**DETERMINANTS OF INFLATION IN INDIA: A VECTOR AUTOREGRESSIVE(VAR) APPROACH**

**Abstract:** This article presents a comprehensive time series Vector Autoregressive (VAR) analysis of the inflation rate in India, unraveling its intricate relationship with crucial economic indicators. We used secondary time series data observed annually from 1972 to 2021 which are Inflation Rate, Gross Domestic Product(GDP), Exchange Rate and Money Supply(M3). Through a rigorous VAR methodology, the research explores the dynamic interactions, capturing the feedback loops and lagged effects among the variables over time. The analysis looks closely at the effects of monetary aggregates, GDP, and exchange rates in an effort to offer more detailed insights into the variables influencing inflationary trends in the Indian economy. The utilization of first differencing enhances the precision of the investigation. Preliminary tests before obtaining vector auto regressive model were carried out before determining the relationship between the variables. We used Granger causality test (GCT) to determine causal- effect relationship between the variables. The results showed that exchange rate and money supply (M3) as well as gross domestic product (GDP) no impact on inflation rate.

**Keywords:** Autoregressive, VAR, inflation, Exchange rate, GDP, Unit Root Test, Cointegration Test, Granger Causality test etc.

**1. INTRODUCTION**

The inflation rate in India is a key economic indicator that reflects the percentage increase in the general price level of goods and services over a specific period. It holds a pivotal position in shaping the economic landscape, influencing consumer purchasing power, investment decisions, and overall economic stability. The inflation rate in India has been a subject of concern with fluctuations impacting the cost of living and financial planning for individuals and businesses alike. As of 2023, the inflation rate in India is approximately 5.46 percent, reflecting a moderate increase compared to the previous year. India's retail inflation, measured by the Consumer Price Index (CPI), recently eased to a four-month low of 4.87% in October 2023, down from 5.02% in the previous month. The Consumer Price Index (CPI) is a benchmark indicator, and in September, it stood at 5%, as reported by the National Statistical Office. Retail inflation dropped to 5.7% in December, while wholesale inflation touched 4.95%, contributing to the evolving inflationary scenario in the country.

Several factors contribute to the complexity of India's inflation scenario, including expectations about future inflation, oil prices, monetary growth, foreign interest rates, and inflationary expectations. The dependence of inflation on such multifaceted factors necessitates a thorough understanding of its time series dynamics. Time series analysis becomes crucial to unveil patterns, trends, and interdependencies over time, providing policymakers and economists with valuable insights for informed decision-making. The integration of time series methodologies allows for a comprehensive examination of the evolving nature of inflation, guiding the formulation of policies aimed at fostering sustainable economic growth.

This article delves into the intricate relationship between the inflation rate in India and two pivotal components of its Gross Domestic Product (GDP) – GDP at factor cost and GDP at market price. Additionally, the examination extends to the influence of the exchange rate, a critical factor in India's economic landscape as well as also includes the influence of money supply(M3) into the analysis.

GDP serves as a comprehensive measure of a nation's economic health, and the variations in its calculation – specifically, GDP at factor cost and GDP at market price – offer unique perspectives. Factor cost encompasses the total value of goods and services produced, excluding indirect taxes but including subsidies, while market price integrates taxes and eliminates subsidies. Understanding how changes in these GDP correlate with inflation provides valuable insights into the underlying economic forces driving price movements.

Moreover, the exchange rate, representing the value of the Indian Rupee against other currencies, is a pivotal external factor impacting the domestic economy. Fluctuations in the exchange rate can influence the cost of imports and exports, subsequently affecting inflation.

Additionally, the total amount of money in an economy, including physical currency, demand deposits, and other liquid assets, is referred to as the money supply, or broad money (M3). Inflation may result from an increase in the money supply because higher liquidity may raise demand for goods and services, which would raise prices.

This article aims to unravel the intricate connections between these variables, employing a comprehensive analysis to shed light on the nuanced dependencies shaping India's inflationary landscape. By doing so, we aim to contribute to a more profound comprehension of the economic forces steering inflation in one of the world's rapidly evolving economies.

**2. LITERATURE REVIEW**

The complex relationship between inflation and key economic indicators has long been a subject of scholarly inquiry, particularly in the context of developing economies like India. This literature review explores the existing body of knowledge surrounding the inflation rates in India and its dependence on various macroeconomic factors.

The research by Venugopal & Aggarwal (2020) employs a co-integration approach to identify factors influencing inflation in India. It considers the contributions of elements like crude oil prices, gold prices, and exchange rates to inflation dynamics.

Goyal’s paper (2005) employs Structural Vector Autoregression (SVAR) to estimate core inflation, combining theory and economic structure. It investigates impulse responses of inflation and output, examines time series properties of core inflation, and explores Granger causality. The study provides valuable insights into the dynamics and determinants of core inflation in the Indian context, contributing to a nuanced understanding of the country's economic landscape.

Sreenu et al. (2023) investigate the impact of exchange rate and inflation rate on stock market volatility. By analyzing the relationships between these economic variables, the research contributes valuable insights into understanding the complex interplay between macroeconomic factors and stock market performance in the Indian financial landscape.

Balakrishnan (2022) explores the factors contributing to the decline in inflation in India. It investigates whether the decrease is primarily attributed to the effectiveness of monetary policy measures or if fluctuations in commodity prices played a significant role. The analysis considers the complex interplay between monetary policy decisions and the impact of commodity price movements on inflation levels in the Indian economy.

The study by Rasool & Tarique (2018) employs the bounds testing approach to identify and analyze the determinants of inflation. By utilizing the Autoregressive Distributed Lagged (ARDL) model, the research aims to understand the dynamics of inflation in the Indian context. The ARDL approach allows for a comprehensive investigation into the long-term relationships between various economic variables and inflation, providing valuable insights into the factors driving inflationary trends in India.

The article by Hussain and Ajmair (2016) aims to explore the factors influencing inflation in the Indian context. The study employs a co-integration approach, investigating the long-term relationships between inflation and various economic variables. By analyzing import prices, interest rates, gross domestic product, and money supply, the research seeks to identify key determinants contributing to inflationary trends in India. The study's findings provide valuable insights into the complex dynamics of inflation, contributing to the broader understanding of economic factors shaping price levels in the Indian economy.

**3. RESEARCH GAP**

Even though the literature on inflation dynamics in India is insightful, there is a clear research gap that this study seeks to fill. Individual inflation determinants, such as exchange rates, GDP, and monetary aggregates, have been the subject of numerous previous studies. Nevertheless, a thorough examination of the interdependent relationships between these variables is absent. Moreover, not much research has been done on the temporal aspect of these relationships over a longer time frame. By performing a Time Series Vector Autoregressive (VAR) analysis, this study seeks to close these gaps by providing a comprehensive analysis of the interactions among the exchange rate, inflation rate, GDP, and broad money (M3).

The study hopes to accomplish this by offering a comprehensive understanding of how these factors collectively contribute to inflation dynamics in India over time, thereby filling a critical void in the existing body of knowledge. Such an investigation would not only contribute to a deeper understanding of the relationships within the Indian economy but also provide policymakers with more insights for effective inflation management.

**4. OBJECTIVES OF THE STUDY**

1) Investigate the influence of GDP, exchange rate and money supply(M3) on inflation dynamics in India.

2) Employ first differencing in the VAR model to account for potential non-stationarity and enhance the accuracy of the analysis.

3) Identify and analyze the long-term relationships between inflation and the specified economic indicators.

4) Offer insights into the persistence and stability of the relationships over time.

5) Contribute to the broader understanding of the complex dynamics shaping price levels in the Indian economy.

**5. MATERIALS**

**5.1 SOURCES OF DATA**

This study’s data was acquired entirely from secondary sources which were compiled annually for the period of 50 years from 1972 to 2021. This is healthy number of observations in any data to take the result on VAR model. I used STATA 17 to analyze the time series data. The data was collected from (1) The World Bank (2) The Ministry of Statistics and Programme Implementation (MoSPI)

**5.2 VARIABLES USED FOR ANALYSIS**

**Dependent Variable:** Inflation Rate

**Independent Variables:** Exchange Rate, Gross Domestic Product & Money Supply

**6. METHOD USED**

**6.1 TECHNICAL CONSIDERATIONS**

**6.1.1 TESTING FOR STATIONARITY (UNIT ROOT TEST)**

Ensuring that statistical properties such as average, standard deviation, and autocorrelation do not change over time is a critical step in time series stationarity testing. Because non-stationary data can produce inconsistent or illogical conclusions, it is critical to evaluate and guarantee stability in these attributes in order to conduct insightful analysis. Augmented Dickey Fuller Test (ADF) was used to test the unit root problem. The ADF was preferred because it includes extra lagged terms of the dependent variables in order to eliminate autocorrelation in the test equation when the error term is unlikely to be white noise. The ADF used to estimate the following equation:

………………………….. (1)

The null hypothesis for the test is that a variable is not stationary (has a unit root) against the alternative hypothesis that it is stationary (has no unit root). If the data is not stationary, we transform them to stationary time series by differencing. The difference time series is the change between each observation in the original series over time.

……………………………………………. (2)

**6.1.2 GRANGER CAUSALITY TEST**

In order to determine the causal relationship between two variables, the Granger Causality Test is crucial in time series analysis. The test aids in determining whether past data from one time series can be utilized to forecast data from another. The findings of the test sheds light on whether variations in one variable can be linked to variations in another's lagged values, which helps to clarify the relationships in a dynamic system.

**6.1.3 CONCEPTUAL FRAMEWORK AND DEFINITION OF VARIABLE**

The conceptual framework involves dependent and independent variables which guides the assessment of the causal–effect relationships hypothesized to exist between the variables. The dependent variable is inflation rate(IR) and is measured in per centage and independent variables are namely money supply (M3), measured in % of GDP , exchange rate (ER), measured in LCU per US$, period average and gross domestic product (GDP) in Crores.

**6.1.4 MODEL SPECIFICATION**

This paper has used Ordinary Least Squares by employing the Vector Autoregressive Model (VAR). This is the suitable estimation technique to be used because it has the ability to provided the existence of the short run relationship or past and causal relationship between the Inflation rate and its determinants such as Growth Domestic Products (GDP), exchange rate (ER) and the money supply (M3) in time. Therefore, VAR commonly employs the multivariate regression time series analysis technique. The model used in this paper have the following functional form:

…………………….()

Where, INF\_RATE denotes an inflation rate (Dependent variable), ln\_GDP denotes the natural log of growth domestic products (GDP), ln\_M3 denotes the natural log of money supply and ln\_ER denotes the Exchange rate, 𝛽0 is a constant term, 𝛽1 − 𝛽3 are parameters estimates, and 𝜀t denotes a stochastic term. It can be seen from the model that the dependent variable is not logarithmic while independent variables are logarithmic. There are three reasons to transform a variable by taking the natural logarithm. These reasons will determine whether one wants to log the explanatory variable(s), response variable or both. The idea is to improve model fit. In our case, we found independent variables (Exchange rate, GDP and Money supply) were not normally distributed and with huge values compared to the response variable (Inflation rate). Taking logarithm of a skewed variable may improve the fit by altering the scale and making the variable more normally distributed.

**7. RESULTS AND DISCUSSION**

**7.1 DESCRIPTIVE STATISTICS RESULTS**

Table 1 gives a summary of descriptive statistics of the explanatory variables and the response variable.

**Table 1:** Summarized Descriptive Statistics

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **VARIABLE** | **OBS** | **MEAN** | **STD. DEV.** | **MIN** | **MAX** |
| INF\_RATE | 50 | 7.794628 | 4.897792 | -7.633948 | 28.59873 |
| LN\_ER | 50 | 3.259005 | .8005523 | 2.02742 | 4.305409 |
| LN\_GDP | 50 | 15.00968 | .8521961 | 13.8042 | 16.49204 |
| LN\_M3 | 50 | 3.908527 | .3844889 | 3.128314 | 4.474874 |

Table 1 reveals that the minimum of inflation rate is -7.633948% and maximum value is 28.59873%. The mean inflation rate is 7.794628 while the standard deviation obtained is 4.897792. The GDP ranged from 13.8042 to a maximum value of 16.49204. The GDP has got a mean value of 15.00968 and a standard deviation of .8521961. Similarly, money supply(M3) ranged from a minimum value of 3.128314 to a maximum value of 4.474874 with an average of 3.908527 and a standard deviation of .3844889. Finally, the Exchange rate ranged from a minimum of 2.02742 to a maximum of 4.305409 with the mean value of 3.259005 and a standard deviation of .8005523.

**7.2 TRENDS OF INFLATION IN INDIA**

The trends of inflation in India from 1972 to 2021 reveal a dynamic and evolving economic landscape. Over these decades, India has witnessed fluctuations in inflation rates, influenced by various domestic and global factors. In the early years, the country experienced relatively high inflation, attributed to factors like food shortages and global oil price shocks. The 1980s saw efforts to address these challenges, leading to a period of stabilization. However, the liberalization of the Indian economy in the early 1990s introduced new dynamics. As markets opened up, inflation underwent changes influenced by factors such as increased competition, monetary policy adjustments, and global economic trends. The early 2000s were marked by a period of moderate inflation, reflecting improved economic management. Notably, the 2008 global financial crisis had a notable impact, causing a temporary spike in inflation.

In the subsequent years, India grappled with a mix of supply and demand-side factors affecting inflation. Government policies, international oil prices, and monsoon patterns played significant roles. The implementation of the Goods and Services Tax (GST) in 2017 also contributed to short-term disruptions. Amidst these fluctuations, the Reserve Bank of India (RBI) employed various monetary tools to manage inflation. The years leading up to 2021 showcased efforts to maintain a target inflation rate, reflecting a commitment to stability. Analyzing this extensive dataset spanning almost five decades provides valuable insights into the complex and multifaceted nature of inflation in India, offering a nuanced understanding of its historical trends and the factors influencing its trajectory over time.



**Figure 1**: Trend line of Inflation Rate in India from 1972-2020

In addition the study reveals that GDP, exchange rate and money supply have an upward trend.

**7.3 ANALYSIS OF THE SERIES STATIONARITY**

Hypothesis for the unit root test;

H0: Variables are not stationary (variables have Unit root).

H1: Variables are stationary (variables have no unit root).

The null hypothesis is rejected if the calculated value of the test statistic is greater than the absolute value of the critical value. Otherwise, we do not reject the null hypothesis. Table 2 below presents the unit root test at 5% level of significance equivalent to 95% level of confidence.

**Table 2**: Unit Root at 95% level of confidence

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **VARIABLES** | **TEST STATISTIC** | **CRITICAL VALUE AT 5%** | **ORDER OF INTEGRATION** | **DECISION** |
| INF\_RATE | -4.928 | -2.933 | 0 | Stationary |
| LN\_ER | -1.176 | -3.508 | 1 | Non-Stationary |
| LN\_GDP | -2.532 | -3.504 | 1 | Non-Stationary |
| LN\_M3 | -1.575 | -3.504 | 1 | Non-Stationary |

The result in Table 2 shows that with respect to the three variables(LN\_ER, LN\_GDP & LN\_M3) the null hypothesis is accepted that the time series data is not stationary but after first differencing, all the data series became stationary or integrated at first order which implies that, the null hypothesis at first difference were rejected in favor of the alternative hypothesis for all data series and this is because Augmented Dickey Fuller (ADF) test for the probability values in all variables is less than 5% level of significance. On the other hand, the data for the values of Inflation Rate(INF\_RATE) was stationary at level(0).



**Figure 2**: Line graph for non-stationary data



**Figure 3**: Line graph for stationarity data (after first differencing)

Figures 2 and 3 shows the line-graphs of the variables ln\_ER (Exchange Rate), ln\_GDP(Gross Domestic Product) & ln\_M3(Money Supply) for non- stationary data and stationary data respectively. Line graph presented in figure 4 was obtained after first differencing. In the first place, data of the above mentioned variables was not stationary. Obtaining stationary data was important in order to proceed fitting of the VAR model.

**7.4 JOHANSEN COINTEGRATION TEST(JCT)**

After performing the stationary test, we found out that the series of Inflation Rate(INF\_RATE) is integrated of order (0),i.e., I(0) and the series of log of Exchange Rate (ln\_ER), log of Gross Domestic Product (ln\_GDP) & log of Money Supply (ln\_M3) are integrated of order (1),i.e., I(1).

To check whether the variables are cointegrated or not, the Johansen cointegration test (JCT) Max-Eigen statistic is applied. Performing a cointegration test is necessary to establish a long run relationship. The test hypothesis for the JCT test is as under :

Null Hypothesis :H0 : There is no cointegrating equation.

Alternative Hypothesis : H1 : H is not true.

Cointegration test should be performed on the level form of the variables and not on their first difference. The decision criteria for the JCT test is that, if the value of trace and max statistics is greater than the 5% critical value, the null is rejected, meaning that the series are cointegrated. The test results of JCT Max - Eigen statistics are displayed in the Table 3.

From the Table 3 it can be inferred that for rank 0, the trace statistic 59.2580 is greater than the critical value 47.21 so we will reject the null hypothesis in this regard. Looking at the rank 1, the trace statistic is 24.5520 which is less than the critical value 29.68 so we cannot reject the null hypothesis and we can conclude that in this model there is a presence of one cointegration. Therefore, the series are cointegrated, i.e., they exhibit a long run relationship. This implies that even if there are shocks in the short run, which may affect movement in the individual series, they would converge with time in the long run. Now, we need to estimate the vector Autoregressive (VAR) model.

**Table 3**: Johansen tests for cointegration results

Trend: Constant Number of obs = 48

Sample: 1974 thru 2021 Number of lags = 2

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| MAXIMUM RANK | PARAMS | LL | EIGENVALUE | TRACE STATISTIC | CRITICAL VALUE 5% |
| 0 | 20 | 124.87305 | . | 59.2580 | 47.21 |
| 1 | 27 | 142.22603 | 0.51473 | 24.5520\* | 29.68 |
| 2 | 32 | 151.22752 | 0.31275 | 6.5490 | 15.41 |
| 3 | 35 | 153.33884 | 0.08421 | 2.3264 | 3.76 |
| 4 | 36 | 154.50204 | 0.04731 |  |  |

\*selected rank

**7.5 VECTOR AUTOREGRESSIVE(VAR) MODEL**

VAR models are useful for analysing the dynamic relationships among multiple time series variables simultaneously, allowing for a comprehensive understanding of their interactions and dependencies over time. VAR models are employed for forecasting future values of the variables in the system. By capturing the lagged dependencies between variables, VAR models provide a framework to make predictions about the future based on historical data. The VAR Model is specified as under:

**Table 4**: Vector Autoregressive Results

|  |  |  |
| --- | --- | --- |
|  | **COEFFICIENT** | **P>Z** |
| INF\_RATE  INF\_RATE  L1  L2  LN\_ER  L1  L2  LN\_GDP  L1  L2  LN\_M3  L1  L2 | .304423  -.3316037 | 0.061  0.014 |
| 8.113483  -10.9543 | 0.400  0.266 |
| 11.87154  -13.8022 | 0.643  0.587 |
| -7.085807  13.88972 | 0.700  0.436 |
| LN\_ER  INF\_RATE  L1  L2 | -.0000787  .0038861 | 0.971  0.032 |
| LN\_GDP  INF\_RATE  L1  L2 | -.0023224  .0015191 | 0.010  0.042 |
| LN\_M3  INF\_RATE  L1  L2 | -.0016074  .0012605 | 0.294  0.319 |

In the VAR model, the smaller the 𝑝 -value, the stronger the evidence that one should reject the null hypothesis which shows statistically significant of the test. The test was carried out at 5% level of significance and the results revealed that no variable had an impact on Inflation rate as no p value was significant in case of any variables. However, it was seen that second lag of Inflation rate is significant and had a positive impact on the Exchange rate. Also, both the first and second lag of Inflation Rate is significant and had a negative and a positive impact respectively on GDP.

**7.6 GRANGER CAUSALITY TEST**

Granger causality helps determine if past values of one variable provide information about future values of another. It assesses whether one variable "Granger causes" another by examining the time lagged effects. The test hypothesis is as follows:

Null Hypothesis: H0: No Granger causality

Alternative Hypothesis: H1: H0 is not true.

The decision criteria for this test is that the null hypothesis is rejected if the prob-value of the chi2-statistic is ≤0.05.

**Table 5**: Granger causality Test results

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **NULL HYPOTHESIS(H0)** | **Χ2** | **df** | **p** | **CONCLUSION** |
| Exchange Rate did not Granger cause Inflation Rate | 2.2685 | 2 | 0.322 | Not reject H0 |
| Gross Domestic Product did not Granger cause Inflation Rate | .74348 | 2 | 0.690 | Not reject H0 |
| Money Supply did not Granger cause Inflation Rate | 1.7894 | 2 | 0.409 | Not reject H0 |
| Inflation Rate did not Granger cause Exchange Rate | 4.706 | 2 | 0.095 | Not reject H0 |
| Gross Domestic Product did not Granger cause Exchange Rate | .5027 | 2 | 0.778 | Not reject H0 |
| Money Supply did not Granger cause Exchange Rate | 3.9464 | 2 | 0.139 | Not reject H0 |
| Inflation Rate did not Granger cause Gross Domestic Product | 9.3064 | 2 | 0.010 | Reject H0 |
| Exchange Rate did not Granger cause Gross Domestic Product | 7.5752 | 2 | 0.023 | Reject H0 |
| Money Supply did not Granger cause Gross Domestic Product | 27.635 | 2 | 0.000 | Reject H0 |
| Inflation Rate did not Granger cause Money Supply | 1.8138 | 2 | 0.404 | Not reject H0 |
| Exchange Rate did not Granger cause Money Supply | 2.6806 | 2 | 0.262 | Not reject H0 |
| Gross Domestic Product did not Granger cause Money Supply | .36468 | 2 | 0.833 | Not reject H0 |

Table 5 revealed that the three variables, i.e., Exchange Rate, Money Supply & GDP did not granger cause Inflation Rate rather it was found that GDP was granger caused by Inflation rate, Exchange rate & Money supply.

**8. CONCLUSION**

The objective of the study was to examine the trend of inflation and its key determinants in India using Vector Autoregressive methodology. Analysis of the data revealed that the chosen variables, i.e., GDP, Exchange Rate & Money Supply did not have significant impact on the Inflation rate. This implies that monetary expansion, changes in economic output, and changes in currency value might not all have a major impact on inflationary pressures. This scenario may point to a complex interaction between various factors that influence the inflation rate independently of the variables listed, such as supply chain dynamics, external shocks, or structural problems in the economy. Furthermore, a lack of correlation may suggest that factors not taken into account in the analysis are the primary cause of inflation in India, thereby requiring a more thorough investigation of a variety of economic indicators and outside influences. To create strategies that effectively manage inflation and promote economic stability, policymakers would need to take these complex dynamics into account.

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