السنة الرابعة والعشرون، العدد 90 ، شهر ايلول، سنة 2026 تاريخ قبول النشر/2026/6/17

https://doi.org/10.31272/ijes.v24i90.1576

المجلة العراقية للعلوم الاقتصادية
Iraqi Journal For
Economic Sciences

PISSN:1812-8742 EISSE :2791-092X Arcif : 0.375

Analysis of Inflation Behavior in Sudan via Long-Memory Models

تحليل سلوك التضخم في السودان باستخدام نماذج الذاكرة الطويلة (ARFIM) خلال الفترة (2000-2024م)

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المستخلص

تهدف هذه الدراسة الى تحليل سلوك التضخم في السودان باستعمال نماذج السلاسل الزمنية ذات الطويلة، تتمثل مشكلة البحث في التحقق من وجود خاصية الذاكرة الطويلة في سلسلة معدلات التضخم وقد تم اجراء التحليل باستعمال انموذج المتوسطات المتحركة والانحدار الذاتي المتكامل كسريا (ARFIMA) ، ونموذج التباين الشرطي غير المتجانس المعمم المتكامل كسريا (FIGARCH(`وذلك بالاعتماد على بيانات شهرية تغطي الفترة من يناير 2002م الى ا ديسمبر 2020م ، واظرت نتائج الدراسة وجود ذاكرة طويلة في سلسلة التضخم، حيث بلغ معامل التكامل الكسري (0.43)، وتصي الدراسة باستخدام نموذج ARFIMA في تحليل التضخم في السودان، اذ تبين انه افضل من نموذج FIGARCH استناداً الى معيار معلومات اكايكي (AIC) ، كما توصى بتبني ساسية نقدية تسهم في تحقيق استقرار التضخم والاقتصاد بصورة عامة، مثل اجراء تعديلات على اسعار الفائدة والتحكم في عرض النقود للحد من الضغوط التضخمية.

الكلمات الرئيسية: التضخم، الذاكرة الطويلة، التنبؤ.

Abstract

This study aims to analyze and forecast inflation behaviour in Sudan. The research problem is to investigate the presence of long memory in the inflation rate series. The analysis was done via autoregressive fractionally integrated moving average (ARFIMA)and FIGARCH (fractionally integrated generalized autoregressive conditional heteroskedasticity) using a monthly series covering the period Jan. 2002–Dec. 2020. The study revealed the existence of long memory in the inflation series, where the fractionally integrated coefficient is 0.43. We recommend the use of ARFIMA in analyzing inflation in Sudan. ARFIMA was preferred to FIGARCH based on Akaike's information criteria. It is also recommended to adopt a monetary policy that leads to stabilizing inflation and the economy as a whole, such as implementing interest rate adjustments and controlling the money supply to mitigate inflationary pressures.

Keywords: inflation, long-memory forecasting, monetary policy

1Introduction

The term "inflation" is the most used economic term, with no consensus on its meaning or causes. It has been used to indicate multifaceted situations, such as the continuous rise in the general price level, monetary wage inflation, profit changes, production cost rises, or excessive money supply expansion. It's not necessarily those phenomena that move together or in the same direction. A price rise might occur without an increase in monetary income; similarly, a cost increase might occur without declining profits, or monetary expansion might occur without a price rise. Thus, those situations highlight inflation complexities. Economic thought has significantly developed in its interpretation of inflation phenomena. The main focus of the 19th-century scholars was the relationship between inflation and money supply and demand for goods and services, whereby a positive movement is expected. John Maynard Keynes introduced a more comprehensive vision of inflation. He focused on monetary-national income determinants, that is, the propensity to consume, interest rate, and marginal efficiency of capital(Abdul Rahman and Arikat, 1999. According to this perspective, inflation occurs when the aggregate demand exceeds the real supply of goods and services, which leads to a series of successive rises and declines in the general price level. Thus, the essence of inflation is the excess demand over the available productive capacity. The development path continued. In the middle of the 20th century was the emergence of the modern Swedish school of thought emerged, focusing on expectations, which played a pivotal role in the interpretation of the inflation phenomenon. The school envisioned that the relationship between aggregate demand and aggregate supply does not solely depend on expense plans and national production; rather, it is also influenced by the balance between investment plans and saving plans, as well as the expectations of individuals and firms regarding the economy's future. Thus, inflation is a complex economic phenomenon that encompasses the interactions of real, monetary, and behavioural elements.

1.2The Study Problem: To detect the presence of long memory in the inflation rate series, the following research question must be answered.

Does the inflation rate in Sudan exhibit the characteristics of long memory models (ARFIMA)?

Can long memory models (ARFIMA) provide better forecasts than traditional ARMA models?

1.3The Study objectives: to investigate the presence of long memory in the inflation rate series by answering the following research questions.

1- Testing the presence of long memory property in the inflation series in Sudan,

2- Estimation of the fractional integration parameter (d).
3- Building an appropriate ARFIMA model for inflation in Sudan

1.4The Study hypotheses:

1-The inflation series in Sudan has a long memory during the study period.
2-Economic shocks have a long-lasting impact on inflation in Sudan during the study period.

1.5 The Importance of the Study:

1- Presenting a modern model for the Sudanese economy.
2-Supporting the Central Bank of Sudan in making monetary policy decisions.

1.6Methodology: An autoregressive fractionally integrated moving average will be implemented to detect if there is any long memory in the inflation rate series. Sudan has been suffering recently from very high and volatile inflation rates as a result of excessive expansion of the money supply, whereby the government resorts to money printing as a major source of financing. Another factor that exacerbated the situation is the continuous devaluation of the Sudanese currency, twin gaps, and foreign shocks, which include fluctuations in global commodity prices and changes in international aid flows. Developing countries often suffer from long memories. Such behaviour means that the effects of shocks will last for a long time, and for this reason, the ARFIMA models become a suitable analytical tool to detect those long memories. To my knowledge, no one has addressed the existence of long memory in the inflation rate series. To this end, I will apply the ARFIMA (Autoregressive Fractional Integrated Moving Average) models to ensure there is such long memory in the inflation rate series. The paper is composed of an introduction, a literature review, the model, results, and a conclusion.

2. Literature Review: Many scholars have applied long memory models to many economic indicators, such as Adam's (2025) study, which compared the results of the Box-Jenkins approach to ARFIMA and exponential smoothing for the prediction of Sudan's nominal effective exchange rate from January 1994 to June 2018. The study used ARFIMA to detect long memory, and the results surpassed exponential smoothing and Box-Jenkins. Madory (2017) conducted a similar analysis, comparing the outcomes of a neural network and ARFIMA for the Algerian dinar versus the US dollar, euro, and sterling using monthly data. The results demonstrated that the Artificial Neural Network (ANN)is the best prediction technique for the Dinar against the Sterling, while ARFIMA performed similarly to the ANN against the Euro and the dollar. Saad and Elsayed (2023) used ARFIMA to determine the presence of long memory in the "EGX30" of the Egyptian stock exchange, using monthly data from January 2015 to December 31, 2017. Arabi and Elotiabi (2021) examined

the existence of long memory in the returns of the Tadawul All Shares Index (TASI) and its realized volatility from January 26, 1994, to December 31, 2020. The researchers examined the presence of long memory using four models: the autoregressive fractionally integrated moving average for returns (ARFIMA_R), for realized volatility (ARFIMA_RV), a heterogeneous autoregressive model (HAR), and a combination of HAR and GARCH (RARFIMA) across the entire period as well as in uptrend and downtrend samples. Long memory was evident in both raw returns and realized volatility, which was consistently positive across all models. Furthermore, dividing the entire sample into six subsamples yielded values that were close to positive but below the threshold for long memory as determined by ARFIMA and the combination of ARFIMA-HAR models. Louzis et al. al (2012) accounted for the presence of heterogeneous leverage effects and the persistence in the volatility of stock index realized volatility. The Heterogeneous Autoregressive (HAR) Realized Volatility (RV) model is extended in order to account for asymmetric responses to negative and positive shocks occurring at distinct frequencies, as well as for the long-range dependence in the heteroscedastic variance of the residuals. Compared with established HAR and Autoregressive Fractionally Integrated Moving Average (ARFIMA) realized volatility models, the proposed model exhibits superior in-sample fitting, as well as out-of-sample volatility forecasting performance. The latter is further improved when the Realized Power Variation (RPV) is used as a regressor, while we show that our analysis is also robust against microstructure noise. The current study is consistent with the previous studies in that the ARFIMA technique is appropriate for identifying long-term memory of economic variables. However, the usage of artificial neural networks (ANNs) in several studies is unrelated to the current research.

3. Theoretical Background: Generally, the inflation rate is defined as the continuous rise in prices; some prices might show a downward trend, but the general rise in prices should be continuous and show an upward trend, as well as eliminate those prices that increase only once. Samuelson defined inflation as the continuous rise in the general price level and factors of production (Abu Saoud 1997). Friedman defined inflation as a monetary phenomenon in every situation. The complexities of the money supply are the main source of changes in prices (Siegel 1987). To reduce inflation, the state should decrease the money supply. Demand-pull inflation arises when aggregate demand exceeds aggregate supply of goods and services. Cost-push inflation occurs when the prices of production factors rise. This notion refers to Wicksell and Keynes' efforts to create the quantity theory (Zaki1980). Structural inflation is linked to capitalism's

production and the principles that regulate economic activity. Inflation impacts how the national income is distributed among classes, particularly among the wealthy. The high-income class benefits at the expense of the lower-income classes. Dependence: Inflation has an impact on growth rates and savings, particularly in emerging countries that rely on deficit finance to fund fixed capital construction, which requires obligatory saving. Inflation affects exports by increasing production costs and decreasing export competitiveness, resulting in lower export volumes and a negative impact on the overall economy. Inflation has a significant impact on imports since rising costs make imported items less expensive than local goods. Thus, inflation affects the balance of payments negatively. Inflation reduces purchasing power and annual income, so the cash flow will differ from one period to another. Causes of inflation according to economists (Abdul Rahman and Arikat 1999; Mubarak 2012)

1/ Increase in production costs: Such as the rise in raw material prices or wage increases due to pressure from labour unions to cope with the rise in the prices of goods and services.

2/ Demand-pull inflation (which occurs due to an excess in demand that is not matched by real production).

3/Economic sanctions imposed on countries lead to inflation due to the prevention of external trade.

4/ The rise in interest rates as economists believe that economic prosperity occurs when interest rates approach zero.

Types of inflation:

1/Accelerating inflation: This type describes the increase in prices at rates higher than creeping inflation over shorter periods (Salman et.al. 1999).

2/ Suppressed inflation: This type describes a situation where prices are controlled by the responsible authorities, so if prices were left without countermeasures, they would rise. However, the authorities' intervention has stabilized prices at levels that do not reflect the actual situation. This is a temporary situation where either the authorities can correct the economic conditions through their measures, such as fixed prices and rationing, or things get out of hand and inflation accelerates, or the situation worsens, and inflation becomes rampant (Ahmed 2012).

3/Cyclical Inflation: It is the inflation that occurs due to changes in aggregate supply and aggregate demand and is linked to economic cycles. Inflation is a closed economic condition, and perhaps the most dangerous types are galloping and runaway inflation. In such cases, people lose confidence in the country's currency, and economic conditions become unstable.

4/Hyperinflation: This type of excessive inflation, which is considered the most dangerous type for the national economy, appears due to a sharp and

excessive increase in the amount of money in circulation, coupled with a decrease in the quantity of goods available. This is a result of the unusual conditions that the national economy may go through. This type is characterized by a sharp rise in price levels, followed by an increase in wages and costs, which may lead to another rise in prices.

5/Volatile inflation: This type of inflation is characterized by a sharp increase in prices for a certain period, which may prompt government and monetary authorities to intervene in limit that increase for a subsequent period. Then, prices rise again freely and at high rates for later periods.

1/The impact of inflation on the distribution of national income (Morsi 1951): Perhaps one of the worst economic effects resulting from inflation in a national economy that largely relies on market forces is the effect it has on the distribution of national income among different social classes and groups. Inflation seizes part of the community's wealth for the benefit of some of its members.

2/ The impact of inflation on savings and economic growth (Zaki 1980): The study of inflation's impact on savings and economic growth in developing countries is, in fact, one of the important issues that sparked extensive intellectual debate among economists in the 1950s and 1960s of this centuries. The debate at that time revolved around the possibility of these countries relying on inflationary financing as an appropriate policy for financing the formation of fixed capital, through the compulsory savings that result from this policy.

3/The effect of inflation on exports (Saleh 1981; Kashmiri 1953): Inflation exerts its negative impact on exports through an increase in production costs in the export-producing sectors, which weakens the competitive strength of the country's exports in foreign markets. The effect is particularly evident in the case of export products for which the country does not hold a monopolistic position in the global market, as it cannot pass on the burden of the cost increase caused by inflation to the buyer or consumer in foreign markets.

3.1Autoregressive Fractionally Integrated Moving Average (ARFIMA) While the moving average component describes the current disturbance as a weighted aggregate of current and lagged innovations, the autoregressive component of ARIMA (and ARFIMA) incorporates the residuals from previous observations into the current model. To achieve stationarity and invertibility, Baum (2013) noted that both autoregressive and moving average polynomials require estimation via (fractional) differencing. Granger and Joyeux(1980)defined an autoregressive fractionally differenced moving average (ARFIMA) process, i.e. $\{y_t\}$ as: Where

$$\Phi(B)(1-B)^d y_t = \Theta(B)\varepsilon_t \qquad (1)$$

$\Phi(B) = 1 + \varphi_1 B + \cdots + \varphi_p B^p$,and $\Theta(B) = 1 + \theta_1 B + \cdots + \theta_q B^q$ are The autoregressive and moving average (ARMA) operators, respectively, and the fractional difference term $(1-B)^d = \Sigma_{j=0}^{\infty} \binom{d}{j} B^j$ has a binomial expansion. The ARIMA process is stationary and invertible second-order, assuming that the roots of the polynomials $\Phi.(B)$ and $\Theta(B)$ are outside the unit circle, and the absolute difference, i.e., |d|=1/2. The variance in daily returns is estimated as follows: $r_t = log(P_t/P_{t-1})$ (2)
where P = TASI closing price, t = period, and the log is the natural logarithm. This approach assumes that the average should be set at zero, taking into account upside and downside trends in the stock price movements.

FIGARCH Model: The FIGARCH (Fractionally Integrated Generalized Autoregressive Conditional Heteroskedasticity) model is an econometric time-series framework used to analyze and forecast volatility in financial markets. It extends standard volatility models by allowing "long memory," meaning the impact of past market shocks decays slowly over time (Caporin 2002). The FIGARCH(p, d, q) model defines the conditional variance of a return series as follows: $\Phi(L)(1-L)^d \epsilon_t^2 = \omega + [1 - \beta(L)]v_t$ Where: $(1-L)^d$ is the fractional integration operator (where L is the lag operator) and d is the fractional differencing parameter 0 < d < 1). Φ(L) and β(L) are polynomials of lag operators.

ϵ_t^2 represents the squared innovations (shocks) of the series

* $\Phi(L)$ and $\beta(L)$ are lag polynomials

Key Characteristics

Long Memory: Captures the slow decay of volatility spikes following major market events.

Flexibility: Bridges the gap between short-memory GARCH and infinite-memory IGARCH models.

Persistence: Highly useful for modelling long-horizon risks and extended temporal dependencies in the market

4. Results

4.1 Data: Data on the inflation series for the period January 2002 - Dec. 2020 were obtained from the Sudanese Central Bureau of Statistics.

Table (1) Unit Root Test

Variable	Augmented Dickey-Fuller			Phillips-Perron		
	Level	First diff	2nd diff	Level	Ist diff	2nd diff
inflation	1.00	0.96	0.03**	0.99	0.00***	

The inflation rate is stationary at the first difference under the Phillips-Perron test; however, it attains stationarity at the second difference according to the Augmented Dickey-Fuller test.

Table 2: Estimation Results

Dependent Variable: INF
Method: ARMA Maximum Likelihood (OPG - BHHH)

Date: 02/02/26 Time: 06:29				
Sample: 2002M01 2020M09				
Included observations: 225				
Convergence was achieved after 46 iterations.				
Coefficient covariance computed using the outer product of gradients.				
D	0.435429	0.048624	8.954977	0.000
AR(1)	0.990534	0.013442	73.68785	0.000
SAR(12)	-0.50562	0.037488	-13.4875	0.000
SIGMASQ	22.23446	0.944103	23.55087	0.000
R-squared	0.969921	Mean dependent var		25.85244
Adjusted R-squared	0.969512	S.D. dependent var		27.24877
S.E. of regression	4.757824	Akaike info criterion		6.031868
Sum squared resid	5002.753	Schwarz criterion		6.092598
Log likelihood	-674.585	Hannan-Quinn criterion.		6.056379
Durbin-Watson stat	1.847671			
Inverted AR Roots	0.99	.91+.24i	.91-.24i	.67-.67i
	.67+.67i	.24-.91i	.24+.91i	-.24+.91i
	-.24-.91i	-.67-.67i	-.67-.67i	-.91-.24i
	-.91+.24i			

Economic interpretation of results adheres to economic theory, whereby the sign and the magnitude of the estimated coefficient match the proposition of economic theory. To this end, the fraction integrated coefficient "D" is positively related to the inflation rate with a magnitude of 0.43, which is less than 0.5 to indicate the presence of long memory in the inflation series. Inflationary pressures do not dissolve rapidly; instead, they have prolonged consequences. AR (1), with a value of 0.99, indicates that the inflation rate exhibits a strong dependence on its historical values. The seasonal autoregressive (SAR) indicates a significant level of persistence or robust momentum in the time series. This indicates a significant persistence in inflation, rendering traditional models less effective at forecasting than long-memory models. Secondly, the statistical criterion: The moving average component, SAR (12) with a coefficient of (-0.50), signifies that prior shocks (errors) exert a moderate negative influence on present values. All estimated coefficients are highly significant. The coefficient of determination (R-squared) is 0.97, signifying that the model accounts for approximately 97% of the variation in the dependent variable. Has the model attained the integration phase? Yes, it is integrated of the first order I(1) and functions on the first difference D(INF), indicating that the first difference of the series has been computed to attain stability. This indicates that the initial series (INF) is non-stationary but has achieved stationarity following the first difference. One thousand six hundred fifteen.

Table 3. FIGARCH Estimation Results

Dependent Variable: INF				
Method: ML ARCH - Student's t distribution (BFGS / Marquardt steps)				
Date: 06/11/26 Time: 05:07				
Sample (adjusted): 2002M01 2020M09				
Included observations: 225 after adjustments				
Convergence achieved after 294 iterations				
Coefficient covariance computed using outer product of gradients				
Presample variance: backcast (parameter = 0.7)				
GARCH = C(1) + C(2)*RESID(-1)^2 + C(3)*GARCH(-1)				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
Variance Equation				
C(1)	25.45824	40.88152	0.622732	0.5335
RESID(-1)^2	-0.85599	0.131219	-6.52334	0.0000
GARCH(-1)	-0.98998	0.029223	-33.8771	0.0000
D	0.779653	0.205414	3.795527	0.0001
T-DIST. DOF	45094.34	2.54E+08	0.000178	0.9999
R-squared	-0.90416	Mean dependent var		25.8524

Adjusted R-squared	-0.89569	S.D. dependent var	27.2488
S.E. of regression	37.51725	Akaike info criterion	8.75084
Sum squared resid	316697.4	Schwarz criterion	8.82675
Log likelihood	-979.469	Hannan-Quinn criter.	8.78148
Durbin-Watson stat	0.024331		

Results reveal the significance of the ARCH and GARCH terms, as well as the fractional differencing parameter. Since the estimated d is greater than 0.5 and less than one, this means that the inflation series is integrated and has finite variance. The preference between ARFIMA and FIGARCH is based on Akaike's information criteria, where ARFIMA obtained a low AIC (6.03) compared with FIGARCH (8.65); therefore, ARFIMA is the best model that estimates long memory of the inflation rate series.

5. Conclusion: This study used the autoregressive fractionally integrated moving average technique to examine whether Sudan's inflation rate had a long memory. The presence of long memory is demonstrated by the estimated coefficient "D," which reflects it; its value is less than 0.5, indicating that long memory exists. The ARFIMA technique is recommended to examine the behaviour of economic indicators in general and inflation in particular. The periodic modernization of the technique includes the arrival of new data and the comparison of prediction performances. More attention should be paid to the consolidation of economic and statistical databases, as this would enhance the accuracy of the ARFIMA technique and improve the analysis of economic indicators and inflation trends. Economic policymakers in Sudan should benefit from the results of predictive models to improve decision-making related to inflation.

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