MODELLING THE NIGERIAN STOCK EXCHANGE SERIES USING EVENT-BASED ARIMAX MODEL

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ABSTRACT
Current investigation looked into dynamics of the Nigerian Stock Exchange with the aid of time series modeling techniques. The All-share index was adopted, with a specific focus on incorporating major economic and political events through event-based ARIMAX models. Weekly ASI data were collected and subjected to analysis and diagnostic checks. The series was differenced to achieve stationarity, and ARIMAX models were fitted. Notably, exogenous variables such as the COVID-19 pandemic, the 2023 general elections, and the removal of fuel subsidy in 2023 were encoded as dummy variables and integrated into the ARIMAX model. Multicollinearity diagnostics using the Variance Inflation Factor (VIF) indicated no serious multicollinearity among the exogenous variables. Comparison was achieved using the Akaike Information Criterion (AIC). The result revealed that the ARIMAX model with lagged event dummies provided improved explanatory power over the standard ARIMA model. Residual diagnostics including the Ljung-Box test confirmed the models' adequacy. Macroeconomic shocks on market behavior and the usefulness of incorporating event-based structures in time series forecasting can be seen to be of great significance from the obtained results.

Keywords: Time series analysis, ARIMA model, event-based ARIMAX model, Exogenous variable, seasonal ARIMAX,

1. Introduction
The Nigerian Stock Exchange (NSE) is one of the leading financial markets in Africa, serving as a platform for resource accumulation and human capital investment. The stock market makes it easier for a country to identify her economic strength as well facilitating her wealth distribution. In Nigeria, the All Share Index (ASI) of the Nigerian Stock Exchange (NSE) is used as tool to track the performance of the stock market. Many researchers have worked on the Nigerian stock exchange. Some of which are contained in Riman et al. (2008), Ogunmuyiwa, (2010), Ogunmuyiwa and Akinlo (2016) and, Adeboye and Ogunnusi (2020). Forecasting the stock exchange is crucial for decision makers, investors, government and the general public.
The Autoregressive Integrated Moving Average (ARIMA) introduced by Box and Jenkins (1976) has been used by many researchers in modelling time varying data especially financial and economic time series datasets (see Akintunde and Ampitan, 2024, Ogunnusi et al., 2024 Wale-Orojo et al., 2024 and Akintunde et al., 2025). The model's ability to capture temporal patterns makes it a veritable tool in this regards. However, financial markets are often affected by internal trends as well as external macroeconomic and political jolts such as pandemics, elections, government interventions and policy reforms. The ARIMA model cannot adequately capture such external shocks sufficiently Shittu and Inyang (2019).
Many studies have been conducted to address this limitation of ARIMA. Such studies include the ARIMA-Intervention model for modelling Nigeria monthly crude oil prices (Shittu and Inyang, 2019). The current study examines the forecasting performance of event-based ARIMAX models, incorporating COVID-19 pandemic, the 2023 general elections, and the fuel subsidy removal as exogenous variables or intervention variables. These allow for quantifying the impact of these

ISSN NUMBER: 1116-249X

specific shocks and improving forecast accuracy which has not been so used in existing literatures. The relevance of these events cannot be overemphasized but few studies have modeled their delayed effects using time series frameworks that include lagged dummy variables which has left a gap in accurately capturing the time-related consequences of such shocks on the ASI. Previous studies only considered one or two of these external factors but in most cases not as exogeneous variables (see Yaya et al.,2020, Adenomon et al., 2022, Adekunle et al., 2022, Inyang et al., 2024 and Abdullahi, 2025).

The study presents a model that can accurately analyze the behavior of the Nigerian Stock Exchange using event-based ARIMAX models, focusing on the impact of selected economic and political events. Event-based dummy variables representing significant national events (COVID-19 (COVID), 2023 General Elections (Election) and Fuel Subsidy Removal (FuelSR)) were incorporated to build an ARIMAX model. A comparison of the performance between the models (proposed and existing ARIMA) was conducted after model validation.

2. Methodology

In this study a time series technique was adopted giving room for the use of a dynamic approach for examining the behavior of the NSE. The approach involves fitting and validating time series models to historical ASI data, incorporating structural events to account for market shocks. The objective is to build a robust forecasting model that captures both endogenous patterns and exogenous shocks affecting the ASI.

The dataset consists of weekly All Share Index (ASI) values of the Nigerian Stock Exchange (2020 to 2024). The data was official records from website NSE. Three significant events that likely impacted the stock market were incorporated into the model as dummy variables: COVID-19 Pandemic (March 2020 – December 2021), 2023 Nigerian General Elections (February – March 2023) and Fuel Subsidy Removal (May 2023 – Till date). Each event was coded as a binary dummy variable (`0 = before or after the event`, `1 = during the event period`) and later lagged to account for delayed investor reactions.

2.1 ARIMAX Model (Event-Based Analysis)

To model the influence of external events on the ASI, the study adopts the ARIMAX (ARIMA with exogenous regressors) model. This extension allows inclusion of variables outside the series to explain variability.

The general ARIMAX:

$$\phi(L) = (1-L)^d Y_t = \theta(L)\varepsilon_n + \beta_1 C_{n-j} + \beta_2 E_{n-j} + \beta_3 F_{n-j} \quad (1)$$

Where: $C_{n-j}, E_{n-j}, F_{n-j}$ are the lagged dummy variables for COVID-19, 2023 Elections, and Fuel Subsidy respectively, and j is the lag (set to 1 for this study). Each major event was introduced as a binary dummy variable and lagged by one period. This lag accounts for the delay in market response to news or policy implementation.

2.2 Stationarity Tests

The stationarity of the ASI series was assessed using Augmented Dickey-Fuller (ADF) Test and the behavioural pattern of the autocorrelation function (ACF) across lag j (for all $j \in Z$) was also used to verify stationarity. The ADF tests the following:

$$x_t = (\lambda - 1) + \Sigma_{j=1}^{t} \beta_j x_{t-j} + w_t \quad (2)$$

$$x_t = \alpha + (\lambda - 1) + \Sigma_{j=1}^{t} \beta_j x_{t-j} + w_t \quad (3)$$

$$x_t = \alpha + \delta_t (\lambda - 1) + \Sigma_{j=1}^{t} \beta_j x_{t-j} + w_t \quad (4)$$

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Which are pure random walk, random walk with drift and random walk with drift and linear trend models.

2.3 Correlograms

The correlograms are the graph of the autocorrelation function and partial autocorrelation function against the lags. These help in determining order for the components of the model. These are visual diagnostics used prior to model estimation. The sample ACF (γ_j) at a given time interval, reveals linear dependence between original series and its lagged form. The plot of γ_j against the lag, j is meant to be plotted up to a maximum lag of about five times the seasonality interval and this should be less than one fourth of the series under study Hipel et al., (1977).

2.4 Residual Diagnostics

Having validated the model structure, the next step is to justify the choice of the ARIMAX frameworks based on the nature of the financial data. The work adopted Ljung–Box test (Ljung and Box, 1998) to evaluate how well the model fits. The null hypothesis in this regard assumes there is no serial autocorrelation among residuals i.e. H_0: $\rho_1 = \rho_2 = \cdots = \rho_j = 0$, with test statistic expressed as:

$$Q(r) = n'(n'+2)\sum_{j=1}^{k}\frac{\mu_j^2}{n-j} \quad (5)$$

Where $n' = (n - d)$, n is the count of observations in the original data, μ_j^2 is the sample autocorrelation of the residuals at lag j and d is the degree of non- seasonal differencing used to transform the original time series values into stationary time series values and k is a sufficiently large integer. This test statistic is the modified Q- statistic originally proposed by Box and Pierce (Box and Pierce, 1970). Under the null hypothesis of model adequacy, Ljung and Box showed that the Q- statistic approximately follows the distribution where m is the number of parameters estimated in the model. If a model is correctly specified, residuals should be uncorrelated and (r) should be small with large p- value.

Diagnostic Checks for Multicollinearity: To ensure the reliability of the exogenous variables incorporated into the ARIMAX model, a multicollinearity diagnostic was conducted using the Variance Inflation Factor (VIF) (Marquardt, 1970). This measure, is computed as:

$$VIF_h = 1 \div (1 - r_h^2) \quad (6)$$

Where r_h^2 is the coefficient of determination when the h^{th} independent variable is regressed against all other independent variables. High value suggests a problematic level of collinearity which violates the basic assumptions.

2.5 Parameter Estimation

Akaike Information Criterion (AIC) was used in the selection of the most appropriate model among competing models while the maximum likelihood method was used for the estimation of the parameters of the models. The AIC achieved model selection by maintaining a balance between goodness of fit and model complexities. They are given as

$$AIC = -2\ln(L) + 2k \quad (7)$$

Where

L is the maximized likelihood function for the model

k is the number of parameters in the model

3 Results

3.1 Descriptive Statistics

The descriptive analysis of the ASI series in Table 1 reveals insightful characteristics of the data. The minimum value observed was 21095, while the maximum value reaches was 105723,

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resulting in a range of 84628, suggesting significant market fluctuations across the years. The mean ASI is approximately 43249, with substantial variation as shown by variance of 473329066. The standard error of the mean (SE) is 952, indicating a relatively precise estimate of the overall average. There is relatively high volatility in the ASI as shown by the variation coefficient of 50.3%. The skewness value of 1.654181311 indicates that the ASI data is moderately positively skewed and kurtosis value of 1.769984641, being less than 3, implies a platykurtic distribution. This suggest that the dataset has fewer extreme deviation (outliers) than would be expected under normality.

Table 1: Descriptive Statistics

Statistic	522 weeks
Minimum	21094
Maximum	105722
Range	84628
Sum	22576120
Median	36137
Mean	43249
SE. Mean	952
Variance	473329066
Standard Deviation	21756
Coef. Variation	50.30%
25th percentile	28206
75th percentile	48988
Skewness	1.654181311
Kurtosis	1.769984641

3.2 Time Plot (Original ASI series)

The plot of the weekly ASI series from 2015 to 2024 in Figure 1, revealed several characteristics: A general downward trend in 2016 and 2020 (likely tied to recession and COVID-19). Periodic spikes in 2018 and post-2023, potentially tied to investor sentiment or policy shifts. Volatility clusters indicating periods of turbulence in the market. Figure 1 implies non-stationarity of the ASI series, suggesting the need for differencing.

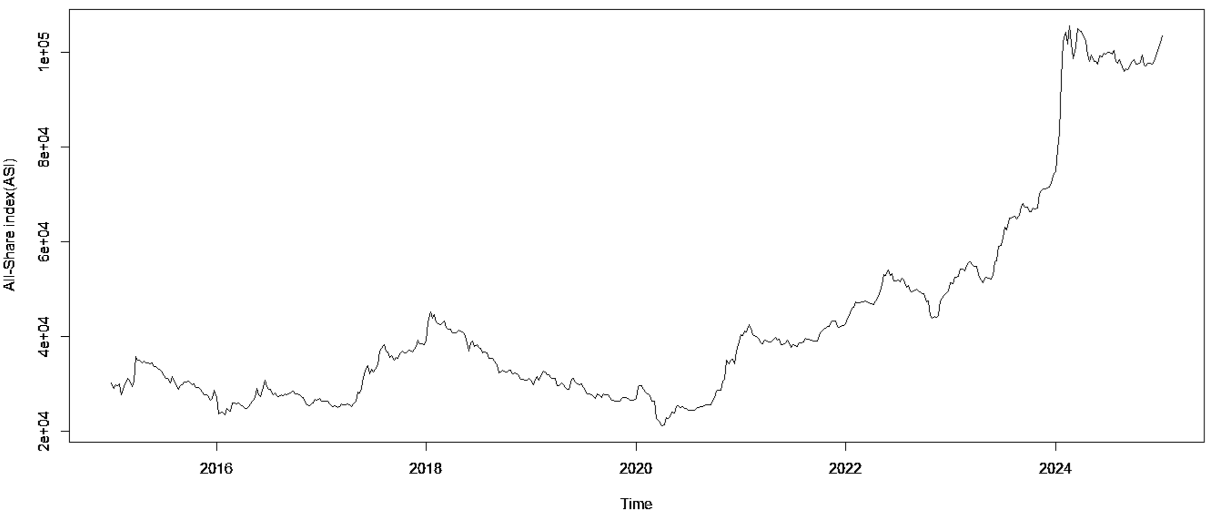

Figure 1: Time Plot (2015–2024)

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3.3 Stationarity Check and Differencing

The correlograms of the original ASI series are shown in Figure 2. The ACF plot shows a very slow decay, almost like a straight declining line. This suggests the presence of trend in the data, also, lags are all significantly positive and decreasing gradually indicating strong persistence in the series. This implies non-stationarity. The PACF shows a tail off after lag 1 (near zero at higher lags). This behaviour suggests that a first-order auto-regressive (AR (1)) model may be appropriate for capturing short-term dependencies after differencing.

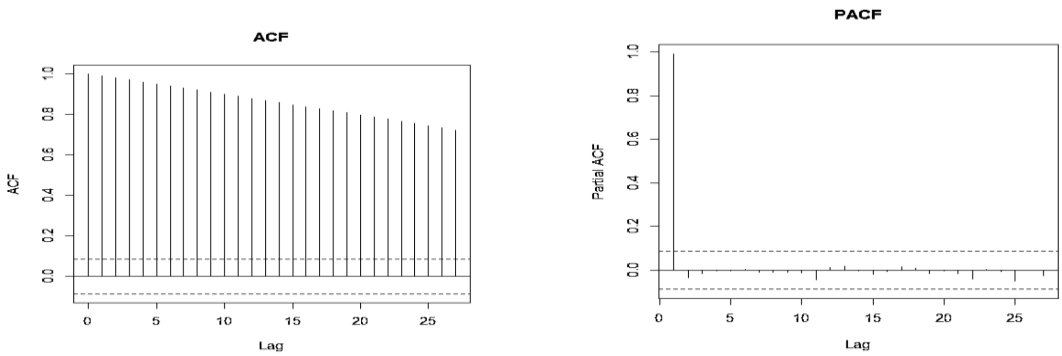

Figure 2: Correlograms of Original ASI Series)

Table 2 shows the ADF results confirming non-stationarity of the series. It can be deduced from both the ACF plot and ADF results that the series needs to undergo differencing.

Table 2: Stationarity Check

	Original Series	Differenced Series
Metric	Value	Value
ADF Statistic	-0.87848	-6.758
p-value	0.9546	0.01
Lag order	8	8

The time plot of the differenced series (Figure 3) appears to fluctuate around a constant mean of zero with no clear upward or downward trend suggesting stationarity. The correlogram (Figure 4) also support the stationarity of the differenced series.

After removing the trend (via differencing), the plot mostly looks like white noise structure exactly what is needed to model with ARIMA. However, intermitted spikes especially around the 10th month highlight the impact of external shocks, justifying the use of an event-based ARIMAX model to account for such structural influences.

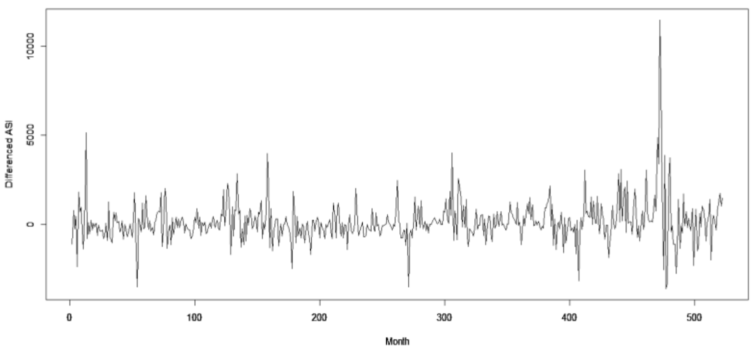

Figure 3: Time Plot of Differenced ASI Series.

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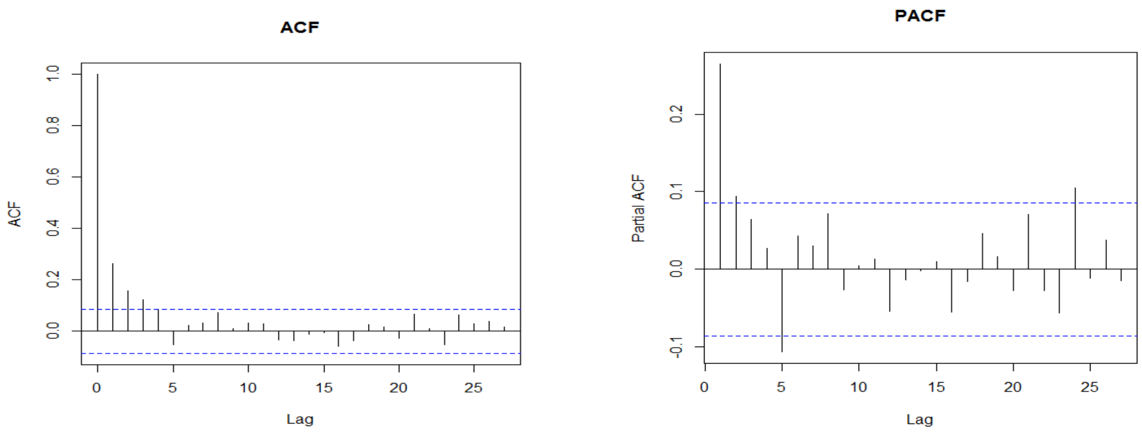

Figure 4: ACF and PACF Plot of Differenced ASI Series

3.4 Fitting ARIMAX Model with Event Dummy Variables

Event dummy variables were created to account for significant economic and political events: COVID-19 (March 2020 to December 2021), 2023 Nigerian General Elections (February to March 2023) and Fuel Subsidy Removal (May 2023 – Till date). The focus of the current study is on the presence versus absence of the event rather than its intensity; therefore, a binary indicator is appropriate for estimating the average effect of the event occurrence.

The selection of events for the ARIMAX model was guided by their significant macroeconomic implications. First, the COVID-19 pandemic (COVID), which began affecting Nigeria in early 2020, introduced widespread economic disruptions and stock market volatility. Second, the 2023 General Elections (Election) were a period of political uncertainty, known to influence investor behavior. Finally, the fuel subsidy removal (FuelSR) policy in May 2023 marked a substantial policy shift with inflationary implications. These events were chosen because they represent structural shocks that are both time-bound and measurable, making them ideal for inclusion as intervention dummies in time series modeling.

3.4.1 Cross-Correlation Analysis for Dummy Lag Selection

Lagged versions of these dummies were also included. The selection of the lag order was done using the cross-correlation analysis. Figure 5 shows the cross-correlation analysis of the events (COVID-19, Nigerian General Elections and Fuel Subsidy Removal) series with the outcome (Stock) series. The result shows that two of the three events (election and Fuel subsidy removal) supported lag one which COVID-19) supported lag 5. The lag one was adopted as adopted by two of the three events variable.

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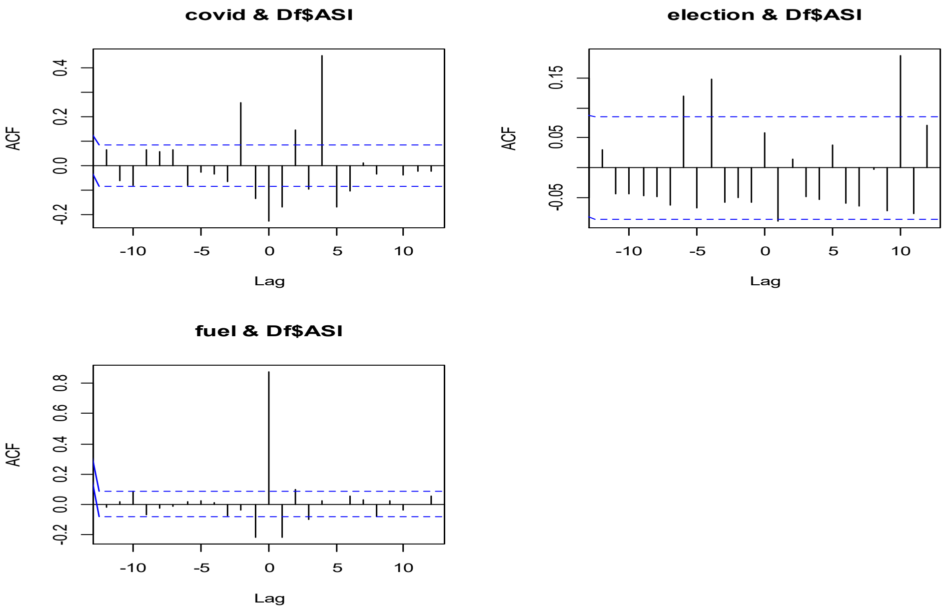

Figure 5: Cross- Correlation of Event Variables Series with the Outcome Series

The choice of the preferred ARIMAX model was guided by that the least value of the Akaike Information Criteria (AIC) value. Table 4 shows the estimated values of the parameters for suggested tentative ARIMAX models, their standard errors, log likelihood values and AIC values. The results highlighted ARIMAX (1,1,1) with AIC value of 11056.02 as the preferred model among the models considered.

Table 4: ARIMAX Models Output

Model	Coefficients	Std. Error	Log likelihood	AIC
ARIMAX (1,1,1)	AR: -0.3141 MA: -1.000 COVID: -11096.25 Election: 14757.08 FuelSR: 47653.87	0.0453 0.005 1593.36 3872.72 1257.14	-5522.01	**11056.02**
ARIMAX (1,2,1)	AR: -0.636 MA: -1.000 COVID: -7434.79 Election: 21166.8 FuelSR: 49183.41	0.0347 0.0048 1604.07 4859.2 1240.99	-5643.7	11299.4
ARIMAX (1,0,1)	AR: -0.2243 MA: -0.1019 COVID: -11275.31 Election: 14581.29 FuelSR: 47625.06	0.2106 0.2236 1630.24 3833.58 1258.57	-5528.57	11071.15
ARIMAX (1,0,0)	AR: -0.3157 COVID: -11118.35 Election: 14725.18 FuelSR: 47632.19	0.0452 1591.35 3867.13 1255.64	-5528.7	11069.4
ARIMAX (0,0,1)	MA: -0.3327 COVID: -11442.94 Election: 14366.07 FuelSR: 47650.93	0.0496 1621.9 3730.81 1265.05	-5528.82	11069.64

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ARIMAX (0,1,1)	MA: -1.000 COVID: -8219.45 Election: 19871.84 FuelSR: 50440.52	0.0049 1602.68 4143.36 1195.5	-5544.67	11099.34
ARIMAX (1,1,0)	AR: -0.6368 COVID: -7438.3 Election: 21151.56 FuelSR: 49186.87	0.0346 1602.46 4855.03 1239.79	-5650.43	11310.86

The findings confirm that macroeconomic shocks exert delayed, heterogeneous impacts on stock performance. This reinforces the importance of incorporating event-based lag structures in time series modeling of financial markets.

The study further compared different competitive ARIMAX (with exogenous variable) with their corresponding ARIMA (without exogenous variables) to see the effect on the inclusion of exogenous variables in ARIMA modelling. The comparison was achieved using the values of their AIC. The results (Table 5) show that the inclusion of exogenous variables improves model outputs. This is to say that ARIMAX models outperform ARIMA models in modeling NSE dataset.

Table 5: ARIMAX Models versus ARIMA Models Comparison

Model	AIC	Model	AIC
ARIMAX (1,1,1)	11056.02	ARIMA (1,1,1)	11853.49
ARIMAX (1,2,1)	11299.4	ARIMA (1,2,1)	12102.6
ARIMAX (1,0,1)	11071.15	ARIMA (1,0,1)	11866.29
ARIMAX (1,0,0)	11069.4	ARIMA (1,0,0)	11868.46
ARIMAX (0,0,1)	11069.64	ARIMA (0,0,1)	11865.56
ARIMAX (0,1,1)	11099.34	ARIMA (0,1,1)	11895.92
ARIMAX (1,1,0)	11310.86	ARIMA (1,1,0)	12115.62

3.4.2 Multicollinearity Diagnostics for Exogenous Variables

To ensure the reliability of the ARIMAX model, multicollinearity diagnostics were conducted on the exogenous dummy variables representing COVID-19, the 2023 General Elections, and the Fuel-subsidy Removal. The VIF values obtained were as in Table 6. According to conventional thresholds, Marquardt (1970), VIF values below 5 are considered acceptable, indicating no severe multicollinearity, while values close to 1 suggest that the regressors are nearly orthogonal (independent). Therefore, the results demonstrate that there is no significant multicollinearity among the event-based dummy variables.

Table 6: Event Dummies VIF Values

Events Dummy	VIF Values
COVID-19	1.020361
Elections	1.003911
Fuel-Subsidy	1.021645

This validates the inclusion of these variables in the ARIMAX model without concern for inflated standard errors or unreliable coefficient estimates.

The study further introduced seasonality into the selected ARIMA (1,1,1) model using seasonal auto-regression of order 1 (SAR (1)) with period 52 (since we have weekly data). This choice

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justified by conducting seasonal diagnostic checks using Box test on seasonal residuals. The test yields a p-value of 0.0005 which justified the use of SAR (1,52). The study therefore proposed seasonal ARIMAX (1, 1, 1)(1, 0, 0)[52] for the analysis and forecasting of NSE. Table 7 shows the coefficients of the proposed seasonal ARIMAX model.

Table 7: Seasonal ARIMAX Model Output

Regression with ARIMA (1,1,1)(1,1,0)[52]						
Coefficients:						
	AR1	MA1	SAR1	Covid_Lag1	Election_Lag1	FuelSubsidy_Lag1
	0.6111	-0.3739	-0.0283	-2095.7387	471.6469	-485.798
Std. Error	0.1132	0.1324	0.0583	781.0685	790.9616	1105.301
Sigma square (σ^2)	1310139					
Log likelihood	-4396.66					
AIC	8809.32					
8809.32						

The seasonal ARIMAX model incorporated three lagged event dummies to assess the delayed impact of major macroeconomic disruptions on the Nigerian Stock Exchange All Share Index (ASI).

3.4.3 Diagnostics for the Seasonal ARIMAX Model

Residual diagnostics for seasonal ARIMAX (1, 1, 1)(1, 0, 0)[52] were conducted to ensure model adequacy. In Figure 6, the residual variance seems more stable, especially around Month 10, indicating that external events (e.g., COVID-19, elections, fuel subsidy removal) helped explain volatility. ACF of Residuals (Bottom Left): Residual autocorrelations are more contained within the 95% bounds compared to the ARIMA model. It suggests better white noise behavior and improved model fit. Histogram + Density (Bottom Right): Residuals distribution appears more symmetric and centered around zero.

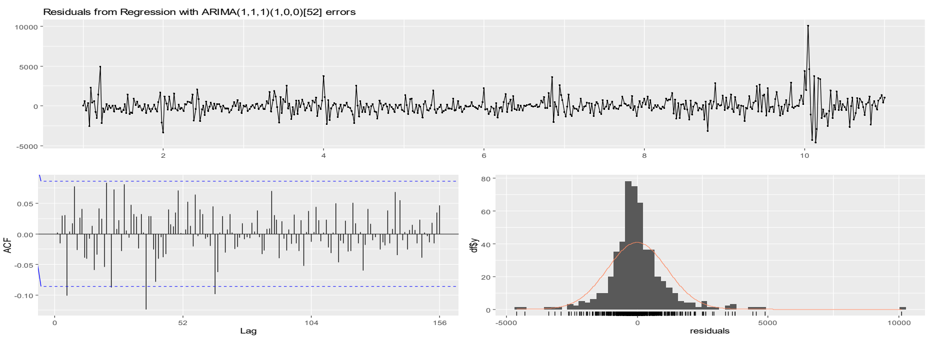

Figure 6: Residual Plot from Seasonal ARIMAX (1, 1, 1)

3.5 Forecasting

3.5.1 Forecast Plot Description

Fifty-two (52) weeks ahead forecasts were generated from the seasonal ARIMAX models. In Figures 7, seasonal ARIMAX model expects continued growth in the NSE influenced by previous events. Also, the model appears to be more responsive to structural changes, making it suitable when external shocks are present.

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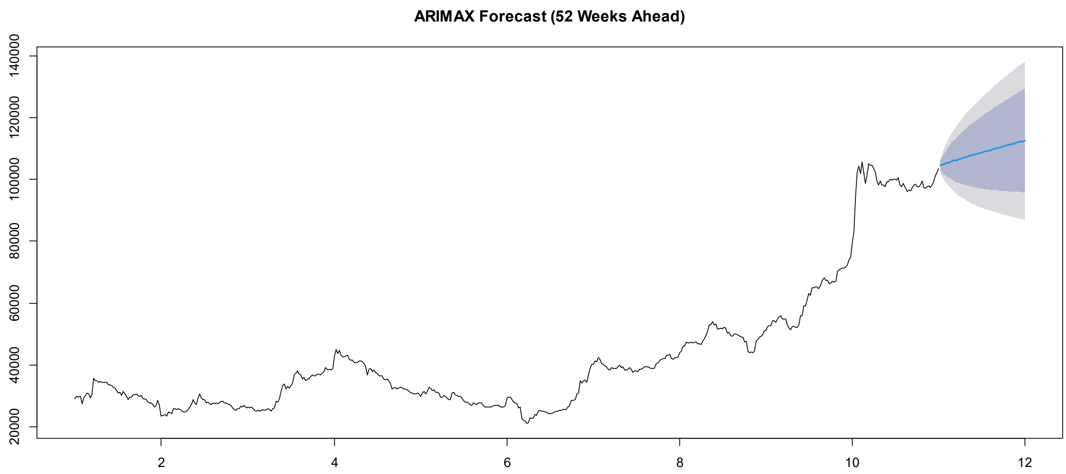

Figure 7: Forecasted ASI Plot from ARIMAX Model

4 Discussions

This study modeled and forecasted the Nigerian Stock Exchange All Share Index (ASI) using both ARIMA and event-based ARIMAX models. The dataset comprised 522 weekly observations from 2015 to 2024. Initial analysis revealed significant volatility and upward drift in ASI over time. After confirming non-stationarity, the series was differenced and tested with the Augmented Dickey-Fuller (ADF) test.

To capture real-world shocks, three major events were modeled using lagged dummy variables: COVID-19, the 2023 general elections, and the fuel subsidy removal in 2023. These were integrated into an ARIMAX (1,1,1) model, which improved model fit (AIC = 11056.02) as compared to ARIMA (1,1,1) with AIC value of 11853.49. Furthermore, the study incorporated seasonality into the chosen ARIMAX model to see the effect of seasons. The study therefore proposed a seasonal ARIMAX (AIC = 8809.32) for modelling all share index of NSE.

The proposed model coefficients, indicate that the COVID-19 pandemic led to an average decline of -2096 index points in the subsequent week, reflecting significant investor uncertainty and market pullback during the health crisis. In contrast, the 2023 general elections produced a small positive effect (472 points), which was statistically insignificant, suggesting market neutrality or early anticipation of election outcomes. The removal of fuel subsidy in May 2023 resulted in the most severe drop, with ASI falling by an average of -486 points in the week following the announcement. This underscores the market's adverse response to economic reforms perceived as inflationary or destabilizing.

Model residuals behaved like white noise, and based on smaller AIC value, the seasonal ARIMAX model when lagged better captured structural breaks, yielding more policy-relevant predictions. The seasonal ARIMAX model, incorporating event-driven dynamics and a lag structure, predicted an even stronger rise from 104220.7 to 122480.8, with a comparable 95% interval of 94503 – 150459.

5 Conclusion

The study concludes that time series models enhanced with exogenous event variables are more effective in capturing market behavior in volatile environments. While ARIMA models handle internal dynamics well, they fall short in accounting for real-world shocks. The ARIMAX model, by including relevant events as regressors, significantly improved model accuracy and interpretability. These findings underscore the importance of integrating macroeconomic signals

ISSN NUMBER: 1116-249X

into financial forecasting tools, especially in developing economies like Nigeria. ARIMAX produces a more conservative forecast, reflecting real-world events like policy shifts and elections. Making ARIMAX model better fit for forecasting. The study used binary indicator, future research can consider intensity-weighted measures as an improvement on the current study. Shittu and Inyang (2019) also applied intervention analysis with lagged dummies for government interventions on crude oil prices. Unlike their approach, the present study selects the lag empirically via cross-correlation and treats the event as a presence/absence indicator, extending their framework.

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