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Macroeconomic Stability in India: Vector Error Correction Estimation of the Causal Relationship between Inflation, GDP, Money Supply, Interest Rate, Exchange Rate, and Fiscal Deficit

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Abstract

The significance, nature, and direction of the effect of inflation on economic growth and macroeconomic stability are contentious both in theory and empirical analysis. This paper examines the causal relationship between inflation and macroeconomic variables – interest rate, exchange rate, money supply, GDP, and fiscal deficit – in India, during the period 1986 to 2016, applying the vector correction (VECM) estimation method. The macro variables are stationary at first difference, and a cointegrating and causal relationship exists between the wholesale price index and interest rate, exchange rate, GDP, broad money, and gross fiscal deficit. The VECM estimates reveal that money supply and GDP are the most important macro variables in explaining the variations in inflation. The estimated error correction term shows that the short-run disequilibrium is corrected by about 20% every period towards the long-run equilibrium. The impulse response results show that inflation responds positively to the money supply from the start to the 9th period. To promote economic growth and keep inflation low, money supply and budget deficits need to be rationalised.

Keywords: GDP, Inflation, Interest Rate, Exchange Rate, Money Supply, Fiscal Deficit, VECM Estimation

Introduction

The significance of inflation to economic growth is contentious both in theory and empirical findings. Originating in the 1950s in the Latin American context, the issue has soon become a sizzling structuralist vs. monetarist debate. The structuralists emphasise that inflation is essential for economic growth; however, for monetarists, inflation is detrimental to economic progress. At the heart of the controversy lies two aspects of this debate: the nature of the relationship if one exists and the direction of causality. Theoretical models on the relationship between money and growth analyse the impact of inflation on growth, focusing on the effects of inflation on the steady-state equilibrium of capital and output per capita. Classical economics emphasises the supply-side theories, while structuralists argue for the institutional features and the structure of the economy. Keynesian and Neo-Keynesian theories attach a significant role to the aggregate output, while the monetarist theory insists on the role of monetary growth in determining the rate of inflation. The open economy models subscribe to the internationalisation of inflation, in that, an increase in the money supply for an individual country leads to an increase in the world money stock, which then transmits to world prices. The open models include not only domestic factors, but also outside factors like exchange rate, and exports and imports of an economy as affecting the price stability of an economy.

Whatever be the theoretical basis of the inflation-growth relationship, most economists recommend that macroeconomic stability, specially defined as a low rate of inflation, is positively related to economic growth, but the high rate of inflation imposes negative externalities on the economy when it interferes with the efficiency of the economy. For every economy around the world,

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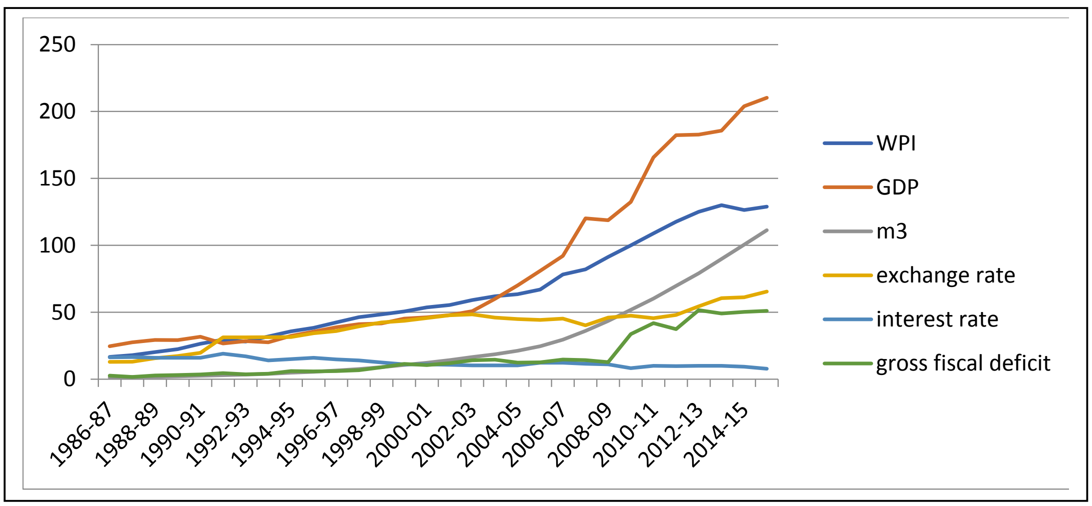
high economic growth and low inflation are the avowed objectives for macro stability. To maintain macroeconomic stability, it is necessary and sufficient to reduce the rate of inflation for price stability and achieve high economic growth.

The most important disturbing concern for a common man with regard to inflation is that it creates more burdens on the cost of living and makes life more miserable. For a businessman, inflation leads to uncertainty about the future profitability of investment projects, especially those that have a long gestation period. The increased price variability may lead to an increase in the cost of production and less profitability. Besides this, inflation may lead to uncertainty over competitiveness, as the export prices of that country may become relatively more expensive than the prices of the competitors, and thus, adversely affect the balance of payments. Inflation also undermines the confidence of domestic and foreign investors about the future course of monetary policy. In addition, inflation also affects the other determinants of economic growth, like investment in research and development (R&D).

Like many countries in the world, India focuses on sustaining high growth with low inflation. Fig. 1 presents the trends in the inflation rate and the important macro variables in India, over time. All macro variables except interest rate show upward trends implying a negative relationship between inflation and interest rate and a positive relation of inflation with other macro variables. The GDP and fiscal deficit show a fluctuating trend over the years. The WPI is rising with a falling interest rate, implying a negative relationship between interest rate and inflation. The sharp increase in the gross fiscal deficit since 2008-09 is due to the interest burden on government borrowings.



Source: Statistical Handbook of RBI (2017-18) and World Development Indicators of World Bank (2018).

Fig. 1: Trends in Inflation, Interest Rate, Exchange Rate, Money Supply, and Fiscal Deficit

Therefore, it is important to understand how inflation impacts the cost of living, which in turn affects the growth of the economy, and the relation of inflation with other macroeconomic variables in the Indian economy. Hence, this study attempts to examine the causal relationship between inflation and macroeconomic variables like interest rate, exchange rate, money supply, GDP, and fiscal deficit in India. The study period is from 1986 to 2016, and the data are derived from the RBI and World Bank world development indicators. Empirically, the study employs the Vector Error Correction (VECM) method to examine the relationship between inflation and macroeconomic variables.

Review of Literature

Bruno and Easterly (1998) analyse the relationship between inflation and economic growth for 100 countries for the period 1960-1990 using the instrumental variable estimation method. The estimated effects of inflation on growth and investment are significantly negative in the long run. The study observes that there is not enough information in the low inflation context, to isolate precisely the effect of inflation on growth; however, this does not necessarily mean that this effect is small at low rates of inflation. The study proposes that about a 40% threshold inflation has a significant effect on growth. They find that growth falls sharply during discrete high inflation crises, then recovers rapidly and strongly after inflation falls.

Bishnoi and Koirala (2006) try to identify the appropriate inflation model for Nepal, applying the robustness and stability criteria. Unit root tests are applied to investigate the validity of random walk of macro variables that determine inflation, and cointegration test to examine the long-run relationship between inflation and its determinants. The error correction estimates reveal the existence of both short- and long-run relationships in Nepal. The error correction model is stable and robust.

Jha and Dang (2012) examine the relationship between inflation variability and growth, covering the period 1961 to 2009 for 182 developing countries and 31 developed countries, using two-stage least squares method and generalised least square with fixed effects method. The study finds significant evidence in developing countries for a negative effect of inflation variability on growth when the inflation rate exceeds 10% inflation variability; an increase in inflation is followed by a decrease in growth, only if inflation is stable. In developed countries, there is no significant evidence that inflation variability is detrimental to growth.

Tabi and Ondoa (2011) analyse the relationship between economic growth, money in circulation, and inflation in Cameroon for the period 1960-2007 using the VAR estimation method. In Cameroon, despite the low inflation level, economic growth is fragile. The results of the study show that there exists a causal relationship between growth and inflation; an increase in money supply increases growth and that growth causes inflation, but an increase in money in circulation need not necessarily increase the general price level in the economy.

Gullapalli (2013) analyses the non-linear effects of inflation on growth for 2l4 countries for 1990-2011. The study notes that many central banks around the world have settled for low inflation targets – 2-5%, with no regard for the economic context of the countries. Such low inflation targets lead to unnecessary monetary tightening and drying up of economic activity. The study finds a structural break at 20% in the average annual rate of inflation. Inflation rates below this have no significant effect on growth, while inflation rates above this have a significantly negative impact on growth. The identified threshold inflation rate for groups of countries are low-income countries at 14.5%, lower-middle-income countries at 9%, upper-middle-income countries at 10%, high-income countries at 2.25%, fast-growing countries at 16%, and slow-growing countries at 14%. The empirical results of the paper indicate that price stability does not have to be captured around the central bank's attempt to make monetary policy to enable growth in the economy. The role of central banks is to be justified in monetary easing, and even working with the government to spur economic growth in high inflation thresholds.

Bozkurt (2014) investigates the relationship between inflation, money supply, and growth in Turkey, for the period 1999 to 2012, applying the VAR model. The study finds that increase in money supply and velocity of money causes inflation in the long run in Turkey. However, a 1% decrease in income directly reduces inflation equally by 1%. The study emphasises planning and implementing structural arrangements that will decrease the dependence on foreign markets in the short run and eliminate it in the long run.

Ghosh and Phillips (1998) estimate the relationship between inflation and growth for 145 countries, during the period 1960 to 1996, using panel regressions and non-linear specifications. A decision-tree technique identifies inflation as one of the most important determinants of growth. The results show a statistically and economically negative relationship between inflation and economic growth, but only after a threshold level. At the single-digit level of inflation, short-run growth is possible.

Malik and Chowdhury (2001) examine the short- and long-run relationship between inflation and GDP growth for four South Asian countries, viz. Bangladesh, India, Pakistan, and Sri Lanka, applying the cointegration and error correction models. The study finds that inflation and economic growth are positively and statistically significantly related for all four countries, and the sensitivity of growth to changes in inflation rates is smaller than that of inflation to changes in growth rates. The fast-growing South Asian economies are on the knife-edge as moderate inflation increases growth, but faster economic growth feeds back into inflation.

Burdekin et al. (2004) analyse the effect of inflation on growth for 21 industrial and 51 developing countries during 1967-1992. The study considers nonlinearities and threshold effects of inflation on growth in different economic settings. The analysis shows that the effects of inflation on growth change substantially as the inflation rate rises. The empirical results support the view that the effect of inflation on growth is non-linear, and the nonlinearities are quite different for industrial countries than for developing countries. This study finds that the threshold inflation rate is 8% for industrial countries and 3% or less for developing countries, at which inflation begins to seriously affect economic growth. Further, the marginal growth costs for developing countries decline significantly above 50% inflation.

Gillman et al. (2004) analyse the relationship between inflation and growth in a cross-section of Organization for Economic Cooperation and Development (OECD) and Asia-Pacific Economic Cooperation (APEC) member countries, for the period 1961-1967, using a monetary model of endogenous growth. The study observes that the economic model suggests a negative inflation-growth effect and the effect is stronger at lower levels of inflation. The empirical results of the study validate the negative inflation effect for the OECD countries, wherein growth increases marginally as the inflation rate declines. The instrumental variables estimation also reveals significant evidence of similar behaviour for APEC countries.

Faria and Carneiro (2001) examine the relationship between inflation and output, both in the short and long run in Brazil, a country with constant high inflation, applying the bivariate vector autoregression method. The results show a negative effect of inflation on output in the short run, but in the long run, inflation does not impact the real output in Brazil. The results also reveal super neutrality of money in the long run, but doubtful short-run implications.

Gokal and Hanif (2004) examine the relationship between inflation and economic growth in Fiji. The study also reviews the theoretical and empirical literature in search of a consensus on the meaningful inflation-growth relationship. The study tests whether the inflation-growth relationship holds for Fiji, by estimating the effect of inflation on economic growth using an extended view of the neoclassical model and regression equations. The results indicate a weak negative correlation between inflation and growth, and the causality between the two variables runs one way from GDP growth to inflation.

Berument et al. (2008) examine how inflation affects economic growth in Turkey, using the unrestricted vector autoregression technique and generalised impulse response method, identifying the sources of shocks and controlling for external factors. The study finds that inflation adversely affects output growth in Turkey and the main underlying factor is the real exchange rate.

Erbaykal and Okuyan (2008) analyse the relationship between inflation and economic growth in Turkey over the period 1987-2006 using the Pesaran Bound Test and ARDL methods. The existence of a cointegrating relationship and the direction of causality are examined. The existence of a cointegration relationship between the two series is detected by the Bounds Test, and a unidirectional causality running from inflation to economic growth is identified by the Yamamoto approach. The study finds no statistically significant long-term relationship; however, there is a negative and statistically significant short-term relationship between inflation and growth.

In the Indian context, the study conducted by Balakrishnan (1991) is an early attempt to understand the effect of inflation on output growth. The study uses data on the Indian manufacturing sector from 1950 to 1980, and regresses inflation on the output gap or the activity variable. The study finds a significant negative effect of inflation on output growth in open pre-reforms India. However, the study notes that inflation is not purely a monetary phenomenon, as the continuous slowing down of money (M3) growth has not been able to dampen the inflationary pressure in India.

Krishna Veni and Choudhury (2007) examine the relationship between inflation and the growth of the Indian economy during 1981-2004, applying causality and cointegration tests. The causality test shows the independence of growth and inflation, and the cointegration test shows no cointegration between inflation and growth in India. Therefore, the study concludes that there is no long-run relationship between inflation and growth in India.

Batura (2008) looks into the trends of inflation surge in India. The study tracks the movements in the wholesale price index to identify when inflation began to accelerate, and analyses the causes for across-the-board price increase and compares consumer prices with wholesale prices.

Patnaik (2010) examines inflation in India as a mix of demand- and supply-side factors, the stabilisation policies that focus on both demand control and supply management, for the period 1991 to 2008, applying the VAR model. The study finds that money supply does influence inflation, but the impact is short-lived. The impact on inflation due to the external sector is also very immediate and short-lived. The study concludes that the Indian inflation is largely demand-pull inflation, and therefore, the stabilisation policies should focus on demand management policies on a long-term basis and supply management policies for short-term impact on inflation.

Sahadudheen (2012) studies the determinants of inflation in India using quarterly data, for the period 1996Q1 to 2009Q3, applying the VECM approach. The VECM results show that GDP and broad money have positive effects on inflation, while exchange rate and interest rate have a negative impact on inflation. While income increases contribute to a 0.37% increase in inflation, money supply leads to a 5% increase in the price level in India.

Kumar (2013) studies inflation dynamics in the Indian economy after the new economic policy, using monthly data between 1992 and 2012 and employing the restricted autoregression method. The money supply is identified to be the most important variable in explaining the variation in inflation over time, followed by the imports. Inflation is negatively related to the industrial output and imports, and inflation has an unstable and explosive relationship with the money supply.

Pattanaik and Nadhanael (2013) try to find the threshold inflation level in the short-run growth-inflation trade-off for India using annual data over the period 1972-2010. The VAR estimation is used to capture the impact of the determinants of growth by lags of growth and the inflation threshold. The study argues that because of the excessive emphasis on growth maximising level of inflation, the welfare costs of inflation and risks to inclusive growth are often ignored. The inflation target that balances both welfare and growth is the inflation target below the threshold level. The estimate of the study suggests a threshold of about a 6 per cent inflation rate for India. The study suggests that the inflation target for monetary policy may have to be lower than the growth maximising threshold, since any positive inflation could be a risk to inclusive and sustainable growth objectives.

Bhowmik (2015) examines inflation and its determinants in India during the time period 1970-2013, applying the vector error correction model (VECM). The covariates considered are the GDP growth rate, lending rate, growth rate of money supply, fiscal deficit as per cent of GDP, degree of openness, the nominal exchange rate of rupee with respect to the US dollar, and crude oil price. The VECM estimates show that the inflation rate is associated with one period lagged interest rate and the previous period inflation rate is associated with the GDP and money supply growth rates. The error correction rate is 14%, implying the slow speed of adjustment towards the long-run equilibrium relationship.

Behera (2016) investigates the dynamic relationship between inflation, GDP, exchange rate, and money supply in India, for the period 1975-2012, applying the vector error correction method. The empirical results show the existence of a long-run equilibrium relationship among the variables. The results also suggest that money supply has a positive effect on GDP growth. The Granger causality test results exhibit a unidirectional causality from GDP to inflation and exchange rate to inflation, and the exchange rate Granger causes both GDP and money supply. The error correction mechanism shows a negative sign for the GDP and exchange rate. The impulse response results show that GDP has a positive response to money supply from the occurrence to the end of the period, whereas the response of the exchange rate to the money supply is negative during the whole lag period. The variance decomposition shows that no significant part of the variance is caused by money supply.

Kaur (2019) examines the macroeconomic determinants of inflation and the proposition of a positive effect of fiscal deficits on inflation in India using quarterly data from 1996-1997Q1 to 2016-2017Q1. The ARDL bounds approach to cointegration reveals the existence of a long-run relationship between inflation, gross fiscal deficit, money supply, exchange rate, crude oil prices, and the output gap. The long- and short-run dynamics indicate that gross fiscal deficit and money supply generate a negative impact on inflation in India. On the supply side, crude oil price and exchange rate play an important role in determining domestic prices. On the demand side, in the absence of a stronger output-inflation relationship, the flexible inflation targeting framework does get encumbered, as the case for the existence of the Phillips curve in India further weakens.

Data and Methodology

The study uses the time series of annual data of 30 years, from 1986 to 2016, for India. The study variables are wholesale price index, interest rate, exchange rate, broad money (M3), gross fiscal deficit, and gross domestic product at the current price. The data on variables interest rate, exchange rate, gross fiscal deficit, and broad money data are obtained from the RBI Handbook of Statistics on Indian Economy, and data on wholesale price index and GDP are derived from the World Development Indicators of the World Bank.

Vector Error Correction Model

The first step in the empirical analysis of a time series is to check for stationarity of series. Most time series are trended, and therefore, in most cases, are non-stationary. Hence, the standard OLS regression procedure yields biased coefficient estimates. Therefore, the series is to be made stationary.

ADF Unit Root Test of Stationarity: A variable is said to be stationary if it has a time-invariant mean, time-invariant variance, and the value of the covariance between the two time periods depends only on the distance or gap or lag between the two time periods and not the actual time at which the covariance is computed. The Augmented Dickey-Fuller (ADF) test is commonly used to test the stationarity of the variables. In this unit root test, the first difference of the variable (Δy_t) is regressed against a constant, a time trend (t = 1, 2, ..., T), and lags of Δy_t, along with the error term. The ADF regression is specified as:

$$\Delta y_t = \beta_1 + \beta_2 t + \delta y_{t-1} + \sum_{i=1}^{m} \alpha_i \Delta y_{t-i} + \varepsilon_t \quad (1)$$

Where, the disturbance term ε_t is a white noise process and is assumed to be independently and identically distributed, with zero mean and constant variance. Sufficient lags of Δy_t are to be included to ensure no autocorrelation in the error term. The Schwarz Information Criterion (SIC) test is to be used to confirm that autocorrelation is not present.

The null hypothesis is that the series has a unit root ($\delta = 0$), meaning that the series is non-stationary, against the alternative hypothesis that the series is stationary. In the presence of a unit root, i.e., non-stationarity, δ would not be statistically different from zero. If the p-value of the coefficient of y_{t-1} is less than 0.05 at 5% level of significance, the null hypothesis is rejected, indicating that the series is stationary.

Phillips-Perron Test: The PP test is used to test the null hypothesis that a time series is integrated of order 1. The Phillips-Perron test considers the higher-order autocorrelation in errors and makes a non-parametric correction to the t-test statistic. The test is robust with respect to unspecified autocorrelation and heteroscedasticity in the disturbance process of the test equation. The PP regression is specified as:

$$y_t = \beta_1 + \beta_2 t + \delta y_{t-1} + \varepsilon_t \quad (2)$$

The null hypothesis restricts $\delta = 1$. Variants of the test, appropriate for series with different growth characteristics, restrict the drift and deterministic trend coefficients, β_1 and β_2, to be 0. If the p-value of the coefficient of y_{t-1} is less than 0.05 at 5% level of significance, the null hypothesis is rejected, indicating that the series is stationary.

VAR Lag Length Selection: The optimal lag for the variables are determined by certain model selection criteria like the Akaike's information criterion (AIC), Schwarz information criterion (SIC), and Hannan-Quinn information criterion (HQIC).

Akaike's Information Criterion: The AIC compares the quality of a set of statistical models and chooses the best model from that set. The AIC is defined by:

$$AIC = -2(log - likelihood) + 2k \quad (3)$$

Where, k is the number of model parameters and log-likelihood is a measure of model fit. The higher the number, the better the fit. However, the quality of the chosen model need not be absolute quality and absolutely the best. Therefore, once the best model is selected, a hypothesis test is to be performed to figure out the relationship between the variables in the model and the outcome of interest.

Schwarz Information Criterion: The SIC chooses the least complex probability model among multiple options using a likelihood function. The SIC is defined by:

$$SIC - kln(n) - 2In(\hat{L}) \quad (4)$$

Where, the likelihood $\hat{L} = Prob(x|\hat{\theta}M)$, where M is the model, x are the data, and $\hat{\theta}$ are the parameters of the model.

Hannan-Quinn Information Criterion: The HQIC is a measure of the goodness of fit, not based on log-likelihood function, but related to the Akaike and Schwarz information criteria. The QC is defined by:

$$HQIC = -2L_{max} + 2kln[ln(n)] \qquad (5)$$

where, L_{max} is the log-likelihood, k is the number of parameters, and n is the number of observations.

Cointegration Test: If the two-time series data are non-stationary, there exists a possibility for a linear combination of the two variables such that the error term is stationary. The two variables are cointegrated if they have a long-term or equilibrium relationship between them. The existence of the cointegration between the variables is tested by the trace and eigenvalue statistics, defined as:

Trace Statistic: $-T\sum \log(1-\lambda_t^1) \qquad t = r+1, \ldots, p$ (6)

Maximum Eigenvalue Statistic:

$$\lambda_{max}(r, r+1) = -Tlog(1-\lambda_{r+1}^1) \qquad (7)$$

Where, $\lambda^1_{r+1}, \ldots, \lambda^1_p$ are (p-r) number of estimated eigenvalues.

The test hypothesis is:

H_0: No cointegration (r = 0), against H_1: presence of cointegration (r > 0)

Where, 'r' implies cointegration relation. If the absolute value of the computed trace statistic and computed eigenvalue statistic are greater than their respective critical values, the null hypothesis is rejected, implying that there exists at least one cointegrating relation between the variables at 5% level of significance. Then, the hypothesis test is:

H_0: presence of one cointegrating relation (r = 1).

H_1: presence of more than one cointegrating relation among the variables (r > 1).

Based on the value of the computed trace statistic and the eigenvalue, the null hypothesis is either accepted or rejected. If the cointegration test indicates that the variables are cointegrated, the Vector Error Correction Mechanism (VECM) is to be used to obtain the rate of adjustment by the variables in the short run to achieve equilibrium in the long run. If the variables are not cointegrated, the Vector Autoregression (VAR) method is used to capture the contemporaneous effects among the variables.

Causality Test: When there is cointegration between the two variables, then the direction of the long-term causal relationship between them is to be ascertained. The causal relationship may be unidirectional or bidirectional. The Granger causality test identifies the direction of causality and the way the variables are built-in in their long-term relationship. The Granger causality test finds out which variable causes the other and allows determining the short-run or forecasting direction of the relations between the variables. Assuming two variables x and y, the following regression equations are to be estimated for the test:

$$y_t = \sum_{i=1}^{n} a_i x_{t-i} + \sum_{i=1}^{m} b_j y_{t-j} + \varepsilon_{1t}$$
$$x_t = \sum_{i=1}^{n} c_i x_{t-i} + \sum_{i=1}^{m} d_j y_{t-j} + \varepsilon_{2t} \qquad (8)$$

Where, n is the maximum number of lagged observations included in the model. The significance of the coefficients a_i, b_j, c_i, and d_j determine the direction of causality and the coefficients are jointly tested for their significance. There are two null hypotheses in the system: the first examines the null hypothesis that x does not Granger cause y and the second examines the null hypothesis that y does not Granger cause x. If the test fails to reject the former null hypothesis and rejects the latter, then x changes are Grange caused by a change in y. If the computed p-values exceed 0.05 at 5% level of significance, the null hypothesis is rejected, indicating causality between the two variables and no causality otherwise. Unidirectional causality exists between the two variables if either null hypothesis is rejected, bidirectional causality exists if both null hypotheses are rejected, and no causality exists if neither null hypothesis are rejected.

Vector Error Correction Mechanism (VECM): The cointegration gives the long-run relationship between the variables. However, the cointegration equation does not say anything about the short-run dynamics of the relationship. It is intuitive that the existence of a long-term relationship itself indicates that there must be some short-term forces that are responsible for keeping the long-run relationship intact. Therefore, the short-run and long-run dynamics have to be built in a more comprehensive model, i.e., equilibrium specification, whereby any short-term deviation from the long-term equilibrium is automatically corrected. Engle and Granger (1987) show that this is accomplished by an error correction mechanism (ECM) in a Vector Autoregression (VAR), which includes the lagged disequilibrium terms as explanatory variables that capture the short-run dynamics and adjust towards the long-run equilibrium. The VECM directly estimates the level to which a variable can be brought back to equilibrium condition after a shock on other variables. Thus, the VECM estimates the short-term effect for the variables and the long-run effect of the time series data, i.e., the speed of adjustment in short-run disequilibrium towards the long-run equilibrium.

The VECM(p) with the cointegration rank $r \leq k$ can be specified as:

$$\Delta y_t = \theta_0 + \theta_1 \Delta x_t + \tau(\hat{\varepsilon}_{t-1}) + v_t \qquad (9)$$

Where, τ is the coefficient of the error correction term, which should be theoretically negative and measures the speed of adjustment back to equilibrium following an exogenous shock. The coefficient θ_1 captures any immediate effect of short-run disturbances. The error correction term , which can be written as $(y_t - x_t)$, is the residual from the cointegrating relationship, which is non-zero (positive or negative) that captures long-run properties of the relationship. The short-run behaviour is partially captured by the equilibrium error term, which says that if y_t is out of equilibrium, it will be pulled towards it in the next period and further aspects of short-run behaviour are captured by the inclusion of ΔX_t.

Impulse Response Function: The IRF measures the response of the dependent variable in the VAR model to shocks in the error terms. The IRF detects the impact of a one-time shock in one of the innovations on the current and future values of the endogenous variables. The IRF can be specified as:

$$y_t = \mu + \omega_0 \varepsilon_t + \omega_1 \varepsilon_{t-1} + \omega_1 \varepsilon_{t-2} + \cdots + \omega_p \varepsilon_{t-p} \qquad (10)$$

Where, y_t is a vector of endogenous dependent variables, α is a vector of the constants, ε_i is a vector of innovations, and ω_i is a vector of parameters that measure the reaction of the dependent variable to innovations in all variables included in the VAR model.

Empirical Analysis

Table 1 presents the descriptive statistics of the variables used in this study. The natural logarithm of money supply, GDP, gross fiscal deficit, and WPI are used.

Table 1: Descriptive Statistics of Variables

Variable	*Description*	*Mean*	*Std. Dev.*
ln(WPI)	Wholesale price index (2010=100)	63.459	36.883
ln(GDP)	Gross domestic product (at 2010 price) (₹)	80.296	11.401
ln(GFD)	Gross fiscal deficit (₹)	16.76.2	16.663
ln(M3)	Broad money supply (₹ billions)	52.95	38.18
IR	Average lending rate of scheduled commercial banks (%)	12.617	2.963
ER	Exchange rate (₹ per US$)	39.685	13.803

ADF Unit Root Test: The variables are tested for stationarity at levels and at first difference using the ADF unit root test. The null hypothesis states the presence of unit root i.e., the series is non-stationary, against the alternative hypothesis that the series is stationary. The ADF test results presented in Table 2 show that the variables are not stationary at levels, but become stationary at first difference. The null hypothesis of unit root is rejected at first difference at 0.05 level of significance, as the computed values are greater than the critical value of 1.96. Thus, all variables are integrated of order one, i.e., I(1) process, and all these variables achieve stationarity at first differencing.

Table 2: Augmented Dickey-Fuller Unit Root Test of Stationarity

Variable	*At Level*	*At First Difference*
ln(WPI)	0.230 (0.2005)	4.308** (0.002)
ln(GDP)	0.819 (0.992)	4.774** (0.007)
ln(GFD)	0.595 (0.856)	4.77** (0.007)
ln(M3)	1.459 (0.538)	3.689** (0.046)
IR	0.909 (0.777)	5.451** (0.0001)
ER	0.748 (0.818)	4.920** (0.005)

Note: Figures are t-values. p-values in parentheses. *indicates rejection of null hypothesis at 5% significance level.

Lag Length Selection: The lag order selection helps in determining the optimal lag length of variables in the VAR estimation. The appropriate lag length is selected using the selection criteria. The results presented in Table 3 identify the optimal lag length as 2 by AIC and HQ criteria.

Table 3: Optimal Lag Length Selection

Lag	*LR*	*HQ*	*AIC*	*SIC*
1	317.80*	−4.968	−5.57984	−3.581*
2	47.122	−5.015*	−6.14989*	−2.438

Note: *indicates lag order selected by the criteria at 5% significance level.

Johansen Cointegration Test: The Johansen cointegration test examines the presence of a long term relationship between variables that are integrated of order 1. The null hypothesis is that there is no cointegration, against the alternative hypothesis of cointegration, between the variables. The Johansen cointegration test results are presented in Table 4. The trace statistic and eigenvalue statistic indicate 1 cointegrating equation at 0.5% level of significance.

Table 4: Johansen Cointegration Test

No. of CE_s	*Trace Statistic*	*0.05 Critical Value*	*Prob.**	*Maximum Eigenvalue Statistic*	*0.05 Critical Value*	*Prob.**
None*	119.422	95.754	0.0005	43.551	34.077	0.001
Atmost1*	85.872	59.819	0.001	32.665	23.877	0.001

Note: *indicates rejection of null hypothesis at 5% significance level.

Pairwise Granger Causality Test: Given the cointegration between the variables, the direction of causation is ascertained by the Granger causality test. The null hypothesis under the test is that the variable under consideration does not granger cause the other variable, against the alternative hypothesis that the variable Granger causes the other variable. The Granger causality test results presented in Table 5 show that the null hypothesis that money supply does not Granger cause WPI is rejected, as the computed F-statistics is greater than the table value and the p-value is less than 0.05 at 5% level of significance. Hence, there is a unidirectional causality from money supply to inflation. In addition, the null hypothesis that WPI does not Granger cause gross fiscal deficit is rejected at 5% level, as the p-value is 0.007 and F-statistics is 6.172, which is greater than the critical value. The Granger causality tests also show that WPI has a unidirectional causality with the current GDP and the exchange rate. Thus, changes in money supply, GDP, and exchange rate have an impact on WPI and a change in WPI has an effect on gross fiscal deficit and interest rate.

Table 5: Pairwise Granger Causality Test

Null Hypothesis	*F-Statistic*	*Prob.*
lnM3 does not Granger cause lnWPI	5.132*	0.014
lnWPI does not Granger cause lnM3	1.824	0.184
lnGFD does not Granger cause lnWPI	1.826	0.183
lnWPI does not Granger cause lnGFD	6.172*	0.007
lnGDP does not Granger cause lnWPI	5.340*	0.012
lnWPI does not Granger cause lnGDP	2.331	0.120
IR does not Granger cause lnWPI	0.823	0.452
lnWPI does not Granger cause IR	8.666*	0.001
EX does not Granger cause lnWPI	12.267*	0.0002
lnWPI does not Granger cause EX	1.824	0.080

Note: *F-value significant at 5% level.

Vector Error Correction Estimates: The cointegration test results show that there exists a long-run relationship between inflation and its identified determinants. If there is any deviation from the long-run relation, the system has a tendency to come back to the original level within a short period of time, i.e., if there is a change in inflation as a result of these variables, inflation will adjust in the next period; the percentage of correction is called the error correction. The cointegration equation is:

$$ECT_{-1} = 1.000\,lnWPI_{-1} + 0.360lnGDP_{-1} - 0.195lnGFD_{-1} - 5.621lnM3_{-1} - 0.018IR_{-1} + 0.001EX_{-1} - 12.433 \quad (11)$$

The estimated VECM equation with WPI as a target variable is:

$$\Delta WPI = -0.199ECT + 0.205lnWPI_{-1} - 0.282lnGDP_{-1} + 0.108lnGFD_{-1} + 0.384lnM3_{-1} + 0.009IR_{-1} - 0.017EX_{-1} + 0.051 \quad (12)$$

Table 6 presents the VECM estimates. The VECM result shows that the previous period deviation from the long-run equilibrium is correlated with the current period at an adjustment rate of 19.9%. The error correction term is statistically significant. Thus, the short-run disequilibrium is corrected towards the long-run equilibrium at the speed of about 20%. This means that if the two series are out of equilibrium, growth rates will adjust to reduce the equilibrium error and vice versa. A 1% change in current period inflation is associated with about a 20% change in its previous period inflation rate. The current inflation is associated with a 3.8% increase in money supply and a 2.8% reduction in GDP. A 1% increase in inflation is associated with about a 1% increase in the gross fiscal deficit. A 1% increase in inflation is followed by a 1.7% reduction in the exchange rate, while a 1% change in WPI is associated with a 1% increase in interest rate.

Table 6: Vector Error Correction Estimates

Variable	*D(lnWPI)*	*D(lnGDP)*	*D(lnGFD)*	*D(lnM3)*	*D(IR)*	*D(EX)*
CointEq1	−0.199* (3.106)	−1.771* (4.336)	−3.865* (4.640)	−0.115 (1.177)	−4.998 (0.803)	61.894* (4.133)
D(lnWPI(-1))	0.205* (3.023)	1.231* (3.115)	−4.194* (5.203)	0.101 (1.068)	22.431* (3.729)	−25.866*** (1.785)
D(lnGDP(-1))	0.282* (2.782)	0.567 (1.501)	−1.306*** (1.694)	−0.131 (1.447)	4.532 (0.788)	−7.543 (0.544)
D(ln GFD (-1))	0.108** (2.329)	−0.221** (2.571)	0.369** (2.104)	0.025 (1.239)	−1.511 (1.155)	9.845* (3.124)
D(lnM3(-1))	0.384* (2.928)	0.799 (1.042)	4.147* (2.650)	0.517* (2.806)	−25.660** (2.197)	−54.653*** (1.942)
D(IR(-1))	0.009 (1.221)	−0.015 (1.081)	0.057** (2.023)	0.004 (1.212)	−0.290 (1.386)	0.562 (1.113)
D(EX(-1))	−0.017* (2.928)	0.012 (1.106)	−0.050** (2.333)	−0.005*** (1.831)	−0.062 (0.382)	−0.316 (0.813)
Constant	0.051 (0.739)	−0.184 (1.428)	−0.072 (0.275)	0.082* (2.646)	1.894 (0.966)	12.435* (2.634)
R-square	0.553	0.505	0.707	0.607	0.520	0.513
Adj. R-square	0.396	0.332	0.605	0.469	0.352	0.343
F-statistic	3.530	2.918	6.905	4.414	3.094	3.016
Log-likelihood	56.823	39.540	19.577	79.494	−36.697	−61.318
AIC	−3.487	−2.253	−0.827	−5.106	3.192	4.951
SIC	−3.107	−1.872	−0.446	−4.726	3.573	5.332

Note: Absolute t-values in parentheses. *, **, ***significant at 1, 5, 10 per cent levels.

Impulse Response Functions: The IRFs generate the effects of shocks to the errors (ε) on the entire time paths of the variables contained in the VAR system. The IRFs presented in Fig. 2 show the response time path of WPI to the one standard deviation innovation to the other variables in the VAR system for ten periods. A shock in GDP will lead to a sudden increase in inflation, which dissipates over time. There is a sharp increase in WPI from the 1^{st} to 2^{nd} period of gross fiscal deficit, after which the response of inflation shows a sudden fall. The impulse response of WPI to M3 shows a positive response over time horizons till the 9^{th} period. An increase in the money supply will push inflation upwards. The impulse response of WPI to interest rate stocks is more or less stable; there is not much fluctuation in the response curve. An impulse of one standard deviation to the exchange rate is negatively reflected in the inflation rate.

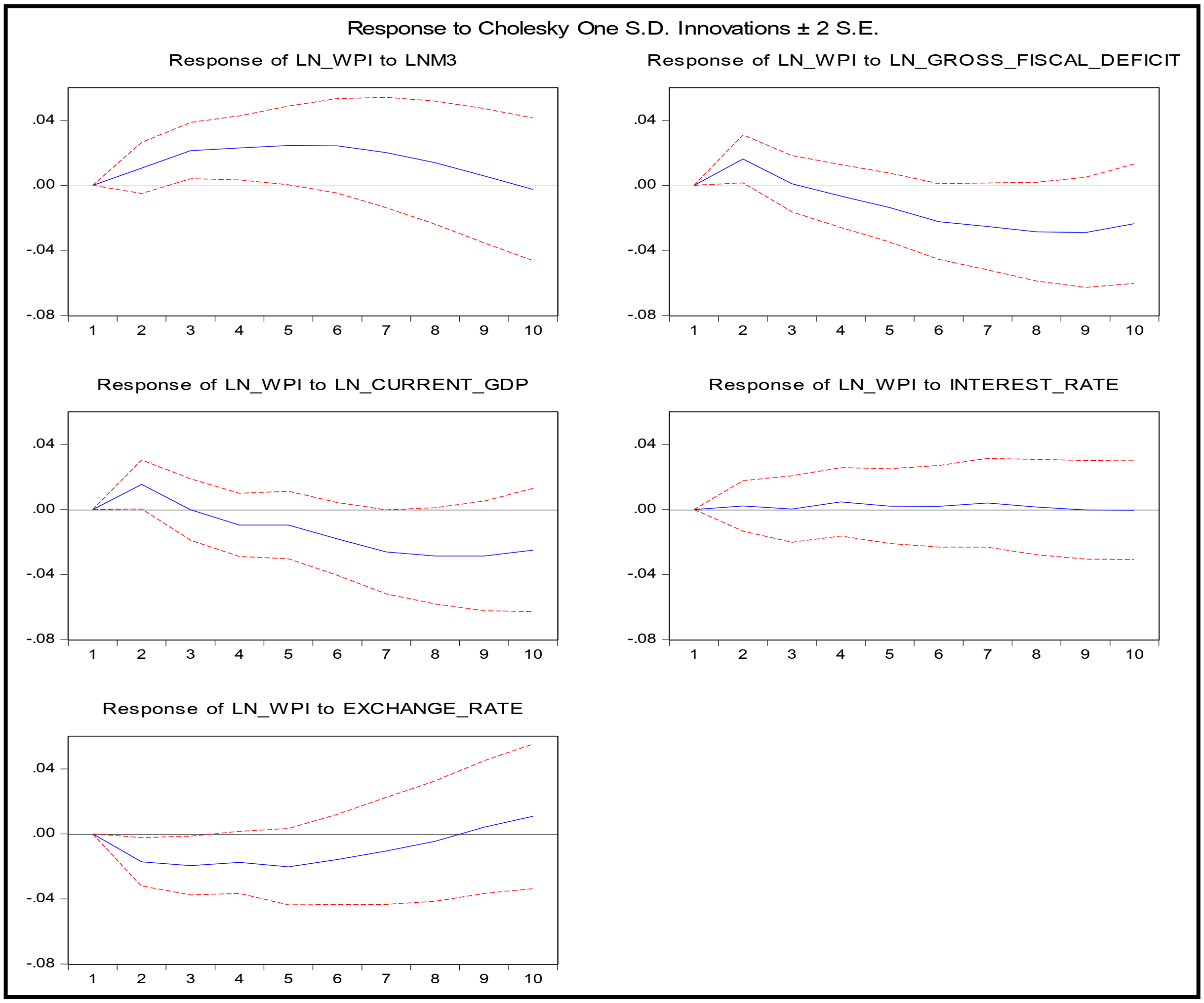


Fig. 2: Impulse Response of WPI to Other Variables

Stability of VAR Model: The stability condition of VAR requires that the characteristic roots of the polynomial lie outside the unit circle. The VAR model is stationary if all roots of the characteristic AR polynomial have an absolute value less than one and lie outside the unit circle. There should be (number of variables) * (number of model lags) roots visible on the graph. Therefore, in the inverse roots of the AR polynomial, all the roots should lie inside the unit root circle. The points in Fig. 3 are the inverse roots of the VAR model and all roots are inside the unit circle, suggesting that the model does not suffer from the problem of autocorrelation or heteroscedasticity. Therefore, the VAR model is stable and the sequences of WPI, GDP, gross fiscal deficit, interest rate, exchange rate, and money supply have a finite and time-invariant mean and variance.

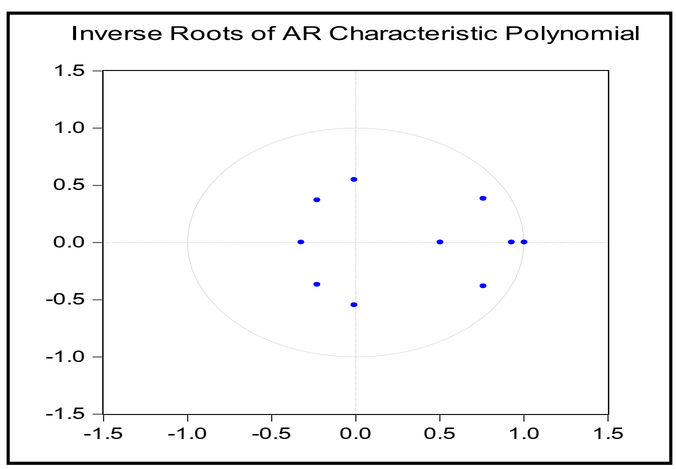


Fig. 3: Stability of VAR Model

Conclusion

Macroeconomic stability with low or moderate inflation is the necessary precondition for sustained economic growth. However, low inflation does not constitute a sufficient condition for growth. The relationship between inflation and macroeconomic variables like growth rate, money supply, fiscal deficit, interest rate, and the exchange rate remains a controversial one in both theory and empirical findings. Though theoretically there seems to be consensus on the negative effects of inflation on economic growth, the effects are not the same across developed and developing countries. Empirical studies also find threshold and non-linear effects of inflation on growth. Some studies even report positive effects of inflation on growth, often comparing inflation with deficit financing. Further, causality is not always one way. To understand the macroeconomic relationship between inflation and other variables in the Indian context in recent years, this study examines the causal relationship between inflation and some macroeconomic variables for the period 1986-2016. The variables considered in this study are wholesale price index, interest rate, exchange rate, GDP, broad money, and gross fiscal deficit. Data for the variables are sourced from the RBI Handbook of Statistics on Indian Economy and the World Bank. Empirically, considering all the variables as endogenous, the vector error correction mechanism (VECM) estimation method is followed. All the variables in the study are considered as a group and are endogenous. The usual diagnostics of time series data, viz. stationarity, cointegration, and causality tests, are performed. The tests show that the macro variables are stationary at first difference; there exists a cointegrating relationship between inflation and other macroeconomic variables; money supply, GDP, and exchange rate cause inflation; and a change in WPI has an effect on gross fiscal deficit and interest rate.

The VECM estimates show that money supply and GDP are the most important macro variables in explaining the variation in inflation. A 1% increase in inflation is due to a 3.8% increase in money supply and a 2.8% decrease in GDP. A 1% change in current period inflation is associated with about a 20% change in its previous period inflation rate. A 1% increase in inflation is associated with about a 1% increase in the gross fiscal deficit. The error correction term shows that any divergence from the long-run relation in the current period should be adjusted to around 20% in the following period. Thus, the short-run disequilibrium is corrected by about 20%, every period, towards the long-run equilibrium. The impulse response results show that inflation responds positively to money supply from the start to the 9th period. The response of WPI to exchange rate, GDP, and fiscal deficit are generally negative. The shock of the interest rate on inflation is more or less stable over the period. The results of this study suggest that to promote economic growth and keep inflation low, the government needs to rationalise money supply and budget deficits. The government should curtail unproductive expenditure, which is bad for both growth and inflation, in favour of investment, to provide macroeconomic stability for promoting growth.

References

Balakrishnan, P. (1991). Money, output and price level. *Economic and Political Weekly*, *26*(24), 1472-1474.

Behera, J. (2016). Dynamics of inflation, economic growth, money supply and exchange rate in India: Evidence from multivariate analysis. *Quarterly Journal of Econometrics Research*, *2*(2), 42-54.

Berument, H., Inamlik, A., & Olgun, H. (2008). Inflation and growth: Positive or negative relationship? *Journal of Applied Sciences*, *8*(2), 192-204.

Bhowmik, D. (2015). An econometric model of inflation in India. *International Journal of Scientific and Research Publications, 5*(2), 1-9.

Bishnoi, T. R., & Koirala, T. P. (2006). Stability and robustness of inflation model of Nepal: An econometric analysis. *Journal of Quantitative Economics*, *4*(2), 114-129.

Bozkurt, C. (2014). Money, inflation and growth relationship: The Turkish case. *International Journal of Economics and Financial Issues*, *4*(2), 309-322.

Bruno, M., & Easterly, W. (1998). Inflation crises and long-run growth. *Journal of Monetary Economics*, *41*(1), 3-26.

Burdekin, R. C. K., Denzau, A. T., Keil, M. W., Sitthiyot, T., & Willett, T. D. (2004). When does inflation hurt economic growth? Different nonlinearities for different economies. *Journal of Macroeconomics*, *26*(3), 519-532.

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.

Engle, R. F. (1982). Autoregressive conditional heteroskedasticity with estimates of the variance of UK Inflation. *Econometrica*, *50*(4), 987-1007.

Engle, R., & Granger. (1987). Co-integration and error correction: Representation, estimation, and testing. *Econometrica, 35*(2), 251-276.

Erbaykal, E., & Okuyan, H. A. (2008). Does inflation depress economic growth? Evidence from Turkey. *International Research Journal of Finance and Economics*, *17*(1), 40-48.

Faria, J., & Carneiro, F. (2001). Does high inflation affect growth in the long and short run? *Journal of Applied Economics*, *4*(1), 89-105.

Ghosh, A., & Phillips, S. (1998). Warning: Inflation may be harmful to your growth. *IMF Staff Papers, 45*(4), 672-710.

Gillman, M., Harris, M. N., & Matyas, L. (2004). Inflation and growth: Explaining a negative effect. *Empirical Economics*, *29*(1), 149-167.

Gokal, V., & Hanif, S. (2004). Relationship between inflation and economic growth. Working Paper No. 2004/04, Economics Department, Reserve Bank of Fiji, Suva, Fiji.

Gullapalli, S. (2013). Analysing the relationship between inflation and growth: Policy implications for Central Banks. Working Paper, Colgate University.

Jha, R., & Dang, T. (2012). Inflation variability and the relationship between inflation and growth. *Macroeconomics and Finance in Emerging Market Economies*, *5*(1), 3-17.

Johansen, S. (1988). Statistical analysis of cointegrating vectors. *Journal of Economic Dynamics and Control*, *12*(2-3), 231-254.

Johansen, S., & Juselius, K. (1990). Maximum likelihood estimation and inference on cointegration - with applications to the demand for money. *Oxford Bulletin of Economics and Statistics*, *52*(2), 169-210.

Kaur, G. (2019). Inflation and fiscal deficit in India: An ARDL approach. *Global Business Review*.

Krishna Veni, L., & Choudhury, P. K. (2007). Inflation and growth dilemma: An econometric analysis of the Indian economy. *IUP Journal of Financial Economics*, *5*(1), 80-87.

Kumar, R. (2013). A study of inflation dynamics in India: A cointegrated autoregressive approach. *Journal of Humanities and Social Science*, *8*(1), 65-72.

Mallik, G., & Chowdhury, A. (2001). Inflation and economic growth: Evidence from four South Asian countries. *Asia-Pacific Development Journal*, *8*(1), 123-135.

Patnaik, A. (2010). Study of inflation in India: A cointegrated vector autoregressive approach. *Journal of Quantitative Economics*, *8*(1), 118-129.

Pattanaik, S., & Nadhanael, G. V. (2013). Why persistent high inflation impedes growth? An empirical assessment of threshold level of inflation for India. *Macroeconomics and Finance in Emerging Market Economies*, *6*(2), 204-220.

Philips, P. C., & Perron, P. (1988). Testing for unit root in the time series regression. *Biometrika*, *75*(2), 335-346.

Sahadudheen, I. (2012). A cointegration and error correction approach to the determinants of inflation in India. *International Journal of Economic Research*, *3*(1), 105-112.

Tabi, H. N., & Ondoa, H. A. (2011). Inflation, money and economic growth in Cameroon. *International Journal of Financial Research*, *2*(1), 45-56.