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Time Series Analysis of Some Crime Data in Nigeria

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Abstract
This research compared and assessed various time series models applied to analyze some crime data in Nigeria. Four distinct time series trend models namely - linear, quadratic, exponential, and s-curve were fitted using annual data spanning from 1993 to 2022. The findings revealed that the quadratic trend model demonstrated the lowest MAPE and MAD, offering a suitable fit for murder, armed robbery, and assault crime data. In contrast, the exponential trend model proved most effective in accurately representing bribery and corruption crime data. It was suggested that the quadratic trend model should be used to study the trend pattern of crime such as murder, armed robbery and assault in the long-term run, while the exponential trend model be used to predict the future behaviours of the bribery and corruption crime in Nigeria. Furthermore, the findings obtained from this study should be a catalyst for additional research and practical implementations within the realm of crime analysis and prevention.

Keywords: Time Series models, Crime data, Linear, Quadratic, S-curve

Introduction

A time series is defined as a set of data collected chronologically. Such data has underlying properties that can only be understood when the time series is studied or analysed using statistical methods. Crime records collected over time qualify as time series data hence it is necessary to study the underlying pattern of the crime data. Statistical analysis such as time series analysis of the crime data in Nigeria will reveal the temporal patterns and trends of criminal activities within the country. Such analyses provide valuable perspectives on the dynamics of crimes and criminalities thereby assisting law enforcement agents, policymakers, and researchers in comprehending the factors that impact crime rates. This in turn aids in formulating effective strategies for preventing and controlling crime. Nigeria, one of the most populous countries in Africa, faces significant challenges related to crime (Ajayi & Oloke, 2018). Understanding the temporal patterns of crime is essential in addressing these issues. Essentially, analyzing crime data over time allows for the identification of long-term trends and short-term fluctuations, providing a comprehensive and holistic view of the evolution of criminal activities. When past data is studied, it can assess whether crime rates are on the rise or decline and whether specific periods exhibit other components such as seasonality or cyclic patterns (Oladele, & Ogunrinde, 2019).

Again, time series analysis can help in identifying the impact of various socio-economic factors on crime rates. Variables such as unemployment, poverty, and urbanization are known to influence criminal activities, and time series analysis can uncover the intricate relationships between these factors and crime trends (Umar & Ahmed, 2020). In addition, understanding the temporal distribution of different crime types is vital for allocating law enforcement resources effectively. Time series analysis can reveal which types of crimes are on the rise, allowing authorities to target specific areas and crimes with greater precision (Oyebade & Akintoye, 2018). Again, time series analysis of crime data in Nigeria also plays a critical role in forecasting future crime rates. By recognizing historical patterns and trends, predictive models can be developed to anticipate potential crime surges and allocate resources proactively.

Furthermore, this field of study can also aid in evaluating the effectiveness of crime prevention strategies and policies over time. By comparing pre-and post-implementation of specific intervention crime data, it can be assessed whether such interventions have had the desired impact on crime rates (Dada & Okonkwo, 2018). An additional aspect of interest is the analysis of spatial-temporal patterns, where time series data can be linked with geographic information systems (GIS) to explore how crime hotspots evolve. This aids in the efficient deployment of law enforcement resources and the development of targeted strategies for high-crime areas. The time series analysis of crime data in Nigeria is a multifaceted field with immense practical implications. It offers a window into the past, present, and future of criminal activities in the country, enabling more informed decision-making by authorities and contributing to a safer and more secure Nigerian society (Salawu & Balogun, 2017). The study aims to generate trend analysis plots for the chosen crime data using each of the individual models, estimate the parameter estimates for the selected models, calculate the accuracy metrics (MAPE, MAD, and MSD) for each specific model, evaluate the outcomes of the four trend models and identify the optimal model for the data sets. This determination will ascertain the nature of the trend followed by the selected crime data.

There has been a growing concern about the elevated occurrence of crime incidences throughout the nation. According to Sulaimon et al. (2021), crime has become cultural in our civilized world, The examination of criminal activities in Nigeria falls under the purview of the Nigerian Police. The country is often characterized by a significant incidence of crime, holding the 17th position among the world's nations with the least peaceful environments (Emerson & Solomon, 2018). In the initial six months of 2022, nearly 6,000 individuals lost their lives due to the actions of jihadists, kidnappers, bandits, or engagements involving the Nigerian army. In 2011, an approximation suggested that political corruption in Nigeria had resulted in a loss exceeding $400 billion since gaining independence. Upon assuming office, the recently elected Nigerian president obtained an $11 million London residence, a property the preceding administration sought to confiscate amid an inquiry into one of the nation's most substantial corruption scandals to date. In the year 2012, a survey revealed that 31% of Nigerian women had encountered domestic violence. Attitudes towards domestic violence in Nigeria vary based on factors such as geographical region, religious beliefs, and social class. For instance, the Tiv community perceives wife-beating as a distinctive "expression of affection" and even endorses it, as evidenced by the belief that "Experiencing marital joy involves being disciplined by your husband." Within major ethnic groups, particularly the Yoruba and Igbo, entrenched patriarchal societal structures contribute to the acceptance and justification of domestic violence.

Nigeria functions as a hub for the origination, transit, and destination of individuals, specifically women and children, who fall victim to trafficking, involving forced labour and prostitution. Recruitment for trafficking often occurs in rural areas within Nigeria. Women and girls may experience involuntary domestic servitude and sexual exploitation, while boys might be compelled into forced labour, encompassing roles such as street vending, domestic work, mining, and begging. Young individuals from West African nations like Benin, Togo, and Ghana, taking advantage of the relaxed entry regulations of ECOWAS, often find themselves coerced into labour within Nigeria, including hazardous occupations like granite mining. Moreover, Nigerian women and girls are trafficked to European destinations, particularly Italy and Russia, as well as to the Middle East and North Africa, where they are forced into prostitution.

In 2015, Nigeria recorded a murder rate of 9.85 per 100,000 people. The following year, in 2016, the homicide rate surged to 34.5 per 100,000 inhabitants.

Nigeria harbours a significant organized crime presence, particularly engaged in drug trafficking. This entails the transportation of heroin from Asia to Europe and America, as well as the movement of cocaine from South America to Europe and South Africa. The organizational structure of criminal entities in Nigeria deviates from the traditional mafia models found in other regions. These groups appear to adopt a more informal approach, organizing themselves along familial and ethnic lines. This informal structure makes them less susceptible to infiltration by law enforcement. The term "area boys" refers to loosely organized gangs primarily composed of male street children and teenagers. These groups operate in the streets of Lagos State, Nigeria. Their activities include extorting money from pedestrians, public transport operators, and traders. Additionally, they engage in the sale of illicit drugs, serve as unofficial security personnel, and take on various informal tasks in exchange for compensation.

Initiating an insurgency in July 2009, the jihadist group Boko Haram reached its peak in the mid-2010s, primarily centred around Maiduguri in Borno State. Spanning across Nigeria, Niger, Cameroon, and Chad, the organization has been implicated in numerous incidents, including abductions, bombings, and mass killings, leading to the tragic loss of tens of thousands of lives (Emerson & Solomon, 2018). In September 2019, the Islamic State of Iraq and the Levant (ISIL) asserted responsibility for the killing of 14 Nigerian soldiers in Borno. Subsequently, in the same month, militants in northeastern Nigeria carried out an assault that resulted in the killing of at least nine individuals. The following day, ISIL asserted responsibility for the attack.

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Numerous Nigerian confraternities, commonly referred to as student "campus cults," are actively engaged in organized crime and political violence, contributing to a pervasive network of corruption within the nation. These groups, closely linked to influential political and military figures, also serve as effective channels for alumni connections. Notably, the Supreme Vikings Confraternity proudly declares that 12 members of the Rivers State House of Assembly have affiliations with their cult. In the less affluent segments of society, one encounters the "area boys," loosely organized gangs primarily operating in Lagos, specializing in mugging and small-scale drug trade. The incidence of gang violence in Lagos during the period from August 2000 to May 2001 led to the tragic deaths of 273 civilians and 84 policemen. Eke et al. (2015) conducted a comparative analysis of three-time series trend models in the context of Nigeria's GDP. Utilizing data spanning from 1982 to 2012, the study evaluated the effectiveness of linear, quadratic, and exponential trend models. Findings indicated that the exponential trend model demonstrated the smallest MAPE and successfully captured the underlying data pattern. Utilizing the exponential trend model, a five-year forecast for Nigeria's GDP was generated, indicating a positive trajectory for the country's economic output in the coming years. Pelumi et al. (2018) undertook an examination of specific crime data in Nigeria, emphasizing that crimes involve actions that lead to legal repercussions. Given the diverse penalties associated with crimes, ranging from fines to the ultimate punishment of death, the topic holds considerable importance. This data article provides a partial analysis, employing both descriptive and inferential methods, of a crime dataset spanning from 1999 to 2013. The study aims to depict the trends and rates of crime in Nigeria based on the compiled data and to elucidate the interconnectedness among various crime types. An in-depth examination of this dataset has the potential to yield valuable insights into the landscape of criminal activities within Nigeria.

In Kunnuji's (2016) research, the primary focus was on examining the connection between population density and armed robbery in Nigeria, with a particular emphasis on variations among states. The research suggested that the frequency and prevalence of crime within a society are frequently linked to elements such as unemployment, urbanization, and the effectiveness of law enforcement. Importantly, there is a limited understanding in Nigeria regarding the connection between population density as an independent variable and the occurrence and rate of crime. To bridge this knowledge gap, the study delved into data encompassing reported armed robbery cases and population statistics across Nigerian states in 2006, employing both Pearson's correlation and multiple regression analysis. The research reveals noteworthy statistical differences in the prevalence of crime among Nigerian states, indicating that Southern states exhibit both more incidents and higher rates compared to their Northern counterparts. Population density emerged as a predictor for the overall volume of crime, although not for the crime rate. Spatial analysis additionally highlights the potential influence of proximity to major cosmopolitan states on the country's crime rate. To tackle the challenge of anonymity and enhance control over crime, the paper suggests the establishment of a national database. Nkpordee and Wonu (2018) conducted a study aimed at utilizing time series analysis to forecast the occurrence of malaria epidemics in Nigeria. The research relied on secondary data obtained from the National Bureau of Statistics, specifically Social Statistics in Nigeria. Employing the Box-Jenkins (1976) methodology, the study estimated a suitable mathematical model by considering the autocorrelation function and partial autocorrelation function correlograms. The ARIMA (1,0,1) model was employed to predict the monthly reported cases of malaria, foreseeing a gradual rise and fall in the series over a 16-month period. The study also assessed the monthly average of reported malaria cases. A recommendation was put forth, advising the government to prioritize the distribution of treated bed nets, insecticides, anti-malaria medications, and other necessary resources in rural areas across Nigeria.

Method and Materials

This study concentrated on the comparative analysis of trend models by examining the characteristics of linear, quadratic, exponential, and S-curve time series models.

Nature and Source of Data: The data utilized in this research is derived from secondary statistical sources. The data was extracted from the World Development Indicators- World Bank and the Food and Agriculture Organization Statistical Databases (FAOStat) covering the period from 1993 to Dec. 2022.

Data Analysis Tools: The researchers utilized the MINITAB software, v. 20.0, to obtain the parameters essential for constructing the models. This software played a crucial role in estimating the parameters for the Linear, Quadratic, Exponential, and S-curve models.

Model Specification: This study employed four different models: the linear trend model, quadratic trend model, exponential trend model, and S-curve model.

The Linear Trend Model

In default mode, trend analysis utilizes the linear trend model.

$$Y_t = \alpha_0 + \alpha_1 X_t + \mu_t \tag{1}$$

Within this model, the symbol α_1 signifies the average shift from one period to the succeeding one.

Linear forecasting model:

$$Y_t = \alpha_0 + \alpha_1 X_t \tag{2}$$

The Quadratic Trend Model:

$$Y_t = \alpha_0 + \alpha_1 X_t + \alpha_2 X_t^{\ 2} + \mu_t \tag{3}$$

Quadratic forecasting model:

$$Y_t = \alpha_0 + \alpha_1 X_t + \alpha_2 X_t^{\ 2} \tag{4}$$

The Exponential Trend Model:

$$Y_t = \alpha_0 \alpha_1^{\ x} \mu_t \tag{5}$$

Exponential forecasting model:

$$Y_t = \alpha_0 \alpha_1^{\ x} \tag{6}$$

The S-curve Trend Model:

The S-curve model aligns with the Pearl-Reed logistic trend model, specifically addressing scenarios where the series adheres to an S-shaped curve. The formulation of the model is as follows:

$$Y_t = \frac{10^a}{\left(\alpha_0 + \alpha_1 \alpha_2^{\ X}\right)} \tag{7}$$

where

α_0 = Estimated Y-intercept

α_1 = Estimated linear effect on Y

α_2 = Estimated quadratic effect on Y

Models Accuracy Measures

To determine the optimal fit model, the one exhibiting the lowest accuracy measures (MAPE, MAD, & MSD) will be selected. The model that minimizes these criteria is deemed the most suitable. In recent times, various criteria have been suggested for selecting models, and this comprehensive approach incorporates MAPE, MAD, and MSD. Several of these criteria are elaborated upon below:

Mean Absolute Percentage Error: It quantifies accuracy as a percentage of the error, as it is presented in percentage form. This metric assesses the precision of the fitted values in a time series.

$$MAPE = \frac{\Sigma\left|(Y_t - \hat{Y}_t) / Y_t\right|}{n} \text{X100} \qquad (Y_t \neq 0) \tag{8}$$

In this context, Y_t corresponds to the actual value at time t, $\hat{Y}_t$ represents the fitted value, and n signifies the total number of observations.

Mean Absolute Deviation: It gauges the precision of fitted time series values by aligning the accuracy in the same units as the data. This approach aids in conceptualizing the error as well.

$$MAD = \frac{\sum_{t=1}^{n}\left|(Y_t - \hat{Y}_t)\right|}{n} \tag{9}$$

In this context, Y_t denotes the actual value at time t, $\hat{Y}_t$ signifies the fitted value, and n corresponds to the total number of observations.

Mean Squared Deviation: The calculation of this metric employs the consistent denominator 'n' across all models, facilitating the comparison of MSD values among different models. This characteristic renders MSD more sensitive to typically larger forecast errors compared to MAD.

$$MSD = \frac{\sum_{t=1}^{n}\left|(Y_t - \hat{Y}_t)\right|^2}{n} \tag{10}$$

In this scenario, Y_t represents the actual value at time t, $\hat{Y}_t$ stands for the fitted value, and n denotes the total number of observations.

Results

Parameter Estimate and Model Identification

Parameter Estimate for Crime A (Murder)

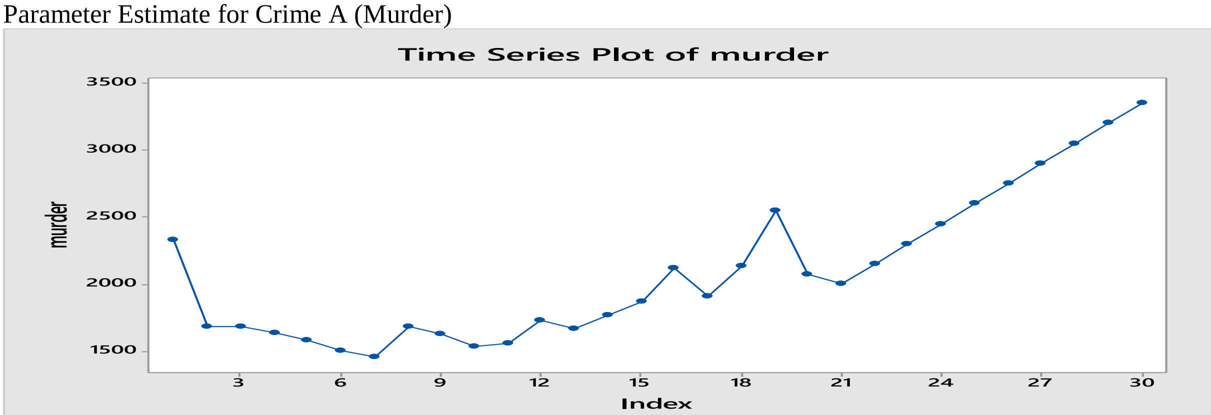

Fig.1: Time series plot of the Murder Crime

Table 1: Parameter Estimate and Accuracy Measures for Murder Crime

Model	Parameter Coefficients			Accuracy Measures		
	α_0	α_1	α_2	MAPE	MAD	MSD
Linear	1300	51.32		11.3	233.5	87970.9
Quadratic	**1908**	**-62.8**	**3.680**	**5.6**	**110.8**	**27367.7**
Exponential	1415.78	1.02362		9.9	208.3	72344.7
S-curve	72.0620	-8.27330	1.05607	6.3	128.3	38774.5

The estimated linear trend model of equation (2) for crime murder is given as $Y_t = 1300 + 51.32 * X_1$ from Table 1.

The estimated quadratic trend model of equation (4) for crime murder is given as $Y_t = 1908 - 62.8 X_1 + 3.680 X_1{}^2$.

The estimated exponential trend model of equation (6) for crime murder is given as $Y_t = 1415.78 * (1.02362)^{X_1}$.

The estimated s-curve trend model of equation (7) for crime murder is given as $Y_t = \frac{10^5}{\left(72.0620 - 8.27330 * (1.05607)^{X_1}\right)}$.

The result of the analysis in Table 1 above also revealed that the murder crime in Nigeria followed a quadratic trend pattern with the lowest values of all the accuracy measures (MAPE=5.6; MAD=110.8; MSD=27367.7).

Parameter Estimate for Crime B (Armed Robbery)

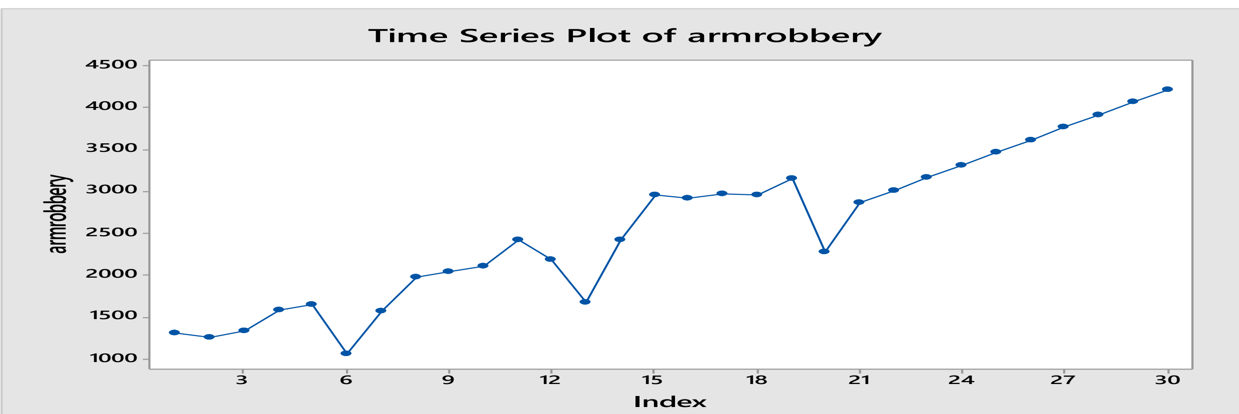

Fig.2: Time series plot of the Arm Robbery Crime

Table 2: Parameter Estimate and Accuracy Measures for Armed Robbery Crime

Model	Parameter Coefficients			Accuracy Measures		
	α_0	α_1	α_2	MAPE	MAD	MSD
Linear	1043	98.64		9.3	195.2	71380.1
Quadratic	**1133**	**81.7**	**0.546**	**9.2**	**192.3**	**70048.3**
Exponential	1270.11	1.04201		10.3	225.5	81045.2
S-curve	20.0077	70.6004	0.920095	9.7	212.6	76279.4

The estimated linear trend model of equation (2) for armed robbery crime is given as $Y_t = 1043 + 98.64 * X_2$ from Table 2.

The estimated quadratic trend model of equation (4) for armed robbery crime is given as $Y_t = 1133 + 81.7X_2 + 0.546X_2^{\;2}$.

The estimated exponential trend model of equation (6) for armed robbery crime is given as $Y_t = 1270.11*(1.04201)^{X_2}$.

The estimated s-curve trend model of equation (7) for armed robbery crime is given as $Y_t = \frac{10^5}{\left(20.0077 + 70.6004*(0.920095)^{X_2}\right)}$.

The result of the analysis in Table 2 above also revealed that the armed robbery crime in Nigeria followed a quadratic trend pattern with the least values of all the accuracy measures (MAPE=9.2; MAD=192.3; MSD=70048.3).

Parameter Estimate for Crime C (Assaults)

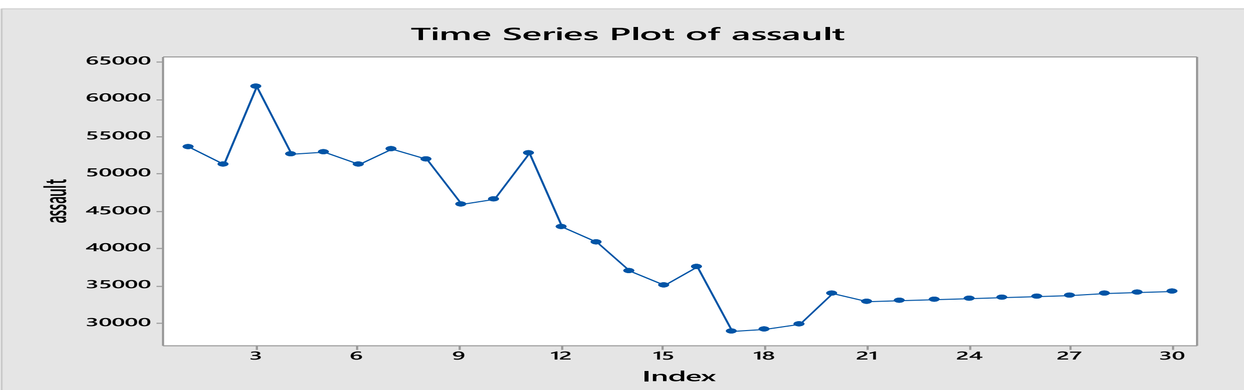

Fig.3: Time series plot of the Assaults Crime

Table 3: Parameter Estimate and Accuracy Measures for Assaults Crime

Model	Parameter Coefficients			Accuracy Measures		
	α_0	α_1	α_2	MAPE	MAD	MSD
Linear	55221	-930		10	3805	22739010
Quadratic	**62445**	**-2285**	**43.7**	**6**	**2660**	**14197365**
Exponential	55904.3	0.97829		9	3468	19789683
S-curve	30.2829	-23.9619	0.851319	12	5578	120191793

The estimated linear trend model of equation (2) for assault crime is given as $Y_t = 55221 - 930 * X_2$ from Table 2.

The estimated quadratic trend model of equation (4) for assault crime is given as $Y_t = 62445 - 2285X_3 + 43.7X_3^{\;2}$. The estimated exponential trend model of equation (6) for assault crime is given as $Y_t = 55904.3*(0.97829)^{X_3}$.

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The estimated s-curve trend model of equation (7) for assault crime is given as $Y_t = \frac{10^6}{\left(30.2829 - 23.9619 * (0.851319)^{X_3}\right)}$.

The result of the analysis in Table 3 above also revealed that the assault crime in Nigeria followed a quadratic trend pattern with the least values of all the accuracy measures (MAPE=6; MAD=2660; MSD=14197365).

Parameter Estimate for Crime D (Bribery and Corruption)

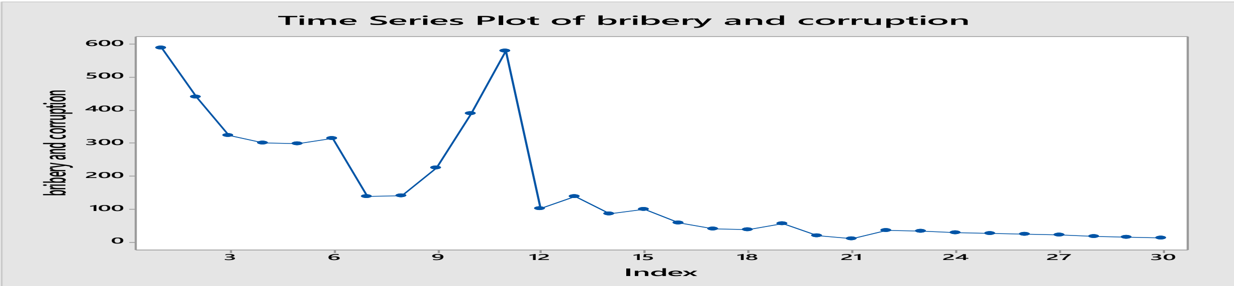

Fig.4: Time series plot of the Bribery and Corruption Crime

Table 4: Parameter Estimate and Accuracy Measures for Bribery and Corruption Crime

Model	**Parameter Coefficients**			**Accuracy Measures**		
	α_0	α_1	α_2	**MAPE**	**MAD**	**MSD**
Linear	392.8	-15.50		148.3	75.4	10635.8
Quadratic	500.6	-35.71	0.652	50.55	51.05	8733.98
Exponential	**603.713**	**0.8745**		**35.87**	**45.78**	**9468.53**
S-curve	-56.2505	54.9466	1.09703	50	138	144668

The estimated linear trend model of equation (2) for bribery and corruption crime is given $Y_t = 392.8 - 15.50X_4$ in Table 2. The estimated quadratic trend model of equation (4) for bribery and corruption crime is given as $Y_t = 500.6 - 35.71X_4 + 0.652X_4{}^2$. The estimated exponential trend model of equation (6) for bribery and corruption crime is given as $Y_t = 603.713 * (0.8745)^{X_4}$. The estimated s-curve trend model of equation (7) for bribery and corruption crime is given as $Y_t = \frac{10^4}{\left(-56.2505 + 54.9466 * (1.09703)^{X_4}\right)}$. The result of the analysis in Table 4 above also revealed that the bribery and corruption crime in Nigeria followed an exponential trend pattern with the lowest values of all the accuracy measures (MAPE=35.87; MAD=45.78).

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Comparing the Accuracy Measures

Table 5: Comparative Accuracy Measures and Model Selection

Variable	Model	MAPE	MAD	MSD	Remark
Murder Crime	Linear	11.3	233.5	87970.9	Quadratic
	Quadratic	5.6	110.8	27367.7	
	Exponential	9.9	208.3	72344.7	
	S-curve	6.3	128.3	38774.5	
Armed Robbery Crime	Linear	9.3	195.2	71380.1	Quadratic
	Quadratic	9.2	192.3	70048.3	
	Exponential	10.3	225.5	81045.2	
	S-curve	9.7	212.6	76279.4	
Assaults Crime	Linear	10	3805	22739010	Quadratic
	Quadratic	6	2660	14197365	
	Exponential	9	3468	19789683	
	S-curve	12	5578	120191793	
Bribery and Corruption	Linear	148.3	75.4	10635.8	Exponential
	Quadratic	50.55	51.05	8733.98	
	Exponential	35.87	45.78	9468.53	
	S-curve	50	138	144668	

Upon reviewing the accuracy measures for the four models presented in Table 5, it is observed that MSD is notably high for all models across variables. However, when focusing on MAPE and MAD as more effective measures among the three, the quadratic trend model stands out with the smallest MAPE and MAD values for variables like murder, armed robbery, and assault in comparison to the other models, while the exponential trend model was identified for bribery and corruption because it has the smallest MAPE and MAD values, therefore, it shows that the murder, armed robbery and assault crime in Nigeria followed a quadratic trend pattern, while bribery and corruption crime in Nigeria followed an exponential trend pattern.

Discussion

This study involved a comparison of four-time series models to conduct a comprehensive time series analysis of crime data in Nigeria. Through an evaluation of model accuracy measures, including MAPE, MAD, & MSD values, it was evident that not all four models (Linear, Quadratic, Exponential, and S-curve) were universally capable of capturing the long-term trends in all crime data in Nigeria. However, based on the accuracy measures—MAPE, MAD, & MSD—the quadratic trend model emerged as the most fitting for accurately representing the long-term trends in murder, armed robbery, and assault crimes in Nigeria. These crime data (murder, armed robbery and assault) were identified to follow a quadratic trend model which was determined by MAPE and MAD values. This study also revealed that bribery and corruption crime in Nigeria followed an exponential trend pattern. The results of this current investigation contradict the conclusions drawn by Eke et al. (2015), who asserted that the exponential trend model exhibited the least MAPE and effectively captured the malaria data.

Conclusion

In conclusion, the time series analysis of crime data in Nigeria has unveiled a wealth of valuable insights into the dynamic nature of criminal activities within the country. This study has shed light on the long-term trends, short-term fluctuations, and seasonality in crime rates, providing a comprehensive understanding of how crime has evolved over time. By analyzing the data, we've discerned the intricate relationships between socio-economic factors, such as unemployment and poverty, and crime rates, emphasizing the importance of addressing these issues in crime prevention strategies. Furthermore, the study has revealed the significance of proactive law enforcement strategies, as forecasting future crime rates becomes a plausible endeavour when analyzing historical patterns. The predictive models developed through time series analysis equip authorities with the tools to anticipate and allocate resources effectively, thereby contributing to more efficient crime control efforts.

The effectiveness of crime prevention policies and interventions has also come under scrutiny, with the analysis indicating that careful evaluation is essential. By comparing pre- and post-implementation crime data, policymakers can make informed decisions regarding the impact of specific measures, allowing for adjustments and improvements where necessary. Moreover, the study's exploration of spatial-temporal patterns, in conjunction with Geographic Information Systems (GIS), has illuminated the evolution of crime hotspots over time. This spatial-temporal perspective highlights the importance of tailored strategies for different regions, ensuring that law enforcement resources are deployed where they are most needed. In sum, the time series analysis of crime data in Nigeria has proven to be an invaluable tool for understanding, preventing, and controlling criminal activities. As Nigeria continues to grapple with various crime-related challenges, this research provides a foundation for more effective law enforcement strategies, ultimately contributing to the creation of a safer and more secure society for its citizens. The insights gained from this study should serve as a springboard for further research and practical applications in the field of crime analysis and prevention.

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