Vol. 2 No. 5 (2024)
e-ISSN: 2963-7589
Economic and Business Journal | ECBIS
https://ecbis.net/index.php/go/index

MODELING AND FORECASTING INFLATION IN ETHIOPIA USING MULTIVARIATE TIME SERIES ANALYSIS

Sedik, Ali*

Department of Statistics, Jigjiga University, Ethiopia
E-mail: hayaan2020@gmail.com

Abstract

Inflation is a fundamental measure of macroeconomic stability that negatively impacts the nation's economy and affects many other macroeconomic variables. Thus, in this study, the major objective was based on modeling and forecasting inflation in Ethiopia and its components using a VAR model. The analysis was based on annual data from 1992 to 2021, encompassing 30 years. The results indicated that all five series were non-stationary at the level but stationary after their first differencing at a 5% level of significance. Johansen's cointegration tests were conducted. The results indicated the presence of at least one co-integration relationship between the variables. The Vector Error Correction Model (VECM) was fitted to model short run and long run relationships among inflation and other macro-econometric series such as GDP growth, government expenditure, money supply, and imports, and the result indicated that the coefficient of error correction term is negative (-0.279), which indicated that the fitted VECM model continues to move toward long run equilibrium and converges. Granger causality tests were employed to explore potential causal relationships. Impulse response analysis and variance decomposition were used to determine the short-run interactions among the variables. Finally, using the fitted model, out-of-sample forecasts were produced, yielding forecasted plots and values for the endogenous variables. According to the forecasted inflation rates for the next five years, prices are projected to decrease by approximately 18.0% in 2022, 6.8% in 2023, and then increase by approximately 8.3% in 2024. Subsequently, prices are expected to decrease by approximately 2% in 2025 and 5% in 2026 over the specified time periods.

Keywords: Co-integration, Forecasting, Granger causality, Inflation, Modeling, VECM

1. INTRODUCTION

Inflation, a fundamental gauge of macroeconomic stability, serves as a key indicator of a government's economic control. Elevated inflation rates signal governance issues and financial mismanagement (Fischer, 1993) . This sustained rise in selected goods' prices impacts economic output, slowing growth, diminishing purchasing power, and lowering living standards (Amisi & Ouma, 2021). Various inflation types, including Demand Pull, Cost Push, and Structural Inflation, exert distinct economic pressures (Ankit, 2011). Balancing price stability and consistent economic growth is crucial for governments globally. High and unstable inflation poses risks to economic growth and social welfare, motivating scholars and policymakers to comprehend the inflationary process (Fischer &

Sahay, 2000). Developing countries, particularly in sub-Saharan Africa, experience significant economic slowdowns due to inflation volatility and uncertainty (Ndiaye & Konte, 2017). Historically, Ethiopia maintained low inflation until conflict and drought triggered major episodes. Recent data from the Central Statistical Agency (CSA) indicates a concerning surge in inflation, reaching 34.5% in January 2022 due to conflict and various macroeconomic instabilities, including droughts and the global impact of events like Russia's invasion of Ukraine (CSA, 2023). This study aims to analyze factors contributing to Ethiopia's recent inflation trends, offering insights for policymakers and researchers.

2. RESEARCH METHOD

High and volatile inflation rates in Ethiopia signal macroeconomic instability, hindering smooth economic development. Despite various empirical investigations, there remains a lack of consensus on the primary drivers of domestic inflation (Danoro, 2020). Some attribute it to supply-side and external factors, while others emphasize demand-side and financial influences. The complexity of Ethiopia's inflation experience over time makes it challenging to explain using traditional macroeconomic approaches, with limited attention given to the relative importance of external, domestic, or structural indicators contributing to recent inflation. Moreover, existing studies often overlook interdependencies among macroeconomic variables and fail to provide accurate inflation forecasts, impeding policymakers' ability to anticipate and respond effectively to inflationary pressures. There is a pressing need for a comprehensive analysis that considers the dynamic interactions among key macroeconomic indicators to enhance our understanding of inflation dynamics and improve forecasting accuracy in Ethiopia. Therefore, the overall aim of this study is to model and forecast inflation in Ethiopia through VAR time series models, which allow for the simultaneous analysis of multiple variables, capture the dynamic interactions among them, and provide a more comprehensive understanding of inflation dynamics. The study aims to accomplish the following goals in particular:

- To model Inflation in Ethiopia using VAR model.
- To investigate short and long run relationship between inflation rate and its determinants.
- To Forecast the overall inflation in Ethiopia based on its determinants.

Hypothesis of the Study

In this study the empirical relationship between inflation rate and its determinants in Ethiopia was investigated. The testable hypotheses are that:

- Null Hypothesis 〖(H〗_0): there is no significant relationship between Inflation rate and its determinants in the long-run.
- Alternative Hypothesis 〖(H〗_1): there is significant relationship between Inflation rate and its determinants in the long-run.

2.1 Data and Variable of the Study

This paper's primary data source and type for its study is secondary macroeconomic time series data. All data used in the analysis was sourced from the National Bank of Ethiopia (NBE) and the Central Statistical Agency of Ethiopia (CSA). The analysis was carried out using 30 annual data points for the analysis of inflation in Ethiopia and the Inflation rate measured by the Consumer Price Index (CPI) of Ethiopia, which spans from 1992 to 2022, as the dependent variable of this study. Moreover, gross domestic product (GDP), broad money supply (M2), import of goods and services (IMP), and Government expenditure (GE) were considered as associated factors with domestic inflation.

2.2 Model Specification

The Multivariate time series models were considered for modeling and forecasting inflation in Ethiopia. The first section was concerned with the Vector Autoregressive (VAR) models for stationary and co integrated variable. In this section model specification and parameter estimation were discussed. The subject of structural vector autoregressive (SVAR) analysis is covered in the second section.

2.2.1 Vector autoregressive (VAR) models

The vector autoregression (VAR) model was first presented by Sims (1980) as a method that macroeconomists might use to describe the collective dynamic behavior of a set of variables without the requirement for stringent limitations similar to those required to determine underlying structural parameters. The basic p-lag vector autoregressive (VAR (p)) model has the form (Hamilton & Susmel, 1994)

$$\mathbf{Y_t = C + \Pi_1 Y_{t-1} + \Pi_2 Y_{t-2} + \cdots + \Pi_p Y_{t-p} + \varepsilon_t, t = 1, 2, \ldots, T} \ldots\ldots\ldots\ldots (1)$$

where $\mathbf{C}$ denotes an n x 1 vector of constants and $\mathbf{\Pi_j}$ is an $n \ x \ n$ matrix of autoregressive coefficients for $j = 1, 2, \ldots, p$. The $n \ x \ 1$ vector $\boldsymbol{\varepsilon_t}$ is a vector generalization of white noise: The functional form of inflation in the term of Consumer Price Index has the following form $\mathbf{lnCPI_t = f\{lnGDP_t, lnM2_t, lnIMP_t, lnGE_t\}}$; is the reduced form of VAR model, then we perform:

$$\mathbf{y_t = C_i + \sum_{j=1}^{4} \Pi_n y_t + v_t \ldots\ldots\ldots\ldots (2)}$$

$\mathbf{y_t}$ is inflation rate measured by consumer price index (**CPI**), $\mathbf{C_i}$ n x 1 vector of constants (intercepts), $\mathbf{\Pi_n}$ represents a $4 \ x \ 4$ matrix of autoregressive coefficients for $j = 1, 2, \ldots, 4$ and the $n \ x \ 1$ vector $\mathbf{v_t}$ is a vector of white noise:

2.2.2 Extension of vector autoregressive model to Vector Error Correction model

In this study, after conforming the existence of co-integration between the series. VEC model was estimated in order to examine both short-run and long run causality between price inflation and other macroeconomic variables.

The relevant error correction representations need to be incorporated into the system when the variables are cointegrated. By doing so, one can avoid misspecification and omission of the important constraints. Thus, the VAR model can be reparametrized as a **Vector Error Correction Model** (VECM) form:

$$\mathbf{\Delta Y_t = \Pi Y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-1} + \alpha\beta X_t + \varepsilon_t} \ldots\ldots\ldots (3)$$

Where: $\mathbf{\Pi = \sum_{i=1}^{p} A_i + I_n, \Gamma_i = -\sum_{i=1}^{p} A_j}$,and $\mathbf{I_n}$is the identity matrix.

By Modeling inflation measured by consumer price index based on this study. Therefore, **Vector Error Correction** (VEC) Model can be formulated as follows:

$\mathbf{\Delta CPI_t} = \alpha_0 - \boldsymbol{\beta}\mathrm{ECT}_{t-1} + \sum_{\mathbf{i=1}}^{\mathbf{2}} \Delta\Gamma_{1i}\mathrm{CPI}_{t-i} + \sum_{i=1}^{2} \Gamma_{2i}\Delta\mathrm{GDP}_{t-i} + \sum_{i=1}^{2} \Gamma_{3i}\Delta\mathrm{GE}_{t-i} + \sum_{i=1}^{2} \Gamma_{4i}\Delta\mathrm{IMP}_{t-i} + \sum_{i=1}^{2} \Gamma_{5i}\Delta\mathrm{M2}_{t-i} + \varepsilon_t$ ……… (4)

Where:

$\mathbf{\Delta CPI_t}$ represent first differenced of consumer price index at time "t".

α_0 represents intercept term and $-\boldsymbol{\beta}$ is coefficient of error correction term (ECT), $\mathbf{\Delta CPI_{t-i}}$ represent the first differences of CPI at lag 1 and lag 2; $\mathbf{i = 1, 2}$; $\mathbf{\Delta GDP_{t-i}}$ represent the first differences of GDP at lag 1 and lag 2; $\mathbf{i = 1, 2}$. $\Delta\mathrm{GE}_{t-i}$ represent the first differences of Government expenditure at lag 1 and lag 2; $\mathbf{i = 1, 2}$; $\mathbf{\Delta IMP_{t-i}}$ represent first differences of imports at lag 1 and 2; $\mathbf{i = 1, 2}$; $\Delta\mathrm{M2}_{t-i}$ represent first differences of broad money supply at lag 1 and lag 2; $\mathbf{i = 1, 2}$. $\boldsymbol{\Gamma}_i$ represent the lagged variables' coefficients for the respective variables. $\boldsymbol{\varepsilon_t}$ is error term (white noise) at time t. $\mathbf{i}$ represent the number of lags of the macroeconomic variables under consideration.

The **error correction term** (ECT) is formulated as follows:

$\mathrm{ECT}_{t-1} = \mathbf{\Delta CPI_t} - \alpha(\sum_{\mathbf{i=1}}^{\mathbf{2}} \Delta\Gamma_{1i}\mathrm{CPI}_{t-i} + \sum_{i=1}^{2} \Gamma_{2i}\Delta\mathrm{GDP}_{t-i} + \sum_{i=1}^{2} \Gamma_{3i}\Delta\mathrm{GE}_{t-i} + \sum_{i=1}^{2} \Gamma_{4i}\Delta\mathrm{IMP}_{t-i} + \sum_{i=1}^{2} \Gamma_{5i}\Delta\mathrm{M2}_{t-i})$ ……… (5)

Where:

$\boldsymbol{\alpha}$ is the coefficient that captures the speed of adjustment in the error correction term (**ECT**). The ECT measures the deviation from the long-run equilibrium relationship between consumer price index (CPI) and explanatory variables under consideration. It captures the adjustment mechanism by which deviations from the long-run equilibrium are corrected in subsequent periods.

2.3 Methods Testing stationarity

The stationarity of the arrangement is tried by utilizing measurable tests such as Increased Dickey-Fuller (ADF) test due to Dickey and More (Dickey & Fuller, 1979) and the Phillip-Perron (PP) due to (Phillips & Perron, 1988). The taking after dialog diagrams the fundamental highlights of unit root tests (Hamilton & Susmel, 1994)

2.4 Estimating the order of the VAR model

The lag length for the VAR show may be decided utilizing slack choice criteria. The common approach is to fit VAR models with orders $m = 0, \ldots, p\_max$ and select the esteem of m which minimizes a few show determination criteria (Lütkepohl, 2005). The common frame demonstrates choice criteria have the following form:

$$C(m) = log\left|\hat{\Sigma}_m\right| + C_T * \varphi(m, k)$$

Where: $\hat{\Sigma}_m = \frac{1}{T}\sum_{t=1}^{T} \hat{\varepsilon}_t\hat{\varepsilon}_t'$ is the residual covariance matrix estimator for a model of order m,$\varphi(m, k)$ is a function of order m which penalizes large VAR orders and C_T is a sequence which may depend on the sample size and identifies the specific criterion. The term $log\left|\hat{\Sigma}_m\right|$ is a non-increasing function of the order m while $\varphi(m, k)$increases with m.

3. RESULTS AND DISCUSSION

3.1. Results

a. Normality Test

Table 1. Normality tes

One-Sample Kolmogorov-Smirnov Test

		Unstandardized Residual
N		35
Normal Parameters[a,b]	Mean	,0000000
	Std. Deviation	1,44627770
Most Extreme Differences	Absolute	,123
	Positive	,083
	Negative	-,123
Test Statistic		,123
Asymp. Sig. (2-tailed)		,197[c]

a. Test distribution is Normal.
b. Calculated from data.

Based on the normality test, it can be concluded that the data is normally distributed for Employee Performance, Service Quality and Consumer Satisfaction data with a significant level of 0.197 > 0.05.

a. Multicollinearity Test

Table 2. Multicollinearity Test

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Collinearity Statistics Tolerance	Collinearity Statistics VIF
1	(Constant)	4,170	2,844		1,466	,152		
	Kinerja Karyawan	,260	,124	,380	2,091	,045	,404	2,474
	Kualitas Pelayanan	,288	,124	,424	2,331	,026	,404	2,474

Based on table 2, it can be seen that there is no independent (free) variable that has a tolerance value of less than 0.10 and the VIF results also show the same thing where there is not a single independent (free) variable that has a VIF higher than 10. Independent variables Employee Performance is at a tolerance value of 0.404, the Service Quality variable is at a tolerance value of 0.404. This is also the same as the Employee Performance variable is at a VIF value of 2.474, the Service Quality variable is at a VIF value of 2.474 so that in this analysis there are no symptoms of multicollinearity or independent variables. (Employee Performance and Service Quality) show different influences on the variability of the dependent variable (Customer Satisfaction).

b. Multiple Linear Regression

Table 3. Multiple Linear Regression

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	4,170	2,844		1,466	,152
	Kinerja Karyawan	,260	,124	,380	2,091	,045
	Kualitas Pelayanan	,288	,124	,424	2,331	,026

From calculations using the SPSS computer program, namely:
a = 4.170; X1 = 0.260; X2 = 0.288

so the multiple linear regression equation for the two predictors (Employee Performance and Service Quality) is:

$$Y= 4.170 + 0.260\ X1+ 0.288\ X2$$

The equation above shows that all independent variables (Employee Performance and Service Quality) have positive coefficients, a constant value of 4.170, a regression value of the employee performance variable of 0.260 and a regression value of the Service Quality variable of 0.288. This means that all independent variables have a unidirectional influence on variable Y (Consumer Satisfaction).

c. Heteroscedasticity Test

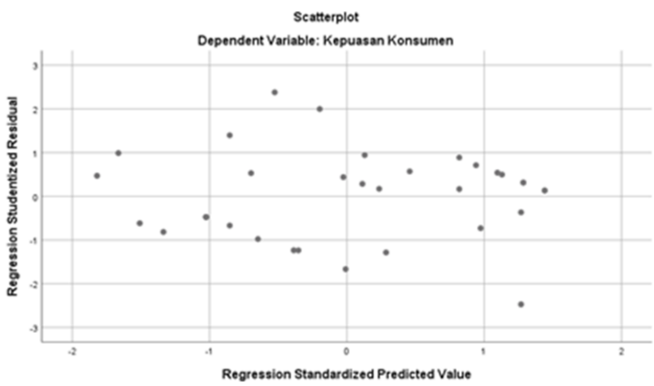

Figure 2. Heteroscedasticity Test

The image above shows that the points are spread randomly, do not form a clear/regular pattern, and are spread both above and below 0 on the Y axis. Thus "heteroscedasticity does not occur" in the regression model.

d. Coefficient of Determination Test (Abjusted R^2)

Table 4. Coefficient of Determination Test Results

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,757[a]	,573	,546	1,49079

a. Predictors: (Constant), Kualitas Pelayanan, Kinerja Karyawan
b. Dependent Variable: Kepuasan Konsumen

From the table above, it can be seen that the Abjusted R-Square value is 0.546 or equal to 54.6%, meaning that Employee Performance and Service Quality have an influence of 54.6%. Meanwhile, the remaining 45.3% was influenced by other variables not included in this research.

e. F Test (Simultaneous)

Table 5. F Test (Simultaneous)

ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig
1	Regression	95,282	2	47,641	21,436	,
	Residual	71,118	32	2,222		
	Total	166,400	34			

a. Dependent Variable: Kepuasan Konsumen
b. Predictors: (Constant), Kualitas Pelayanan, Kinerja Karyawan

The results of the F Test using the SPSS application showed the following results: F count = 21,436; F Table = 3.29

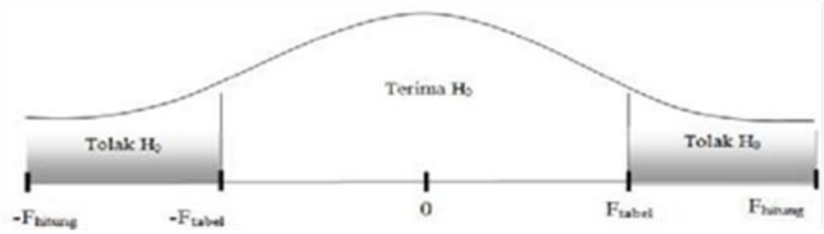

Figure 3. Hypothesis Testing Criteria

Based on the table above, it is known that F_{count} is 21.436 while F_{table} is 3.29. This means that $F_{count} > F_{table}$ is 21.436 > 3.29, so it can be concluded that there is a joint influence of Employee Performance and Service Quality on Customer Satisfaction.

f. Partial Test (T Test)

Table 6. Persial test (t test)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	4,170	2,844		1,466	,152
	Kinerja Karyawan	,260	,124	,380	2,091	,045
	Kualitas Pelayanan	,288	,124	,424	2,331	,026

Employee Performance (X1) on Customer Satisfaction (Y) is obtained with a significance level of 0.45 > probability 0.05. From these results it can be concluded that H1 is rejected. This means that Employee Performance (X1) does not partially have a significant influence on Customer Satisfaction (Y).

DISCUSSION

The aim of this study was the modeling and forecasting of the inflation in Ethiopia, which can be used to forecast the rate of inflation in Ethiopia using a restricted VAR model (VECM).

The Augmented Dickey-Fuller (ADF) and Phillip-Perron (PP) tests were applied to test the variables for unit root, and all five series were non-stationary at level and stationary at their first difference at 5% level of significance. The Johansen cointegration test suggests that there is at least one cointegration vector, which describes the long run relationship between CPI, with endogenous variables GD, GE, IMP and M2 concluded that there is at least one form of cointegration equation which shows that the variables have a balanced relationship and movement similarity in the long run and Vector Error Correction model (restricted VAR) was used for modeling and forecasting inflation rate to restricts the long-run behavior of the endogenous variables converging to their cointegrating relationships while allowing for short-run adjustment dynamics and results indicate that the coefficient of error correction term is negative (-0.279) which suggesting 27.9 percent annual adjustment towards long run equilibrium when happens any shocks based on variables under considerations. Therefore, the resulting models are highly parsimonious and appear reasonably well specified.

Furthermore, Granger causality tests were applied to explore long run relationships. The result indicates that there was a unidirectional relationship between variables of lnGDP with lnCPI, lnGE with CPI, IMP with CPI, M2 with CPI and M2 with IMP at 5% significance level. However, the lnIMP and lnGE are independent from each other at 5% significance level. In addition, impulse response functions were also used to study short-term dynamics variable relationship. The impulse response function result obtained by applying Standard Cholesky decomposition. The results provided the percentage of the forecast error in each variable that could be attributed to innovations in the other variables, for different time period. The Cholesky ordering employed is CPI, GDP, GE, IMP and M2. Each row represents the percentage of forecast error variance for the variable indicated.

Finally, forecasting is made using the vector error correction (VEC) model. The results of mean square error (MSE), mean absolute error (MAE), and Theil's U statistics revealed that the estimated model is good enough to describe the data set. Therefore, post forecasts are made for CPI as well as four endogenous variables from 2022 to 2026. According to the forecasted inflation rates in the coming five years suggest that the prices, on average have decreased by approximately 18.0% in 2022; 6.8% in 2023, and increased by approximately 8.3% in 2024; again, have decreased by approximately 2% in 2025 and 5% in 2026 over the specified time periods.

RECOMMENDATION

Based on the results of this empirical study, the following policy recommendations were made:

- Political intervention by further devaluing the Ethiopian birr against the dollar, aimed at addressing international competitiveness issues and boosting the export sector, will lead to sustained and redundant inflation in the economy. To curb inflation in Ethiopia, it is necessary for the government to improve farmers' production and productivity through investment in agriculture and establish suitable policy intervention tools for fighting inflation.
- Inflation has reached a high level, imbalanced supply and demand, and the sharp rise in domestic product prices due to shortages of production materials is causing distortions in macroeconomic indicators and a lack of modernization of the market system to create the conditions for economic competition and selectively enforce norms that evolve as the economy develops. Without immediate action, inflation will continue to be a national challenge and a threat. Therefore, the government must find short- and long-term solutions through political reform and can reduce spending and increase taxes as a way to help reduce inflation.
- Align money distribution and management with economic growth, and review the organization of institutions. Overall, it is recommended that the market system be regulated by law.
- It is important for the government to intervene to control domestic price developments. However, such intervention requires careful observation of the forces behind price movements and an appropriate strategy

REFERENCES

Amisi, B., & Ouma, P. (2021). Forecasting Kenya's inflation rate using a VARMA for price of imported crude oil and Kenya's previous inflation rate time series. Maseno university.

Ankit, S. (2011). Factors Influencing Online Banking Customer Satisfaction and Their Importance in Improving Overall Retention Levels : An Indian Banking Perspective. Information and Knowledge Management, 1(1), 45–55.

Danoro, D. D. (2020). Modeling And Forecasting Volatility Of Price Inflation In Ethiopia Using GARCH Family Models. 4(1), 10–11

Dickey, D. A., & Fuller, W. A. (1979). Distribution of the Estimators for Autoregressive Time Series With a Unit Root. Journal of the American Statistical Association, 74(366), 427–431. https://doi.org/10.1080/01621459.1979.10482531

Fischer, S., & Sahay, R. (2000). IMF Working Paper INTERNATIONAL MONETARY FUND. WP/06/212, Asian Pacific Department.

Fischer, S. (1993). deficits also reduce both capital accumulation and productivity growth . Examination of. NBER Working Paper Series, 4565, 36.

Hamilton, J. D., & Susmel, R. (1994). Autoregressive conditional heteroskedasticity and changes in regime. Journal of Econometrics, 64(1–2), 307–333. https://doi.org/10.1016/0304-4076(94)90067-1

Ndiaye, C. T., & Konte, M. (2017). The Role of Inflation Uncertainty on Economic Growth : The Case of the WAEMU The Role of Inflation Uncertainty on Economic Growth : The Case of the WAEMU Cheikh Tidiane Ndiaye * and Mamadou Abdoulaye Konte. January, 1–11.

Phillips, P., & Perron, P. (1988). Testing for a Unit Root in Time Series Regression Author (s): Peter C . B . Phillips and Pierre Perron Published by : Oxford University Press on behalf of Biometrika Trust Stable URL : https://www.jstor.org/stable/2336182 REFERENCES Linked references ar. 75(2), 335–346.

Lütkepohl, H. (2005). New introduction to multiple time series analysis. New Introduction to Multiple Time Series Analysis, 1–764. https://doi.org/10.1007/978-3-540-27752-1