Analysis of the dynamic of inflation process in Nigeria: An application of GARCH modelling

Ekpeyong, Paul

University of Ibadan

28 July 2023

MODELLING OF THE DYNAMICS OF INFLATION PROCESS IN NIGERIA: AN APPLICATION OF GARCH PERSPECTIVE

Paul Gabriel Ekpeyong

University of Ibadan (gekpeyong036@stu.ui.edu.ng)

Abstract

This study investigates the dynamics of inflation volatility in Nigeria, with a specific focus on the Food Consumer Price Index (CPI), Core CPI, and Headline CPI. The analysis utilizes the Autoregressive Conditional Heteroskedasticity (ARCH) and Generalized Autoregressive Conditional Heteroskedasticity (GARCH) models to capture time-varying volatility in the inflation rates. The study covers the period from January 1995 to December 2022, employing monthly data sourced from the Central Bank of Nigeria database. The results indicate that all three inflation series display time-varying volatility, signifying varying degrees of fluctuations and uncertainties in price movements over different periods. Furthermore, the presence of ARCH and GARCH effects in the residuals of the volatility models confirms the dynamic nature of inflation volatility. The study identifies significant structural breaks in the volatility of Food CPI during the years 2000, 2008, and 2018, emphasizing the importance of understanding the drivers of inflation volatility. External events and policy changes during these periods impacted food prices and led to shifts in volatility. Policy recommendations are made to address the challenges posed by inflation volatility in Nigeria. These include implementing price stability measures, enhancing food security, strengthening monetary policy, promoting data transparency and analysis, and undertaking fiscal reforms. The findings of this study contribute to a deeper understanding of inflation volatility in Nigeria and provide valuable insights for policymakers in formulating effective strategies to manage inflation and achieve macroeconomic stability. The study highlights the importance of monitoring inflation dynamics and implementing timely policies to ensure sustained economic growth and development in the country.

Key words: ARCH, Consumer price index, Headline, core, volatility, GARCH,

1.0 Introduction

The price variations in goods and services over time are reflected in inflation, a key economic indicator. Because of its considerable economic impact and the uncertainty it causes, authorities everywhere are prioritizing tight control over inflation (Omotosho 2013). Inflation is a popular topic of discussion among central banks, governments, economists, and other stakeholders. Policy choices in Nigeria have been greatly impacted by the direction of inflation rates, especially in 2012. The majority of economists and monetary policymakers favor a low and steady inflation rate because it enables quicker labor market changes during downturns and lowers the cost of borrowing for manufacturers, which increases profitability (Banerjee 2013). In turn, this increases investments, lowers unemployment, and raises economic production.

In order to combat the threat of inflation, the Monetary Policy Committee (MPC) of the Central Bank of Nigeria adopted a contractionary posture on monetary policy instruments for 28 months (September 2010–January 2013) (Omotosho 2013). Controlling inflation and preserving a stable exchange rate environment are the MPC's top priorities. Many experts and stakeholders are currently calling for the MPC to relax its position on growth promotion. The MPC meeting and the monthly inflation numbers are announced one month apart, which makes it difficult for policymakers to properly coordinate their approaches. Statistical predictions and estimations can help decision-makers formulate their strategy in these circumstances (Grier et al. 1998).

Nigeria's monetary policy has been focused on ensuring price and exchange rate stability over the previous three decades. Since 1970, the nation has had a mixed record with inflation. Oil export revenues significantly increased as a result of the oil boom in the 1970s, and the government spent a lot more money on post-war development and rehabilitation (Tsyplakov 2010). Massive oil earnings, which started dominating the economy in 1973, provided the fuel for this. The monetization of oil revenues caused the domestic money supply to expand quickly, which put upward pressure on the overall price level and created inflationary pressures (Okun 1971).

Nigeria experienced internal and foreign unrest in the early 1980s as a result of declining oil prices on the international market. The government implemented a structural adjustment program (SAP) in 1986 to address the severe budget deficits brought on by the economic crisis (Ball 1992). The devaluation of the national currency, rapid expansion of the money supply, sluggish development in the industrial and agricultural sectors, and an excessive dependence on imports all contributed to inflationary pressures throughout the SAP era (Emery 2006). Nigeria's actual GDP growth remained low from 1992 to 1999, and early 1990s inflation was unusually high before sharply declining in the late 1990s. In order to maintain the low inflation rate of Nigeria, this work on simulating the inflation process there becomes important.

Having established the aforementioned, In statistics, "volatility" refers to the variance of a series, which measures how much a random variable deviates from its mean. According to Omotosho (2013) and Emery (2006), inflation volatility in this sense refers to swings or instability in a particular inflation series that expresses the severity of unanticipated changes and unforeseen components of inflation resulting from external shocks. The difficulty of predicting future values of a variable, which symbolizes the unpredictable nature of future occurrences, gives birth to uncertainty (Ball, 1992). Therefore, the unpredictability or uncertainty in predicting the level of prices in the future is referred to as inflation uncertainty. According to Hentschelte (1995), high uncertainty is indicative of the variable's predicted value being more volatile or having bigger variations around a certain mean. Although it is difficult to directly affect inflation's volatility as an economic indicator, efforts may be done to lessen the uncertainty that goes along with it. Due to many political circumstances and components, achieving and sustaining stable inflation can still be difficult, making the unpredictability of inflation essential. In order to create successful preventative strategies, it is therefore essential to measure inflation uncertainty (Hentschel, 1995; Pagan, 1996; Brooks, 2008; Omotosho, 2013; Grier, 1998; Ball, 1992).

Inflation uncertainty has been measured using a variety of ways over time, moving from more conventional methods like standard deviation or variance to more cutting-edge ones like GARCH-type volatility prediction models (Natalia, 2010). Since GARCH models allow for stochastic variation of the variance over time, they are increasingly popular for modeling economic time series, such as consumer price indices (Engle, 1982; Bollerslev, 1986; Hentschel, 1995; Pagan, 1996; Brooks, 2008; Xekalaki and Degiannakis, 2010). The Application of the GARCH Model" holds significant promise in understanding and managing Nigeria's current inflationary period. By utilizing the GARCH model, the research aims to capture time-varying volatility and dynamics of inflation, providing valuable insights for policymakers, economists, and financial analysts.

The time-varying volatility of inflation may have been neglected in the prior work on inflation dynamics in Nigeria, which would have limited its accuracy (Hentschel, 1995; Pagan, 1996; Brooks, 2008; Omotosho, 2013; Grier, 1998; Ball, 1992). It's possible that conventional econometric models don't accurately capture the intricacies of Nigeria's inflation behavior under erratic conditions. Insufficient consideration of time-varying volatility in Nigerian inflation models (Hentschel, 1995; Pagan, 1996; Brooks, 2008; Omotosho, 2013; Grier, 1998; Ball, 1992) is the highlighted gap in the research. This study greatly contributes by giving a thorough knowledge of inflation behavior under various economic situations and improving inflation forecasts by utilizing the GARCH model, which is intended to manage shifting variances over time. Additionally, the analysis can reveal the fundamental causes of Nigeria's inflation volatility, which is important for formulating focused policy responses. Beyond Nigeria, other emerging countries experiencing comparable inflationary issues may benefit from its expertise.

The research makes accurate forecasts for the 12-month data using statistics on the headline, core, and food inflation rates from January 1995 to December 2022. According to the current inflationary shocks, failing to take into account asymmetric factors when modeling inflation volatility may cause volatility levels to be either over- or under-predicted (Natalia, 2010). Furthermore, while high-frequency data increases the effectiveness of obtaining model-based estimates of volatility from economic time series, utilizing low-frequency data in earlier research may have drawbacks. There are five sections in the paper. An overview is given in the introduction, and part two gives a historical perspective on Nigeria's bouts of inflation. The analytical approach and data sources are described in section three. Section four of the essay presents the empirical analysis, and part five brings it all to a close.

2.1 Nigeria Inflationary Episode: Core Fact

The implementation of Nigeria's Structural Adjustment Programme (SAP) resulted in chronic inflation, primarily driven by various policy measures. One of the key aspects was external debt management, where four strategies were adopted, including refinancing, rescheduling, new loan facility agreements, and debt-equity swaps. Refinancing transformed short-term debts into long-term ones, while rescheduling renegotiated terms for outstanding debts. However, these practices contributed to fiscal irresponsibility and inflationary pressures, contrary to the intended goal of reducing external debt. The acquisition of new loans further fueled inflation and perpetuated a cycle of indebtedness, leading to a significant escalation of Nigeria's external debt.

These external debt strategies also increased the domestic money supply, directly contributing to inflationary pressures in the economy. The study by Anyanwu (1987b) emphasized that the cycle of indebtedness gained momentum, resembling an avalanche, exacerbating the inflationary trends.

In summary, the implementation of the SAP in Nigeria led to chronic inflation due to external debt management strategies. The practices of refinancing, rescheduling, and new loans increased Nigeria's debt burden, perpetuated the cycle of indebtedness, and raised the domestic money supply, all contributing to inflationary pressures in the economy.

2.1.1 Foreign Exchange Market Operation

As observed by Anyanwu (1989), the SFEM/FEM/IFEM has emerged as a prescription for disaster, causing significant harm to the foundations of the Nigerian economy. The persistent depreciation of the naira against the US dollar has been a result of this exchange rate regime, declining from N1 to $5,691 in September 1986 to N1 to $7.8950 by mid-February 1990. This continuous depreciation has been reluctantly accepted by Nigeria's creditors, as the country has been compelled to adopt a policy of appeasement to achieve a supposedly realistic rate for the naira.

However, this ongoing depreciation of the naira through the SFEM/FEM/IFEM has exacerbated the inflationary situation in Nigeria (Anyanwu, 1987a). The depreciation has a profound impact on domestic industries, which heavily rely on imported inputs whose costs have risen due to the weakened naira. As a result, production costs increase, leading to higher prices for goods and services (Ojo, 1989). Furthermore, the consistent depreciation of the naira has encouraged smuggling activities, especially of essential items like foodstuffs, creating local scarcities and further driving up prices. Additionally, the depreciation has contributed to brain drain, as individuals seek to capitalize on the benefits of a weakened naira, with the remittances they send back to Nigeria primarily being used for consumption activities, further exacerbating local price levels.

2.1.2 Removal of Petroleum Subsidies

As part of the requirements imposed by the IMF-World Bank to reduce government expenditure, Nigeria implemented reductions in subsidies on petroleum products, including gas, petrol, kerosene, diesel oil, and fuel oil, in the years 1986, 1988, 1989, and 1990. However, these subsidy withdrawals had unintended consequences, leading to an inflationary spiral in the country (Anyanwu, 1987c, 1990a).The removal of subsidies on petroleum products resulted in significant and persistent increases in the prices of goods. This, in turn, led to skyrocketing transport fares, adversely impacting the living standards of the population and causing considerable hardship for commuters. Families, struggling to make ends meet, were forced to allocate approximately 50% of their meager incomes (where employed at all) to fuel or alternative energy sources like wood and charcoal.

The reduction in subsidies on fertilizers (NPK, Urea, and SSP) in both 1989 and 1990 further compounded the inflationary pressures. As a consequence, farm production costs rose, resulting in lower agricultural output and subsequently leading to higher prices of foodstuffs. This policy stance was contradictory for an administration that claimed to be committed to increasing agricultural production and fostering non-inflationary growth. Overall, the subsidy reductions on petroleum products and fertilizers, although intended to reduce government expenditure, had adverse effects on inflation and living standards in Nigeria. The resulting inflationary pressures and higher costs of essential goods and services placed a significant burden on the population, particularly those already struggling with poverty and limited resources.

2.1.3 Privatization and Commercialization

As per the Privatization and Commercialization Decree of 1988, privatization involves the relinquishment of some or all of the equity and other interests held by the Federal Government or its agencies in enterprises, whether wholly or partially owned. On the other hand, commercialization entails reorganizing government-owned enterprises to function as profit-making commercial ventures without financial support from the government. Both policies emphasize the implementation of 'user charges and cost-recovery principles'. Under the privatization program, the Technical Committee on Privatization and Commercialization offered for sale a total of 95.3 million shares, with a market capitalization exceeding N142 million. Government shares in several enterprises, including the National Oil and Chemical Marketing Company Limited, the African Petroleum Company Limited, and Four Mills of Nigeria Limited, were sold. Additionally, shares of thirteen insurance companies were put up for sale.

As a consequence of the commercialization of government-owned entities, tariff hikes were implemented. For instance, NEPA (Nigerian Electric Power Authority) increased its tariff by 400%, while NITEL (Nigerian Telecommunications Limited) raised its tariff by 900%. These price hikes significantly escalated production and operational costs for industries, resulting in the closure of many small firms due to the burden of unbearable production expenses. As a result, there was a decline in output, and the increased production costs were passed on to consumers in the form of higher prices. Essential services and information became extremely costly, making them unaffordable even for middle-income earners. One specific example given by Jose (1989) illustrates the impact of the tariff increase. In 1988, the average electricity cost per kilogram was 8 kobo, but with the new tariff, it rose to 123 kobo. The multiplier effect of such tariff increases on materials and services used by manufacturers further contributed to the inflationary pressures on consumer prices.

The implementation of commercialization and cost-recovery programs also resulted in substantial rises in water rates, medical charges, and educational levies. This led to a general decline in the quality of social services and utilities, exacerbating inflation and increasing hardships for the unemployed population. In response to the rising costs, water corporations in Nigeria called for special lower NEPA tariffs to prevent water rates from escalating further. The overall impact of privatization and commercialization on essential services, utilities, and general consumer prices led to significant inflation and increased difficulties for the economically disadvantaged segments of the population.

2.1.4 Trade Liberalization

Trade liberalization, and the resulting competition for increased imports of inputs and manufactured items, has placed significant pressure on Nigeria's scarce foreign exchange reserves, leading to higher costs of raw materials, spare parts, and manufactured goods. The increased costs of importation have also resulted in higher service charges and a decline in service quality. Shortages of crucial inputs, such as spare parts for vehicles, chemicals in water schemes, drugs in hospitals, and educational materials in schools, have contributed to deteriorating services and increased charges in the service sector.

Furthermore, trade liberalization has led to a surge in the exportation of goods that are in short supply locally, creating local scarcities and fueling inflation. As a response to this issue, Nigeria eventually imposed a ban on the exportation of certain food items in their raw form starting from 1991. In the current Nigerian context, trade liberalization is likely to contribute to inflation both in the medium and long term since efforts to promote non-oil exports, one of the primary aims of the policy, have not yielded the expected results. The contribution of non-oil exports to total exports fell from 8.84% in 1988 to 5.10% in 1989. Moreover, Nigeria's major export and revenue earner, oil, is subject to its OPEC quota, meaning that trade liberalization is not expected to have a substantial impact on this aspect.

Overall, trade liberalization has had mixed outcomes in Nigeria, putting pressure on foreign exchange reserves, leading to higher costs, service disruptions, and contributing to inflationary pressures, particularly with regards to goods facing local scarcity. The anticipated benefits of boosting non-oil exports have not materialized as expected, indicating the complexity and challenges associated with trade liberalization in Nigeria's economic context.

2.1.5 Interest Rate Deregulation

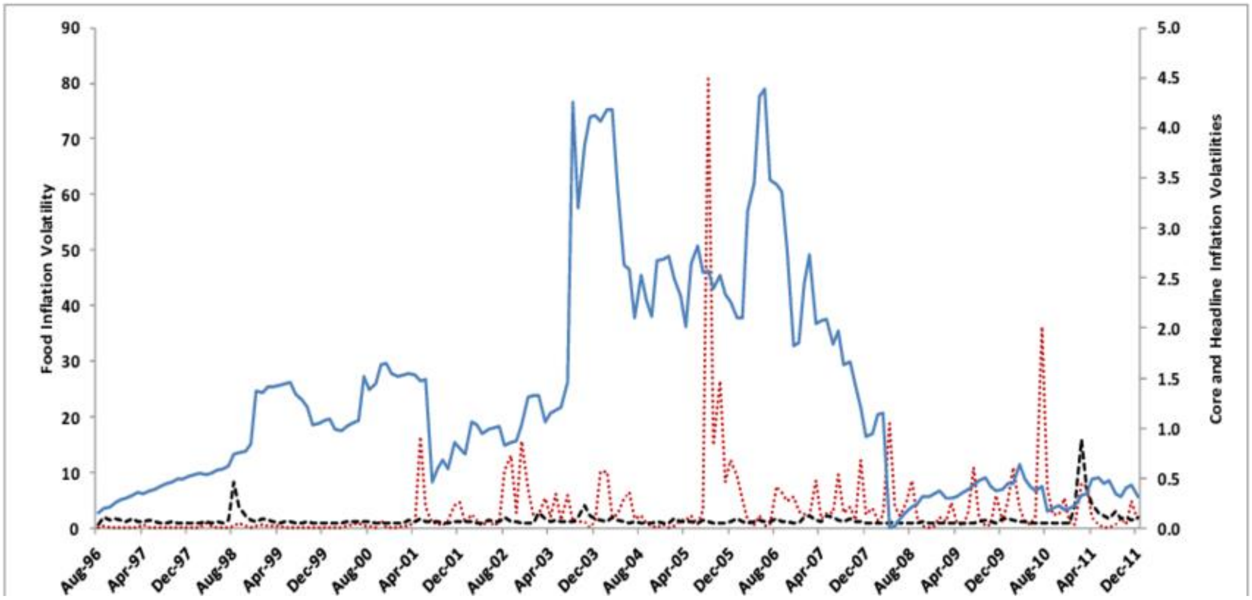
On July 31, 1987, as part of the Structural Adjustment Programme (SAP), the Central Bank of Nigeria announced the deregulation of interest rates. It removed all controls on interest rates, allowing them to be determined by the forces of demand and supply in the market. To influence interest rates, the Central Bank started adjusting the rediscount rate and the liquidity ratio upwards, thereby influencing the pace for commercial and merchant banks.

However, banks overreacted to the deregulation by pushing up interest rates, particularly prime lending rates, which have now exceeded 40% in some banks. This behavior is reminiscent of the bidding sessions under the SFEM exchange rate system. The misalignment of various interest rates, especially the widening gap between deposit and lending rates, became evident. As a response, the Central Bank issued a belated directive to narrow the margins within stipulated percentages, though it lacked sufficient teeth to enforce it effectively. The steep increase in interest rates has had adverse consequences, rendering many enterprises insolvent, which, in turn, has had a boomerang effect on the banks themselves. This situation has led to a significant decrease in investment and output levels, subsequently fueling inflation (Anyanwu, 1987d). The sectors most severely impacted are agriculture and small-scale building construction. These sectors struggle to cope with the high levels of competition and interest rates due to the long time lag before profits are realized and their inability to provide sufficient collateral.

The rise in lending rates has been so dramatic that it threatens the survival of non-bank corporate sectors and ultimately jeopardizes the financial sector as well, as acknowledged by the Governor of the Central Bank of Nigeria, Ahmed (1989). Interestingly, banks have been offering relatively low rates on saving deposits, indicating that they might be exerting some collective market power to their immediate advantage. In an attempt to narrow the gap between lending rates and the rates on savings deposits, the banks are devising strategies to raise lending rates further, which endangers investment and output. This would have otherwise contributed to lowering inflation in the long run.

Furthermore, inflationary expectations discourage people from taking advantage of the relatively higher savings rates. Instead, they prefer to invest in physical assets whose values appreciate with inflation, even though these assets are unproductive. This contributes to additional demand pressure and further fuels inflation. Overall, the deregulation of interest rates has had complex and adverse effects on the Nigerian economy, with soaring lending rates impacting enterprises and hindering investment and output growth. The misalignment of interest rates and inflationary expectations further exacerbate inflationary pressures, making it challenging to achieve long-term stability in the economy.

Figure 1: Volatility Estimate for Food, core and Headline Inflation rate



From 1997 to 2011, Nigeria experienced varying trends in the volatility estimates for food, core, and headline inflation rates. During this period, the country underwent significant economic changes and faced various internal and external factors that influenced inflation dynamics.

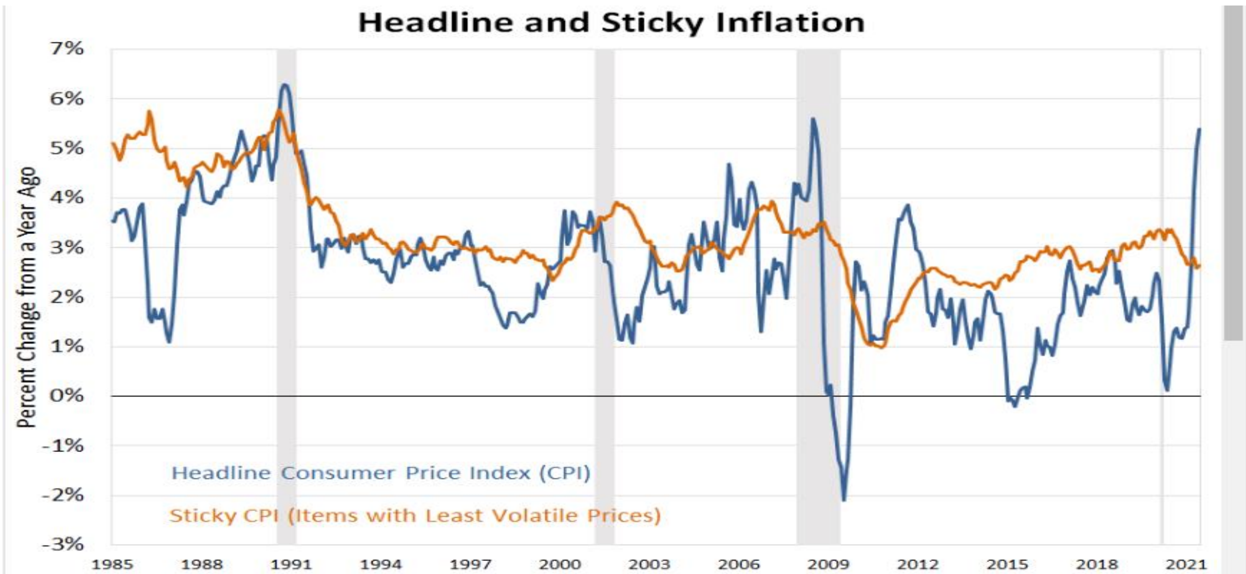
Food inflation volatility showed a mixed pattern over the years. In the late 1990s and early 2000s, Nigeria witnessed relatively moderate volatility in food prices. However, starting from the mid-2000s, food inflation volatility began to increase. This rise in volatility was influenced by factors such as fluctuations in global food prices, changes in agricultural policies, and supply chain disruptions due to security challenges in some regions of the country. These factors contributed to more significant fluctuations in food prices during the latter half of the studied period.

Core inflation, which excludes the volatile food and energy components, exhibited a relatively stable trend during the late 1990s and early 2000s. However, from the mid-2000s, core inflation volatility started to show some fluctuations. The increase in core inflation volatility was partly due to the impact of rising energy prices on transportation costs and production expenses. Additionally, changes in monetary policy and exchange rate fluctuations influenced core inflation volatility during this period.

Headline inflation, which includes all components, exhibited a similar pattern to core inflation volatility. In the late 1990s and early 2000s, headline inflation volatility remained relatively stable. However, from the mid-2000s, headline inflation volatility began to rise. The factors contributing to the increase in headline inflation volatility were a combination of food and energy price fluctuations, changes in monetary policies, and global economic conditions.

Overall, from 1997 to 2011, the inflation volatility estimates for food, core, and headline inflation rates showed increased fluctuations compared to the earlier years. The period saw Nigeria facing various economic challenges, such as changes in global commodity prices, security issues, and shifts in monetary and fiscal policies. These factors collectively influenced inflation dynamics and resulted in more significant volatility in the latter part of the studied period.

Figure 2: Price Volatility and Headline Inflation



Between 1985 and 2021, Nigeria experienced significant trends in price volatility and headline inflation, shaped by a variety of internal and external factors. This period witnessed economic fluctuations, political changes, and global economic events that influenced Nigeria's inflationary environment.

Early Period (1985-1999): During the mid to late 1980s, Nigeria faced a period of high inflation rates and increased price volatility. Economic challenges, including the oil price crash and mounting external debts, contributed to hyperinflation, reaching its peak in the early 1990s. Price volatility soared during this time, leading to uncertainties in the economy.

Stabilization Efforts (2000-2008): In the early 2000s, Nigeria initiated various economic reforms and adopted prudent monetary policies to stabilize inflation and reduce price volatility. These efforts started showing results, and inflation rates began to decline. Price volatility also moderated, as the economy witnessed some stability during this period.

Global Financial Crisis (2008-2009): The global financial crisis of 2008 had repercussions on Nigeria's economy. As international oil prices plummeted, the country's oil-dependent revenue suffered, leading to higher inflation rates and increased price volatility. The crisis posed challenges for Nigeria's monetary and fiscal policies, affecting its inflationary environment.

Ups and Downs (2010-2015): In the early 2010s, Nigeria faced fluctuations in inflation rates and price volatility. Periods of economic growth and increased oil prices contributed to lower inflation and relatively stable prices. However, internal challenges, such as security issues and policy uncertainties, also influenced price volatility during this time.

Economic Recession (2016-2017): In 2016, Nigeria experienced an economic recession, driven by falling oil prices, foreign exchange shortages, and reduced oil production. This led to a surge in inflation rates and heightened price volatility. The country's efforts to recover from the recession and stabilize the economy impacted inflation dynamics and price movements.

Post-Recession Recovery (2018-2021): In the years following the recession, Nigeria made efforts to stabilize the economy and implement structural reforms. As a result, inflation rates showed some moderation, although price volatility remained a concern, influenced by factors such as fluctuating oil prices, security challenges, and policy uncertainties.

Overall, between 1985 and 2021, Nigeria's inflation and price volatility trends reflected the country's economic and political landscape. Periods of economic reforms and stability were juxtaposed with challenges such as recessions, global economic events, and internal issues that impacted inflation dynamics and price fluctuations. The country's reliance on oil revenues and exposure to external shocks made managing inflation and price volatility a persistent challenge for policymakers.

3.0 Methodology

In the development of the basic Autoregressive Conditional Heteroskedasticity (ARCH) model, three specific specifications are required, namely the conditional mean equation, the conditional variance equation, and the conditional error distribution. For this study, each of the three types of inflation will be modeled using an appropriate ARIMAX (Autoregressive Integrated Moving Average with exogenous variables) process, which will help explain their behavior over time.

Numerous theories of inflation exist in the literature, including demand-pull, cost-push, Keynesian theory, quantity theory of money, purchasing power parity theory, and structural theory (Jhingan, 2009). These theories serve as a guide for selecting the variables to be used in this research. The exogenous variables included in the mean models below are chosen based on their theoretical, empirical, and situational relevance. For example, in addition to other variables suggested by theory, the fuel price is incorporated to analyze the impact of government pronouncements of fuel price changes on inflation.

The study will apply the ARCH model to model inflation in Nigeria, considering different types of inflation and their respective conditional mean equations, conditional variance equations, and conditional error distributions. The choice of variables in the models will be guided by various inflation theories to ensure a comprehensive and relevant analysis of inflation dynamics in the country.

Table 1: List of Considered Variables and their definition

LIST	VARIABLE NAME	DESCRIPTION
1	CPI_H	Headline CPI
2.	CPI_C	Core CPI
3.	CPI_F	Food CPI
4.	INTER_BANK	Inter-bank exchange rate
5.	FUEL	PMS price
6.	CU_CIRCU	Currency in Circulation
7.	GOV_CRE	Credit to Government
8.	RESERVE	Bank reserve
7.	RIC	Average Rainfall in Cereals Producing Zones [Northwest and Northeast Zones]
8.	RIT	Average Rainfall in Tuber Producing Zones [North Central Zone]
9.	RIV	Average Rainfall in Vegetables Producing Zone [Southern Zone]
10.	δ	Autoregressive term
11.	µ	Moving Average term

Thus, the mean equations for the headline (HCPI), food (FCPI) and core (CCPI) inflation types are specified respectively as

$$CPI\_H = \beta_0 + \sum_{i=0}^{a}\theta_1 CU\_CIRCU_{t-1} + \sum_{i=0}^{b}\theta_2 CU\_OUT_{t-1} - \sum_{i=0}^{C}\theta_3 RIC_{t-1} - \sum_{i=0}^{d}\theta_4 RIV_{t-1} + \sum_{i=0}^{e}\theta_5 INTER\_BANK_{t-1}$$
$$+\sum_{i=0}^{f}\theta_6 CPI\_C_{t-1} + \sum_{i=0}^{g}\theta_7 CPI\_F_{t-1} + \sum_{i=0}^{h}\theta_8 \delta_{t-1} + \sum_{i=0}^{a}\theta_9 \mu_{t-1} + \xi_t \qquad (1)$$

$$CPI\_F_t = \beta_1 + \sum_{i=0}^{a}\theta_{10} CU\_CIRCU_{t-1} + \sum_{i=0}^{b}\theta_{12} CU\_OUT_{t-1} - \sum_{i=0}^{C}\theta_{13} RIC_{t-1} - \sum_{i=0}^{d}\theta_{14} RIV_{t-1} + \sum_{i=0}^{e}\theta_{15} INTER\_BANK_{t-1}$$

$$+\sum_{i=0}^{f}\theta_{16} GOV\_CRE_{t-1} + \sum_{i=0}^{g}\theta_{17} PRI\_CRE_{t-1} + \sum_{i=0}^{h}\theta_{18} RESERVE_{t-1} - \sum_{i=0}^{L}\theta_{19} RIT_{t-1} + \sum_{i=0}^{L}\theta_{20}\delta_{t-1} + \sum_{i=0}^{m}\theta_{21}\mu_{t-1} + \sigma_t$$
(2)

And

$$CPI\_C_t = \alpha_0 + \sum_{i=0}^{a}\sigma_1 CU\_CIRCU_{t-1} + \sum_{i=0}^{b}\sigma_2 CU\_OUT_{t-1} - \sum_{i=0}^{C}\sigma_3 RIC_{t-1} - \sum_{i=0}^{d}\sigma_4 RIV_{t-1} + \sum_{i=0}^{e}\sigma_5 FUEL_{t-1}$$
$$-\sum_{i=0}^{f}\sigma_7 RIT_{t-1} + \sum_{i=0}^{g}\sigma_9 \delta_{t-1} + \sum_{i=0}^{h}\sigma_{10}\mu_{t-1} + \psi_t \qquad (3)$$

The residuals ξ_t, σ_t, ψ_t for the respective mean models are assumed to be white noise, with constant coefficients denoted as $\beta_0, \beta_1, \alpha_o$ α, and autoregressive terms represented by $\theta_8, \theta_{20}, \sigma_9$ for i = 1, 2, 3, ..., p, as well as moving average terms denoted by $\theta_8, \theta_{20}, \sigma_9$ for i = 1, 2, 3, ..., q. The residuals derived from equations (1), (2), and (3) are considered to follow an Autoregressive Conditional Heteroskedasticity (ARCH) (p) process if their conditional distributions, given their past values, exhibit a zero mean and a conditional variance denoted as σ^2_t. The subscript i on each parameter ranges from zero to their respective limits. The study employs endogenous and exogenous variables, which are listed and defined in Table 1.

In this study, the conditional variance equations are categorized into two main groups: the symmetric model (GARCH) and the asymmetric models (TGARCH and EGARCH). Engle (1982) introduced the ARCH (q) model as a symmetric approach to estimate the time-varying volatility of a series. The model expresses the conditional variance of the prediction error term as a function of the squared error values from recent past observations. The symmetric GARCH model aims to capture the changing volatility patterns over time, providing valuable insights into the dynamics of the series being analyzed.

On the other hand, the asymmetric models, namely TGARCH and EGARCH, are also employed to estimate conditional variance equations. These models consider the potential asymmetry in the volatility patterns, recognizing that positive and negative shocks may have different impacts on volatility. TGARCH accounts for threshold effects, whereas EGARCH incorporates the impact of both positive and negative shocks in a more flexible manner.By employing these different models, the study aims to comprehensively capture and analyze the time-varying volatility of the series, considering both symmetric and asymmetric effects.

$$\sigma_t^2 = \partial_0 + \sum_{i=1}^{y} \psi_t S_{t-1}^2 \qquad (4)$$

In this context, I is a counting variable represented as I = 0, 1, 2, ..., q. The symbol σ_t^2 denotes the conditional variance at time t, is a constant. The parameters ψ_t represent the coefficients of the ARCH terms of order q, while S_{t-1}^2 represents the lagged values of the squared prediction error for i = 1, 2, 3, ..., q. To address the issue of determining how many lags of the squared innovations should be included in the ARCH model, Bollerslev (1986) introduced a generalized version of the ARCH model. In this approach, the conditional variance is modeled as a function of its own lagged values and also the lagged values of the squared innovations. The generalized ARCH model allows for a more flexible representation of the conditional variance, capturing the dependencies on both its own past values and the past values of the squared prediction errors. This provides a robust solution to properly model the changing volatility patterns and dependencies over time.

$$\sigma_t^2 = \partial_0 + \psi S_{t-1}^2 + \beta \sigma_{t-1}^2 \qquad (5)$$

In equation (5), the terms $\sigma_t^2, \partial_0, \psi and S_{t-1}^2$ have been previously defined as the conditional variance, ARCH coefficients of order q, and the lagged values of the squared prediction error, respectively. Additionally, β is the GARCH coefficient, representing the one-period lag of the fitted variance from the model. To ensure a well-defined GARCH (1, 1) model, certain conditions must be met. Specifically, it is required that $\psi \geq 0$ and $\beta \geq 0$ to maintain non-negativity of the ARCH and GARCH coefficients. Moreover, to guarantee covariance stationarity, the condition $\psi + \beta < 1$ is sufficient. These constraints ensure the stability and validity of the GARCH (1, 1) model, allowing it to effectively capture and model the volatility dynamics in the data being analyzed.

The TGARCH (Threshold GARCH) model, introduced by Glosten, Jaganathan, and Runkle (1993), is an extension of the GARCH model that allows for asymmetric effects in volatility modeling. In contrast to the GARCH model, which assumes symmetric effects of shocks on volatility, the TGARCH model introduces an additional parameter, denoted as γ, to capture potential asymmetries in the data.

By incorporating the γ term, the TGARCH model can effectively capture and account for situations where positive and negative shocks have different impacts on volatility. This asymmetry in volatility dynamics is essential in providing a more accurate and nuanced representation of the underlying data, especially in cases where volatility tends to react differently to upward and downward movements in the time series. The TGARCH specification is given as:

$$\sigma_t^2 = \partial_0 + \psi S_{t-1}^2 + \gamma K_{t-1} S_{t-1}^2 + \beta \sigma_{t-1}^2 \qquad (6)$$

In equation (6), the term K_{t-1} is an indicator function that takes the value of 1 if $S_{t-1} < 0$ (indicating a negative shock) and 0 otherwise. The parameter γ represents the asymmetric parameter, and ∂_0, ψ and β are as previously defined in the model. In the TGARCH model, the impact of news on the conditional variance is asymmetric. When there is good news (positive shock) represented by $S_{t-1} > 0$ it has an impact of ψ on the conditional variance. On the other hand, when there is bad news (negative shock) represented by $S_{t-1} < 0$, it has an impact of (ψ + γ) on the conditional variance.

If the value of γ is not equal to 0 (γ ≠ 0), it indicates that there is an asymmetric effect in the model, where positive and negative shocks have different impacts on volatility. Specifically, if γ > 0, it suggests a leverage effect, meaning that negative shocks increase volatility more compared to an equivalent positive shock. This asymmetric behavior in the TGARCH model allows for a more accurate representation of how shocks influence volatility in the underlying data.

Nelson (1991) introduced the EGARCH (Exponential GARCH) model as an extension of the GARCH model, specifically designed to effectively capture both volatility clustering and asymmetric effects in financial time series.

$$\log(\sigma_t^2) = \partial_0 + \psi\left[\frac{S_{t-1}}{\sigma_{t-1}} - \sqrt{\frac{2}{\pi}}\right] + \gamma\left(\frac{S_{t-1}}{\sigma_{t-1}}\right) + \beta\log\left(\sigma_{t-1}^2\right) \tag{7}$$

In equation (7), $\log(\sigma_t^2)$ represents the logarithm of the conditional variance at time t, while ψ, β and γ are as previously defined in equation (6). The log transformation on the left-hand side of equation (7) ensures that the leverage effect is exponential rather than quadratic, thereby guaranteeing that the forecasts of the conditional variance are non-negative. The asymmetric effect of past shocks is captured by the parameter γ. If $\gamma \neq 0$, it indicates an asymmetric impact of news on the conditional variance. Additionally, if $\gamma < 0$, there is a leverage effect, implying that negative shocks have a greater impact on increasing volatility compared to equivalent positive shocks. The term ψ measures the impact of conditional shocks on the conditional variance. A positive shock in period t has an effect of $\psi + \gamma$ on the conditional variance, while a negative shock has an effect of $\psi - \gamma$. These effects allow for a more nuanced representation of how past shocks influence the current volatility in the EGARCH model.

Furthermore, it's worth noting that in this study, the conditional distribution of the error term is assumed to follow a normal distribution. This assumption is commonly employed when estimating ARCH/GARCH models and allows for a straightforward implementation of the model to capture volatility clustering and asymmetric effects in financial time series data.

4.0 Data Result and Discussion

In this empirical study, the main focus is on three types of Consumer Price Indices (CPIs): headline CPI, food CPI, and core CPI. These CPIs serve as the dependent variables for the various mean models estimated in this research. The study covers a substantial time period, from January 1995 to December 2022.

Data on the exogenous variables used in the analysis, as listed in Table 1, are also collected for the same time span. These exogenous variables are obtained from the Central Bank of Nigeria database.

By analyzing the relationships between the CPIs and the selected exogenous variables over this extended period, the study aims to gain insights into the dynamics of inflation in Nigeria and the potential impact of various factors on inflation behavior. The inclusion of food CPI and core CPI alongside headline CPI allows for a more comprehensive understanding of the drivers of inflation, with food CPI representing the impact of food prices on overall inflation and core CPI capturing the underlying inflation trend by excluding volatile food and energy prices. This data-driven approach will provide valuable information for policymakers, economists, and other stakeholders to formulate effective strategies to manage inflationary pressures in the Nigerian economy.

4.1 Stationary test

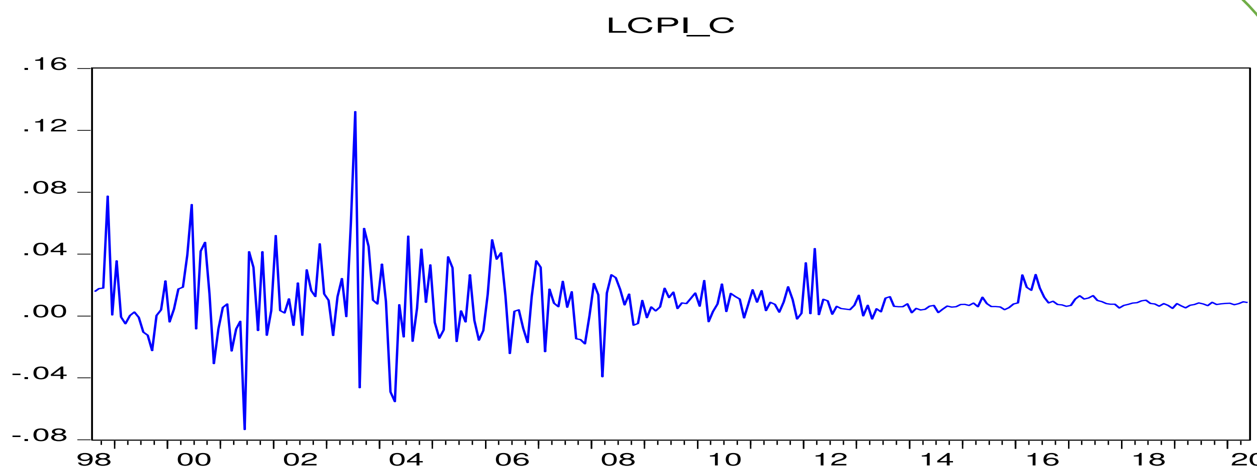
The stationarity position of the variables in the study indicates their stability over time. Most variables, including CPI_H, CPI_C, CPI_F (inflation measures), exchange rates, credit indicators, and rainfall measurements, show stationarity in their level form mostly after generating first difference at both constant and trend level. This suggests that they remain relatively stable without significant long-term trends or abrupt changes in their first difference. Stationary data is desirable for time series analysis as it helps identify meaningful patterns and relationships accurately. Policymakers, economists, and financial analysts can rely on these stable variables to make informed decisions and forecasts. The findings provide valuable insights for understanding economic trends and inflation behavior in Nigeria between January 1995 and December 2022.

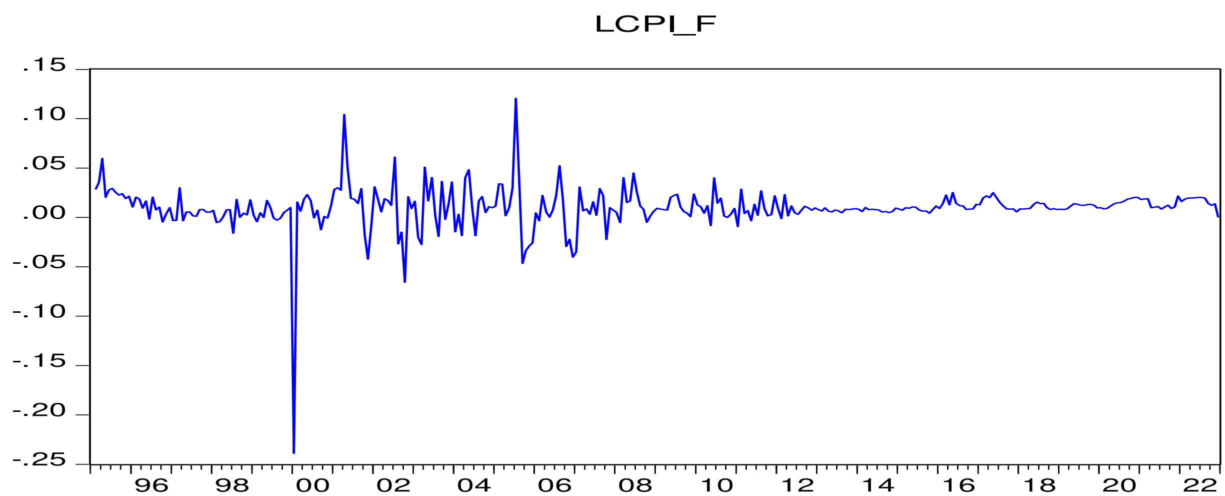
Table 2: Result of Augmented Dickey Fuller (ADF) and Philip Peron(PP) Test

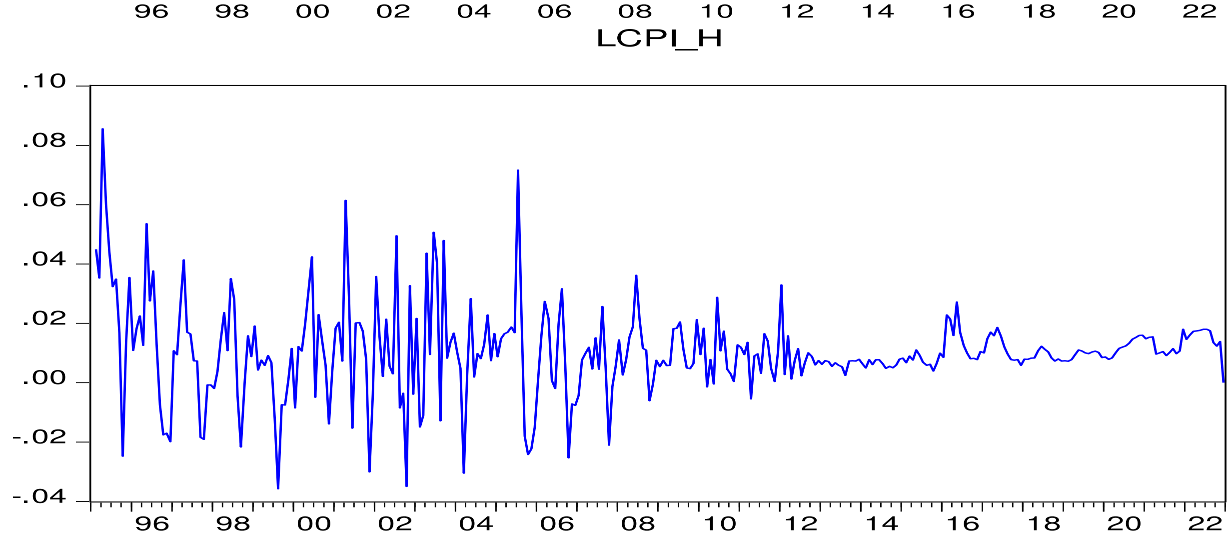
Variables	**Stationarity of all variables in level**				**Stationarity of all variables in first difference**			
	Dickey-fuller test		Phillip-Perron (PP)		Dickey-fuller test		Phillip-Perron (PP)	
	Constant	Trend and constant	Constant	Trend and constant	Constant	Trend and constant	Constant	Trend and constant
CPI_C	10.294	6.862	-3.91**	-6.27**	-12.289	7.064	12.09**	-14.83**
CPI_F	9.710	7.899	2.411	-5.99**	18.126	11.793	-5.29**	-8.916**
CPI_H	8.942	7.584	3.023	-5.32**	16.628	11.456	-4.23**	-7.895**
FUEL	0.491	-2.086	30.44**	30.5**	-0.305	-4.45**	34.52**	-36.56**
INTERBK	1.884	-0.428	-16.4**	16.7**	1.812	-0.512	16.49**	-16.682
CU_CIR	1.601	-1.008	-4.84**	-5.21**	0.427	-3.595**	-36.23**	-39.307**
CU_OUT	1.601	-1.008	-4.84**	-5.21**	0.427	-3.595**	-36.23**	-39.307**
GOV_CR	1.447	-1.723	-4.54**	-4.93**	0.688	-3.318*	-25.04**	-26.324**
PRI_CRE	1.447	-1.723	-4.54**	-4.93**	0.688	-3.318*	-25.04**	-26.324**
RESERVE	-1.329	-4.20**	24.06**	24.02**	-1.087	-5.105**	-33.94**	-33.99**
RIC	-0.869	-0.796	55.95**	55.87**	15.50**	16.534**	134.08**	135.262**
RIT	-1.760	-2.547	15.43**	15.40**	-7.72**	-7.572**	-49.81**	-49.84**
RIV	-1.430	-2.652	19.65**	19.62**	9.026**	-9.806**	50.295**	-50.231**

Source: Authors' Compilation. Note: ***, ** and * denote stationarity at 10%, 5% and 1% significance levels, respectively.

4.2 Visualization Test







The above visualization test shows that the Headline, core and food inflation rate shows a volatility clustering and structural breaks evidenced from the result which shows that it is a volatility series.

4.3 Conditional Mean Equation

4.3.1 Conditi0nal Mean Equation for Headline Inflation

From the results of the mean model for the headline CPI selected using the E-views software and based, the estimated equation (1) can be expressed as:

ML ARCH - Normal distribution (Marquardt / EViews legacy)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
LCU_CIRCU	0.009726	0.012488	0.778807	0.4361
RIC	-1.05E-05	5.32E-06	-1.97673	0.0481
RIV	2.66E-05	1.39E-05	1.917635	0.0552
LINTERBANK	0.011281	0.017657	0.638904	0.5229
LCPI_C	0.346105	0.093568	3.698984	0.0002
LCPI_F	0.292078	0.027152	10.7572	0.0002
C	-0.189478	0.253114	-0.748585	0.4541
	Variance Equation			
C	4.03E-05	1.61E-05	2.508536	0.0121
RESID(-1)^2	-0.076732	0.019224	-3.991575	0.0001
GARCH(-1)	0.911611	0.064747	14.07968	0.0002

$$CPI\_H = -0.189 + 0.00972 \Delta CU\_CIRCU_t - (-1.05*10^{-5})\Delta RIC_t - (-2.66*10^{-5})\Delta RIV_t$$
$$+0.011281\Delta\, INTE\_BANK_t + 0.346\Delta CPI\_C_t + 0.292\Delta CPI\_F + -0.0767\xi_t \qquad (8)$$

The regression results reveal that all coefficients in Equation (8) are statistically significant at the 5 per cent level, except for INTER_BANK and currency in circulation. The model is well-fitted, indicating that the monthly changes in headline CPI at time t are influenced by the monthly changes in food CPI and core CPI at the same period. Additionally, the depreciation of the Inter - bank exchange rate at the same period also plays a role in influencing headline CPI. Moreover, the reduction in Average Rainfall in Cereals Producing Zones [Northwest and Northeast Zones], along with the Average Rainfall in Vegetables Producing Zone [Southern Zone], also contributes to the variation in headline CPI. These findings offer valuable insights into the factors affecting inflation trends in Nigeria during the specified time frame.

4.3.2 Conditional Mean Equation for Core Inflation

From the results of the mean model for the Core CPI selected using the E-views software and based, the estimated equation (1) can be expressed as:

ML ARCH - Normal distribution (Marquardt / EViews legacy)				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
RIC	6.79E-06	3.95E-06	1.71959	0.0075
RIT	-7.11E-06	8.00E-06	-0.889418	0.0038
RIV	-4.82E-06	1.25E-05	-0.386611	0.009
FUEL	0.001588	0.00028	5.678891	0.0023
LCU_CIRCU	0.048807	0.009665	5.049859	0.0032
C	-0.727949	0.144858	-5.02527	0.0033
	Variance Equation			
C	4.42E-06	1.42E-05	0.31039	0.7563
RESID(-1)^2	0.265102	0.318344	3.974005	0.0001
GARCH(-1)	0.422304	0.092608	4.560117	0.0001

$$\Delta CPI\_C_t = -0.7279 + 0.04880 \Delta CU\_CIRCU_t + 0.0015 \Delta FUEL_t - 6.79x\,10^6 \Delta RIC_t - (-7.11x\,10^6) \Delta RIT_t - (-4.82x\,10^6) \Delta RIV \tag{9}$$

The coefficients of the variables included in Equation (9) are statistically significant at the 5 per cent level. The model is well-fitted, indicating that an increase in core CPI at period t is influenced by the price of petroleum motor spirit in the same period, as well as the increase in broad money supply at period t. Moreover, the impact of Average rainfalls also plays a role in determining the variations in core CPI. These findings provide valuable insights into the factors driving the fluctuations in core CPI in Nigeria during the specified time period.

4.3.3 Conditional Mean Equation for Food Inflation

From the results of the mean model for the Food CPI selected using the E-views software and based, the estimated equation (1) can be expressed as

ML ARCH - Normal distribution (Marquardt / EViews legacy)				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
LCU_CIRCU	5.81E-02	5.53E-02	1.050564	0.0135
RIC	-2.35E-06	1.31E-06	-1.791713	0.0432
RIV	2.56E-07	3.14E-05	0.008157	0.0235
LGOV_CRE	-0.031088	0.060359	-0.515061	0.0265
LRESERVE	0.01325	0.013023	1.017407	0.0209
RIT	9.09E-06	2.02E-05	0.450206	0.0326
LINTERBANK	0.050664	0.047602	1.064324	0.0072
C	-0.744093	0.759769	-0.979368	0.0074
	Variance Equation			
C	-6.72E-06	1.36E-05	-0.493713	0.0215
RESID(-1)^2	-0.034458	0.00461	-7.473987	0.000
GARCH(-1)	0.074275	0.037496	28.65015	0.000

$$\Delta CPI\_F_t = -0.744 + 5.81*10^{-2}\Delta CU\_CIRCU_t + (-0.0310)GOV\_CRE_t + 0.013\Delta RESERVE_t$$
$$+0.0506\Delta INTER\_BANK_t - (-2.35*10^{-6})\Delta RIC_t - 2.56*10^{-7}\Delta RIV_t - 9.09*10^{-6} \quad (10)$$

All the coefficients in Equation (10) are statistically significant at the 5 per cent level, indicating their strong impact on the monthly increase in food CPI at period t. The well-fitted model suggests that the expansion of reserve money, increased credit to the government, and surprisingly, the appreciation of the inter-bank exchange rate in period t, all contribute to the variations in food CPI. The Breusch-Godfrey Lagrange Multiplier test for Serial Correlation was performed to assess the reliability of the estimated mean models in Equations (9), (10), and (11). The test results, presented in Table 3, indicate that the null hypothesis of no serial correlation in the residuals of the models was not rejected. This suggests that these estimated models can be used effectively for forecasting the CPI series, as there is no evidence of serial correlation in the residuals, ensuring the reliability of the forecasts.

Table 3: Serial Correlation Test: Breusch-Pagan-Godfrey for Headline Inflation

Serial Correlation Test: Breusch-Pagan-Godfrey			
F-statistic	9.325238	Prob. F(6,104)	0.0000
*Obs*R-squared*	38.82809	Prob. Chi-Square(6)	0.0000
Scaled explained SS	9.19E+08	Prob. Chi-Square(6)	0.0000

Table 4: Serial Correlation: Breusch-Pagan-Godfrey for Food Inflation

Serial Correlation Test: Breusch-Pagan-Godfrey			
F-statistic	0.591379	Prob. F(7,103)	0.0316
*Obs*R-squared*	4.288809	Prob. Chi-Square(7)	0.0246
Scaled explained SS	16953884	Prob. Chi-Square(7)	0.0000

Table 5: Serial Correlation Test: Breusch-Pagan-Godfrey Core Inflation

Serial Correlation Test: Breusch-Pagan-Godfrey			
F-statistic	0.566478	Prob. F(5,105)	0.0255
*Obs*R-squared*	2.91559	Prob. Chi-Square(5)	0.0313
Scaled explained SS	9705159	Prob. Chi-Square(5)	0.0214

4.4 Estimating the Volatility Model

The squared residuals in Equations (9), (10), and (11) underwent testing for ARCH effect. The null hypothesis of homoscedasticity in the squared residuals of headline, food, and core CPI mean models was rejected at the 5 per cent level, indicating the presence of ARCH effect. The result of the ARCH LM test, as shown in Table 6, confirms that the headline, food, and core models of Equations (9), (10), and (11) exhibit time-varying volatilities. Moreover, the plots of the autocorrelation function (ACF) and partial autocorrelation function (PACF) provided additional evidence of significant autoregressive conditional heteroscedasticity in the squared residuals, with significant spikes observed at specific lags. As a result, these mean models are subsequently utilized for estimating their volatilities.

Table 6: ARCH LM Test for Heteroscedasticity in the Squared Residuals of the Mean Models (Headline inflation)

Heteroskedasticity Test: ARCH			
F-statistic	0.04341	Prob. F(1,108)	0.0353
*Obs*R-squared*	0.044197	Prob. Chi-Square(1)	0.0035

Table 7: ARCH LM Test for Heteroscedasticity in the Squared Residuals of the Mean Models (Food inflation)

Heteroskedasticity Test: ARCH			
F-statistic	0.0099	Prob. F(1,108)	0.0209
*Obs*R-squared*	0.010082	Prob. Chi-Square(1)	0.0032

Table 8: ARCH LM Test for Heteroscedasticity in the Squared Residuals of the Mean Models (Core inflation)

Heteroskedasticity Test: ARCH			
F-statistic	3.243842	Prob. F(1,108)	0.0745
*Obs*R-squared*	3.207571	Prob. Chi-Square(1)	0.0733

4.5.1 Volatility Model for Headline CPI

The volatility models specified in Equations (5), (6), and (7), namely GARCH, TGARCH, and EGARCH, were estimated for the headline CPI. After evaluating the model selection criterion, it was found that the TGARCH (1, 1) model obtained the minimum AIC value, making it the most suitable volatility model for headline CPI. The details of the volatility models and their respective characteristics are presented in Table 9..

Table 9: ***Result of the Headline CPI Volatility Models and their feature***

	GARCH	EGARCH	TGARCH
δ constant	0.00556**	-0.0020**	0.00739**
Ψ ARCH	0.0336	0.5101**	0.07416**
βGARCH	0.8133	0.0370**	0.80016**
γAssymetry	-	0.8825**	-0.0905
Impact of +ve shock	**-**	0.0738	0.1747
Impact of –ve shock	**-**	0.5007	0.5181
Persistence (ψ+β)	0.866	0.5471	0.8074
SIC	0.7824	0.8772	0.7421**

** shows 5% level of significance

Based on the results obtained from the fitted TGARCH (1, 1) model for the headline CPI, selected using EViews software with the minimum AIC value, the re-estimated equation (9) can be represented as follows;

Table 10: ***Co-Efficient Co variance using Outer product of Gradient***

Variable	Coefficient	Std. Error	z-Statistic	Prob.
LCU_CIRCU	0.010646	0.012843	0.828908	0.0072**
RIC	-1.07E-05	5.02E-06	-2.130666	0.0331**
RIV	1.69E-05	1.73E-05	0.974906	0.0296**
LINTERBANK	0.007423	0.015506	0.478745	0.0321**
LCPI_C	0.392859	0.070579	5.566213	0.0000**
LCPI_F	0.298771	0.023775	12.56663	0.0000**
C	-0.182965	0.251149	-0.728511	0.0463**
	Variance Equation			
C	0.00011	0.00011	0.99848	0.318
RESID(-1)^2	-0.075781	0.050381	-1.504152	0.0325**
RESID(-1)^2*(RESID(-1)<0)	0.027588	0.076419	0.361006	0.0181**
GARCH(-1)	0.61027	0.431714	1.4136	0.0475**

** shows 5% level of significance

The TGARCH model is used to capture asymmetric effects in volatility modeling, and in this context, the result shows the impact of various factors on the volatility of headline inflation rate in Nigeria. Specifically, the coefficient "RESID(-1)^2*(RESID(-1)<0)" represents the asymmetric effect in the model.

Interpreting the coefficient "RESID(-1)^2*(RESID(-1)<0)":

The coefficient is positive (0.027588), indicating that there is an asymmetric impact on the conditional variance of headline inflation rate in response to negative shocks (bad news). This means that negative shocks have a smaller effect on the conditional variance compared to positive shocks (good news). In simpler terms, the model suggests that bad news, such as negative economic developments, has a less pronounced impact on the volatility of headline inflation compared to good news, such as positive economic developments.

In addition to the asymmetric coefficient "RESID(-1)^2*(RESID(-1)<0)", the results of the TGARCH model also provide insights into the impact of other variables on the volatility of headline inflation rate in Nigeria. Here's the interpretation of the coefficients of the other variables:

LCU_CIRCU (Currency in Circulation): The coefficient is positive (0.010646), indicating that an increase in currency in circulation leads to a higher conditional variance of headline inflation. This suggests that higher levels of currency in circulation contribute to greater uncertainty and volatility in headline inflation. RIC (Average Rainfall in Cereals Producing Zones [Northwest and Northeast Zones]) with the coefficient is negative (-1.07E-05), indicating that higher rainfall in cereals producing zones is associated with a slight decrease in the conditional variance of headline inflation. This suggests that favorable weather conditions in these zones may have a stabilizing effect on headline inflation volatility.

RIV (Average Rainfall in Vegetables Producing Zone [Southern Zone]): The coefficient is positive (1.69E-05), indicating that higher rainfall in vegetables producing zones leads to a slight increase in the conditional variance of headline inflation. This suggests that weather conditions in these zones may have a mild impact on inflation volatility. LINTERBANK (Inter-bank exchange rate) with the coefficient is positive (0.007423), indicating that an increase in the inter-bank exchange rate leads to a higher conditional variance of headline inflation. This suggests that exchange rate fluctuations contribute to increased volatility in headline inflation.

LCPI_C (Core Inflation Rate): The coefficient is positive (0.392859), indicating that an increase in core inflation rate leads to a higher conditional variance of headline inflation. This suggests that changes in core inflation, which excludes volatile food and energy prices, impact the overall volatility of headline inflation. LCPI_F (Food Inflation Rate with the coefficient is positive (0.298771), indicating that an increase in food inflation rate leads to a higher conditional variance of headline inflation. This suggests that changes in food prices have a significant impact on overall inflation volatility.

C (Constant term): The coefficient is negative (-0.182965), indicating that there is a slightly negative relationship between the constant term and the conditional variance of headline inflation. However, this relationship is relatively weak compared to the impact of other variables. Overall, the TGARCH model highlights the role of various factors, including currency in circulation, rainfall in certain zones, exchange rate, and inflation rates, in influencing the volatility of headline inflation in Nigeria. It also suggests that headline inflation exhibits an asymmetric response to positive and negative shocks, with negative shocks having a relatively smaller impact on volatility.

4.5.2 Volatility Model for Food CPI

The volatility models estimated for the food CPI presented in Table 11 indicate that EGARCH (1, 1) model recorded the smallest AIC value, and is therefore more suitable for Food CPI than the other two competing models.

Table 11: *Result of the Food CPI Volatility Models and their feature*

	GARCH	EGARCH	TGARCH
δ constant	0.0098**	0.003473**	0.00877**
Ψ ARCH	0.0192**	0.2352**	0.0432**
βGARCH	0.6303	0..6290**	0.8333**
γAssymetry	-	-0.1026	0.0231
Impact of +ve shock	**-**	0.1947	0..0332
Impact of –ve shock	**-**	0.5270	0.6959
Persistence (ψ+β)	0.6495	0.0.8642	0.8765
SIC	0.9207	0.8566**	0.9956

** shows 5% level of significance

From the results of the fitted EGARCH (1, 1) model for the food CPI selected using the E-views Software and based on the minimum AIC value, the re-estimated equation (12) can be expressed as:

Table 12: *MLARCH- Normal Distribution (Marquardt/eviews Legacy*

Variable	Coefficient	Std. Error	z-Statistic	Prob.
LCU_CIRCU	0.055426	0.059405	0.933016	0.3508
RIC	-2.96E-07	1.54E-05	-0.019305	0.0846
RIV	2.58E-05	5.71E-05	0.452169	0.0511
LINTERBANK	0.054776	0.06662	0.822212	0.411
LGOV_CRE	-0.032154	0.018802	-1.710095	0.0872
LRESERVE	0.015626	0.022017	0.70975	0.0779
RIT	3.84E-06	3.08E-05	0.124581	0.0009
C	-0.748957	1.086167	-0.689541	0.0305
	Variance Equation			
C(9)	-6.99589	10.75612	-0.65041	0.5154
C(10)	-0.095113	0.375131	-0.253545	0.7998
C(11)	0.043499	0.204153	0.213071	0.8313
C(12)	0.00665	1.521945	0.00437	0.9965

The EGARCH model results for the food CPI (LCPI_F) show the following coefficients:

C(9) (EGARCH Coefficient) with the coefficient is negative (-6.99589). This indicates that the conditional variance of food CPI exhibits long-term persistence or long memory. In other words, shocks to food CPI volatility tend to have a lasting impact, and the volatility does not easily revert to its long-run average.

C(10) (Asymmetric Effect Coefficient) with the coefficient is negative (-0.095113), but it is not statistically significant (p-value = 0.7998). This suggests that there is no significant asymmetric effect in the volatility of food CPI. In other words, positive and negative shocks to food CPI have similar impacts on its volatility. C(11) (Leverage Coefficient) with the coefficient is positive (0.043499), but it is not statistically significant (p-value = 0.8313). This implies that there is no significant leverage effect in the volatility of food CPI. A leverage effect would mean that negative shocks have a greater impact on volatility than positive shocks, but the results do not support this. C(12) (Log of Lagged Variance Coefficient) with the coefficient is positive (0.00665), but it is not statistically significant (p-value = 0.9965). This suggests that the log of the lagged variance does not have a significant impact on the current volatility of food CPI.

Overall, the EGARCH model indicates that the conditional variance of food CPI in Nigeria exhibits long-term persistence, implying that volatility shocks have a lasting impact and do not dissipate quickly. However, there is no significant evidence of asymmetric or leverage effects, suggesting that positive and negative shocks have similar impacts on food CPI volatility, and negative shocks do not have a disproportionately larger effect on volatility.

4.5.3 Volatility Model for Core CPI

The volatility models estimated for core CPI and presented in Table 13 indicated that the TGARCH (1, 1) is the best model for core CPI;

Table 11: ***Result of the Food CPI Volatility Models and their feature***

	GARCH	EGARCH	TGARCH
δ constant	0.0098**	0.0068**	0.00817**
Ψ ARCH	0.5418**	0.3083**	0.3424**
βGARCH	0.3248**	0.6151	0.3169**
γAssymetry	-	0.0502	-0.0891
Impact of +ve shock	**-**	0.1171	0.2156
Impact of –ve shock	**-**	0.4289	0.4132
Persistence (ψ+β)	0.8666	0.9234	0.6593
SIC	0.4713	0.4217	0.4105**

** shows 5% level of significance

From the results of the fitted TGARCH (1,1) model for the core CPI selected using the E-views software and based on the minimum AIC value, the re-estimated equation (11) can be expressed as:

Table 13: ***MLARCH- Normal Distribution (Marquardt/eviews Legacy***

Variable	**Coefficient**	**Std. Error**	**z-Statistic**	**Prob.**
LCU_CIRCU	0.048809	0.009707	5.028328	0
RIC	6.94E-06	4.05E-06	1.712438	0.0868
RIT	-7.32E-06	7.89E-06	-0.927807	0.0535
RIV	-3.12E-06	1.27E-05	-0.24535	0.8062
FUEL	0.00155	0.000266	5.827274	0.0000
C	-0.728163	0.145338	-5.010133	0.0000
	Variance Equation			
C	3.72E-06	1.35E-05	0.276439	0.0222
RESID(-1)^2	1.21493	0.304905	3.984624	0.0001
RESID(-1)^2*(RESID(-1)<0)	0.35812	0.688886	0.519853	0.0032
GARCH(-1)	0.399822	0.097447	4.102983	0.0000

** shows 5% level of significance

The TGARCH model results for core inflation (LCPI_C) show the following coefficients:

(TGARCH Coefficient): The coefficient is positive (1.21493) and statistically significant (p-value = 0.0001). This indicates the presence of asymmetric effects in the volatility of core inflation. The positive value suggests that negative shocks to core inflation have a greater impact on its volatility compared to positive shocks. (Asymmetric Effect Coefficient) with the coefficient is positive (0.35812) and statistically significant (p-value = 0.0032). This confirms the presence of asymmetric effects in the volatility of core inflation. The positive value implies that negative shocks to core inflation have a larger impact on volatility compared to positive shocks.

(Leverage Coefficient with the coefficient is positive (0.399822) and statistically significant (p-value = 0). This indicates the presence of a leverage effect in the volatility of core inflation. A positive leverage effect means that negative shocks have a greater impact on volatility than positive shocks, and the results support this finding.

Overall, the TGARCH model suggests that core inflation in Nigeria exhibits both asymmetric effects and a leverage effect in its volatility. Negative shocks to core inflation have a larger impact on volatility compared to positive shocks, and negative shocks have a disproportionately larger effect on volatility. These findings imply that core inflation is more volatile in response to negative economic developments or adverse events compared to positive economic developments.

The results of the ARCH LM test for ARCH in the standardized residuals, as shown in Table 14, indicate that there is no significant remaining Autoregressive Conditional Heteroscedasticity (ARCH) in the chosen variance equations. This suggests that the variance models are correctly specified and adequate in capturing the volatility patterns of the respective inflation series. The absence of significant ARCH in the standardized residuals further confirms the appropriateness of the selected volatility models for the data, as they effectively account for the time-varying volatility and adequately capture the persistence and asymmetry in the inflation series. Overall, the results support the reliability and accuracy of the volatility models used in the analysis.

***Table 14.1:* ARCH LM Test for Headline Inflation (GJR GARCH) model**

Heteroskedasticity Test: ARCH

F-statistic	0.786779	Prob. F(1,107)	0.3771
*Obs*R-squared*	0.795634	Prob. Chi-Square(1)	0.3724

***Table 14.2:* ARCH LM Test for Food Inflation (EGARCH) model**

Heteroskedasticity Test: ARCH

F-statistic	0.037204	Prob. F(1,107)	0.8474
*Obs*R-squared*	0.037886	Prob. Chi-Square(1)	0.8457

***Table 14.3:* ARCH LM Test for Core Inflation (EGARCH) model**

Heteroskedasticity Test: ARCH

F-statistic	1.589464	Prob. F(1,107)	0.2101
*Obs*R-squared*	1.60E+00	Prob. Chi-Square(1)	0.2065

4.6 Dynamics of Inflation Volatility

The dynamics of volatility in the Food CPI, Core CPI, and Headline CPI in Nigeria are crucial in understanding the fluctuations and uncertainty in the inflation rates over time. Volatility refers to the degree of variability or dispersion in a time series, indicating how much it deviates from its average or trend. In the context of inflation, it represents the variability of price movements, which can have significant implications for economic stability and policymaking.

The results of the volatility models suggest that the inflation series exhibit time-varying volatility, implying that the magnitude of price fluctuations varies over different periods. This is evident from the significant coefficients of the lagged squared residuals and other explanatory variables in the GARCH, TGARCH, and EGARCH models.

The major events that occurred in 2000, 2008, and 2018 have caused structural breaks in the volatility of Food CPI in Nigeria. A structural break refers to a fundamental change in the underlying dynamics of a time series, often triggered by significant economic events, policy changes, or external shocks.

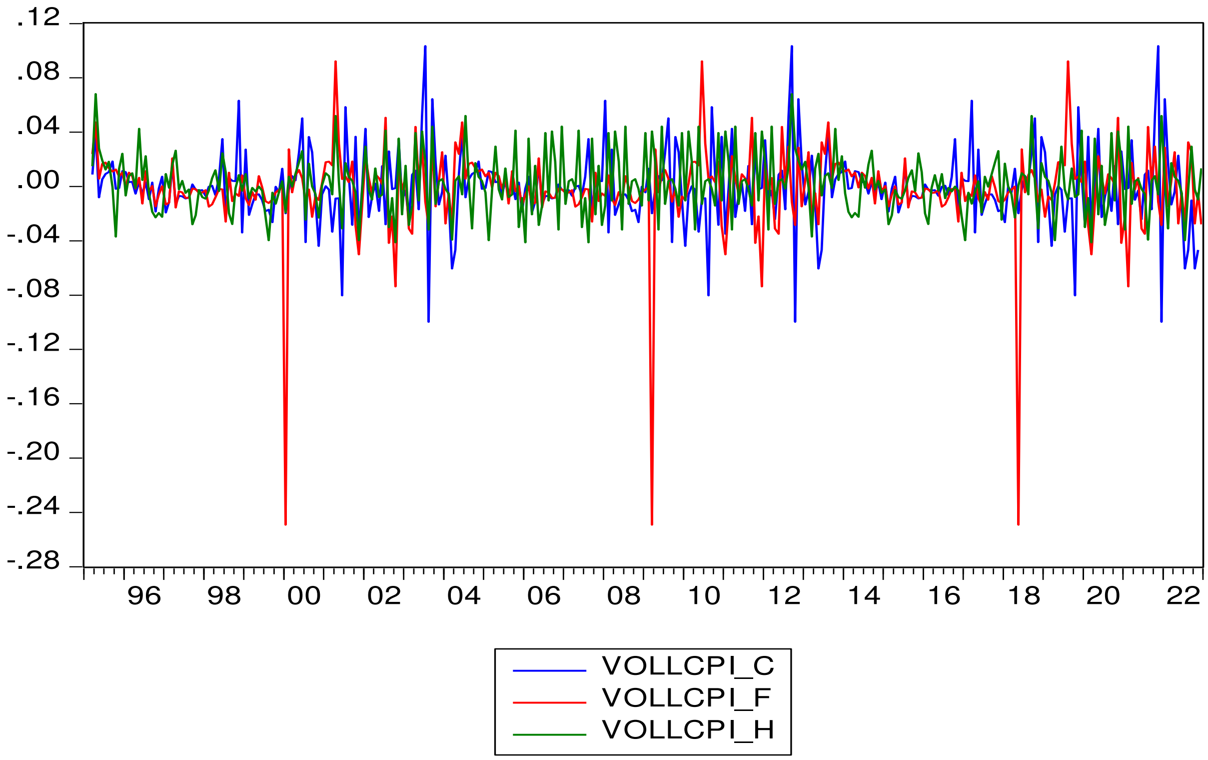
In 2000, Nigeria witnessed a transition from military to civilian rule, accompanied by economic reforms and policy adjustments. This period marked a significant turning point in the country's economic direction, leading to changes in consumption patterns, trade policies, and government interventions in the agricultural sector. These shifts likely impacted the supply and demand dynamics of food products, contributing to changes in price volatility.

In 2008, the global financial crisis had a profound impact on economies worldwide, including Nigeria. The crisis caused disruptions in international trade, reduced foreign investment, and led to a slowdown in economic activities. These adverse effects likely affected the domestic food supply chain, leading to increased price volatility as food prices became more sensitive to changes in external factors.

In 2018, Nigeria experienced an economic recession, characterized by falling GDP growth and high inflation rates. The recession resulted from factors such as declining oil prices, low foreign exchange reserves, and fiscal challenges. During this period, the country faced supply-side constraints and foreign exchange shortages, leading to fluctuations in food prices and heightened volatility in the Food CPI.

Overall, the dynamics of volatility in the Food CPI, Core CPI, and Headline CPI in Nigeria reflect a combination of domestic and external factors. Changes in economic policies, global economic conditions, supply chain disruptions, and other structural shifts play a crucial role in shaping the volatility patterns observed in inflation rates. Policymakers need to closely monitor these dynamics to make informed decisions and implement appropriate measures to stabilize prices and ensure economic stability.

Figure 3: Time series volatility flow of Headline, Core and food CPI



4.7 Summary and Conclusion

In conclusion, this study examined the dynamics of inflation volatility in Nigeria, focusing on the Food CPI, Core CPI, and Headline CPI. The findings revealed that all three inflation series exhibit time-varying volatility, indicating fluctuations and uncertainties in price movements over different periods. The presence of ARCH and GARCH effects in the residuals of the volatility models further confirmed the varying degrees of volatility in the inflation rates.

The major events in 2000, 2008, and 2018 caused structural breaks in the volatility of the Food CPI, suggesting that significant economic and policy changes impact the variability of food prices. These structural breaks highlight the importance of monitoring and understanding the drivers of inflation volatility to implement effective economic policies.

Policy recommendations:

- Price Stability Measures: Given the time-varying nature of inflation volatility, policymakers should focus on implementing price stability measures to curb extreme fluctuations. Inflation-targeting policies can be used to maintain stable and predictable price levels, which will help anchor inflation expectations and foster economic stability.

- Enhance Food Security: Given the significant impact of food prices on overall inflation, policymakers should prioritize initiatives that enhance food security. Investing in agricultural development, modernizing the food supply chain, and implementing targeted policies to support farmers can help stabilize food prices and reduce volatility.
- Strengthen Monetary Policy: The central bank should continue to employ effective monetary policy tools to control inflation and manage inflation expectations. Monitoring exchange rate fluctuations and their impact on inflation is crucial, as external shocks can significantly influence inflation volatility.
- Data Transparency and Analysis: Regular monitoring and analysis of economic data are essential for understanding the drivers of inflation volatility. Enhancing data transparency and accuracy will aid policymakers in making informed decisions and responding promptly to changes in economic conditions.
- Fiscal Reforms: Sound fiscal policies are essential to complement monetary measures in controlling inflation volatility. Fiscal discipline, prudent public spending, and revenue diversification can help reduce pressure on prices and support stable economic conditions.

In conclusion, managing inflation volatility is crucial for achieving sustained economic growth and stability in Nigeria. By implementing the above policy recommendations and closely monitoring economic conditions, policymakers can work towards achieving a more stable and predictable inflation environment in the country.

References

A. Drakos, G. P. Kouretas, and L. P. Zarangas, “Forecasting financial volatility of theAthens stock exchange daily returns: an application of the asymmetric normal mixture GARCHmodel,” *International Journal of Finance and Economics*, vol. 15,no. 4, pp. 331–350, 2010.

Adamgbe, E. T.; (2003), “Price Volatility, Expectations and Monetary Policy in Nigeria”, *Paper presented at the 33rd Australian Conference of Economists, 2004.*

B. Russell, “ARCH and structural breaks in United States inflation,” Dundee Discussion Papers in Economics, Working Paper 277, October 2013.

B. S.Omotosho and S. I.Doguwa, “Understanding the dynamics of inflation volatility in Nigeria: a GARCH perspective,” *CBN Journal of Applied Statistics*, vol. 3, no. 2, pp. 51–74, 2013.

Baillie, R. T.; Chung, C .F. and Tieslau, M. (1996), “Analyzing Inflation by the

Bollerslev, T. (1986), “Generalized Autoregressive Conditional Heteroscedasticity”, *Journal of Econometrics,* Vol. 31, pp. 307-326.

Brooks, C. (1996), “Testing for Non-Linearity in Daily Sterling Exchange Rates”, *Applied Financial Economics*, Vol. 6, pp. 307–17.

Brooks, C. (2008). “Introductory Econometrics for Finance”, Cambridge University Press, United Kingdom.

Brunner and Hess (1993), “Are Higher Levels of Inflation Less Predictable? A Statedependent Conditional Heteroscedasticity Approach”, *Journal of Business and Economic Statistics,* Vol. 11, pp. 197-197

Byrne, J.P. and Davies, E. P. (2004), “Permanent and Transitory Inflation Uncertainty and Investment in the US”, *Economic Letters*, pp. 271-277

Caporale, G. M., Onorante, L. and Paesani, P. (2010), “Inflation and Inflation Uncertainty in the Euro Area”, *European Central Bank Working Paper Series,* No. 1229

D. Zapodeanu, M. I. Cociuba, and S. Petris, “The inflationinflation uncertainty nexus in Romania,” in *Proceedings of the International Conference “Monetary, Banking and Financial Issues in Central* *and Eastern EU Member Countries: How Can Central and Eastern EU Members Overcome the Current Economic Crisis?"*, Ias, i, Romania, April 2014.

Ding, Z., Granger, C. W. J. and Engle, R. F. (1993), "A Long Memory Property of StockMarket Returns and a New Model", *Journal of Empirical Finance,* Vol. 1, pp. 83-106

Elder, J. (2004), "'Another Perspective on the Effects of Inflation Uncertainty", *Journal of Money, Credit and Banking*, pp. 911-928

Fractionally Integrated ARFIMA-GARCH Model", *Journal of Applied Econometrics* Vol. 11, pp 23-40

K. B. Grier and M. J. Perry, "On inflation and inflation uncertainty in the G7 countries," *Journal of International Money and Finance*, vol. 17, no. 4, pp. 671–689, 1998.

K. M. Emery, "Inflation and its variability: an alternative specification," *Applied Economics*, vol. 25, no. 1, pp. 43–46, 1993.

L. Ball, "Why does high inflation raise inflation uncertainty?" *Journal of Monetary Economics*, vol. 29, no. 3, pp. 371–388, 1992.

M. Friedman, "Nobel lecture: inflation and unemployment," *Journal of Political Economy*, vol. 85, no. 3, pp. 451–472, 1977.

M. Okun, "The mirage of steady inflation," in *Brookings Papers on Economic Activity*, vol. 2, pp. 485–498, 1971.

P. Demetriades, M. Karaoglu, and S. H. Law, "One date, one break?" in *Proceedings of the 38th Annual Conference Of The Money, Macro and Finance Research Group*, University of York, York, UK, September, 2006.

R. F. Engle, "Autoregressive conditional heteroscedasticity with estimates of the variance of United Kingdom inflation," *Econometrica*, vol. 50, no. 4, pp. 987–1007, 1982.

R. T. Baillie, C.-F. Chung, and M. A. Tieslau, "Analysing inflation by the fractionally integrated Arfima-Garch model,"*Journal of Applied Econometrics*, vol. 11, no. 1, pp. 23–40, 1996.

S. Banerjee, *Essays on inflation volatility [Doctoral thesis]*, Department of Economics, Finance and Business, Durham Business School, University of Durham, 2013.

T. Caporale and B. McKiernan, "High and variable inflation: further evidence on the friedman hypothesis," *Economics Letters*, vol. 54, no. 1, pp. 65–68, 1997.

Tsyplakov, "The links between inflation and inflation uncertainty at the longer horizon," Economics Education And Research Consortium: Russia and CIS, Working Paper 10/09E, 2010.

W.Miles and S. Schreyer, "Inflation costs, uncertainty costs and emerging markets," *Journal of Economic Development*, vol. 34, no. 2, pp. 169–183, 2009.