412	7.24e-05	-1.020	-0.618	-0.859
4	180.601	26.382	6.98e-05	-1.057	-0.534	-0.847
5	192.035	21.502*	6.85e-05*	-1.075*	-0.799*	-0.816
6	198.676	12.339	6.98e-05	-1.057	-0.293	-0.751
7	201.825	5.782	7.29e-05	-1.014	-0.129	-0.658
8	206.325	8.159	7.55e-05	-0.980	0.025	-0.576

***** *indicates lag order selected by the criterion*

Source: *Authors' compilation*

Table 4.2 indicates that lag order 5 is the optimal lag length on the basis of Akaike information criteria (AIC), Schwarz criteria (SC), final predictor error (FPE), and the likelihood ratio (LR) test.

4.3 Unit Root Test Results

The time series characteristics of the variables were examined to ascertain the order of integration. The study adopted both the conventional stationarity test approach (ADF) and the regime shift approach which accounted for structural breaks (Zivot-Andrews, 1992). The summary of the result is shown in Table 4.3. Evidently, except for the exchange rate (LNECR) and exchange rate severe shock (ECR_SES), which were stationary in level form in the Zivot-Andrews (1992) unit root test, the series became stationary after first difference in both tests. The choice of the optimal lag for each of the series was guided by information criteria.

Table 4.3: Unit Roots Test Results

	ADF_URT				Zivot-Andrews unit root test (ZAURT) with breaks					
Variables	**Level**	**1st diff**	**I (d)**	**Lag**	**Level**	**B-P**	**1st diff**	**B-P**	**I(d)**	**Lag**
LNECR	-0.03	-12.1**	I (1)	0	-5.35**	2015/05	-	-	I (0)	2
LNSTP	-2.37	-14.3**	I (1)	1	-3.1	2002/11	-6.8**	2021/12	I (1)	4
LNINP	-1.22	-5.86**	I (1)	3	-3.5	2014/02	-4.4**	2016/02	I (1)	3
LNECR_MIS	-1.85	-12.5**	I (1)	1	-3.6	2007/07	-12.9**	2021/12	I (1)	1
LNECR_MOS	1.30	-14.9**	I (1)	0	-3.9	2017/05	-10.4**	2017/05	I (1)	1
LNECR_SES	-0.14	-12.1**	I (1)	0	-5.99**	2016/05	-	-	I (0)	1

Source: *Authors' compilation*

Note: *** (*) shows the variable is stationary at the 1% (5%) level of significance*

The ADF unit root test result indicates uniform order of integration, while the Zivot-Andrews unit root test result shows varying order of integration. This result upholds the view that unit root results are sensitive to structural breaks as failure to account for structural breaks can lead to misleading inference (Perron, 1989, 1997; Odionye & Chukwu, 2021). The requisite condition for estimating the MTNARDL model is satisfied given that none of the variables was integrated of order two, hence the need for the cointegration test.

4.4 Cointegration Test Results

Given that the condition for the bounds cointegration test in the MTNARDL model is satisfied, the study estimated the bounds cointegration test within the model frameworks of ARDL. The results of the NARDL, MTNARDL, and the summary are presented in Table 4.4:

Table 4.4: Bounds Cointegration Test Result

	ARDL			NARDL			MTNARDL		
Response Variable	**F-Stat**	**I(0)**	**I(1)**	**F-Stat**	**I(0)**	**I(1)**	**F-Stat**	**I(0)**	**I(1)**
LNSTP	4.5*	3.62	4.16	2.1	3.1	3.87	4.4**	2.79	3.67
LNINP	5.1*	3.62	4.16	6.1**	3.1	3.87	4.9**	2.79	3.69

Source: *Authors' compilation*

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

Table 4.4 indicates that there exists a long-run relationship between industrial output (LNINP) and exchange rate swings (LNECR) since the null hypothesis of no cointegration is rejected on the basis of the data and the three models, while no cointegration exists for stock prices (LNSTP) as the null hypothesis cannot be rejected using the NARDL model. However, based on ARDL and MTNARDL, stock prices and exchange rate are cointegrated.

Thus, we estimated the ARDL model on the basis of equations (3.3) and (3.4) and the selected lag value. The results are presented in Table 4.5:

Table 4.5: Summary of ARDL

	Response Variable (LNSTP)		**Response Variable (LNINP)**	
Predictors	**Coefficient**	**t-Statistic**	**Coefficient**	**t-Statistic**
Panel I		**Short-Run Result**		
D(Y(-1))	0.138*	2.307	0.241**	4.018
D(Y(-2))	0.088	1.465	0.193**	3.171
D(Y(-3))	0.121*	2.026	0.138*	2.301
D(Y(-4))	-0.131*	-2.182	0.089	1.592
D(Y(-5))	0.129**	2.604		
D(LNECR(-1))	-0.127*	-2.119	-0.099**	-3.924
ECT(-1)	-0.021**	-2.752	-0.005**	-3.924
Panel II		**Long-Run Result**		
LNECR	-0.518	-1.057	-2.161**	-3.993
Constant	7.653	3.018	-3.456	-1.243
R^2 (adj. R^2)	0.79 (0.77)		0.62 (0.61)	
Panel III		**Robustness Checks**		
J-B Test		91.921**		8292.65**
B-G Serial test		0.972		0.122
B-P-G Het test		0.877		1.918
R-RESET test		1.600		1.566
CUSUM	Stable			Stable
CUSUM sqr.	Stable			Unstable
Recursive coeff.	Stable			Stable

Source*: Authors' compilation* **Note:** *** (*) shows the variable is stationary at the 1% (5%) level of significance. Y is the response variable for the respective model (LNSTP/LNECR). The B-G Serial test represents the q order of autocorrelation, the B-P-G Het is the test for constant variance, R-RESET represents the test of the model specification.*

The short-run coefficients result in panel I indicates that both share prices and industrial outputs respond inversely to a rise in the exchange rate. This conforms with the conventional wisdom that both share prices and industrial output respond negatively to exchange rate variation. This result supports the findings of Mesagan et al. (2021), and Akanni and Isah (2018). Specifically, a one per cent depreciation in the exchange rate will lead to a 0.13% and a 0.1% decline in share prices and industrial output in the short run, respectively. Interestingly, a one per cent depreciation in the exchange rate will reduce industrial output by 2.2% in the long run, whereas stock prices respond inversely but insignificantly to currency weakening in the long run. This suggests that the adverse effect of the exchange rate on industrial output will be more in the long run than in the short run. The lag values of the response variables suggest that the variables reinforce their current values. The error correction terms show a low degree of convergence to equilibrium for both models. Specifically, about 2% and 0.5% of disequilibrium in stock prices and industrial output, respectively, converge to equilibrium within one month. The coefficients of determination suggest that the models are well fitted. The robustness checks on the estimated models indicate that the residuals are not normally distributed. These results further confirm the necessity of using a non-linear model for the estimation. The tests of autocorrelation confirm the non-existence of serial correlation in both models. In addition, the residuals exhibit constant variance, while both models were well specified as indicated in the heteroskedasticity test and Ramsey REST test, respectively. The graphs of the CUSUM, CUSUM square, and recursive coefficients show the stability of the parameters in the stock price-exchange rate model, whereas in the industrial output-exchange rate model they show stable parameters in the CUSUM and recursive coefficients, but unstable parameters in the CUSUM square graph.

In order to explore the asymmetric reactions of stock prices and industrial output to exchange rate depreciation and appreciation, this study estimated the non-linear ARDL model in equations (3.8) and (3.9) as presented in Table 4.6:

Table 4.6: Summary of NARDL Results

	Response Variable (LNSTP)		**Response Variable (LNINP)**	
Predictors	**Coefficient**	**t-Statistic**	**Coefficient**	**t-Statistic**
Panel I		**Short-Run Result**		
D(Y(-1))	0.142*	2.396	0.232**	3.924
D(Y(-2))	0.099	1.678	0.194**	3.238
D(Y(-3))	0.111	1.871	0.145**	2.461
D(Y(-4))	-0.141*	-2.355	0.101	1.825
D(Y(-5))	0.120**	2.003		
D(LNECR_POS(-1))	-0.374**	-2.989	-0.112**	-2.902
D(LNECR_NEG)	-0.674	-0.621	0.913	0.879
D(LNECR_NEG(-1))	-1.238	-1.104		
D(LNECR_NEG(-2))	0.767	0.685		
D(LNECR_NEG(-3))	0.819	0.732		
D(LNECR_NEG(-4))	-3.502**	-3.247		
ECT(-1)	-0.025**	-2.889	-0.021**	-4.955
Panel II		**Long-Run Result**		
LNECR_POS	-0.749	-0.904	0.655**	3.113
LNECR_NEG	0.639	0.162	-5.688**	-5.882
Constant	9.564**	23.017	5.236	37.563
R^2 (adj. R^2)	0.63 (0.60)		0.74 (0.72)	
Panel III		**Robustness Checks**		
J-B Test		98.46 **		7969.76**
B-G Serial test		1.384		0.449
B-P-G Het test		1.953		1.78
R-RESET test		1.749		3.44*
CUSUM	Stable			Marginally stable
CUSUM sqr.	Stable			Unstable
Recursive coeff	Stable			Stable
SR_Wald		8.01**		3.81*
LR_Wald		4.2**		6.01**

Source*: Authors' compilation*

Note: *** (*) shows the variable is stationary at the 1% (5%) level of significance. Y is the response variable for the respective model (LNSTP/LNECR). B-G Serial test represents the q order of autocorrelation, B-P-G Het is the test for constant variance, R-RESET represents the test of the model specification. SR_ Wald represents the short-run Wald test of symmetry; LR _Wald is the long-run test of symmetry.*

As indicated in panel I of Table 4.6, both stock prices and industrial output asymmetrically react inversely to variations in exchange rate in the short run. The coefficients of the exchange rate indicate that a one per cent depreciation in exchange rate reduces stock prices and industrial output by 0.37% and 0.12%, respectively. This supports the conventional wisdom that currency depreciation increases firms' input costs as most firms depend on foreign inputs for production. The high cost of raw materials arising from currency depreciation leads to a decrease in firms' output and profit and hence reduces stock prices. This may explain the decline in industrial output to an all-time low in 2016 following the currency depreciation in 2015, with the resultant economic recession. The manufacturing sub-sector experienced a fall in imports of factor inputs of 56% in 2021 due to a shortage of foreign currency (CBN, 2021; NBS, 2021). This finding supports the findings of Mesagan et al. (2021) and Akanni and Isah (2018). The short-run result suggests that exchange rate appreciation does not significantly influence either variable in the short run. This implies that exchange rate appreciation would reduce stock prices if it lasted up to four months as the value of foreign investors' shares would fall, and the investors would be worried about their investments and may want to sell their shares, which would cause a further decline in share prices. The coefficients of lag of response variables indicate positive reinforcement of their current values. The long-run result indicates that currency depreciation improves industrial output in the long term, while appreciation worsens it. Thus, industrial outputs may decline due to the panic sale of shares by foreign investors occasioned by currency appreciation.

The error correction terms for the two models are 2.5% and 2.1% of the disequilibrium in stock prices and industrial output, respectively, which could be corrected every month, suggesting that it would take between 40 and 47 months for disequilibrium to be corrected. The R^2 and the adjusted R^2 indicate that the models are well fitted. The tests of robustness of the models show that the residuals are not normally distributed. These results justify the use of an alternative nonlinear model for the estimation. The tests of autocorrelation confirm the non-existence of serial correlation in both models. The residuals exhibit constant variance. While the stock prices model is well specified, as indicated in the Ramsey RESET test, the same cannot be said of the industrial output model, as the null hypothesis of a well-specified model is rejected at the

5% level of significance. The residuals exhibit constant variance, as evidenced by the test of heteroskedasticity. The CUSUM, CUSUM square, and recursive coefficients graphs indicate stability of the parameters in the stock market-currency changes model whereas the industrial output-currency changes model shows unstable parameters in the CUSUM square graph, marginally stable in the CUSUM graph, and stable parameters in the recursive coefficients graph. The Wald test of symmetry confirms the asymmetric reactions of industrial output and stock prices to the exchange rate in Nigeria as the null hypothesis of symmetry was rejected in both models. Finally, the results of the asymmetric reactions of stock prices and industrial output to exchange rate shocks are presented in Table 4.7:

Table 4.7: Summary of MTNARDL Results

	Response Variable (LNSTP)		Response Variable (LNINP)	
Predictors	**Coefficient**	**t-Statistic**	**Coefficient**	**t-Statistic**
Panel I		**Short Run Result**		
D(Y(-1))	0.183**	3.042	0.231**	3.753
D(Y(-2))	0.070	1.161	0.172**	2.804
D(Y(-3))	0.085	1.418	0.098	1.620
D(Y(-4))	-0.114	-1.888	0.093	1.617
D(Y(-5))	0.109	1.873		
D(LNECR_MIS_POS)	-151.192	-1.332	-26.759	-0.897
D(LNECR_MIS_NEG(-1))	77.440	0.678	36.521	1.225
D(LNECR_MOS_NEG(-1))	215.020	1.867	-1.044**	-2.221
D(LNECR_MOS_POS(-1))	-0.214**	-4.248	-34.682**	-2.188
D(LNECR_MOS_POS(-2))	170.156	1.436		
D(LNECR_SES_NEG(-1))	38.683	0.324	49.576	1.613
D(LNECR_SES_NEG(-2))	23.995	0.207	-0.081**	-2.111
D(LNECR_SES_POS(-1))	163.553	1.423	-64.137**	-2.099
D(LNECR_SES_POS(-2))	-3.879**	-3.393	-76.230**	-2.507
ECT(-1)	-0.027**	-3.524	-0.001**	-5.005
Panel II		**Long Run Result**		
LNECR_MIS_POS	-1.204	-1.185	-33.166	0.132
LNECR_MIS_NEG	49.027	0.735	3.318	0.009
LNECR_MOS_POS	-1.804**	-2.210	-0.346**	-5.969
LNECR_MOS_NEG	120.388	1.185	0.019	0.019
LNECR_SES_POS	-5.293**	-4.596	-43.452**	-7.955
LNECR_SES_NEG	-0.204**	-3.078	-0.331	-3.905
Constant	9.996**	24.518	0.719	0.019
R^2 (adj. R^2)	0.70 (0.65)		0.72 (0.69)	
Panel III		**Robustness Checks**		
J-B Test		3.7		4.06
B-G Serial test		1.09		0.43
B-P-G Het test		1.78		0.92
R-RESET Test		1.63		1.29
CUSUM	Stable			Stable
CUSUM sqr.	Stable			Unstable
Recursive coeff.	Stable			Stable
SR_Wald		4.617**		3.48*
LR_Wald		3.996*		3.01*

***Source**: Authors' compilation.*

Note: *** (*) shows the variable is stationary at the 1% (5%) level of significance. Y is the response variable for the respective model (LNSTP/LNECR). B-G Serial test represents the q order of autocorrelation, B-P-G Het is the test for constant variance, R-RESET represents the test of the model specification. SR_Wald represents the short-run Wald test of symmetry; LR _Wald is the long-run test of symmetry. LNECR_MIS represents the mild shocks in the exchange rate, LNECR_MOS depicts the moderate shocks in the exchange rate; LNECR_SES represents the severe shocks in the exchange rate. POS is positive (depreciation) while NEG means negative (appreciation).*

This study decomposed shocks in the exchange rate into lower and upper quantiles in line with Li and Guo (2022). Whereas Li and Guo used 30th and 70th quantiles for lower and upper quantiles, the study used the 25th and 75th percentiles to construct three thresholds of shocks to estimate the reactions of stock prices and industrial output to exchange rate shocks in Nigeria.

Panel I of Table 4.7 indicates that mild shocks in the exchange rate (LNECR_MIS_POS and LNECR_MIS_NEG) are not a significant cause of variations in stock prices and industrial output. This means that changes within the 25th percentile of the exchange rate insignificantly affect both industrial output and stock prices. As anticipated, stock prices and industrial output respond significantly in the opposite direction to moderate shocks in exchange rates. Specifically, a moderate positive change in the exchange rate inversely influences both stock prices and industrial output. This upholds the assertion that a huge depreciation negatively affects firms' output and profit and hence stock prices. The result also indicates that severe shocks in the exchange rate (LNECR_SES_POS) inversely affect both variables. Obviously, the coefficients of LNECR_SES_POS of (-3.88) and (-76.23) for the stock prices (LNSTP) and industrial output (LNTNP) models, respectively, are greater than those of the moderate shocks of LNECR_MOS_POS (-0.21 and -34.68). This means that the reactions of stock prices and industrial outputs to currency weakening are sensitive to the size of the shocks in the exchange rate and thus implies that, as the country's exchange rate shock increases high and above the 75th percentile (severe shocks in the exchange rate), its effect on both share prices and industrial output in the country becomes more pernicious in the short-term. The error correction term (ECT (-1)) indicates a low degree of convergence to equilibrium.

Similarly, the long-run result in panel II points to the fact that moderate and severe shocks in the exchange rate inversely influence both industrial output and stock prices. It further indicates that during severe shocks, both exchange rate depreciation and appreciation will have devastating effects on both share values and industrial output. It also confirms the short-run analysis that the long-run reactions of stock prices and industrial output to exchange rate shocks are asymmetrically sensitive to percentile variation in the exchange rate. This result corroborates the findings of Uche et al. (2022), who found the response of

household expenditure of selected African countries to exchange rate dynamics to be sensitive to quantile change.

The diagnostic tests confirmed the validity of the result as the residual satisfies the condition of normal distribution, constant variance, and absence of serial correlation as indicated by the J-B test, the B-P-G heteroskedasticity test, and the B-G Serial test, respectively, in both models. In addition, the short-run and long-run Wald tests indicate that the stock prices and industrial output are asymmetrically connected to currency weakening. The coefficients of the model variables are highly stable in the case of the stock prices model given the CUSUM, CUSUM square, and recursive graphs, whereas in the case of the industrial output model there is mild stability in the parameters as the CUSUM and recursive parameter graphs show stability, but the CUSUM square indicates unstable parameters.

5. CONCLUSION AND POLICY IMPLICATIONS

Motivated by swings in the exchange rate of many developing economies which regularly exert influence on firms' input costs, output, stock prices, and profits, the study investigated the asymmetric reactions of stock prices and industrial output to multifarious shocks in the exchange rate in Nigeria using a newly developed MTNARDL model and monthly data from January 2009 to December 2021.

The ARDL result indicates that stock prices and industrial output react inversely to upward swings in the exchange rate. Similarly, the NARDL results indicate an asymmetric nexus between the variables and that stock prices and industrial output react in the opposite direction to exchange rate depreciation, upholding the conventional wisdom. Using the MTNARDL model, the study found evidence that the reactions of both stock prices and industrial output to variations in exchange rate are sensitive to the extent of the shock: mild, moderate, or severe. In specific terms, the results indicate that exchange rate shocks below the 25^{th} percentile do not affect the variables, but as shocks increase beyond the 25^{th} percentile, they significantly and inversely affect both stock prices and industrial output. However, the impacts of exchange rate shocks on stock prices and industrial output become damaging if they are extremely large, beyond the 75^{th} percentile. The empirical results further suggest that stock prices and industrial

output react asymmetrically in the opposite direction to exchange rate depreciation. Furthermore, they indicate that the reactions of both stock prices and industrial output to exchange rate variations are sensitive to the size of shocks.

The main economic implication of the empirical finding is that in the upper quantile, both exchange rate depreciation and appreciation are detrimental to industrial output and, hence, the value of stocks in Nigeria. The main contribution to knowledge is the emphasis on the degree of currency weakening exchange rate shocks, which is likely due to the extent of the impacts of a misaligned exchange rate transmitted to stock prices and industrial output. The study recommends that the monetary authority should be proactive in policy intervention to ensure stability in the foreign exchange market, since large and extensive exchange rate swings will have a devastating impact on industrial output and firms' stock values.

It is important to note a core shortcoming of the study is the lack of monthly data from January 2022 to July 2022. Two main possible directions for further studies are, first, to conduct a comparative analysis between any two top African economies and, second, to conduct a panel data analysis of selected African economies.

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